Challenge to Apollo:

The Soviet Union and the Space Race, 1945–1974

NASA SP-2000-4408

Challenge to Apollo:

The Soviet Union and the Space Race, 1945–1974

by

Asif A. Siddiqi

National Aeronautics and Space Administration
NASA History Division
Office of Policy and Plans
Washington, DC

2000

Library of Congress Cataloguing-in-Publication Data

Siddiqi, Asif A., 1966-
Challenge to Apollo: the Soviet Union and the space race, 1945-1974 / by Asif A. Siddiqi
p. cm.—(The NASA history series) NASA SP ; 2000-4408

Includes bibliographical references and index.
1. Astronautics—Soviet Union—History. 2. Space race—History. I. Title. II. Series. III. NASA SP ; 4408.

TL789.8S65 S47 2000
629.4'0947-dc21

00-038684 00031047

To my mother and my father,

who taught me the value of knowledge

History is always written wrong, and so always needs to be rewritten.

—*George Santayana*

You can't cross the sea merely by standing and staring at the water.

—*Rabindranath Tagore*

TABLE OF CONTENTS

Acknowledgments

This book is, in essence, sixteen years in the making. I first attempted to compile a history of the Soviet space program in 1982 when, encouraged by my mother, I put together a rough chronology of the main events. A decade later, while living on a couch in a college friend's apartment, I began writing what I thought would be a short history of the Soviet lunar landing program. The first draft was sixty-nine pages long. Late the following year, I decided to expand the topic to handle all early Soviet piloted exploration programs. That work eventually grew into what you are holding in your hand now. I wrote most of it from 1994 to 1997 in Northampton and Amherst, Massachusetts, and in Philadelphia, Pennsylvania, and completed the manuscript in December 1998.

It would have been difficult, if not impossible, to write this book without the generous assistance of numerous individuals who have spent years and in some cases decades trying to understand and analyze the arcana of the former Soviet space program. Writing this book was as much an exploration into research as it was a long journey making new acquaintances and friends from all over the world.

I am indebted to the staff at the NASA History Office—in particular to Lee Saegesser, Steve Garber, and Nadine Andreassen—for assisting me in my research despite their own busy schedules. Louise Alstork, Jonathan Friedman, Patricia Talbert, and John Edison Betts, Jr., were especially patient in proofreading the entire manuscript, making changes where necessary, and helping with the layout and final production. A most special note of gratitude to NASA Chief Historian Roger Launius, whose comments, encouragement, and guidance were indispensable to the completion of this book. This book would not have existed without his untiring support.

Of all the individuals who helped me with this book, I would particularly like to acknowledge the contributions of Peter Gorin, a recent Guggenheim Fellow at the Smithsonian's National Air and Space Museum. He generously shared notes, books, articles, comments, and his encyclopedic knowledge on any and every topic related to the Soviet space program. He also provided a lion's share of the illustrations and drawings used in this book.

I would also mention U.S. Air Force Lt. Colonel William P. Barry. Our countless exchanges via e-mail or letters were invaluable to coming to some understanding of the political and institutional processes that drove the early Soviet space program. I would have found it virtually impossible to write this book without the use of his remarkable analyses of the institutional history of the Soviet space program.

Dwayne Day at the Space Policy Institute at The George Washington University was an invaluable source for recently declassified U.S. government documents relating to Soviet programs. His insightful comments allowed me to frame many of my arguments in a more cogent manner.

My exchanges over e-mail with Bart Hendrickx and Mark Hillyer were essential to reexamining old events in a new light and eliminating many errors. Bart was very generous in sharing any materials that passed his way—a rare quality that set him apart from many other scholars in the field. Mark's vast knowledge about the sometimes mind-boggling and confusing histories of Soviet-era design bureaus helped me with my own studies on this arcane topic.

I want to give special thanks to T.A. Heppenheimer for his support throughout the project. His exhaustive knowledge of the history of space technology was useful in framing many of the main arguments of this work.

Igor Lissov of VideoCosmos in Moscow warrants special mention. He graciously answered many of my questions.

A very special thank you goes to Dennis Newkirk, the Russian aerospace analyst, for his never-ending efforts to provide me with materials useful for my work. He was one of the first Soviet "space watchers" with whom I communicated, and it was partially because of his encouragement that I began writing this book in the first place.

I would like to thank Glen Swanson, the founding editor of *Quest: The History of Spaceflight Magazine*, for his constant material and moral support during the writing of this book. Glen also graciously shared his complete database of remarkable photographs, many of which I used in the book.

I would like to acknowledge the tireless contributions of the late Maxim Tarasenko for kindly facilitating my contacts with the RKK Energiya archivist Georgiy Vetrov. Maxim was one of the most brilliant space historians of his generation, and he will be sorely missed.

A very special note of thanks goes to Sergey Voevodin of Kostroma, Russia, who was an excellent source of information on the Soviet cosmonaut team.

Special thanks go out to Dr. Sergey Khrushchev, the late Dr. Georgiy Vetrov, and Dr. Gerbert Yefremov, all of whom graciously agreed to answer questions relating to the history of the Soviet space program and their own role in its early years. Their comments were invaluable in ferreting out details of previously hidden events in Soviet space history.

In addition to those named above, I would like to acknowledge the following for not only providing me with Russian-language material and photographs but also in many cases for answering detailed questions on various topics. They are: Igor Afanasyev, Vladimir Agapov, Michael Cassutt, Andrew Chaikin, Phillip Clark, James Harford, Christian Lardier, Jonathan McDowell, Peter Pesavento, and Joel Powell. I would also like to thank the following for providing many of the diagrams or photographs for the work: R. F. Gibbons, Dietrich Haeseler, Don Pealer, Charles Vick, Mark Wade, David Woods, and Steven Zaloga.

On a personal note, I would like to thank my mentor in Bangladesh, Fazlul Huq, and also Paul Thompson, Fred Ruppel, Inji, Sabina, Munmun, Karin Bell, Nadeem, Rahila, Bill Sparks, Rika, Dave Parnell, Pat, Jacqueline, the late musician Greg Black, Becky (who inspires), Heather, Karen Barth, Jill, and Danny. Thanks to the amazing Mandar Jayawant in the hope that he will one day forgive me for not sharing my lunch with him. Thanks also to Paul, Iggy, Kurt, and Maynard.

A very special thank you to Anoo for being her wonderful self and for being so interested.

A very special note of love to my mother, who always told me that I could achieve anything as long as I worked hard enough for it; to my father, who bought me my first encyclopedia on spaceflight when I was twelve years old; to my sister Rochona, who endured years of my uncontrollable excitement over Soyuzes and Salyuts as an adolescent; and to her husband David, who graciously offered me an abode in which I could finish the book. Finally, a special thank you to Karen for being my best friend through all of this. I could not have written this book without her love and friendship.

PREFACE

On the Internet one day, I came upon a discussion of the space dog Layka, launched into orbit by the Soviet Union in 1957. Some people believed that the dog had died when oxygen finally ran out in her cabin. Others had heard that an automatic injection of poison had put her to sleep. Still others had read somewhere that poor Layka had literally burned up in the atmosphere when her capsule gradually fell to Earth. No one could point to a single source with any reasonable claim to authority on Layka's ultimate fate. The same news group carried a spirited discussion of U.S. space policy. The topic of choice was the heady period after the first Apollo Moon landing in 1969, in particular the political maneuvering behind the Nixon administration's approval of the Space Shuttle in 1972. Instead of quibbling over historical events, the emphasis was clearly on interpretation—a problem that had more to do with analysis than simply verifying the facts. The contrast between these two threads of conversation perfectly illustrated both the challenges and the differences in writing histories of the Soviet and American space programs. In one case, we are still disputing elementary facts and sources. In the other, we are disputing interpretations of facts and sources.

As astonishing as it may seem, the story of the Soviet space program, the world's first, has never been told in full. That is not to say that much has not been written on the topic. Western researchers during the 1970s and 1980s were able to interpret official exhortations in the Soviet press and discern some logic of the inner workings of the Soviet space program. All of these works had one major drawback: they were written at a time when the Soviets maintained very strict control over information, especially any that portrayed the space effort in a negative light. Many "facts"—that is, the raw skeleton of the story—were missing. All we had were accounts from the official Soviet media and rumor or speculation from unconfirmed sources—or a combination of both. Thus the range of issues that Western or even Soviet historians could address was severely limited.[1]

Within Russian-language works, there are two relatively clear divisions in the historical record: those published before 1988, when the Soviet censorship apparatus consistently prevented an impartial representation of their efforts to explore space, and those published after, when the doors of the archives finally started opening up. The rupture was so great, it was as if everything written about the Soviet space program—and indeed almost every area of Soviet history—suddenly became obsolete by the turn of the 1990s. Entire programs, personalities, and even space missions of which we never knew all of a sudden came into focus, filling huge gaps in our understanding of the Soviet space effort during the Cold War. But it was not just a matter of filling in the blanks. The revisions and reassessments have been so pervasive that we could point to almost any event in the thirty-year span of the Soviet space and missile

1. For the best Western accounts of the Soviet space program, see F. J. Krieger, *Behind the Sputniks: A Survey of Soviet Space Science* (Washington, DC: Public Affairs Press, 1958); William Shelton, *Soviet Space Exploration: The First Decade* (New York: Washington Square Press, 1968); Nicholas Daniloff, *The Kremlin and the Cosmos* (New York: Alfred A. Knopf, 1972); Peter Smolders, *Soviets in Space* (New York: Taplinger Publishing Co., 1973); Nicholas L. Johnson, *Handbook of Soviet Manned Spaceflight* (San Diego: Univelt, 1980); James E. Oberg, *Red Star in Orbit* (New York: Random House, 1981); Phillip Clark, *The Soviet Manned Space Program: An Illustrated History of the Men, the Missions, and the Spacecraft* (New York: Orion, 1988); Dennis Newkirk, *Almanac of Soviet Manned Space Flight* (Houston: Gulf Publishing Co., 1990); Steven J. Zaloga, *Target America: The Soviet Union and the Strategic Arms Race, 1945–1964* (Novato, CA: Presidio, 1993); James Harford, *Korolev: How One Man Masterminded the Soviet Drive to Beat America to the Moon* (New York: John Wiley & Sons, 1997).

programs after World War II and find that our understanding of that singular occurrence has changed irrevocably.[2]

The recent disclosures have relevance far beyond the limited purview of Soviet space history. In the 1950s and 1960s, U.S. space policy to a large degree was a series of responses to what the Soviets were doing—or at least what policymakers *thought* the Soviets were doing. But despite its key role in shaping American space policy, there continues to be an abundance of ignorance or misinformation on the Soviet program. Many erroneous conjectures on Soviet space motives advanced by Western analysts during the Cold War have remained unquestioned by more recent scholars. Ultimately, any effort to make sense of the dynamics of space exploration during the Cold War, no matter how well-intentioned, will fall short without taking account of the recent revelations from the Russian side. What may be possible now is to take a second look not only at the Soviet space program, but also the U.S. space program—that is, to reconsider again humanity's first attempts to take leave of this planet.

Writing on a topic that has two dynamic parallel histories—one from the Cold War era and one from the post–Cold War era—is, for obvious reasons, a difficult problem. First, there is the challenge of creating context. One could easily lose the main thread of the story by annotating every episode with interpretations from two different time periods—that is, this is how the event was reported in the 1960s, and this is what *really* happened. I have tried as much as possible to avoid the pitfalls of such an approach, but at the same time, I have also not tried to shirk from the opportunity to contrast these two voices when they have served to embellish my story.

A second problem is one of identifying the right sources for the story. As much as possible, I have relied exclusively on Russian-language archival sources available in the post–1988 era. There are, however, several episodes in the narrative that warrant a wider historiographical context. Because of the dual nature of the history of the Soviet space program, different players in the effort have continued to promote contradictory accounts of the same event. For instance, Russian historians have never adequately addressed the use of German expertise in the immediate postwar period. They have generally minimized the German role as extremely peripheral. On the other side, the popular press in the West has had a tradition of dismissing early Soviet successes as merely an extension of German work. Can these two positions be reconciled in a scholarly treatise? In this case, the writing of history as an exercise in impartiality is caught between what is a somewhat dubiously established paradigm of history in the West and what is at best a history with missing chapters on the Soviet side. What I have tried to do is to use recently declassified information to provide a newer perspective, but one that is not necessarily divorced from the existing paradigms of yesteryears.

There are many such other cases in which Soviet space history has been artificially constrained between propaganda and speculation. This is one reason, I believe, that Soviet space achievements have generally been marginalized in the West and mythologized at home. For American historians, there is little debate on the holy grail of space history: it is the first landing of American astronauts on the surface of the Moon in 1969. On that July night in 1969, two men represented humanity's thirst for exploration, serving as ambassadors of the human

2. For the best recent Russian-language works, see Yu. A. Mozzhorin, *et al.*, eds., *Dorogi v kosmos: I* (Moscow: MAI, 1992); Yu. A. Mozzhorin, *et al.*, eds., *Dorogi v kosmos: II* (Moscow: MAI, 1992); Yaroslav Golovanov, *Korolev: fakty i mify* (Moscow: Nauka, 1994); Yu. A. Mozzhorin, *et al.*, eds., *Nachalo kosmicheskoy ery: vospominaniya veteranov raketno-kosmicheskoy tekhniki i kosmonavtiki: vypusk vtoroy* (Moscow: RNITsKD, 1994); B. Ye. Chertok, *Rakety i lyudi* (Moscow: Mashinostroyeniye, 1994); B. Ye. Chertok, *Rakety i lyudi: Fili Podlipki Tyuratam* (Moscow: Mashinostroyeniye, 1996); Yu. P. Semenov, ed., *Raketno-kosmicheskaya korporatsiya "energiya" imeni S. P. Koroleva* (Korolev: RKK Energiya, named after S. P. Korolev, 1996); V. V. Favorskiy and I. V. Mescheryakov, eds., *Voyenno-kosmicheskiye sily (voenno-istoricheskiy trud): kniga I: kosmonavtika i vooruzhennyye sily* (Moscow: VKS, 1997); B. Ye. Chertok, *Rakety i lyudi: goryachiye dni kholodnoy voyny* (Moscow: Mashinostroyeniye, 1997).

race in our first visit to another celestial body. For most American historians, everything before was simply a prelude and everything after has been a disappointment. Historians in Russia see things much differently. It was, after all, the Soviet Union that launched the first handiwork of humankind into orbit around Earth in 1957—Sputnik, or "fellow traveler." Only four years later came the second big milestone: the Soviet Union sent the first human into space, Yuriy Gagarin. Here was another huge moment, like that of the Apollo landing eight years later: for the first time since human life emerged on this planet, one of us had broken through the atmosphere that surrounds us and sped into the cosmos. But history has remembered Gagarin's short flight much differently. With the race to the Moon won, the American view of the Soviet space program changed dramatically; American historians remembered Sputnik and Gagarin not for their importance in human history, but only as catalysts for the decision to send humans to the Moon. There are works, too numerous to mention, on the repercussions of both Sputnik and Gagarin in the United States, but few on the historical meaning of these events divorced from geopolitics—as there was on Apollo. It is not surprising that this is so. With little film footage, paranoid secrecy, and no advance warning, the Soviets themselves were mostly responsible for consigning these events into that blurry historical limbo between propaganda and speculation. They eventually lost any claim to resonance that they might have had otherwise.

The Soviet space program was, of course, not simply propaganda nor speculation. It emerged from the ashes of World War II, when with Stalin's blessing, a group of ambitious engineers began testing old German missiles from the desert near the Aral Sea. With the onset of the Cold War and the explosion of the first Soviet atomic bomb in 1949, these experiments with rockets gained a new urgency. Many considered rockets, especially long-range ballistic missiles, an ideal way to deliver deadly atomic bombs across continents. Throughout the 1950s, as missile designers made vast advances in rocket design, it became possible to consider options that had little direct military utility—ideas such as space travel. Spurred by a small handful of visionary engineers devoted to the cause of space exploration, the Soviets diverted a strand of their military rocketry program into a single project to launch a satellite into orbit. Conceived as an exercise in scientific research, Sputnik was meant to be a modest contribution to an international effort to study Earth and its surroundings. While its scientific dividends might have been anticipated, no one could have predicted its political repercussions. After the launch of Sputnik on October 4, 1957, in the public image, the Soviet Union moved from being a nation of obsolete agricultural machines to a great technological superpower. Gagarin's flight less than four years later eliminated any remaining doubts about Soviet prowess in space exploration. In both cases, the Americans had lagged behind badly. These two pivotal achievements led eventually to the race to the Moon—a race of epic proportions that culminated in the Apollo landing in 1969. A span of only eight years separated the resounding victory of Gagarin and the crushing humiliation by Apollo. So what happened? What kind of effort did the Soviets mount to compete with Apollo? And why did it fail? I have tried to answer these questions by weaving together a record of the technical, political, and personal histories behind these three endeavors: the launch of Sputnik, the flight of Gagarin, and the challenge to Apollo.

My goal was not to write a history simply because it had never been written before. Certainly, recording the facts is an important exercise, but that would limit the job to a simple chronology. There are several major questions of interpretation that still have to be answered. I have only tackled a few of these.

The first major question has to do with discerning the institutional underpinnings of the Soviet space program. Given the new evidence, can we identify the primary constituencies that drove the effort? What kind of patterns of decision-making did they display? What interests were they serving? The record seems to indicate the importance of both individuals and institutions, all of whom emerged to power not because of the space program, but because of its antecedent ballistic missile development effort.

The second question addresses Soviet space technology. Our conventional understanding of Soviet space technology is generally framed in terms of obsolete products pushed through production-line processes that discourage major innovation. In the evolution of their early missile and space programs, did the Soviets adhere to the idea of incremental advances, or were there technological leaps? Did the Soviets benefit from foreign expertise during these early years? More often than not, the answers to these questions do not conform to our entrenched notion of how the Soviets managed technology in the Cold War era.[3]

Finally, why did the Soviets manage to beat the Americans in launching the first intercontinental ballistic missile, the first satellite, and the first human into space, but fail to beat the United States in landing the first person on the Moon? Was it simply because the last goal was significantly more challenging than the previous three? Or was it because, as was conventionally thought for many years in the West, that the Soviets simply did not want to race the Americans to the Moon? The answers to these questions are not simple: personal, institutional, political, and technological issues intersected in the complex schema of the Soviet Moon program, leading it to its final ignominious failure in 1969.

For this work, I have specifically focused on piloted space programs. In the first four chapters of this book, however, I delve into the origins of the Soviet long-range ballistic missile program and the events leading up to the launch of Sputnik. The following seven chapters cover the rise of the Soviet piloted space program under the tutelage of its founder, Sergey Pavlovich Korolev, ending with his premature death in 1966. The next seven chapters take the story up to 1974, covering the Soviet loss in the Moon race under the direction of Korolev's successor, Vasiliy Pavlovich Mishin. Finally, in the remaining two chapters, I briefly tell the story after 1974.

Note on Transliteration

I have used a modified version of the standard used by the U.S. Board on Geographic Names preferred by the University of Chicago Press. The drawback of this system is that it is often phonetically inappropriate. For example, the letter "ë" is pronounced as "yo" in Russian. Thus "Korolev" should actually be pronounced as "Korolyov." There was one major exception to the Board of Geographic Names system: I have omitted the use of inverted commas (the "soft" and "hard" signs) within Russian words to reduce clutter in the text for those not familiar with the Russian language.

One other note is that NASA's normal convention has been to spell the Soviet cosmodrome "Baikonur," with an "i" instead of a "y." In this book, to be consistent with the rest of the transliteration, it is spelled "Baykonur." The reader will also find a difference in the spelling of some common first names, such as Sergei as Sergey and Yuri as Yuriy.

3. For Western works on the history of Soviet technology, see, for example, Ronald Amann, Julian Cooper, and R. W. Davies, eds., *The Technological Level of Soviet Industry* (New Haven, CT: Yale University Press, 1977); Kendall E. Bailes, *Technology and Society Under Stalin: Origins of the Soviet Intelligentsia, 1917–1941* (Princeton, NJ: Princeton University Press, 1978); Ronald Amann and Julian Cooper, eds., *Industrial Innovation in the Soviet Union* (New Haven, CT: Yale University Press, 1982); Bruce Parrot, *Politics and Technology in the Soviet Union* (Cambridge, MA: MIT Press, 1983); Matthew Evangelista, *How the United States and the Soviet Union Develop New Military Technologies* (Ithaca, NY: Cornell University Press, 1988); Loren R. Graham, *What Have We Learned About Science and Technology from the Russian Experience?* (Stanford, CA: Stanford University Press, 1998).

Glossary

AN SSSR	USSR Academy of Sciences
BOR	Unpiloted Orbital Rocket-Glider
BS	lateral stabilization
CIA	(U.S.) Central Intelligence Agency
CSAGI	Special Committee for the International Geophysical Year
DLB	Long-Duration Lunar Base
DOK	Engine Orientation Complex
DOS	Long-Duration Orbital Station
EOR	Earth-orbit rendezvous
EKR	Experimental Winged Missile
EPAS	Apollo-Soyuz Experimental Flight (Soviet name for the Apollo-Soyuz Test Project)
EPOS	Experimental Piloted Orbital Aircraft
EVA	extravehicular activity
FIAN	(P. N. Lebedev) Physical Institute of the USSR Academy of Sciences
FOBS	Fractional Orbital Bombardment System
GAU	Chief Artillery Directorate
GDL	Gas Dynamics Laboratory
GeoFIAN	Geophysical Institute of the USSR Academy of Sciences
GIPKh	State Institute of Applied Chemistry
GIRD	Group for Study of Reactive Motion
GKAT	State Committee for Aviation Technology
GKB	Lead Design Bureau
GKNPTs	State Space Scientific-Production Center
GKO	State Committee for Defense
GKOT	State Committee for Defense Technology
GKRE	State Committee for Radio Electronics
GMT	Greenwich Mean Time
GNII AiKM	State Scientific-Research Institute for Aviation and Space Medicine
GOGU	Chief Operations and Control Group
Gosplan	State Planning Organ
GR	global missile
GSKB	State Union Design Bureau
GSMZ	State Union Machine Building Plant
GTsP	State Central Range
GU	Chief Directorate
GUKOS	Chief Directorate of Space Assets
GULag	Chief Directorate of Camps
GURVO	Chief Directorate of Reactive Armaments
IAE	Institute of Atomic Energy
IAKM	Institute of Aviation and Space Medicine
ICBM	intercontinental ballistic missiles
IGY	International Geophysical Year
IKI	Institute of Space Research
IMBP	Institute for Biomedical Problems

IP	Measurement Point
IS	Satellite Destroyer
KB	Design Bureau
KB OM	Design Bureau of General Machine Building
KGB	Committee for State Security
KIK	Command-Measurement Complex
KORD	Engine Operation Control (system)
KPSS	Communist Party of the Soviet Union
KSU	command and signal instrument
KVTs	Coordination-Computation Center
LH_2	liquid hydrogen
LII	Flight-Research Institute
LK	Lunar Ship
LKS	Light Space Aircraft
LOK	Lunar Orbital Ship
LOR	lunar-orbit rendezvous
LOX	liquid oxygen
MAI	Moscow Aviation Institute
MAP	Ministry of Aviation Industry
MEK	Martian Expeditionary Complex
MEP	Ministry of Electronics Industry
MIAN	Mathematics Institute of the Academy of Sciences
MIK	Assembly-Testing Building
MKB	Machine-Building Design Bureau
MKBS	Multirole Space Base-Station
MMZ	Moscow Machine-Building Plant
MNII	Moscow Scientific-Research Institute
MNII RS	Moscow Scientific-Research Institute for Radio Communications
MO	Ministry of Defense
MOK	Multirole Orbital Complex *or* Martian Orbital Complex
MOL	Manned Orbiting Laboratory
MOM	Ministry of General Machine Building
MOP	Ministry of Defense Industry
MP	maneuvering, piloted
MPK	Martian Landing Complex
MRP	Ministry of Radio Industry
MSM	Ministry of Medium Machine Building
MTKVP	Reusable Vertical-Landing Transport Craft
MVTU	Moscow Higher Technical School
MZ	Machine Building Plant
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NEK	Scientific-Experimental Complex
NIEI PDS	Scientific-Research and Experimental Institute of the Parachute Landing Service
NII	Scientific-Research Institute
NII AP	Scientific-Research Institute for Automation and Instrument Building
NII AU	Scientific-Research Institute for Aviation Equipment
NII IT	Scientific-Research Institute for Measurement Technology
NII P	Scientific-Research Institute for Instrument Building
NII PM	Scientific-Research Institute for Applied Mechanics

NII RP	Scientific-Research Institute for Rubber Industry
NII TP	Scientific-Research Institute for Precision Instruments *or* Scientific-Research Institute for Thermal Processes
NIIP	Scientific-Research and Test Range
NIP	Scientific-Measurement Point
NITI	Scientific-Research and Technical Institute
NKVD	People's Commissariat for Internal Affairs
NORAD	North American Air Defense Command
NPO	Scientific-Production Association
NS	normal stabilization
NTK	Scientific-Technical Committee
NTS	Scientific-Technical Council
OK	orbital ship
OKB	Special or Experimental Design Bureau
OKB MEI	Experimental Design Bureau of the Moscow Power Institute
OPM	Department of Applied Mathematics
OPS	Orbital Piloted Station
OTK	Special Technical Commission
PKA	Gliding Space Apparatus
PVO	Air Defense Forces
RKK	Rocket-Space Corporation
RKS	Adjustment of Apparent Velocity
RNII	Reactive Scientific-Research Institute
RVSN	Missile Forces of Strategic Designation (Strategic Missile Forces)
SALT	Strategic Arms Limitation Talks
SKB	Special Design Bureau *or* Serial Design Bureau
SKG	Special Design Group
SOBIS	simultaneous emptying of tanks
SOKB	Union Experimental Design Bureau
SOUD	System of Orientation and Motion Control
SOZ	System for Ensuring Firing
SP	Special Publication (NASA)
SR	Suborbital Rocket-Glider
TASS	Telegraph Agency of the Soviet Union (Soviet news agency)
TDU	Braking Engine Unit
TGU	Third Chief Directorate
TKA	Transport-Supply Ship
TLI	translunar-injection
TMK	Heavy Interplanetary Ship
TMKB	Turayevo Machine-Building Design Bureau
TMZ	Tushino Machine Building Plant
TNT	trinitrotoluene
TOS	Heavy Orbital Station
TsAGI	Central Aerohydrodynamics Institute
TsIAM	Central Institute of Aviation Motor Building
TsK	Central Committee
TsKB	Central Design Bureau
TsKBEM	Central Design Bureau of Experimental Machine Building
TsKBM	Central Design Bureau of Machine Building
TsKIK	Central Command-Measurement Complex

TsNII	Central Scientific-Research Institute
TsNIIMash	Central Scientific-Research Institute for Machine Building
TsPK	Cosmonaut Training Center
TsSKB	Central Specialized Design Bureau
TsUKOS	Central Directorate of Space Assets
TsUP	Flight Control Center
UDMH	unsymmetrical dimethyl hydrazine
UHF	ultrahigh frequency
UNKS	Directorate of the Commander of Space Assets
UNRV	Directorate of the Commander of Reactive Armaments
UPMK	Cosmonaut Maneuvering and Motion Unit
UR	universal missile
US	Controlled Satellite
USSR	Union of Soviet Socialist Republics
UZKA	Directorate of the Deputy Commander of Artillery
VHF	very high frequency
VIAM	All-Union Institute for Aviation Materials
VMF	Soviet Navy
VNII	All-Union Scientific-Research Institute
VNII EM	All-Union Scientific-Research Institute for Electro-Mechanics
VNII IT	All-Union Scientific-Research Institute for Current Sources
VPK	Military-Industrial Commission
VSNKh	All-Russian Council of the National Economy
VTs	Computation Center
VVS	Soviet Air Force
YaERD	nuclear-electric rocket engine
ZIKh	M. V. Khrunichev Machine Building Plant

CHAPTER ONE
PRESAGE

Origins

The rocketry and space programs of the Soviet Union had their origins in the late 1800s with the farsighted and at times farfetched writings of a deaf, self-taught school teacher named Konstantin Eduardovich Tsiolkovskiy. Born in 1857, Tsiolkovskiy had produced a series of thirty small monographs in the late 1800s, culminating in his classic work "Exploration of the Universe with Rocket-Propelled Vehicles," published in the May 1903 issue of the St. Petersburg journal *Nauchnoye obozreniye* (*Scientific Review*).[1] In this and later works, Tsiolkovskiy elucidated his complex ideas on rocketry and space exploration, supporting most of his conceptions with complex mathematical analyses. In his most revolutionary idea, he proposed that humans could hope to fly to very high altitudes and ultimately into outer space only by using liquid-propellant rockets. One of his most important conclusions was that a rocket would be capable of carrying up a cargo of any size, and develop any speed desired, as long as the rocket was sufficiently large and the ratio of the mass of the propellant to the mass of the entire rocket was large enough—a relationship that is known as the Tsiolkovskiy Equation.[2]

While some of his work was clearly in the realm of fantasy, the breadth of his contribution to astronautics is astounding. In his early work, he wrote eloquently on such topics as multistage rockets, high-energy liquid propellants such as liquid oxygen and liquid hydrogen, giant space stations in Earth's orbit with food regeneration systems, and the dangers of high temperatures on an object returning to Earth. He even investigated the idea of a spacesuit for activity in open space. Tsiolkovskiy was a generation older than two other equally famous founders of theoretical and practical astronautics: the American Robert H. Goddard and the Rumanian Hermann Oberth. All three, quite independently, pursued their extraordinary ideas on rocketry and space exploration, but Tsiolkovskiy was perhaps a bit more pessimistic than his peers. Unlike Goddard, who launched the world's first liquid propellant rocket in 1926, Tsiolkovskiy was unable to build even a small rocket. He apparently believed that few of his conceptions of the future would ever be brought to fruition.

1. V. P. Glushko, *Development of Rocketry and Space Technology in the USSR* (Moscow: Novosti Press Publishing House, 1973), p. 9; Evgeny Riabchikov, *Russians in Space* (Moscow: Novosti Press Publishing House, 1971), p. 98; Nicholas Daniloff, *The Kremlin and the Cosmos* (New York: Alfred A. Knopf, 1972), p. 17. The 1903 publication was only the first part of the article. When the journal was closed down with the May issue, Tsiolkovskiy had to wait until 1911 to see the second part published in *Vestnik vozdukhoplavaniya*.

2. For an English language summary of Tsiolkovskiy's work, see A. A. Blagonravov, *et al.*, *Soviet Rocketry: Some Contributions to its History* (Jerusalem: Israel Program for Scientific Translations, 1966), pp. 68–126; Daniloff, *The Kremlin and the Cosmos*, pp. 13–17.

In the early part of the 1900s, Tsiolkovskiy's ideas received little if any attention as a result of both the extreme mathematical nature of his work and a general disinterest from the Czarist government. The Bolshevik Revolution in 1917 seems to have aroused a modicum of interest in his ideas from the new Soviet leadership. This was partly to illustrate the Czarist government's lack of foresight, but also tied to new ideology: "In Communist theory, technological progress was virtually equivalent to the march of history."[3] The year after the Revolution, Tsiolkovskiy was elected a full member of the prestigious Russian Socialist Academy. Later in 1921, he was granted a lifetime pension in honor of his groundbreaking scientific contributions on space exploration and rocketry.[4] Given his strong support for the Revolution, the Soviet government was only too eager to promote his writings.

In the Western historiography of the early history of astronautics, Tsiolkovskiy's name is the best known. But within Russia and later the Soviet Union, there were two other remarkable visionaries who played as great a role in inspiring a new generation of young amateurs as the great Tsiolkovskiy himself. One of these was Yuriy Vasilyevich Kondratyuk, a man who had a life as amazing as any figure in the history of Soviet rocketry. He was born Aleksandr Ignatyevich Shargey in 1897 in the Ukraine. Brilliant even in his childhood, he published his seminal works in his twenties and thirties, the first, *Tyem, kto budet chitat chtoby stroyit* (*To Those Who Will Read in Order to Build*), in 1919 and the second, *Zavoyevaniye mezhplanetnykh prostranstv* (*The Conquest of Interplanetary Space*), in 1929. In these works, Shargey showed a remarkable grasp of problems in rocket dynamics and engineering. Unaware of Tsiolkovskiy, he came to many of the same conclusions and extended the field of astronautics to new areas. Among the topics he described were minimum-energy spaceflight trajectories to other planets, the theory of multistage rockets, intermediate interplanetary ship refueling bases, and the landing of probes on planets using atmospheric drag. One of his most famous contributions to the literature was the formulation of a mission profile for a lunar landing using two separate vehicles, a mother ship in lunar orbit, and a lander on the surface. When American astronauts landed on the Moon in 1969, they used very much the same idea.[5]

Shargey's career was cut short by the strangest of circumstances. In 1916, he had been conscripted into the Army to fight on the Caucasus front in Turkey. After the Bolsheviks came to power in October 1917, Shargey decided to leave the Army, but on his journey back home, he was conscripted by the rebel White Army to fight the communists. He eventually deserted but was found by the White Army again in Kiev, where he joined their ranks briefly before deserting again. After the Revolution, he was in a difficult position. To the Whites, he was a habitual deserter, and to the Reds, he was an officer in the White Army—both sides wanted him shot. To save his life, his stepmother sent him some documents of a man named Yuriy Vasilyevich Kondratyuk, who was born in 1900 and died on March 1, 1921, of tuberculosis. On August 15 of the same year, Shargey assumed his new identity and tried to lead an inconspicuous life, far from the public eye. Terrified of being found out, he did not join the amateur rocketry groups of the Soviet Union in the 1920s and 1930s despite his lifelong passion for rocketry. He died sometime in late February 1942 defending Moscow against the Nazis. His grave was never found.[6]

3. Walter McDougall, . . . *the Heavens and the Earth: A Political History of the Space Age* (New York: Basic Books, 1985), p. 27.

4. Daniloff, *The Kremlin and the Cosmos*, 1972, p. 19; William P. Barry, "The Missile Design Bureaux and Soviet Piloted Space Policy, 1953–1970," Ph.D. thesis in Politics, Faculty of Social Studies, University of Oxford, 1996.

5. G. V. Petrovich, ed., *The Soviet Encyclopedia of Space Flight* (Moscow: Mir Publishers, 1969), pp. 209–10.

6. Valeriy Rodikov, "Who Are You, Engineer Kondratyuk?" (English title), in V. Shcherbakov, ed., *Zagadki zvezdnykh ostrovov: kniga pyataya* (Moscow: Molodaya gvardiya, 1989), pp. 36–53.

The third major figure of the period was Fridrikh Arturovich Tsander, born in 1887 in Riga, the capital of Latvia. By his late twenties, Tsander had but one aim: to acquire the necessary knowledge to make a journey into space. In 1921, he gave a report at an inventors' conference on his pet project for an interplanetary aircraft. Three years later, he published his landmark work in the journal *Tekhnika i zhizn* (*Technology and Life*) titled "Flight to Other Planets," in which he expounded on the design of rocket engines, calculations for interplanetary trajectories, and conceptions of safety systems. One of his favorite ideas was of a combined rocket-aircraft for takeoff from Earth, which would consume its own metallic wings as propellants after flight through the atmosphere. He amplified this and several other concepts in another book published in 1932 titled *Problema poleta pri pomoshchi reaktivnykh apparatov* (*The Problem of Flight by Means of Reactive Vehicles*). Perhaps Tsander's most famous contribution was his untiring popularization of spaceflight in the late 1920s by lecturing on the topic across the Soviet Union.[7]

The increased visibility of rocketry and space exploration in the public eye in the late 1920s, through exhibitions and special publications, were crucial to inspiring a new, younger generation of Soviet engineers—those born this century, who would eventually direct the course of the world's first space program. This group of individuals came to prominence in the 1930s with the formation of small rocketry societies in Moscow and Leningrad dedicated to the design and construction of short-range liquid-fueled rockets. In many ways, the influence and power that these men wielded in their later years was far more imposing than the same possessed by their counterparts in the concurrent rocketry societies in the United States and Germany. This is, perhaps, one of the key distinctions in historical perspective in looking at the space programs of the United States and the Soviet Union. In the former, the pioneers were defined by their institutions, and in the latter, the pioneers *were* the institutions.

In the Soviet Union, the most important of these individuals was Sergey Pavlovich Korolev, a former mechanical engineer who was to become the *de facto* head of the Soviet space program and remained so until his untimely death in 1966. It would not be an overstatement to say that without his guidance, administrative powers, and vision, the Soviet Union would not have become the foremost space-faring nation in the world in the late 1950s and early 1960s. Korolev was born on December 30, 1906, in the town of Zhitomir in the Ukraine.[8] His natural parents were divorced when he was three years old, and the young Korolev was shuffled from city to city until his mother remarried. He did not attend school until he was fourteen, studying only at home with tutors.

Korolev's first passionate interest was aeronautics, and from an early age, he read voraciously on the exploits of aviation pioneers throughout the world. At the age of seventeen, he joined a glider club in the town of Odessa and eventually became the leader of the aeronautics club there. In 1926, he enrolled in the Moscow Higher Technical School in the Department of Aerodynamics as an advanced student and for the first time came into contact with famous Soviet aeronautical designers such as Andrey N. Tupolev, who was a professor at the university. As part of his thesis work at the school, Korolev designed and built a full-scale glider that he later flight-tested; this and other glider projects were brought to fruition by 1930, and Korolev graduated in February of that year as an "aeromechanical engineer."[9] Immediately following graduation, he was asked to begin work as an engineer at the V. P. Menzhinskiy Central Design Bureau headed by Chief Designer Dmitriy P. Grigorovich, where the work was far more ambitious than his modest

7. Petrovich, ed., *The Soviet Encyclopedia of Space Flight*, p. 468.

8. A. P. Romanov and V. S. Gubarev, *Konstruktory* (Moscow: Politicheskoy literatury, 1989), p. 16; Yaroslav Golovanov, *Sergei Korolev: The Apprenticeship of a Space Pioneer* (Moscow: Mir Publishers, 1975), p. 23. The date of his birth in the "new" Gregorian calendar adopted following the Great October Revolution is January 12, 1907.

9. Golovanov, *Sergei Korolev*, pp. 135–36, 170; Romanov and Gubarev, *Konstruktory*, pp. 31–33. Among his graduating class was the later chief designer of aircraft and missiles, Semyon A. Lavochkin.

gliders. There, he was part of an engine design group working on a new heavy bomber named the TB-5. Within five months, he was finally transferred to the prestigious Central Aerohydrodynamics Institute (known as "TsAGI" in its Russian abbreviation) in Moscow. By all accounts, he was considered a promising aeronautical engineer and by that time had authored several articles on aviation, gliders, and light aircraft.[10]

It was during this period that Korolev for the first time became seriously enamored with the possibilities of space exploration and rocketry. He had maintained a fairly cursory interest in space travel since the late 1920s as a result of several well-publicized exhibitions in the Soviet Union that showcased the works of Goddard, Oberth, Tsiolkovskiy, and Kondratyuk. Korolev's overriding passion during the late 1920s was, however, aeronautics, and it seems that he was not "converted" until he had contact with several resourceful engineers employed at TsAGI in 1930. Among these individuals was the forty-four-year-old Tsander. By that time, Tsander had unsuccessfully requested the government to support his rocketry experiments, but such practical efforts evoked little interest from the leadership.[11] In December, Tsander posted an advertisement in the Moscow newspaper *Vechernyaya moskva* calling for responses from those interested in "interplanetary communications," a euphemism for space travel.[12] Many of the 150 people who responded met several times in early 1931 under Tsander's direction to discuss the possibility of establishing an amateur group to focus on the practical aspects of rocketry and space exploration. The early meetings led to the formation, on July 18, 1931, of the so-called Bureau for the Investigation of Reactive Engines and Reactive Flight. By early September, the society's name was changed to the Group for the Investigation of Reactive Engines and Reactive Flight (better known by its Russian acronym "GIRD").[13] Korolev joined forces with Tsander at this time, impressed by Tsander's claim that he could build a rocket engine. The young Korolev had the germ of an idea to combine a rocket engine with a glider and create a high-altitude aircraft.

Tsander's group at GIRD was formally under the jurisdiction of the voluntary Society for the Promotion of Defense, Aviation, and Chemical Production (or "Osoaviakhim"), a governmental entity that sponsored amateur and premilitary activities among Soviet youth in such areas as gliding, auto racing, hot-air balloons, and glider construction. The Moscow branch of GIRD was only the first of many groups interested in rocketry that sprouted in the ensuing months in such cities as Arkhangelsk, Baku, Bryansk, Kharkov, Leningrad, Novocherkassk, and Tiflis. By June 1932, Osoaviakhim had formalized a relationship with the Moscow GIRD (also called the Central GIRD) that set the stage for modest amounts of financial support for their activities. Under Tsander's leadership, the Moscow GIRD was particularly successful in its early incarnation and conducted public lectures and courses and even published a number of books on rocketry. Along with these promotion efforts, Tsander and Korolev were also interested in practical work in the building of rockets and were able to work overtime on their experiments in a small wine cellar on Sadovo-Spasskiy Street in Moscow.[14]

10. Aleksandr Romanov, *Korolev* (Moscow: Molodaya gvardiya, 1996), pp. 88–89. The works of the Central Design Bureau and TsAGI were actually merged at the time.

11. An English language summary of Tsander's work can be found in F. A. Tsander, *Problems of Flight by Jet Propulsion: Interplanetary Flights* (Jerusalem: Israel Program for Scientific Translations, 1964). See also Barry, "The Missile Design Bureaux."

12. Romanov and Gubarev, *Konstruktory*, p. 35; Christian Lardier, *L'Astronautique Soviétique* (Paris: Armand Colin, 1992), p. 19.

13. G. S. Vetrov, *S. P. Korolev i kosmonavtika: pervye shagi* (Moscow: Nauka, 1994), pp. 35–36. The actual date for the formation of GIRD has not been ascertained by Soviet or Russian historians. The current interpretation is that the group was set up sometime between September 1 and 20. The earliest preserved document mentioning the organization is dated September 23, 1931, and is reproduced in Vetrov, *S. P. Korolev i kosmonavtika*, p. 38.

14. Glushko, *The Development of Rocketry and Space Technology*, p. 15; Riabchikov, *Russians in Space*, p. 105.

The original members of the GIRD team are shown here in 1932. Top center is Yuriy Pobedonostsev, while bottom center is Sergey Korolev. On the extreme right is Fridrikh Tsander, the space visionary who founded the group. (files of Asif Siddiqi)

Among the other early members of GIRD were Mikhail Klavdiyevich Tikhonravov, who was thirty-one years old, and Yuriy Aleksandrovich Pobedonostsev, only twenty-four, both of whose contributions to the early achievements of the Soviet rocketry and space programs would be invaluable. Although they were not officially supported by the Soviet government, the engineers and technicians at GIRD were infected by an unusually vivid sense of enthusiasm and optimism. In particular, Korolev's whole life had begun to revolve around ideas of rocketry and astronautics, and there were many discussions during GIRD's early days of sending rockets into space and landing people on Mars. One of the more common inspiring phrases of the engineers was reportedly: "To Mars! To Mars! Onward to Mars!" This was a phrase that Tsander would use to greet his fellow workers. He had even named his two children Merkuriy ("Mercury") and Astra.[15] The economic situation in the Soviet Union at the time, however, necessitated that their interests in rocketry and aeronautics would have to be financed by themselves. These limitations, although considerable, did not cause much hesitation on their part, and the group often sold family valuables to finance their private endeavors. They usually labored in their spare time, and the fact that there was no obvious profit in such work was not an issue of great concern. Unlike Tsander, who had little interest in acquiring leadership skills, Korolev was a natural focus of the group, and in addition to his increasing technical expertise, he developed sharp managerial and administrative skills—assets that would serve him well in his later days. He had become completely absorbed in the idea of spaceflight by this time. It was a dream that he would never abandon.

15. Riabchikov, *Russians in Space*, p. 106; Yaroslav Golovanov, *Korolev: fakty i mify* (Moscow: Nauka, 1994), p. 132.

On May 1, 1932, Korolev replaced the ailing Tsander as the formal leader of the GIRD organization, and simultaneously four different divisions were formed to further optimize their rocketry efforts—groups led by Tsander, Tikhonravov, Pobedonostsev, and Korolev himself. Most of their efforts were focused on the development of low-thrust liquid-propellant engines for small handmade rockets and gliders.[16] Under Korolev's leadership, the work at GIRD also took a significant turn as he began to extract larger amounts of funding to pay GIRD members and obtain better equipment for building rockets and gliders. He also encouraged strict professionalism among all the workers and quickly became known among larger circles as not only a bright engineer but also an efficient organizer. Just three months following Korolev's appointment, the Soviet government's Directorate of Military Inventions began financing some of the organization's work, although the group still remained subordinate to the amateur Osoaviakhim.[17] The work at the organization finally culminated in the late summer of 1933 with the first launches of what would eventually be the first Soviet liquid-propellant rocket. Designated the 09, the 2.2-meter-tall vehicle had been designed by a team under Tikhonravov. Powered by jellied petroleum burning in liquid oxygen, the rocket was loaded up in a truck and taken to the Nakhabino firing range outside of Moscow for its first launch on August 11, 1933. This attempt and a second one on August 13 were failures, but a third try on the 17th went down in history. After a precariously slow liftoff, the rocket reached a modest altitude of about 400 meters during thirteen seconds of flight.[18] In a moment of exhilaration, Korolev authored a short article for the GIRD news flyer:

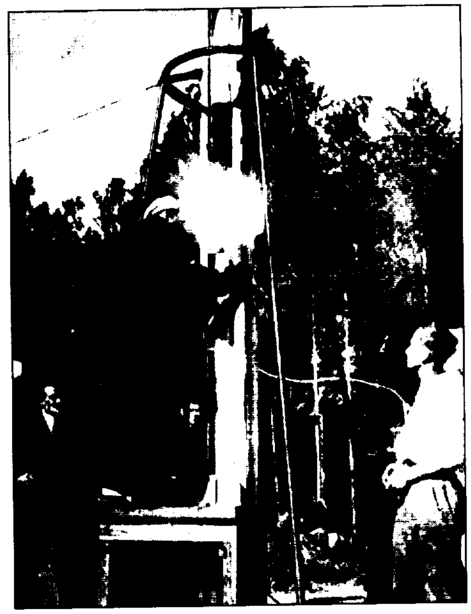
> *The first Soviet liquid-propellant rocket has been launched. The day of August 17 will undoubtedly be a memorable day in the life of GIRD, and from this moment Soviet rockets should start flying above the Union of Republics. . . . Soviet rockets must conquer space!*[19]

Although it was the first resounding success for GIRD, the organization's spiritual guide was not present to witness the event. Tsander had been suffering from exhaustion caused by overwork, and some of his associates had forced him to take a vacation. On the journey to a health spa, Tsander contracted typhus and collapsed. He died without regaining consciousness on the morning of March 28, 1933.[20] In one sense, Tsander's death presaged the end of an era of amateur Soviet rocketry. Within months, Korolev and his associates would find themselves in the employ of the Soviet government.

The Soviet military had actually sanctioned the formation of a small government rocketry research laboratory in Moscow on March 1, 1921, to conduct work on "rocket projectiles."[21] Unlike the GIRD efforts, however, all the research at this laboratory was dedicated to the development of solid-fuel rocket engines for artillery. This group, headed by a chemical engineer named Nikolay I. Tikhomirov, was moved to Leningrad in June 1928 and renamed the Gas Dynamics Laboratory (GDL) of the Military Scientific Research Commission. The following year, in May 1929, a special group (the "Second Section"), headed by a young engineer named Valentin Petrovich Glushko, had been brought into GDL to specifically conduct research on electric rocket engines.[22] Born on August 20, 1906, Glushko had converted to space exploration

16. The main work at GIRD prior to March 1932 was the development of the OR-1 and OR-2 rocket engines for use with an experimental glider named the BICH-11. See Vetrov, *S. P. Korolev i kosmonavtika*, p. 46.
17. *Ibid.*, pp. 50, 70.
18. *Ibid.*, p. 69; Golovanov, *Sergei Korolev*, pp. 273–74.
19. Golovanov, *Sergei Korolev*, pp. 274–75.
20. Riabchikov, *Russians in Space*, p. 109; Golovanov, *Korolev*, pp. 147–48.
21. Glushko, *The Development of Rocketry and Space Technology*, p. 6.
22. *Ibid.*, p. 12; Riabchikov, *Russians in Space*, p. 86.

early through his voracious readings of the works of Jules Verne—so much so that at the age of fifteen, he had written a letter to Tsiolkovskiy.[23] Just three years later in July 1924, only eighteen years old, he had published an article in the popular press titled "Conquest of the Moon by the Earth." Even more impressively, in 1926, Glushko authored a work titled "Extraterrestrial Station" in the journal *Nauka i tekhnika* (*Science and Technology*).[24] A soft-spoken individual with somewhat of a stern disposition, Glushko no doubt saw a chance at realizing his dream of space exploration as an engineer for GDL. Recognizing his exceptional technical capabilities, the leaders of GDL had redirected Glushko in 1931 to start work on *liquid*-propellant rocket engines for military applications.



The GIRD team is shown here in 1933 feeding liquid oxygen to the "09," the first Soviet liquid-propellant rocket. From left to right are Sergey Korolev, Nikolay Yefremov, and Yuriy Pobedonostsev. (files of Asif Siddiqi)

By 1931, there were two major independent rocketry organizations in the Soviet Union—one active in the design of rockets (GIRD) and the other focused on rocket engines (GDL). Around this time, the two groups began developing informal contacts with each other and began negotiations to explore the possibility of coordinating their work. Following a long and elaborate series of discussions, aided by strong lobbying from Marshal Mikhail I. Tukhachevskiy, the Deputy People's Commissar for the Army and Navy, GIRD and GDL were consolidated into one organization in the fall of 1933. The official decree (no. 0113) from the Revolutionary Military Council was issued on September 21, 1933, and called for the formation of the Reactive Scientific-Research Institute (RNII).[25] Tukhachevskiy appointed Ivan T. Kleymenov, the former head of the now defunct GDL, to serve as the new RNII's first director. Korolev, no longer an amateur rocketeer, was appointed Kleymenov's deputy.

Tukhachevskiy had originally envisioned RNII as a breeding ground for advanced liquid- and solid-propellant missiles for use by the artillery sector, but this idea faced some resistance from higher placed military leaders. Uninterested in the future prospects of rockets, the military refused to let Tukhachevskiy have jurisdiction over the new institute. Instead, a little over a month after its formation, on October 31, RNII placed under the jurisdiction of the People's Commissariat of Heavy Industry, the "ministry" responsible for production of several major ground-based weapons.[26] At the same time, there was a clash between Kleymenov and Korolev

23. Romanov and Gubarev, *Konstruktory*, p. 274. The letter was dated September 26, 1923. Tsiolkovskiy replied within a month.

24. Col. M. Rebrov, "Specific Impulse" (English title), *Krasnaya zvezda*, August 26, 1989, p. 4. The 1926 article was published as V. P. Glushko, "Extraterrestrial Station" (English title), *Nauka i tekhnika* 40 (October 8, 1926): 3–4.

25. Vetrov, *S. P. Korolev i kosmonavtika*, p. 76; Glushko, *The Development of Rocketry and Space Technology*, p. 17.

26. Glushko, *The Development of Rocketry and Space Technology*, pp. 17–18. This was formalized by a second decree (no. 104) from the Council of Labor and Defense on October 31, 1933.

over the thematic direction of the institute. The former was not a rocketry specialist; it was well known that he had a poor understanding of the field in general, believing that the institute's most urgent mandate should be the creation of solid-propellant artillery shells. When Korolev disagreed, Kleymenov demoted him to the section chief on winged missiles.[27] It was a change in jobs that probably saved Korolev's life in later years. A former GDL veteran and accomplished solid-propellant engineer named Georgiy E. Langemak was tapped to fill Korolev's old position. To the latter's disappointment, some of the more interesting projects, such as the development of liquid-propellant rocket-powered aircraft, were dropped from the institute agenda at the time.[28]

A second reorganization was enacted by Kleymenov in May 1935 as RNII was divided into four major sectors emphasizing solid-propellant missiles, solid-propellant takeoff accelerators for military aircraft, launch installations for solid-propellant rockets, and liquid-propellant missiles.[29] Korolev's primary interest was the development of rocket gliders, but this area of focus seems to have rapidly diminished in terms of its value in the eyes of the RNII leadership. Korolev himself initially worked on several high-altitude rockets before he found himself leading efforts on a number of promising long-range winged missiles for military applications. Glushko and Tikhonravov undertook most of the work on liquid-propellant engines, and although some of these engines found use on gliders and missiles, most were never installed on any working designs.

Unhappy with the work at RNII, Marshal Tukhachevskiy sanctioned the establishment, in August 1935, of a separate organization in the General Staff's Chief Artillery Directorate, designated Design Bureau No. 7, to focus exclusively on liquid oxygen missiles—an area of research that the RNII leadership had neglected.[30] The original goal of creating a centralized rocketry research organization gradually became subsumed under conflicts resulting from clashes between the proponents of solid propellants and liquid propellants. Earlier, on the seventy-fifth anniversary of Tsiolkovskiy's birth, several speakers from the USSR Academy of Sciences mocked the great visionary's ideas as impractical and of little use. The conflict was exacerbated by the opinions of former GDL researchers at RNII who continued to view the amateur GIRD veterans as "crackpots" without any connection to reality.[31] After Tsiolkovskiy's death in 1935,

27. Vetrov, *S. P. Korolev i kosmonavtika*, p. 77.

28. Yu. Biryukov, "Life, Aspiring to Higher Goals (on the 90th Birthday of S. P. Korolev)" (English title), *Novosti kosmonavtiki* 1 (January 1–12, 1997): 63–67.

29. Lardier, *L'Astronautique Soviétique*, pp. 31–34.

30. Glushko, *Development of Rocketry and Space Technology*, p. 19; Barry, "The Missile Design Bureaux." Design Bureau No. 7 (KB-7) was primarily composed of engineers who had "defected" from RNII. Later histories of the early Soviet rocketry program dismissed the efforts of KB-7 as a failure, but in truth, the activities at this bureau were quite successful given the circumstances. Led by former RNII engineers L. K. Korneyev and A. I. Polyarniy, KB-7 developed a series of increasingly complex rockets for exploring high altitudes. One of these, although never launched, was the R-05, one of the first Soviet rockets designed exclusively for investigations of the upper atmosphere. Special instruments were developed by the Optics Institute and the Chief Geophysical Observatory for this rocket. KB-7 also designed several complex guidance and gyroscope systems, some of them as sophisticated as those developed at RNII. A second independent effort was continued by amateur engineers of the former GIRD who had elected not to be part of the governmental RNII. Solid-propellant missiles such as the VR-3 and the TR-3 were developed under the leadership of I. A. Merkulov in the Reaction Section of the Stratospheric Committee of Osoaviakhim. The latter organization also developed some of the first ramjet engines for rocket applications. Both these efforts, however, were discontinued by the late 1930s. KB-7 itself was dissolved in 1939, following a decision by the Artillery Directorate that liquid-propellant missile research was not a useful avenue of military research. See Glushko, *The Development of Rocketry and Space Technology*, p. 19; the author writes that KB-7 "failed to produce the desired results." See also I. A. Merkulov, "Organization and Results of the Work of the First Scientific Centers for Rocket Technology in the USSR," in Frederick I. Ordway III, ed., *History of Rocketry and Astronautics, Vol. 9* (San Diego, CA: American Astronautical Society, 1989), pp. 70, 72–73; Lardier, *L'Astronautique Soviétique*, pp. 39, 41–43; Riabchikov, *Russians in Space*, pp. 128–29.

31. For an excellent summary and analysis of the events at RNII in the 1930s, see Barry, "The Missile Design Bureaux."

interest in rocketry, let alone space travel, very visibly declined as the Soviet government began to slowly withdraw from its earlier support for such technologies.

Despite the organizational discord in RNII, there was a significant amount of research on rocketry conducted during that period. Korolev himself made a presentation at the All-Union Conference on Stratospheric Studies in Leningrad in March and April 1934, calling for the development of scientific instruments for high-altitude rockets to study the upper atmosphere.[32] In December, Korolev authored a slim volume titled *Raketnyy polet v stratosfere* (*Missile Flight Into the Stratosphere*), in which he considered for the first time the launch of humans to high altitudes. He conceded that given the current state of Soviet technology, such a plan might be somewhat premature. The following year, Korolev, Glushko, Tikhonravov, Pobedonostsev, and other engineers at RNII actively participated in a Moscow workshop, the All-Union Conference on the Uses of Rocket-Propelled Craft for the Exploration of the Stratosphere, dedicated completely to the possibilities of high-altitude science using powerful rockets.[33]

Korolev was personally involved in the design of several missiles for military applications beginning in the mid-1930s. These initially included high-altitude missiles but progressively encompassed the design and construction of winged missiles.[34] Work on the latter rockets was used as the basis for the development of one of the first practical rocket plane designs in the Soviet Union, designated the RP-318. Conceived in July 1936, intensive static engine firings were conducted in late 1937 and early 1938 in preparation for the first flight, which Korolev intended to make himself.[35] Glushko and Tikhonravov at the same time worked independently on other projects, the former developing at least fifty different low-thrust nitric-acid–based rocket engines for a variety of applications. Many of these units had relatively high-performance characteristics, with thrust levels as high as 600 kilograms. Thus, although the original goals of Korolev, Glushko, and Tsander had been put to the side for the time being, it is clear that the work at RNII was not only productive but also extremely important in terms of the later achievements of the Soviet rocketry program. Apart from the purely technological advancements and the mastery of important practical processes, the years at RNII also gave the young engineers their first active involvement in issues of organization and management. Although the political and social institutions under which they worked under were obviously vastly different, the work at RNII in many ways parallels that of the Germans and the Americans with their own amateur rocketry societies, which also attracted the interest of their respective governments. However, while all three independent early rocketry efforts in the late 1930s had to address the impending war, only one was to face the full brunt of the government's attack on its own people.

32. Vasili Mishin and Boris Raushenbakh, "The Scientific Legacy of Academician Sergei Korolyov," in *History of the USSR: New Research 5: Yuri Gagarin: To Mark the 25th Anniversary of the First Manned Space Flight* (Moscow: Institute of the History of Natural Science and Technology of the USSR Academy of Sciences, 1986), p. 106; Vetrov, *S. P. Korolev i kosmonavtika*, p. 80.

33. Peter Stache, *Soviet Rockets*, Foreign Technology Division Translation, FTD-ID(RS)T-0619-88 (from unnamed source), Wright-Patterson Air Force Base, Ohio, November 29, 1988, p. 206. This is a translation of Peter Stache, *Sowjetischer Raketen* (Berlin: Militarverlad der DDR, 1987). See also Mishin and Raushenbakh, "The Scientific Legacy," p. 106; Vetrov, *S. P. Korolev i kosmonavtika*, p. 89.

34. Lardier, *L'Astronautique Soviétique*, pp. 35–39. The high-altitude missiles included Objects 209, 609-1, RDD-604, and RAS-521. The winged missiles included Objects 48, 201, 212, 216, 217, and 218.

35. *Ibid.*, pp. 37–38; Glushko, *The Development of Rocketry and Space Technology*, p. 18. The original designation of the RP-318 was Object 218.

The Purges

All Soviet-era histories of early rocketry programs came to an abrupt end in 1937 when Stalin's Great Purges reached its zenith. The purges had a profound effect, not only on the scientific community but also on almost every other sector of Soviet society. Directed by the secret police—the People's Commissariat for Internal Affairs (NKVD)—and by Soviet leader I. V. Stalin's personal vision of suspicion, paranoia, and complete terrorization, the purges effectively decimated a whole generation of the Soviet Union's best engineers, writers, politicians, military officers, academics, and scientists. No one was safe at the time, however tenuous their ties to ideological trappings; people were picked up off the street for completely arbitrary reasons and never seen again. Not surprisingly, a feeling of paranoia crept into almost every level of society, fed by the suspicion and mistrust, as millions faced the threat of possible execution or internment in labor camps. "Informing" on an associate became less a compromise of one's value system than simply a means to live through the torture of NKVD agents.

RNII had been renamed the Scientific Research Institute No. 3 (NII-3) on January 2, 1937.[36] Within a year after that reorganization, the engineers of the institute were left with little doubt that their safety was no longer assured. The first effective indication that their luck had run out came in the late spring of 1937. The NKVD suddenly arrested Marshal Tukhachevskiy, the early patron of NII-3 and one of the more brilliant strategists of the Soviet military, on May 22, 1937. Recently appointed the commander of the Volga Military District, Tukhachevskiy was charged with having been part of an "anti-Soviet Trotskiyite conspiracy."[37] Interrogated and beaten savagely along with several other "accomplices" during the ensuing days, Tukhachevskiy was sentenced to death after a short trial. His sentence was carried out on June 12. Executed along with him were his mother, sister, and two brothers. Almost overnight, the name Tukhachevskiy became a dreaded word, and association with his name was a sure method of attracting suspicion. The marshal's links to NII-3 were not passed over by the NKVD, and the secret police seemingly put the entire group under surveillance, allegedly through the services of an ambitious communications specialist named Andrey G. Kostikov. Having joined NII-3 in 1934, Kostikov eventually became the prime motivator of the purges at the institute on behalf of the NKVD. Working with Glushko and others on liquid-propellant engines, Kostikov rose quickly through the ranks of NII-3; by mid-November 1937, he had become deputy director of the institute.

Kostikov's ascendance to power was preceded by the arrest of former NII-3 Director Kleymenov on the night of November 2 on charges of being a member of an anti-Soviet Trotskyite organization that had been part of a trade delegation to Germany.[38] Within days, Kleymenov's deputy Langemak was also arrested. Despite intense torture, the former refused to confess to any of the charges; Langemak, on the other hand, believing that he had a chance to save his life, broke under duress, and he confessed that Glushko had also been a member of the secret organization. Both were executed after signing false charges—Kleymenov on January 10, 1938, and Langemak the day after. Kostikov, meanwhile, continued to support the NKVD

36. Valeriy Zharkov, "Pobedonostsev's Criteria" (English title), in Shcherbakov, ed., *Zagadki zvezdnykh ostrovov*, p. 73.

37. Aleksey Khorev, "How Tukhachevskiy Was Condemned: The USSR State Security Committee Has Declassified Materials Related to the Conviction of Marshal of the Soviet Union Tukhachevskiy and the Other Military Leaders in 1937. The Archives Have Revealed the Documents on Their Execution and Cremation" (English title), *Krasnaya zvezda*, April 17, 1991, p. 4.

38. N. L. Anisimov and V. G. Oppokov, "Incident at NII-3" (English title), *Voyenno-istoricheskiy zhurnal* no. 10 (October 1989): 81–87. Kleymenov had been removed from his post on August 30, 1937.

in their senseless vendetta, having provided fabricated evidence for the arrest of the two executed RNII leaders.[39]

Kleymenov and Langemak were the first of many to pay a dear price because of their tenuous links to Tukhachevskiy. By the end of 1937, the NKVD had a statement denouncing Korolev and Glushko as "wreckers" of the rocket group—a statement probably extracted from Kleymenov and Langemak. This led to an expanded meeting on February 13, 1938, of the Scientific and Technical Council of the institute. One of the items on the agenda was the "denigration of the personality" of rocket engine designer Glushko.[40] He was charged with maintaining connections with "enemies of the people," disclosing military secrets, and avoiding public work. Officially, his accusers included Kleymenov and Langemak. On February 20, a second meeting was held, again to present more "evidence" against Glushko. All of Glushko's colleagues, save one, denounced him; Korolev was not present at this meeting. A resolution was adopted to the effect that Glushko was "unreliable," and a few days later, on March 23, 1938, he was arrested on charges of being an "enemy of the people."[41]

Following Glushko's arrest, the focus shifted to Korolev, certainly the leading NII-3 engineer at the time.[42] Korolev himself publicly stated that he could not believe that Glushko had intentionally been involved in "wrecking" activities, only to arouse suspicions against him. At the time, Korolev was directing tests of Object 212, a winged surface-to-air missile, but these had to be temporarily suspended following a head injury on May 29, 1938, that left him hospitalized for a few weeks.[43] The NKVD, however, moved ahead with their agenda, and after several weeks of deliberations, on June 20, they formally denounced Korolev on charges of being a member of an anti-Soviet organization. The final piece of "evidence" against Korolev was a letter signed by four senior engineers at the institute denouncing Korolev of various disruptive activities.[44] The NKVD proffered five separate charges, including an accusation that Korolev had destroyed the RP-318 rocket-plane, even though at the time it sat quite intact in the hangar of the institute's headquarters. The denunciation also stated that both Korolev and Glushko had been "responsible for all errors, omissions, mistakes, and disruptions at the test stands."[45] Exactly a week later, on June 27, 1938, Korolev, barely recovered from his accident, was arrested and taken to the Lubyanka prison.[46] By all accounts, Korolev sincerely believed that his conviction and arrest was a bureaucratic mistake; it seems, however, that his distraught mother, Mariya N. Balanina, had realized the gravity of the situation and sent at least three letters addressed to Stalin himself pleading her son's innocence and expressing grave concern for his health.[47]

39. The new director of NII-3, B. N. Slonimer, and the new deputy director, Kostikov, were formally appointed to their new positions less than two weeks after Kleymenov's arrest. See Golovanov, *Korolev*, p. 235.

40. Rebrov, "Specific Impulse."

41. Vetrov, *S. P. Korolev i kosmonavtika*, pp. 121–22; Mikhail Rudenko, "O chem dymal zhyul vern," *Trud*, September 1, 1993, p. 3.

42. Korolev had been the senior engineer of Group No. 2 at NII-3 since January 1938.

43. Zharkov, "Pobedonostsev's Criteria," p. 76; Vetrov, *S. P. Korolev i kosmonavtika*, p. 122.

44. Romanov and Gubarev, *Konstruktory*, pp. 48–49. Further biased evidence was supplied investigators Bykov and Shestakov.

45. Rebrov, "Specific Impulse." For a detailed explanation of the charges against Korolev, see G. Vetrov, "In Difficult Years" (English title), *Aviatsiya i kosmonavtika* no. 1 (January 1989): 36–37.

46. Anisimov and Oppokov, "Incident at NII-3." The order for Korolev's arrest was issued by the Chief Economic Directorate of the NKVD on the directive of First Deputy Chief Military Procurator G. K. Raginskiy, who himself was arrested in 1939. See B. A. Viktorov, "Restoration of Name" (English title), *Nauka i zhizn* no. 5 (May 1988): 78–82. Korolev was arrested under stipulation of article 58 of the RSFSR criminal code, points 7 and 11, which included charges of being "a member of an anti-Soviet underground counter-revolutionary organization."

47. The first two letters are reproduced in full in Anisimov and Oppokov, "Incident at NII-3," and were dated July 15 and July 22, 1938. An excerpt from the third, dated August 19, 1938, was published in Viktorov, "Restoration of Name."

Korolev was interrogated twice during this period. The first time he denied all charges. During the second occasion, after severe torture and beating, he "confessed" and signed a document implicating himself in the charges. Kostikov had also personally written a letter to the NKVD in July documenting Korolev's "anti-Soviet character." Combined with the false accusations from Kleymenov, Langemak, and Glushko, Korolev did not have to wait very long. On September 27, the Military Collegium of the USSR Supreme Court, under Vasiliy V. Ulrikh, sentenced Korolev to ten years in a "correctional labor camp," with a "deprivation of all rights" for five years and the confiscation of all personal property.[48] The second part of the sentence was merely a euphemism for hard labor at one of the many slave labor camps located throughout the Soviet Union; Korolev was to be sent to the Kolyma Arctic death camp at the Maldyak gold mine near Nagayev Bay in Siberia.[49] Korolev later said of the accusations against him:

> *During the investigation of my case, I could not prove or explain anything because there was no investigation in the proper sense of the word. I was bluntly accused of sabotaging research in new technology. I could not imagine a more absurd and incredible charge because the development of this new technology was the cause of my life and the work I loved.*[50]

Until his transfer to the labor camps, Korolev continued to make efforts to obtain a retrial. Put away at the Novocherkasskiy Prison in southern Russia, he wrote to Stalin himself in February 1939, pleading his innocence against the false charges.[51]

These letters most likely never reached Stalin's eyes and not surprisingly had little effect on Korolev's fate. There were, however, two factors that intersected in 1938–39 that saved Korolev's life. Soon after his imprisonment, a close friend of Korolev's, famed pilot Valentina S. Grizodubova, had joined forces with another famous Soviet aviator, Mikhail M. Gromov, and Korolev's own mother to author a letter to the Central Committee of the Communist Party requesting a review of Korolev's case.[52] The statement apparently reached the office of Nikolay I. Yezhov, the chairman of the NKVD. Although Yezhov was abruptly arrested in November 1938, his successor, Lavrentiy P. Beriya, happened to have a particular interest in the Korolev case. Beriya would eventually make his reputation as one of the cruelest perpetrators of state terror in the Soviet Union, but when he assumed his new role in January 1939, he was more interested in cultivating an image of himself as a humane and fair person. After Beriya's appointment, prosecutor Ulrikh himself wrote to the NKVD to protest Korolev's original sentence. Prompted by the lobbying of Supreme Soviet members Grizodubova and Gromov, Beriya was convinced that Korolev was a good example to display his "humanity." Thus, at a special meeting of the Plenum of the High Court on June 13, 1939, the NKVD agreed to Ulrikh's protest and signed an order changing Korolev's official charge from a "member of an anti-Soviet counter-revolutionary organization" to the less serious "saboteur of military technology" and requested a new trial.[53]

48. Vetrov, *S. P. Korolev i kosmonavtika*, p. 122; Col. M. Rebrov, "The Leader: Little-Known Pages From the Life of S. P. Korolev" (English title), *Krasnaya zvezda*, July 1, 1989, p. 4.

49. Romanov and Gubarev, *Konstruktory*, pp. 48–49.

50. Mariya Pastukhova, "Brighter Than Any Legend" (English title), *Ogonek* 49 (December 1987): 18–23; N. Kidger, "Arrests 'Limited' Rocket Development," letter to the editor, *Spaceflight* 30 (1988): 169.

51. Anisimov and Oppokov, "Incident at NII-3." Other letters were also allegedly written in August and October 1938 and April 1939. See Romanov, *Korolev*, p. 158. Korolev was moved to Novocherkasskiy on October 10, 1938.

52. Viktorov, "Restoration of Name." At the time, it was the All-Union Communist Party (VKP). Gromov's status in the Soviet Union then was in many ways comparable to that of Charles Lindbergh's in the United States. Gromov, along with A. B. Yumashev, had completed the first nonstop airplane flight from the Soviet Union to the United States in 1937.

53. *Ibid.*; Romanov, *Korolev*, p. 159.

Unfortunately for Korolev, it was too late. Less than two weeks prior to the new order, on June 1, he had already started his journey to the Kolyma camp.[54] He traveled by rail in an over-crowded cattle car across the Ural and Baykal mountain ranges before being transported in the hold of a ship along with hundreds of other prisoners across the Sea of Okhotsk. Korolev arrived at Kolyma in August 1939. Given the conditions at the camp, it would have been surprising if he ever believed he would leave it alive. He worked as an Earth digger in a gold mine off the Kolyma River for the ensuing months. It was well known even at the time that of all labor camps of the GULag system, Kolyma was the most brutal and cruel.[55] During operations throughout World War II, the camp claimed the lives of between 2 and 3 million people. Most of the deaths were from overwork, famine, cruelty from the guards, and the harsh Arctic climate. In the first months, Korolev was so brutally treated that he was left with a huge scar on his head and lost half his teeth from scurvy. He also had the misfortune of arriving at Kolyma during one of the worst winters in its entire history of operations. Despite the inhuman conditions at Kolyma, Korolev continued to make efforts to deny his guilt. In a letter dated October 15, he wrote to the Soviet Union's chief procurator demanding his immediate return to Moscow.[56] Addressed to Andrey Yu. Vyshinskiy, the powerful lawyer and diplomat who was personally responsible for sending thousands to their deaths, Korolev wrote, "I have been foully slandered by the institute director, Kleymenov, his deputy, Langemak, and engineer Glushko."[57] He was apparently unaware that Kleymenov and Langemak had been executed.[58]

Glushko meanwhile had been sentenced in absentia to eight years in prison on August 15, 1939, during a special session of the NKVD. They sent him to a prison for scientists and engineers in Tushino near Moscow, part of a larger network of prisons that specifically held the scientific intelligentsia of the country.[59] The inmates referred to such prisons as *sharashka*, a word deriving from the Russian slang expression meaning a "sinister enterprise based on bluff or deceit."[60] Of the other major individuals at NII-3, both Tikhonravov and Pobedonostsev, for reasons unclear, escaped hardship, and they remained behind to work at a revamped NII-3. In November 1937, the institute had been transferred to the Commissariat for Ammunitions, the "ministry" responsible for the production of a variety of artillery weapons systems.[61] This change also presaged a major thematic restructuring in the direction of work at NII-3 as Kostikov was appointed director of the institute in late 1939. Most of the post-purge efforts at NII-3 were focused on the development of launch equipment and solid-fuel missiles for use by the artillery forces. Some work on earlier projects, such as Korolev's 212 missile and the RP-318 rocket-plane, was allowed to continue, but it is clear that there was a significant turn in research at the institute—one that effectively stilted many years of fruitful work.

54. Golovanov, *Korolev*, p. 264.

55. GULag is the Russian acronym for Chief Directorate of Camps.

56. Vetrov, *S. P. Korolev i kosmonavtika*, pp. 126–30; Pastukhova, "Brighter Than Any Legend." An earlier letter to Stalin was dated August 13, 1939.

57. German Nazarov, "You Cannot Paper Space With Rubles: How to Save Billions" (English title), *Molodaya gvardiya* no. 5 (April 1990): 192–207.

58. In fact, as late as July 1940, Korolev was still in the dark about their fate.

59. This was Plant No. 82. Initially, Glushko worked under a section headed by the noted aeronautical engineer B. S. Stechkin. See Boris Katorgin and Leonid Sternin, "Pushing Back the Missile Technology Frontiers," *Aerospace Journal* no. 5 (September-October 1997): 88–90; N. L. Anisimov and V. G. Oppokov, "Incident at NII-3: II" (English title), *Voyenno-istoricheskiy zhurnal* no. 11 (November 1989): 65–71.

60. Aleksandr Solzhenitsyn, *The First Circle* (New York: Harper & Row, 1958), p. ix, referenced in James Harford, *Korolev: How One Man Masterminded the Soviet Drive to Beat America to the Moon* (New York: John Wiley & Sons, Inc., 1997), p. 57.

61. Lardier, *L'Astronautique Soviétique*, p. 44. Another source suggests that this transfer occurred in 1940. See B. Ye. Chertok, *Rakety i lyudi* (Moscow: Mashinostroyeniye, 1994), p. 35.

Beriya's change-of-heart in 1939 prompted officials to search out Korolev in the camps. After what must certainly have been the most torturous period of his life, in December 1939, the starved Korolev was located at Kolyma and put on a train back to Moscow. Of the 600 individuals who had been at the camp when Korolev had arrived, only 200 remained alive when he left. In Khabarovsk in the Soviet far east, he received medical attention for the first time and eventually ended up in Moscow on March 2, 1940, incarcerated in cell number 66 at the notorious Butyrskiy Prison, one of the more physically and psychologically degrading facilities of the GULag system.[62] Soon after, the NKVD, under Beriya's watchful eye, undertook an investigation into Korolev's case, which concluded on May 28, 1940. The secret police handed down its sentence more than a month later on July 10, effectively sealing Korolev's fate for several years: the official sentence stated the Korolev would be "deprived of his freedoms" for the next eight years.[63] Although the verdict saved him from another trip to the death camps, it was another cruel blow for Korolev. Once again, he wrote several letters to Stalin, Beriya, and the chief procurator in the following months.[64] It was clear that he was not willing to give up on his plight.

While his lobbying efforts may not have had an effect on his imprisonment, an unrelated event at the time would eventually save Korolev from the trials of the Butyrskiy Prison. Famous Soviet aircraft designer Andrey N. Tupolev had also been incarcerated during the purges in October 1937. He had been sent off first to Moscow's dreaded Lubyanka Prison and then soon to the slightly "better" Butyrskiy facility also in Moscow.[65] Perhaps because of the impending war effort, Stalin apparently took a personal interest in those who had worked or studied under Tupolev. Stalin ordered Tupolev to prepare a list of individuals who could be useful for work in support of the aeronautical industries. One of those on the list of twenty-five was Korolev, who had studied under Tupolev as a young college student.[66] Thus in September 1940, Korolev was transferred from Butyrskiy to a newly formed aviation design bureau located in Stakhanov village near Moscow under Tupolev's nominal command. The facility remained under the direct control of the 4th Special Department (for new technology) of the NKVD.[67] Officially designated the Central Design Bureau No. 29 (TsKB-29), the plant was another of the *sharashka* system, with all the engineers serving as prisoners of the Soviet state. The inmates were housed in a special prison with barracks and were guarded at all times. One of those who was also incarcerated at TsKB-29 recalled his own arrival at the *sharashka*:

> *We were taken to the dining room . . . heads turned to our direction, sudden exclamations, people ran to us. There were so many well-known, friendly faces. At the tables we can see A. N. Tupolev, V. M. Petliakov, V. M. Myasishchev, I. G. Neman, S. P. Korolev, A. I. Putilov, V. A. Chizhevskiy, A. M. Cheremukhin, D. S. Makarov, N. I. Vazenkov—the elite, the cream of Russian aircraft technology. . . . It was impossible to conceive that they had all been arrested, and they were all prisoners—this meant a catastrophe for Soviet aviation!*[68]

62. Vetrov, *S. P. Korolev i kosmonavtika*, p. 123.

63. Anisimov and Oppokov, "Incident at NII-3: II."

64. The letter dated July 13, 1940, to Stalin and the documents dated July 23 to the chief procurator and Beriya and September 13 to the chief procurator are reproduced in full in *ibid.*

65. Robert Conquest, *The Great Terror: A Reassessment* (New York: Oxford University Press, 1990), p. 295.

66. There are differing accounts as to how many names were actually on this alleged list. For example, one fellow prisoner whose name was also on the same list, L. L. Kerber, recounted in 1991 that there were 200 names on Tupolev's list. See Harford, *Korolev*, p. 59. See also A. Romanov, "Force of Spirit" (English title), *Trud*, February 26, 1988, p. 3, in which S. M. Yeger, another prisoner, claims that twenty-five people were on the list.

67. Vetrov, *S. P. Korolev i kosmonavtika*, p. 125; Romanov and Gubarev, *Konstruktory*, pp. 50–51; Romanov, *Korolev*, p. 160.

68. A. Sharagin, *Tupolevskaya Sharaga* (Frankfurt: Georgi Aleksandrovich Ozerov, 1971), pp. 13–14. A slightly different translation is used in McDougall, . . . *the Heavens and the Earth*, p. 38.

Prisoners of War

The beginning of World War II was an unexpected blow for the Soviet Union. The German invaders advanced rapidly over Soviet territory toward the major cities of the nation. While the Great Purges had been a tragic setback for Soviet rocketry, the war provided an unexpected setting for the organization of sporadic and disparate rocketry efforts that trained and gave experience to a new generation of engineers weaned on wartime conditions. In the initial period of the war, none of the efforts were directed toward anything more than modest solid-fuel rockets for use on either aircraft or as short-range artillery weapons.

For Korolev, the work at TsKB-29 was a far cry from his earlier goals. The primary thematic work of the group was the quick fruition of project 103 to build a military bomber designated the Tu-2.[69] The bomber eventually went into operation in October 1942, and it was then that the NKVD acted on Korolev's repeated requests to be transferred to work on rocket engines. In November, Korolev was moved to a special design bureau working at Aviation Plant No. 16 in Kazan.[70] This facility was also part of the NKVD prison system and effectively operated by the secret police. It comprised several subordinate teams working on different problems. By coincidence, one of these groups, Design Bureau No. 2, was headed by none other than Korolev's former NII-3 associate Glushko. The latter had spent the immediate prewar years in Tushino working for ramjet specialist Boris S. Stechkin before being moved to Kazan in 1940. The primary goal at the design bureau in Kazan was to develop auxiliary liquid-propellant rocket engines to assist in the takeoff phases of a variety of propeller-driven aircraft. Korolev himself was appointed chief of Group No. 5 in charge of reactive units in January 1943.[71] Thus, about five years after his arrest, Korolev eventually found his way back into the design of liquid-propellant rocket engines, although clearly it was not with the same goals in mind as RNII or GIRD had proposed years before.

While few personal details are available of Korolev's time at the Kolyma mines, his years at the Tupolev prison and at Plant No. 16 in Kazan have been better documented. The first impressions of those who saw Korolev after he first arrived to work for Tupolev were not encouraging. Another prisoner recalled:

> *He [Korolev] looked terrible. He was emaciated and exhausted. Tupolev showed a lot of care in his relationship with Korolev which we could not understand. Apparently, he valued qualities of Korolev that we did not notice at the time. He was industrious, responsible, and had an interest in creative solutions.*[72]

The NKVD never really relinquished their hold on Korolev. Legend has it that their agents told Korolev, upon arrival at the Tupolev *sharashka*, that "our country doesn't need your fireworks. Or maybe you're making rockets for an attempt on the life on our leader?"[73] There are reports that Korolev was "absolutely firm, never disguising his contempt for the regime."[74]

69. Yuriy Biryukov and Vikentiy Komarov, "S. P. Korolev in the 'Sharashka'" (English title), in Shcherbakov, ed., *Zagadki zvezdnykh ostrovov*, p. 103. The airplane flew its first flight in January 1941. Because of the rapid advance of Germans into Soviet territory, TsKB-29 itself was moved in July of that year to a different location at Plant No. 166 in Irtysh, near Kulomzino in the Omsk region. See Biryukov and Komarov, "S. P. Korolev in the 'Sharashka'," p. 103; Lardier, *L'Astronautique Soviétique*, p. 46.

70. Biryukov and Komarov, "S. P. Korolev in the 'Sharashka'," p. 104; Romanov and Gubarev, *Konstruktory*, p. 53.

71. Biryukov and Komarov, "S. P. Korolev in the 'Sharashka'," p. 105.

72. Rebrov, "The Leader." The associate was S. M. Yeger.

73. Conquest, *The Great Terror*, p. 294.

74. James E. Oberg, "Korolev and Khrushchev and Sputnik," *Spaceflight* 20 (April 1978): 144–50.

Professor Georgiy A. Ozerov, a Soviet engineer who knew Korolev in the *sharashka*, described him as "a cynic and a pessimist who took the gloomiest view of the future." One of Tupolev's deputies also recalled later that Korolev's favorite phrase in prison was "we will all vanish without a trace."[75] Apparently, he was very contemptuous of the regime and fully expected to be shot. Others say that Korolev never doubted the "honesty and sense of justice" of Stalin.[76] This is partly borne out by his letters addressed to Stalin from both Kolyma and the Butyrskiy Prison. It seems that only after the denunciations by Khrushchev in 1956 did Korolev realize the magnitude of Stalin's ruthlessness during the purges. A fellow prisoner of Korolev's at the NKVD prison, Esfir M. Rachevskaya, relayed one particularly touching anecdote. She recalled later how one day the radio was playing Aram Khachaturyan's violin concerto:

> *I felt homesick. I wanted to be back home, in Moscow, with my family and friends. Tears ran down my cheeks, and I looked round to see Korolev standing beside me with tears in his eyes too. After looking at him, I began to cry most bitterly. He went back into the office, and when I returned, he was sitting at his desk absorbed in his work.*[77]

The Presidium of the Supreme Soviet, no doubt on orders from the NKVD, signed an official order (protocol no. 18) on July 27, 1944, officially releasing both Glushko and Korolev from confinement.[78] They were among a group of thirty-five engineers freed at the time, cited for their "contribution in building aircraft jet boosters."[79] The effects of the decree went into effect on August 10, but it is clear that given the wartime conditions and the continuing threatening nature of the NKVD, little changed in either of their lives. In fact, both Korolev and Glushko still officially remained convicts of the Soviet state because their original sentences were not overturned. With their release, Glushko's group, Design Bureau No. 2 of Plant No. 16, was officially moved from under the jurisdiction of the NKVD to the aviation industry and renamed the Special Design Bureau for Special Engines (OKB-SD).[80] Glushko was appointed the chief designer and Korolev his deputy. The irony of Korolev's position as Glushko's deputy was not lost on either as their positions had been effectively reversed from the days of RNII in the 1930s.

Still focused more on aviation applications than pure rocketry, all of the work at this location was dedicated to the use of liquid-propellant rocket engines, such as the RD-1KhZ, RD-2, and RD-3, on Soviet fighter planes designed by Lavochkin, Sukhoy, and Yakovlev.[81] In his new state of "freedom" and as the deputy chief designer of OKB-SD, Korolev apparently made an attempt to interest the leaders of the aviation industry in long-range missiles. On October 14, 1944, just over two months after his release, he submitted a report to First Deputy People's Commissar of Aviation Industry Petr V. Dementyev on the possibility of developing two long-range missiles fueled by solid propellants. Both of these, the unguided ballistic D-1 and the winged guided D-2, used elements of a prewar missile named the 217, which had been the

75. Leonid Vladimirov, *The Russian Space Bluff* (New York: The Dial Press, 1973), p. 146; Vetrov, *S. P. Korolev i kosmonavtika*, p. 135. The deputy was L. L. Kerber.

76. Pastukhova, "Brighter Than Any Legend."

77. V. Lysenko, ed., *Three Paces Beyond the Horizon* (Moscow: Mir Publishers, 1989), pp. 33–34. See also A. Yu. Ishlinskiy, ed., *Akademik S. P. Korolev: ucheniy, inzhener, chelovek* (Moscow: Nauka, 1986), p. 141.

78. Romanov, *Korolev*, pp. 192–93.

79. Katorgin and Sternin, "Pushing Back the Missile Technology Frontiers."

80. Biryukov and Komarov, "S. P. Korolev in the 'Sharashka'," pp. 106–07. When NII-1 was formed in May 1944, Glushko's design bureau may have been subsumed as part of the NII-1 system as a sector in the institute. See C. Wachtel, "The Chief Designers of the Soviet Space Program," *Journal of the British Interplanetary Society* 38 (1985): 561–63; Lardier, *L'Astronautique Soviétique*, p. 62.

81. A good summary of the work at OKB-SD is provided in Vetrov, *S. P. Korolev i kosmonavtika*, pp. 157–74.

focus of work at NII-3. The proposed ranges of the vehicles were, respectively, sixty and a half kilometers and 115 kilometers.[82] The missiles had capabilities comparable to the German A-4 but were obviously derived from different antecedents. In a clear indication of Korolev's long-dormant dreams, he even proposed using the D-2 for "manned flight."

In submitting a later report on the D-1 and D-2 in December 1944, Korolev laid down a specific timetable for the development of the two vehicles, emphasizing their military utility. Korolev did not understate the required leap of technology and management required for such a project, adding that: "The tasks we face are immense and the altitudes we want to reach are such as our predecessors and teachers of the pioneer days . . . could only dream. . . ."[83] As the war raced to a close in early 1945, Korolev was allowed to work on a second version of the D-1/D-2 project draft, although much if not all the work at the OKB-SD remained focused on rocket accelerators for airplanes. It seems that the leadership of the aviation industry had little interest in involving itself in the development of ballistic missiles, an attitude that eventually put the early postwar Soviet efforts in rocketry firmly in the hands of a resourceful group of artillery people.

The work at OKB-SD may have given refuge to a beleaguered Korolev, but the most important Soviet liquid-propellant rocketry research was carried out elsewhere, in a new institute formed in 1944 by combining the efforts of two other aeronautical and rocketry organizations. The first of these was Kostikov's NII-3, which during the early part of the war developed missiles for the famous *Katyusha* system to which most Russian historians continue to refer in almost mythical terms.[84] On July 15, 1942, the aviation industry took control of NII-3 at the same time that Kostikov's rising star reached its zenith. Having gained innumerable honors in his rise to power, Kostikov was suddenly arrested on March 15, 1944, on charges of deceiving the Soviet government and Stalin personally in connection with a rocket plane project.[85] By this time, aviation industry leaders had formulated a plan to merge NII-3, now renamed the State Institute for Reactive Technology, with a second organization.

This second entity had been formed in Moscow in the mid-1930s as a small aircraft design bureau under the leadership of Viktor F. Bolkhovitinov. After relocating in 1937 to Kazan, two years later, the group settled down at Khimki as the Special Design Bureau of Plant No. 293. By 1944, the team, made up mostly of young talented engineers, had developed one of the first Soviet rocket planes, the BI-1, and they were moving on to more advanced designs.[86] Among this group were Aleksandr Ya. Bereznyak, Konstantin D. Bushuyev, Boris Ye. Chertok, Aleksey M. Isayev, Mikhail V. Melnikov, Vasiliy P. Mishin, and Arvid V. Pallo—individuals who would all eventually play critical roles in the emergence of the Soviet space program in the 1950s and 1960s. To consolidate scarce resources during the war, the aviation industry signed a merger decision on May 29, 1944, which effectively united the old NII-3 and Bolkhovitinov's team into a new institute designated Scientific Research Institute No. 1 (NII-1).[87] Maj. General Petr I.

82. *Ibid.*, pp. 178–85; Biryukov and Komarov, "S. P. Korolev in the 'Sharashka'," p. 108. The ranges were thirty-two and seventy-six kilometers, respectively, in the initial draft of the project.

83. Stache, *Soviet Rockets*, p. 162.

84. Riabchikov, *Russians in Space*, pp. 135–36. The RS-82 and RS-182 missiles designed by the executed Langemak were used as a basis to design the Katyusha rockets, although Kostikov apparently took credit for their genesis.

85. Anisimov and Oppokov, "Incident at NII-3"; Romanov and Gubarev, *Konstruktory*, p. 46; Lardier, *L'Astronautique Soviétique*, p. 46; Vetrov, *S. P. Korolev i kosmonavtika*, p. 141.

86. Riabchikov, *Russians in Space*, p. 134; Chertok, *Rakety i lyudi*, pp. 18–21.

87. Chertok, *Rakety i lyudi*, p. 144; Lardier, *L'Astronautique Soviétique*, p. 61; Wachtel, "The Chief Designers of the Soviet Space Program." The old NII-3 (known as GIRT since July 15, 1942) was originally reorganized into the Scientific-Research Institute for Reactive Aviation (NII RA) on February 18, 1944. The same NII RA was then combined with Bolkhovitinov's Plant No. 293 later on May 29 of the same year to become NII-1. See Rostislav Angelskiy, ". . . And if not Korolev?" (English title), *Aviatsiya i kosmonavtika: vchera, segodnya, zavtra* no. 4 (1998): 22–26.

Fedorov, the former deputy director of a major research institute in the Soviet Air Force, was appointed the first director of NII-1, with Bolkhovitinov as his deputy. Fedorov established at least five sections in the new institute, three of which were exclusively dedicated to the development of liquid-propellant rocket engines for use on military aircraft. Although the thematic direction of the work at the new NII-1 was little different from that of its component organizations, the unification served as a means to bring some order into the somewhat chaotic rocketry efforts during World War II.

Raketa

The Soviet leadership in 1944 had no interest in creating a program for the development of ballistic missiles in support of the war effort. Despite this lack of enthusiasm for indigenous efforts, there was considerable interest in acquiring and studying concurrent German rocket technology. Without a doubt, the most technologically sophisticated and advanced rocketry program during the war existed in neither the United States nor the Soviet Union, but at Peenemünde in Germany under the administrative leadership of General Walter Dornberger. With the young Wernher von Braun as the technical head of operations, Dornberger's group of highly talented individuals had, by the end of the war, developed one of the most feared weapons of World War II, the A-4 ballistic missile. More commonly known as the V-2, or "vengeance weapon," in German, the A-4 performed its first successful launch on October 3, 1942, after three failures in March, June, and August of the same year. With a maximum range of about 300 kilometers and a capability to reach altitudes of close to ninety kilometers, the A-4 was produced in the thousands by slave labor in the latter part of the war as almost a last-gasp attempt by the Nazis to turn the inevitable course of the war. A second weapon, the Fieseler Fi-103 "flying bomb," also known as the V-1, was part of this intense German campaign to numb Great Britain into submission. Although casualties were relatively low compared to aerial bombing, the specter of the two missiles produced an unimaginable sense of terror among the mostly civilian victims.

In a letter dated July 13, 1944, British Prime Minister Winston Churchill personally requested Stalin's cooperation in locating and retrieving A-4 and Fi-103 production materials that the Germans were leaving behind with their retreat.[88] Churchill's prime concern was that British intelligence officers be allowed to inspect and examine any captured A-4 components from the experimental missile station at Debica near Krakow in Poland, which, by July 1944, was only about fifty kilometers from the Soviet frontlines. As they began their retreat in mid-1944, the Germans had, however, done a fairly good job of destroying all possible remnants of their research.

Stalin ordered the formation of a secret expeditionary group of Soviet specialists to investigate the remains at Debica. People's Commissar of Aviation Industry Aleksey I. Shakhurin tapped the NII-1 organization to help set up an advance team. Under the watchful eye of the NKVD, on August 5, Maj. General Fedorov led a small group of NII-1 engineers, including Korolev's old RNII associates Tikhonravov and Pobedonostsev, to Debica.[89] Initially, the Soviet team collected some interesting parts, such as an A-4 combustion chamber and parts of propellant tanks, before allowing British teams to enter a week later to conduct their own investigations. Highly accurate aerial maps prepared by the latter were instrumental in locating more fallen A-4 debris from test firings that the Germans had conducted. Recovered parts from the missile were soon loaded into

88. The complete text of this letter is reproduced in Chertok, *Rakety i lyudi*, pp. 86–87.

89. *Ibid.*, pp. 87–88; Yu. P. Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya "Energiya" imeni S. P. Koroleva* (Korolev: RKK Energiya, named after S. P. Korolev, 1996), p. 18. Others going to Debica were N. G. Chernyshov, R. Ye. Sorkin, M. Ye. Shekhtman, and Yu. A. Fedosyuk.

Li-2 transport aircraft and returned to Moscow under tight NKVD security. Upon return to Moscow, with the exception of NII-1 Director Fedorov and Deputy Director Bolkhovitinov, almost all the employees of NII-1 were kept in the dark about the entire operation. Eventually, the NKVD loosened some of their restrictions, and Bolkhovitinov was ordered to establish a very small group of talented engineers to study the engineering aspects of the A-4. This section of A-4 researchers was given the top-secret designation *Raketa*, the Russian word for "missile," and included RNII veterans Tikhonravov and Pobedonostsev, Plant No. 293 alumni Bereznyak, Bushuyev, Chertok, Isayev, and Mishin, and newcomers Nikolay A. Pilyugin and Leonid A. Voskresenskiy.[90]

Possibly the youngest of the group was Vasiliy Pavlovich Mishin, a specialist in control systems who, twenty years later, would lead the Soviet program to land a cosmonaut on the Moon. He was born on January 5, 1917, in the village of Byualino not far from Moscow. His brother and sister died in childhood, and his family disintegrated soon after. The young Mishin was raised by his grandfather because his father had been jailed for several years for not informing on a person who had told a joke about Stalin. After his father's release, Mishin moved to Moscow and qualified as one of the lucky entrants into the prestigious Moscow Aviation Institute in 1935. He was 18 at the time and apparently considered a very bright student. There, Mishin did his prediploma work under the aircraft designer Bolkhovitinov. Passionately in love with flying, Mishin was also well known as one of the first pilots in the Soviet Union to master a "self-starting" piloting technique without outside assistance. Later in 1940, he was called up for work at Bolkhovitinov's Plant No. 293 and took part in the development of the one of the world's first rocket-powered airplanes, the BI-1, which flew successfully in 1942.[91] Mishin was one of many of Bolkhovitinov's engineers transferred to NII-1 in early 1944, and after the A-4 fragments were recovered in August, he became one of the leading members of the group. Equipped with a very assertive personality, he was instrumental in extracting important information on the workings of the German missile from the few scraps that were recovered. Because of his father's "suspect" background, Mishin was apparently considered somewhat of a state risk and was not allowed to travel anywhere without permission.

The primary goals of the 1944 recovery operations were to determine whether the possibility existed of creating an analog of the A-4 weapon in Soviet industry. It seems that the evaluation team was actually organized on two different levels. While the Raketa group at NII-1 was kept busy with a technical investigation of the recovered remains, a second group was tapped to advise Stalin and the Soviet leadership on the possible uses of such weapons—that is, their utility in wartime conditions. This process was the catalyst for introducing a second group of individuals, the artillery officers, who would play a very significant role in the future development and operation of the Soviet space program.

In the late summer of 1944, the Chief of Staff of the Third Army's Katyusha Rocket Launcher Unit Operations Group, Major Georgiy A. Tyulin, was recalled from his duties for a top secret assignment.[92] A thirty-year-old officer serving in the Chief Artillery Directorate, Tyulin had studied at the aerodynamics laboratory at Moscow State University in the late 1930s and, since 1941, had been one of the leading experts in handling rocket operations. His reassignment led him to a top secret scientific and technical division headed by a Lt. Colonel Anatoliy

90. Romanov and Gubarev, *Konstruktory*, p. 57; Romanov, *Korolev*, pp. 203–04; Chertok, *Rakety i lyudi*, p. 88. Others in the Raketa group were Bordachev, A. A. Borovkov, I. F. Florov, and Yu. A. Konovalov.

91. A. Tarasov, "Missions in Dreams and Reality" (English title), *Pravda*, October 20, 1989, p. 4; Mikhail Rebrov, "The Last Argument: A Study of the Designer in Black and White" (English title), *Krasnaya zvezda*, March 25, 1995, p. 6.

92. Lt. Gen. (Ret.) G. Tyulin, "The 'Seven': Years, Accomplishments, People" (English title), *Krasnaya zvezda*, April 1, 1989, pp. 3–4.

I. Semenov, under whose leadership he was to study captured German Fi-103 and A-4 missiles. The entire effort was coordinated by the Communist Party through the auspices of Maj. General Lev M. Gaydukov, a member of the Military Council of the Mortar Guards Unit and simultaneously chief of the Party Central Committee's department for artillery affairs.[93]

It is not clear whether the NII-1 Raketa group had any significant personal interaction with artillery officers Tyulin or Semenov, but clearly their individual findings were coordinated. According to Tyulin, he was to "thoroughly study models of German field rocket artillery, large quantities of which were available at the captured ammunition depots, and to prepare proposals on developing future rocket systems."[94] In studying the Fi-103 cruise missile, Tyulin was evidently not impressed with its wartime capabilities and concluded that it would not be worthwhile to engage in immediately developing a replica of the vehicle. His reasoning may have stemmed from its slow speed and vulnerability to anti-aircraft defenses. On the other hand, it seems Tyulin had been far more impressed with the A-4. On developing some vision of future military strategy, Tyulin's assessments may have been limited by the minuscule knowledge about the A-4 available to the Soviets at the time. At one early meeting with his superior, he was asked what his group had learned about the missile; Tyulin recalled saying that "we know practically nothing about the [A-4] missile except that it flies."[95] By late 1944, Semenov and Tyulin prepared a recommendation for Maj. General Gaydukov that called for heightened efforts to capture as much A-4 materials as possible; they strongly emphasized the importance of such weapons for the artillery sector in wartime conditions.

In the NII-1 Raketa group, work on reconstituting the A-4 progressed slowly at first but began to pick up pace by the end of 1944. Engineer Isayev later recalled that:

> *In the summer of 1944 a pile of bent steel, broken glass, electrical cable, and battered housing, filled with electronic devices, was brought into the conference room of our institute. . . . For the next two months the conference room became a laboratory where designers reconstructed the Hitlerite "wonder weapon" from broken pieces of sheet metal, aluminum, and electron tubes. . . .*[96]

Mishin added: "We quickly traced out from the pieces the layout of the rockets and the pneumatic systems, and calculated trajectories; our mathematician, Yuriy Konovalov, was outstanding in this task."[97] What the Soviets extrapolated from the recovered debris stunned the members of the Raketa group. The capabilities of the A-4 were far in advance of any missile produced or even planned by the Soviets during the war. Swallowing their collective pride, in two months, Raketa head Bolkhovitinov was able to produce a lengthy report on their findings and submitted it officially to his bosses, Commissar of the Aviation Industry Shakhurin and his First Deputy Dementyev.[98] Bolkhovitinov's recommendations were clear: efforts should be made to reconstitute and recreate the German A-4 missile, while at the same time creating a modernized version for the military. Unfortunately for those at NII-1 and the aviation industry in general, neither Shakhurin nor Dementyev were particularly interested in putting resources into developing missiles. Both apparently were perfectly happy to let the People's Commissariat of Ammunitions do that job, given that the latter sector had manufactured the literally thousands of solid-fuel Katyushas that the Soviets had used to terrorize the Nazis. Shakhurin did not make

93. For Gaydukov's posts, see, Chertok, *Rakety i lyudi*, pp. 123–24; Lardier, *L'Astronautique Soviétique*, p. 49.
94. Tyulin, "The 'Seven'."
95. *Ibid.*
96. Stache, *Soviet Rockets*, p. 168.
97. Tarasov, "Missions in Dreams and Reality."
98. Carl-Fredrik Geust, *Under the Red Star* (Shrewsbury, UK: Airlife, 1993), p. 114.

the decision blindly. He apparently called together a meeting of the most prominent Soviet aviation designers, such as Tupolev, Yakovlev, Mikoyan, and Lavochkin, to hear their recommendations on the issue. Not surprisingly, none believed that rockets had any utility as military weapons in the near future; fighters and bombers would do fine for now.[99] Shakhurin dissolved the Raketa team in November and put them back into their earlier work. This decision was apparently taken very hard by Bolkhovitinov's team, and he, "at his own risk," instructed Mishin to continue calculations on the A-4 missile based on the analysis of recovered parts.[100]

There was a short resurgence of interest in early 1945, when information was received at the institute that additional pieces had been located at Debica. To investigate, a second team, this one headed by NII-1 Director Maj. General Fedorov, left Moscow on February 7, 1945. Unfortunately, over Kiev, the aircraft lost control and crashed, killing all twelve crew members and passengers on board. Mishin was supposed to be on the flight, but at the last minute Soviet security officials did not allow him to board the aircraft, replacing him with engineer Aleksey A. Borovkov. The secret police believed that he would be a security risk because his father had an unfavorable prison record.[101]

Shakhurin's rejection of the possible uses of the A-4 missile in late 1944 eventually had significant repercussions for the institutional backdrop of the Soviet space program. Twenty years in the future, the Soviet Air Force would pay the price for Shakhurin and Dementyev's decision to stay out of missiles. While not interested in the A-4, Shakhurin was, however, much more attracted to the capabilities of the Fi-103 cruise missile. Perhaps because of its physical similarity to aircraft, Shakhurin and Dementyev believed that this weapon held greater promise. This interest in the cruise missile helped start the *third* wartime rocketry effort, other than Glushko's OKB-SD and Bolkhovitinov's NII-1—one to reproduce the German Fi-103. The job went to a brilliant thirty-year-old mathematician named Vladimir Nikolayevich Chelomey, whose later role as one of the powerhouses of the Soviet space program would be the stuff of legends.

Born on June 30, 1914, in the small Ukrainian town of Sedlets, Chelomey graduated from the Kiev Aviation Institute in 1937—the same institute at which Korolev had studied in the mid-1920s. He was an exceptionally gifted student. As an undergraduate, Chelomey published his first textbook on vector analysis, and in 1938 alone, he published fourteen articles on mathematics in the official journal of the Kiev Aviation Institute. In 1939, he defended his master's dissertation at the Institute of Mathematics at Kiev. Based on his remarkable intellectual gifts, Chelomey was selected as one of fifty of the most promising students in the Soviet Union and entered a special postgraduate program soon after. By 1941, he was a sector chief at the P. I. Baranov Central Institute of Aviation Engine Building and began some fairly important work on the development of pulse-jet engines—research that in many ways paralleled that of the Germans on the Fi-103 missile. Unaware of the German work, Chelomey had proposed the development of a pulse-jet cruise missile in 1943, but his idea had been rejected at the time. Later in 1944, Stalin had called in Shakhurin and Air Force Commander-in-Chief Marshal Aleksandr A. Novikov and ordered them to start a crash program to develop an analog of the German missile. On the night of June 13, 1944, at a meeting of the State Committee for War

99. Mikhail Rebrov, "Plans That Failed to Live up to Hopes, or No Prophets in Our Fatherland" (English title), *Krasnaya zvezda*, December 27, 1997, p. 6.

100. B. Konovalov, "From Germany to Kapustin Yar" (English title), *Izvestiya*, April 6, 1991, p. 3. See also Boris Konovalov, *Tayna Sovetskogo raketnogo oruzhiya* (Moscow: ZEVS, 1992), p. 7.

101. Tarasov, "Missions in Dreams and Reality"; Chertok, *Rakety i lyudi*, p. 89; Lardier, *L'Astronautique Soviétique*, pp. 61–62. Among those killed were Raketa veterans A. A. Borovkov and Yu. V. Konovalov, solid-propellant specialist L. E. Shvarts, and NII-1 Sector Heads S. S. Dementyev and R. I. Popov. NII-1 Director Fedorov was replaced by Ya. L. Bibikov.

attended by Shakhurin and Novikov, Stalin signed an order for Chelomey to proceed with work on creating a long-range winged missile using a pulse-jet engine.[102] Chelomey received all the facilities he needed; on October 19, he was officially appointed chief designer at Plant No. 51 of a design bureau that had been headed by the recently killed famous aviation designer Nikolay N. Polikarpov.[103]

It seems Chelomey that had enacted a very accelerated program and went through ten different design configurations before settling on a missile that was quite similar to the German Fi-103. Designated the 10X, Chelomey directed sixty-three launches of the missile between March and August 1945.[104] Air-launched from the Pe-8 bomber, the tests produced modest results, and there was little hope that the missile could be used actively in battle during the waning days of the war. In March 1945, Chelomey was summoned to the presence of Stalin and Beriya to discuss the future of the missile. In a moment of tension, Beriya bluntly asked Chelomey whether he had appropriated the design of the 10X from the German Fi-103. Chelomey replied, "I obviously could not have borrowed their ideas. Whether the Germans [stole] my ideas is a question for you, Lavrentiy Pavlovich."[105] It was a typically fearless response from Chelomey, and such ambition and assertiveness would eventually posit him as one of the major players in the early Soviet space program. As for the 10X missile, in the end it did not produce very encouraging results, although Chelomey continued to pursue the work by upgrading the performance characteristics of the rocket. Meanwhile, by late 1945, the Soviets had captured the remains of the German Fi-103, and the Fi-103's clear superiority to the 10X may have prompted Chelomey to rethink his future plans.[106]

Chelomey's work at OKB-51 was the third major Soviet rocketry effort during the war. It seems that all three groups—NII-1, OKB-SD, and OKB-51—worked fairly independently of each other, despite the fact that from 1944, all were employed by the same "ministry," the People's Commissariat of Aviation Industry. Clearly none of the design bureaus conducted any major work on long-range ballistic missiles, the necessary prerequisite to the early space program. It would, in fact, take firsthand experience with the remains of the German rocketry program in the immediate postwar years to finally integrate and produce the first dedicated ballistic missile program in the Soviet Union. By 1945, however, each of the major players in that program had served their apprenticeship. For Korolev, and the rest of the aeronautical engineers in particular, despite severe obstacles and setbacks such as the Purges and the war itself, a solid training ground in the 1930s and 1940s had produced a number of bright and sharp individuals—all equipped to handle postwar challenges. If the rocket societies of the 1930s can be called the schools of apprenticeship for Korolev, Glushko, Tikhonravov and others, then the years 1945 and 1946 were to be their baptism from isolated technicians into pragmatic scientists, who would eventually have the industrial might of the nation behind them.

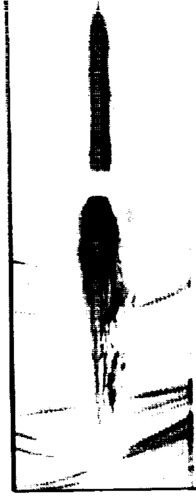
102. N. N. Bogolyubov, *et al.*, eds., *V. N. Chelomey: izbrannyye trudy* (Moscow: Mashinostroyeniye, 1989), pp. 6–7, 10.

103. Rostislav Angelskiy, "Like the German 'V' There Was the Russian 'Tenth X'" (English title), *Aviatsiya-kosmonavtika* 19 (August 1996): 27–40. Note that another source suggests that the date of his appointment was September 17, 1994. See Golovanov, *Korolev*, p. 727. The official order to produce an Fi-103-type analog was signed by Shakhurin on January 18, 1945.

104. Angelskiy, "Like the German 'V'"; Steven Zaloga, *Target America: The Soviet Union and the Strategic Arms Race, 1945–1964* (Novato, CA: Presidio, 1993), p. 113. Other sources suggest that the tests began in December 1944. See Bogolyubov, *et al.*, eds., *V. N. Chelomey*, p. 10.

105. Nina Chugunova, "V. N. Chelomey. Highlights of His Biography" (English title), *Ogonek* no. 4-5 (January 1993): 24–29; Valeriy Rodikov, "Im vremya dast tainstvennuyu znatnost . . . ," in Shcherbakov, ed., *Zagadki zvezdnykh ostrovov*, pp. 5–7.

106. One of the major limitations of the 10X was the inaccuracy of its guidance system, and it was this particular factor that seems to have precluded full production of the missile for the Soviet Air Force. See Zaloga, *Target America*, p. 113.



CHAPTER TWO
FIRST STEPS

At the end of World War II in May 1945, the Soviet Union was in almost total ruins. No other nation in the world was as devastated and crippled by the war. Approximately 27 million Soviet people lay dead by the end of 1945.[1] In addition, with as many as 1,700 of the nation's cities destroyed, the industrial infrastructure was stretched to the limit. Half the housing in the country that had existed at the beginning of the war was no longer standing, and the productivity of the agricultural sector was close to famine proportions. To add hardship to the lives of ordinary Soviet citizens, the internal repression that had reached its peak in the late 1930s did not disappear after the end of the war. The millions who expected the end of hostilities with Germany to presage an era of societal order were to be very disappointed. In the immediate postwar years, the combined cruelty of Stalin and Beriya reached inhuman proportions, as wave after wave of Soviet citizens continued to disappear into the depths of the GULag system.

Given these distressing conditions, one would expect that an interest in such an esoteric idea as rocketry would have receded from the minds of engineers. In most Soviet accounts of postwar rocketry, however, descriptions abound in a peculiar sense of patriotism and sense of purpose that are difficult to explain. Filtering out what is obvious propagandistic prose, there is a clear subtext of "the mission," not among the bureaucrats and Communist Party officials, but among the young engineers themselves, most, if not all, of whom had already passed through immense hardships at the hands of both Hitler and Stalin. Some of this feeling is clearly attributable to the nature of the relentless aggression of the Nazis against Soviet citizens and the obvious wish to preclude such attacks on the Soviet Union ever again. But this patriotism, if it can be termed such, was also steeped in contradiction for the military scientist in the postwar Soviet Union. While one was actively pursuing science in the name of defending one's native land from attack, one was also implicitly maintaining the status quo of societal oppression that kept the country's paranoid leaders safe in their offices in the Kremlin. And compounding all else was fear. As there is a subtext of patriotism in descriptions of postwar rocketry, there is also a sense of almost mortal fear of the activities of Stalin and Beriya. It was this combined fear of the country's leaders and love of the country itself that provided the context within which the young aeronautical engineers of the 1930s and 1940s began slowly to regroup and start anew in 1945.

1. The post-*glasnost* official count was set at 27 million dead, although there is reason to believe that the actual count was as high as 34 million. See Fyodor Setin, "How Many Did We Lose in the War?," *New Times* no. 7 (1990): 46–47; Steven Zaloga, *Target America: The Soviet Union and the Strategic Arms Race: 1945–1964* (Novato, CA: Presidio, 1993), pp. 30, 280.

In Germany

As the war in Europe ended in the late spring of 1945, all of the major allied powers began quickly to investigate and exploit the advances in German military technology. Even before the conclusive end of hostilities, the major rocketry centers of Peenemünde and Nordhausen had become prime targets for intelligence services. In the case of the Soviet Union, Stalin may have played a role in diverting troops first toward Peenemünde rather than Berlin in the last few months of the war. Precisely five days after Adolf Hitler's suicide in Berlin, on May 5, 1945, an infantry unit led by a Major Anatoliy Vavilov from the Second Belorussian Front took control of Peenemünde. The place was evidently deserted, and Vavilov faced little or no resistance.[2] Later, when Soviet forces occupied the A-4 plant at Nordhausen, the soldiers found the remains of thousands of concentration camp prisoners who had been forced to manufacture A-4s during the last days of the war.[3]

For Soviet officials who had been expecting a treasure trove of important information on the German rocketry program, the situation was indeed disappointing. As the Soviets would later learn, almost all the major German engineers working on the A-4 program had willingly surrendered to American military forces. In particular, Wernher von Braun, perhaps the most talented and powerful engineer among the Germans, had begun making plans for such a move well before the end of the war. As early as January 1945, von Braun and others had commenced preparations to relocate to a region that had a high probability of being occupied by U.S. forces.[4] By early May, they were securely in the hands of the U.S. Army. They did not come empty handed. Apart from the 525 odd individuals who constituted the elite of the rocketry team, they also carried documentation on rockets spanning thirteen years. Earlier in April, U.S. forces had also stumbled into the giant A-4 plant at Nordhausen. Alongside the stacked bodies of hundreds of murdered camp slaves were scores of missiles in various stages of assembly. Within days, parts for at least 100 A-4 missiles were packed and shipped back into the U.S. zone before the arrival of Soviet forces.[5] A major portion of what could not be taken back in the given time was simply destroyed. Soviet leaders who had expectantly awaited capture of this most precious war booty were in some cases stunned by the efficiency and swiftness with which these weapons were taken from under their noses. Stalin was reportedly quoted as saying:

> *This is absolutely intolerable. We defeated the Nazi armies; we occupied Berlin and Peenemünde; but the Americans got the rocket engineers. What could be more revolting and more inexcusable? How and why was this allowed to happen?*[6]

The Soviet effort to capture both German missile technology and expertise in the last days of the war seems to have been rather disorganized. There was clearly interest from a variety of

2. Walter A. McDougall . . . *the Heavens and the Earth: A Political History of the Space Age* (New York: Basic Books, Inc., 1985), pp. 42–43; Frederick I. Ordway III and Mitchell R. Sharpe, *The Rocket Team* (New York: Thomas Y. Crowell, 1979), p. 261. The actual events leading to the capture of Peenemünde by the Soviet Army still remain somewhat unclear. Authoritative sources state that the site first came under Soviet control as early as March 9 or 10, 1945. See Ordway and Sharpe's text on page 11 (for March 9) and B. Ye. Chertok, *Rakety i lyudi* (Moscow: Mashinostroyeniye, 1994), p. 98 (for March 10). However, it is clear that when Vavilov's unit first entered Peenemünde on May 5, there were still SS troopers at the site who had been awaiting the arrival of Soviet soldiers.

3. The Mittelwerk plant for the A-4 missiles was actually closer to the town of Niedersachswerfen rather than Nordhausen, although Soviet teams used the latter name more commonly than the former.

4. Ordway and Sharpe, *The Rocket Team*, pp. 254–55.

5. McDougall, . . . *the Heavens and the Earth*, pp. 44–45.

6. Dr. G. A. Tokaty, "Soviet Space Technology," *Spaceflight* 5 (March 1963): 58–64. This quote is also excerpted in McDougall, . . . *the Heavens and the Earth*, p. 44, but referenced to a different source.

sectors in the A-4 and the Fi-103, but at least in the first few months of Soviet operations in occupied German territory, these activities were not well coordinated or clearly defined. The Soviet Air Force had much incentive to gather information on these missiles, and the Commissariat of the Aviation Industry tapped its subordinate NII-1 as a source for engineering knowledge to support initial Air Force missions into newly captured territory. This was an obvious choice because many of the NII-1 engineers who had worked in the defunct *Raketa* group in 1944 had a rudimentary knowledge of some of the A-4's systems. Soviet artillery, primarily represented by the Mortar Guards Unit and the Chief Artillery Directorate, also had more than a cursory interest in German rocketry, and it seems that there was some degree of overlapping duties if not outright conflict between the needs of the Air Force and the needs of the Red Army Artillery in this matter.

Artillery officers viewed these advanced liquid-propellant missiles as merely extensions of the small *Katyusha* rockets that had been used so successfully during the war, and thus they were reluctant to share jurisdiction over missiles. In addition, the recommendations of the commission under Semenov and Tyulin in late 1944 clearly played a major role in the artillery branch's interest in these weapons. While the artillery and aviation sectors originally had autonomous and perhaps conflicting goals and duties, at the lower levels, there seems to have been a significant amount of interdependence. Most of the artillery officers had little or no expertise in missile technology and relied heavily on the interpretations of the young aviation engineers from NII-1. Furthermore, the latter group realized early on that their own bosses would not be very supportive of expending time and money to study German missiles. The engineers from NII-1 thus developed important relationships with powerful artillery officers who not only were far more favorable to the exploitation of German rocket technology, but who also saw missile weapons in general as potent tools of war.

One of the first teams to enter Germany to investigate German missiles was established in early May under the leadership of Maj. General Andrey I. Sokolov, who at the time was the deputy chief of the Mortar Guards Unit. He tapped Lt. Colonel Georgiy A. Tyulin to be part of the initial teams into Germany, presumably because Tyulin was familiar with both the Fi-103 and A-4 missiles. On May 24, the first group flew from Moscow to Berlin to begin the organization of an inspection team. Artillery officers on board included Lt. Colonel Anatoliy I. Semenov and Colonel Aleksandr G. Mrykin, both from the Chief Artillery Directorate, who were there to make assessments on production and procurement.[7] The group was rounded out by several aeronautical engineers who had been asked to assist the artillery officers on technical issues during their field operations in Germany. The latter group included a number of NII-1 employees, including Aleksey M. Isayev, the leading rocket engine specialist at NII-1, and Arvid V. Pallo, a pre-Purge associate of Korolev's from NII-3.[8]

Flying first into Berlin, Sokolov and Tyulin's team slowly made their way to Peenemünde by the end of May. The scene that awaited them at the famous rocketry center was not encouraging. Not only was the place almost completely deserted by Germans, but there was almost nothing left behind to claim for the Soviet side. What still remained had been destroyed by the fleeing Germans or the Americans prior to the Soviet Army's capture of the launch site.[9] For

7. Lt. Gen. (Ret.) G. Tyulin, "The 'Seven': Years, Accomplishments, People" (English title), *Krasnaya zvezda*, April 1, 1989, pp. 3–4; Yu. A. Mozzhorin, *et al.*, eds., *Dorogi v kosmos: I* (Moscow: MAI, 1992), p. 156; Carl-Fredrik Geust, *Under the Red Star* (Shrewsbury, UK: Airlife, 1993), p. 115. In this last source, the author suggests that the May 24 team was led by Lt. General Gaydukov, the Communist Party's point man on artillery affairs, but it seems that Gaydukov arrived in Germany much later.

8. Chertok, *Rakety i lyudi*, p. 67; Yu. A. Mozzhorin, *et al.*, eds., *Dorogi v kosmos: II* (Moscow: MAI, 1992), pp. 42–43. Others along with Isayev and Pallo included Rayetskiy, Raykov, and Berglyezov.

9. G. A. Tokaty, "Foundations of Soviet Cosmonautics," *Spaceflight* 10 (October 1968): 335–46.

several days, Sokolov's team literally scoured through piles of garbage attempting to make some sense of what might have existed at Peenemünde. According to Tyulin:

> *The test beds, the laboratory buildings, the shops of the experimental plant and the launching equipment of the [A-4] were depressing to look at. The bombing of Hitler's missile citadel . . . had attained its goal. The full-scale production plants in the vicinity of Nordhausen created the same impression.*[10]

Equally disappointing for the Soviets was the fact that of all the Germans captured at the site, none were key officials in the development of either the Fi-103, the A-4, or any of the other many tactical missiles created during the war. As the inspection team members interrogated the remaining Germans through May and June, it was increasingly clear that not one was an expert in any field, although many did have extensive technical experience in manufacturing shops and plants.

On June 1, another group of Soviet engineers and officers, the latter from the Air Force, arrived at Peenemünde. Among this team was Boris Ye. Chertok, a thirty-three-year-old guidance systems engineer who had worked in the Raketa group at NII-1 in 1944.[11] At Peenemünde,

A rare photo showing artillery Colonel Georgiy Tyulin (left) and Sergey Korolev in Germany in 1946 during the A-4 missile recovery operations. Tyulin would rise swiftly in later years, becoming one of the most important managers of the Soviet space program in the 1960s. (files of Peter Gorin)

10. Tyulin, "The 'Seven'."

11. Chertok, *Rakety i lyudi*, p. 66. Chertok had actually arrived earlier in Germany. He had been on one of the first inspection teams to arrive in late April as part of an Air Force group interested in German radar and precision instrument research.

Chertok took a leading role in making impartial assessments of leftover German remains. The preliminary impressions resulting from the combined inspection of the artillery and Air Force groups at Peenemünde in May and June had repercussions not only on the perceived level of German missile technology, but they also reflected poorly on the accomplishments of the Soviets themselves. By the end of the war, the most powerful operational Soviet rocket engine had a thrust of one and a half tons. The A-4, meanwhile, had used an engine with a thrust of twenty-seven tons—a staggering gap, especially when one considers the roughly comparable activities of the rocketry groups in the 1930s in both Germany and the Soviet Union. The Soviets did not have a single program for the development of a long-range ballistic missile. Tyulin had no doubt as to the reasons for the lag:

> *In Germany we realized that if there were no arrests, we would have reached a very high technical level as early as the late thirties. As a result of repressions in the army and the scientific community, the development of our rocketry had stopped at powder rockets, and only when our leaders learned about the "V" rockets, Stalin took an interest in rocketry.*[12]

Despite the apparent weaknesses in Soviet expertise, officials were quick to emphasize that there was also reason to feel somewhat positive. Following the initial survey of German technology, a member of the Air Force evaluation team recalled that:

> *. . . so far as theories and projects were concerned, the Soviet rocket scientists and engineers appeared to be, basically, as advanced, as inventive and as clever as their German counterparts; but in putting these theories into practical technology we turned out to be miles behind the Germans.*[13]

Among the more curious finds at Peenemünde was a German edition of a book by Tsiolkovskiy on rocketry and spaceflight. To the surprise of the Soviets, almost every page of the monograph was embellished by von Braun's comments and notes. Elsewhere in the archives of the Nazi Air Ministry, the Soviets were even more surprised to find detailed drawings of a missile designed by Tikhonravov during the late 1930s at NII-3, during a time when all such work was classified.[14] There was no apparent explanation of how the information made its way into German hands.

Chertok and the others arrived at the Mittelwerk plant in Nordhausen on July 14 and immediately began to create some sense of order out of the chaotic state at the factory. The visiting Soviets were without doubt much more impressed by the facilities at Mittelwerk than those at Peenemünde. The plant was built into the side of a mountain, with two three-and-a-half-kilometer-length galleries, allowing entire trains to enter the facility. Here, the Soviet team discovered several A-4s in various stages of assembly, and team members carefully documented all available findings for later analysis and study. German technicians who had remained behind at Mittelwerk shocked the Soviet occupiers by stating that production levels at the facility had remained at peak levels until almost the end of May. Approximately thirty-five complete missiles were apparently being turned out every day that month.[15] Having collated the preliminary

12. Mariya Pastukhova, "Brighter Than Any Legend" (English title), *Ogonek* 49 (December 1987): 18–23.

13. Tokaty, "Foundations of Soviet Cosmonautics."

14. Roald Z. Sagdeev, *The Making of a Soviet Scientist: My Adventures in Nuclear Fusion and Space From Stalin to Star Wars* (New York: John Wiley & Sons, 1993), p. 5, fn. 2; Michael Stoiko, *Soviet Rocketry: Past, Present and Future* (New York: Holt, Rinehart and Winston, 1970), p. 64.

15. Chertok, *Rakety i lyudi*, p. 108.

information on the plant, the inspection group moved to Bleicherode on July 18 and set up shop at the Villa Franka, which had served as von Braun's home during the latter days of the A-4 effort. By this point, the Soviet group had managed to gather together about 200 German technicians who had worked on missiles during the war. There still seems to have been efforts, both overt and covert, to capture some of the more important individuals in the A-4 program, in particular von Braun. A German engineer related to U.S. authorities on August 15:

> *I had been for several days in [the] Russian occupied zone around Bleicherode to pick up my baggage, which had been left there. At this occasion I spoke to an old collaborator. . . . He told me that the Russians intended to develop a big rocket for a normal range of 3,000 miles and that they are needing specialists with knowledge of the theory of flight mechanics and control equipment. He told me that the Russians set big prices for getting over to Russian area Prof. V. Braun and Dr. Steinhoff.*[16]

None of these efforts met with success, although several members of the inspection commission continued to travel to the U.S. occupation zone to make offers to middle-level engineers.

At Bleicherode, the engineers on the Soviet inspection team settled down with their information and were given permission to establish a joint Soviet-German centralized coordination center not only for the further collection of information, but also to attempt to reestablish production of the A-4 at the Mittelwerk plant as soon as possible. The Soviet military administration in Germany named it the Institute Rabe, for "raketenbau und entwicklung," which was German for rocket manufacture and development.[17] Major Chertok was named the co-leader of the institute along with a German engineer named Gunther Rozenplenter. NII-1 veteran Isayev was appointed to handle all propulsion issues.

Upon the formation of the Institute Rabe, a veritable flow of Soviet aeronautical engineers from NII-1 and elsewhere began to converge first in Berlin and then at Bleicherode. On July 25, Yuriy A. Pobedonostsev, Korolev's old GIRD associate, arrived in Germany, quickly becoming one of the leading engineers in the A-4 restoration operation.[18] A major influx of technically competent Soviet engineers occurred in early August. This group was sent to Germany under extremely strict secrecy, far more than had been subjected to the earlier team in May. All the individuals in the new group had been summoned the day prior to their departure to a Party Central Committee department and were only told that they were to leave for Germany the next day as members of a secret Special Technical Commission. None were told the goal of the mission, and all were given military ranks on the spot to preclude questions from the other Allies on the role of civilians in the occupied zones. Flying aboard the Li-2 aircraft on August 9, 1945, were Yevgeniy Ya. Boguslavskiy, Vasiliy P. Mishin, Nikolay A. Pilyugin, Viktor A. Rudnitskiy, Mikhail S. Ryazanskiy, and less well-known engineers Bakurin, Floreyskiy, and Goryunov.[19] Both Mishin and Pilyugin were well acquainted with the A-4's basic elements, having worked on the examination of parts recovered at NII-1 in 1944. Upon his arrival at Rabe, Pilyugin, an expert on guidance systems, was appointed the first deputy chief of the institute. Further arrivals later in August represented a variety of fields in rocketry, such as liquid-propulsion rocket engines, guidance systems, control systems, gyroscopes, launch facilities, and flight testing. The tech-

16. Ordway and Sharpe, *The Rocket Team*, p. 290.

17. *Ibid.*, p. 320; Chertok, *Rakety i lyudi*, p. 116. Rabe itself was also the German word for "raven."

18. Valeriy Zharkov, "Pobedonostsev's Criteria" (English title), in V. Shcherbakov, ed., *Zagadki zvezdnykh ostrovov: kniga pyataya* (Moscow: Molodaya Gvardiya, 1989), p. 94.

19. B. Konovalov, "From Germany—To Kapustin Yar" (English title), *Izvestiya*, April 6, 1991, p. 3. One source says that Ryazanskiy had actually arrived in Germany before, in either late April or early May 1945. See Mozzhorin, *et al.*, eds., *Dorogi v kosmos: I*, p. 160.

nical expertise of the Institute Rabe swelled as individuals such as Vladimir P. Barmin, Aleksandr Ya. Bereznyak, Vasiliy S. Budnik, Semyon G. Chizhikov, Vasiliy I. Kharchev, Nikolay M. Kurilo, Viktor I. Kuznetsov, Yevgeniy M. Tsetsior, and Leonid A. Voskresenskiy converged at the former German rocketry centers in August 1945.[20]

While these engineers were essentially part of the technical aspect of the operations, the artillery sector began to take control over many of the higher decision-making levels. Based on information received in Moscow through the summer, in August, the commander of the Mortar Guards Unit, Maj. General Nikolay N. Kuznetsov, established a central command for rocketry operations in Berlin to serve as the nerve center of the Special Technical Commission (OTK in its Russian abbreviation).[21] As the first head of OTK, Kuznetsov explained to all those involved that the Institute Rabe and all subsidiary work on restoring A-4 operations would now be under the command of the artillery sector, specifically the Chief Artillery Directorate. It was understood by the members of OTK that the question of which "ministry" would take over missile production was still being debated, a result of vacillation on the part of the aviation sector on its role in ballistic missile development.

Kuznetsov's boss back in Moscow, Maj. General Lev M. Gaydukov, apparently was a vigorous advocate for moving the whole sector to the armaments industry, which had produced the solid-propellant Katyushas during the war. Gaydukov himself visited Nordhausen in August to make a personal assessment of the work of the 284-strong team in Germany. Gaydukov and Kuznetsov appointed the young Lt. Colonel Tyulin as a deputy chief of OTK to be stationed at Berlin to direct and coordinate field operations of all the aviation engineers. Former NII-1/Raketa and GIRD member Pobedonostsev served as the top engineering coordinator of OTK. By this time, the field of operations in Germany comprised: the Zentralwerke, an assembly plant located at an old A-4 repair depot at Klein Bodungen; the Institute Rabe under Chertok and Pilyugin, whose duties were focused on reconstructing the A-4 guidance systems; and the propulsion test stands at Lehesten, where Pallo and Isayev were in the process of cataloguing information on rocket engines.[22]

Perhaps one of the more successful phases of the early work in Germany was carried out at Lehesten. Located close to Nordhausen in southern Thuringia, OTK engineers Isayev and Pallo had essentially taken over control of the facility in the early summer of 1945 in the interest of restoring "normal" levels of testing, which was understood to be more than thirty firings per day. In July, Pallo became the chief of static testing at about the same time that the Soviets uncovered one of the more significant treasures, a set of more than fifty brand new tested and certified combustion chambers in an underground depot at Lehesten.[23] In addition, the Soviets discovered fifteen completely undamaged railway cars containing a plethora of equipment, some of which were also cars used for transporting the A-4 missiles and propellant to various sites.

In their operations in Germany, the Soviets were assisted by German engineers and technicians at every site. While the Soviets early on conceded that the best and brightest from the Peenemünde team were in the hands of the Americans, they did not shirk from using the services of those who remained as much as possible. In addition, every effort was made to "capture" more technically adept Germans. In the early fall of 1945, the Soviets started a dedicated program, designated Operation *Ost*, to explore the possibility of adding more capable Germans to the services of OTK. Led by Institute Rabe head Chertok, these efforts were partially

20. Chertok, *Rakety i lyudi*, pp. 121–22, 124. The assigned military ranks of some of these engineers were: Barmin (Colonel), Chertok (Major), Isayev (Lt. Colonel), Kuznetsov (Colonel), Mishin (Lt. Colonel), Pallo (Major), Pilyugin (Colonel), Pobedonostsev (Colonel), Ryazanskiy (Colonel), and Voskresenskiy (Lt. Colonel).

21. *Ibid.*, pp. 123–24; Mozzhorin, *et al.*, eds., *Dorogi v kosmos: II*, pp. 75–76.

22. Mozzhorin, *et al.*, eds., *Dorogi v kosmos: I*, p. 137.

23. Chertok, *Rakety i lyudi*, pp. 155–56.

successful. He coordinated several trips by the Burgomeister of Bleicherode, who crossed the Werra River into U.S.-captured territory to make offers to Germans at Witzenhausen. One of those who responded favorably was Helmut Grottrup, the former assistant to the director of the Guidance, Control, and Telemetry Laboratory at Peenemünde, who made at least two secret trips into Soviet-controlled territory to discuss his future. In mid-September of 1945, Grottrup and his family finally moved permanently to the Institute Rabe at Bleicherode, adding a very significant asset to the capabilities of OTK.[24] Grottrup's reasons for siding with the Soviets had evidently less to do with political affiliations than his reluctance to leave Germany. Others who eventually put their lot with the Soviets included aerodynamicist Dr. Werner Albring, design engineer Josef Blass, guidance and control expert Dr. Johannes Hoch, gyroscope and theoretical mechanics specialist Dr. Kurt Magnus, propellants chemist Dr. Franz Mathes, propulsion specialist Dr. Joachim Umpfenbach, and ballistics expert Dr. Waldemar Wolff.[25] While none of them had played any major roles in the development of the A-4 or any of the other missiles developed by the Peenemünde team, their services were indispensable to the Soviets in mastering construction, production, and testing operations.

OTK was augmented by two further and certainly more important additions in September 1945. Maj. General Gaydukov, the Communist Party's representative for OTK and the head of all A-4 recovery operations in Germany, was apparently very conscious of the need for qualified engineers to be in Germany to participate in the work of the commission. He also happened to be aware of the rich history of rocketry in the Soviet Union, including the activities at GIRD and NII-3 in the 1930s. In the late summer of 1945, Gaydukov prepared a list of aeronautical engineers who he believed would be great assets to the OTK effort in Germany but who had all been incarcerated in the late 1930s as a result of the Great Purges.[26] It was a calculated move on Gaydukov's part, but it worked. Two of the names on the list given to Stalin himself were Sergey P. Korolev and Valentin P. Glushko.

Korolev had been working at OKB-SD since July 1944 in Khimki on a variety of rocket engines to assist fighter planes in taking off. An effort to interest the aviation industry in long-range missiles did not produce fruit.[27] In late August, both Glushko and Korolev were finally discharged from work at OKB-SD, the latter immediately returning to Moscow to see his wife Kseniya and daughter Natalya, whom he had not seen since 1940. It was his first real taste of freedom in more than seven years. The holiday with his family proved to be unusually short. In early September, Korolev was summoned to the Commissariat of Armaments in Moscow and informed of the work of scientists and engineers in Germany working on restoring A-4 production; he was immediately assigned to join that effort.[28] Summarily given the military rank of Lt. Colonel, Korolev flew via Warsaw into Berlin on September 8 and was received by

24. *Ibid.*, p. 126; Peter Smolders, "I Meet the Man Who Brought the V-2 to Russia," *Spaceflight* 37 (July 1995): 218–20; Ordway and Sharpe, *The Rocket Team*, p. 319.

25. Christian Lardier, *L'Astronautique Soviétique* (Paris: Armand Colin, 1992), pp. 72–73; Ordway and Sharpe, *The Rocket Team*, p. 335; Chertok, *Rakety i lyudi*, pp. 125–26.

26. Chertok, *Rakety i lyudi*, pp. 137–38.

27. On June 30, 1945, Korolev submitted a second draft of his D-1/D-2 missile proposal to the leaders of the Commissariat of the Aviation Industry. As in his prior report, Korolev advocated the establishment of a special design bureau attached to NII-1 to focus on bringing the D-2 project to fruition. In addition to a list of engineers that he believed should be transferred to this new bureau, he also set out a timetable for work on the missile, to begin on November 1, 1945. Perhaps most significantly, Korolev emphasized the need to study not only captured German missile technology, but also U.S. and British efforts in the field. See Yuriy Biryukov and Vikentiy Komarov, "S. P. Korolev in the 'Sharashka'" (English title), in Shcherbakov, ed., *Zagadki zvezdnykh ostrovov*, pp. 108–09; G. S. Vetrov, *S. P. Korolev i kosmonavtika: pervye shagi* (Moscow: Nauka, 1994), p. 184.

28. Aleksandr Romanov, *Korolev* (Moscow: Molodaya Gvardiya, 1996), pp. 200–05. First Deputy People's Commissar of Armaments V. M. Ryabikov informed Korolev of his new assignment.

Lt. Colonel Tyulin. By this time, the latter, in addition to his duties as a deputy head of OTK, was also the head of the new Institute Berlin, established to gather and analyze all available documentation on German missiles in one place.[29] Glushko, given the rank of colonel, arrived in Berlin at this time, although he did not fly in with Korolev.

The addition of both Korolev and Glushko to OTK added very significantly to the expertise of the investigation team in Germany. They were undoubtedly two of the brightest and most experienced engineers in the field of rocketry in the Soviet Union, and the majority of the other members of the team were well acquainted with their work in the 1930s. In late September, after a few weeks familiarizing himself with the nerve center of operations at the Institute Berlin, Korolev was taken to the Institute Rabe in Bleicherode. Characteristically, he did not waste much time, and within days, he began to take a leading part in the operations of OTK. One of his first actions was to establish a special subgroup of the commission, designated *Vystrel* ("Shot"), specifically for studying and learning the preparations for launching the A-4. He appointed two of the former NII-1 veterans, Voskresenskiy and Rudnitskiy, as leading members of the team to gather and sift through all available documentation. Glushko meanwhile was sent to Lehesten to oversee work on A-4 engines. Isayev and Pallo, both of whom had been instrumental in laying a solid base for future work at the site, were ordered to return back to Moscow, and all the work at the plant was taken over by Glushko and his deputy Vitaliy L. Shabranskiy.[30]

The actual search for documentation turned out to be somewhat harder than anticipated. For example, in the fall of 1945, rumor reached the Institute Berlin that a railway truck loaded with missile drawings that were to have been sent to Austria by the fleeing Germans had been captured by Czechoslovak insurgents near Prague. Mishin, being one of the most well acquainted with the design of the A-4 rocket, immediately left for Prague to investigate the matter. In the Czech capital, he was able to locate an A-4 production coordination office, which had directed the supply of parts from scores of companies in Austria, Hungary, Poland, and Czechoslovakia during the war. Despite this obviously significant prize, he was still unable to locate the mysterious train. After pleas to the British administration officials nearby fell on deaf ears, he was able to use some "unorthodox measures" to finally locate and secure all the missile documentation. It seems that OTK engineer Bereznyak's sister Mariya, who had been imprisoned in a concentration camp by the Germans, played a major but still unknown role in the find.[31]

Korolev and Glushko both assumed relatively important roles in the work of OTK by late 1945, and there clearly seems to have been an implicit recognition in the abilities of both individuals by the leadership. Both were highly talented and professional engineers with formidable theoretical and practical backgrounds in missile and aviation technology. In addition, Korolev had a tremendous ability for administrative and managerial tasks. At least in the initial stages of cooperation, he was very cooperative with all the German engineers, no doubt helped by his fluency in the German language. Glushko, on the other hand, while probably a better engineer, was less successful in dealing with either the Germans or his subordinates. He was a perfectionist and insisted on being involved in every last detail of the work of his assistants. In

29. Mozzhorin, *et al.*, eds., *Dorogi v kosmos: II*, p. 76; Chertok, *Rakety i lyudi*, p. 141. The original head of the Institute Berlin was D. G. Dyatlov.

30. Konovalov, "From Germany—To Kapustin Yar"; Chertok, *Rakety i lyudi*, pp. 144, 147, 157. The *Vystrel* group was originally headed by Korolev, but after his appointment as chief engineer of the Institute Nordhausen, Voskresenskiy replaced him.

31. Konovalov, "From Germany—To Kapustin Yar"; Geust, *Under the Red Star*, pp. 116–17; Boris Konovalov, "Soviets Rocket Triumphs Started in Germany" (English title), *Izvestiya*, March 5, 1992, p. 5.

addition, it seems that he had little appreciation or tolerance for any of the German work from the Peenemünde team.[32] It was perhaps the cumulative effect of their different approaches to the work in Germany that eventually resulted in the effective reversal of their roles during the war. It was increasingly clear by the end of 1945 that of all the engineers working for OTK, Korolev was the one to watch.

During their time in Germany, on only one occasion did either Korolev or Glushko come into contact with U.S. or British forces. In early October 1945, the three Western powers conducted a series of preliminary firings of the A-4 from Cuxhaven on the North Sea shore. For the third launching on October 15, Soviet representatives were invited to witness the launch. Five officials were sent on behalf of the Soviet side, Lt. General Sokolov, who led the initial teams into Peenemünde, Lt. Colonel Tyulin, Pobedonostsev, Glushko, and Korolev. Despite much "arm waving and shouting," Korolev was not allowed into the launch-viewing area by U.S. Maj. General Alexander M. Cameron, chief of the Air Defense Division, Supreme Headquarters, Allied Expeditionary Force. Korolev was escorted outside the compound and had to view the launch from a much farther distance. Later that day, he was also prohibited from viewing the assembly and checkout area despite angry complaints. Pobedonostsev, for his part, spoke briefly with one of the German observers, a Lieutenant Hochmuth, casually telling him that he was aware that the A-4 material from Mittelwerk was going to White Sands in New Mexico—a piece of information that was supposed to be top secret at the time. Pobedonostsev also complained of having "a hell of a time" at Nordhausen because the U.S. side had "cleaned the place out." He offered the Allies a tour of Nordhausen if the U.S. side would reciprocate with a similar offer to show White Sands to the Soviets. The U.S. Army refused the offer, although it seems that the Allies would definitely have been in a position to gain much more, because White Sands at the time was essentially barren.[33] The Soviet team returned from Cuxhaven to their side of Germany with little concrete information. The time ahead was to be critical for laying the groundwork for their own launchings.

Research on the A-4 was only a part of the overall work of the engineers in Germany. A significant portion of the occupation was focused toward capturing a myriad of other types of military technology, such as fighters, bombers, and tanks. In the case of missiles, OTK had groups working on acquiring knowledge on such surface-to-air German missiles as the Schmetterling, Typhoon, and Wasserfall. Perhaps the most interesting of these areas of investigation was a theoretical study from August 1944 authored by Viennese engineers Dr. Eugen Sänger and Dr. Irene Bredt of the Ainbring firm Deutsche Luftfahrtforschung, titled "Über Einen Raketenantriebe Fernbomber" ("On a Rocket Propulsion Engine for Long-Range Bombers"). The Nazis had evidently published only 100 copies of the study. Sänger and Bredt foresaw the use of a 100-ton single-stage piloted rocket-aircraft for dropping 300-kilogram bombs over transcontinental ranges. The vehicle, also called the "antipodal bomber," was designed to be launched from a sled, reaching a maximum velocity of six kilometers per second and a maximum altitude of more than 160 kilometers. Sänger and Bredt theorized that following launch, the spaceship would dip into the atmosphere at a shallow angle and skip once again back into space—a process that would be repeated several times until, during one of the dips, the ship would drop a bomb over the desired target.[34] The Luftwaffe had initially supported the project,

32. Zaloga, *Target America*, p. 119.
33. Ordway and Sharpe, *The Rocket Team*, pp. 306–07; Tyulin, "The 'Seven'."
34. Irene Sänger-Bredt, "The Silver Bird, A Memoir," *History of Rocketry and Astronautics, Vol. 7, part 1* (San Diego, CA: American Astronautical Society, 1986); Kenneth Gatland, ed., *The Illustrated Encyclopedia of Space Technology: A Comprehensive History of Space Exploration* (New York: Harmony Books, 1984), pp. 199, 204; Henry Matthews, *The Secret Story of the Soviet Space Shuttle* (Beirut, Leb.: Henry Matthews, 1994), p. 22; Ordway and Sharpe, *The Rocket Team*, p. 327.

encouraged by the assertion that the bomber would be capable of reaching New York City. Little work on the bomber was carried out by the Germans, however, as the war ground to a halt. During the exploratory work of Soviet engineers in Germany, Isayev had initially discovered the document at Peenemünde in May 1945. The capabilities of the antipodal bomber had apparently startled the Soviets, and news had even reached Stalin's ears. It seems that his interest was serious enough for him to appoint a special group from the Air Force to investigate the issue.[35]

The months of indecision on the part of the aviation sector on the issue of developing long-range ballistic missiles finally came to a resolution. In November 1945, a representative from the Central Committee of the Communist Party arrived in Berlin to inform the leaders of OTK that while the Party leadership was satisfied with the work of the commission, efforts in Germany would cease in early 1946, until a final decision on which industrial sector to allocate the work had been made.[36] The representative also announced that Maj. General Gaydukov would take over the position as chairman of OTK, replacing the indisposed Maj. General Kuznetsov, who was recovering from an automobile accident in late September. Gaydukov's appointment was propitious for he was not only one of the most vigorous supporters of the valuable work in Germany, but he had also personally given Stalin the list including Korolev's name that had added the latter's valuable talents to the work of OTK.

Gaydukov inherited the honor of making perhaps one of the most important policy decisions in the early history of the Soviet rocketry and space programs. Stalin had given him the responsibility of selecting a "ministry" to oversee the missile effort in Germany. There were three choices: the Commissariat of the Aviation Industry, the Commissariat of Ammunitions, or the Commissariat of Armaments.[37] Gaydukov first offered the role to People's Commissar of the Aviation Industry Aleksey I. Shakhurin, but the latter was not impressed. Similar to his earlier decisions in 1944, Shakhurin saw no future in missiles and continued to believe in the possibilities of rocket-powered aircraft. Shakhurin's rejection had grave implications for OTK because most of the engineers of the commission were still officially under the employ of the aviation sector.[38] People's Commissar of Ammunitions Boris L. Vannikov was interested, but Stalin unexpectedly tapped him to oversee administrative aspects of the atom bomb project. For Gaydukov, this left one remaining choice, the Commissariat of Armaments, headed by a thirty-seven-year-old former mechanical engineer who would go on to play one of the most crucial roles in the history of the Soviet space program, Dmitriy Fedorovich Ustinov.[39]

Ustinov was born on October 30, 1908, in Samara, and he graduated from the Leningrad Military Mechanical Institute as a mechanical engineer in 1934. By 1938, he was the director of the Bolzhevik Arms Factory, one of the most important armaments facilities in the Soviet Union. Certainly, his quick rise to this prominent position was partly because of the massive toll of the Purges in the late 1930s, which resulted in much of the original and more experienced industrial hierarchy being decimated. The lack of qualified individuals at the beginning of the war prompted Stalin to pick the thirty-two-year-old Ustinov as the People's Commissar

35. Zaloga, *Target America*, p. 122; Chertok, *Rakety i lyudi*, p. 91. The chief of the Air Force department of the Soviet Military Administration in Germany, Lt. General T. F. Kutsevalov, was the most enthusiastic and vigorous advocate of the project. See D. A. Sobolev, *Nemetskiy sled v istorii sovetskoy aviatsii* (Moscow: RITs Avianbik, 1996), pp. 83–85.

36. Chertok, *Rakety i lyudi*, p. 137.

37. *Ibid.*, p. 138.

38. *Ibid.*, p. 160. In late 1945, all NII-1 employees who were part of the commission in Germany were immediately ordered to return to the Soviet Union to resume work on aircraft. A second attempt to reduce the rocketry recovery effort in Germany occurred in early 1946. Both of these potentially disastrous orders seem to have been stalled by Gaydukov as he looked for a more acceptable alternative.

39. *Ibid.*, p. 140.

of the Armaments in 1941. The inexperienced industrialist was responsible for the design and production of a host of Soviet ground and tactical weaponry. Ustinov did not disappoint Stalin, and it was clear by the end of the war that he had done an outstanding job marshaling the resources of the state to produce huge amounts of ammunitions. Younger than both Korolev and Glushko, Ustinov was well respected in the government and seems to have managed to somehow remain outside of ongoing political intrigues that inevitably landed many a bureaucrat in the GULag. Prior to finalizing the arrangement of transferring all Soviet ballistic missile efforts to the Commissariat of Armaments, Stalin and Gaydukov had Ustinov send his deputy, Vasiliy M. Ryabikov, to Germany to personally assess the level of work at Berlin, Nordhausen, Lehesten, and elsewhere. It was a short visit, but it was pivotal for the landmark decisions of 1946.

Minister of Armaments Dmitriy Ustinov, shown here in the 1940s, was the principal industrial architect of the Soviet ballistic missile program. In various posts, he remained the manager of the missile and space programs during a period spanning almost forty years. (copyright Steven Zaloga)

NII-88

The work of OTK continued in early 1946 with two clear goals: the restoration of wartime production of A-4 missiles and the accomplishment of the first postwar launches of these missiles from German soil. As Korolev assumed more of a pivotal role in the work of the commission, plans were falling into place for testing a series of A-4 vehicles in 1946 in coordination with the scores of German engineers who had either been captured or voluntarily aligned themselves with the Soviets. These plans had evidently originated from suggestions from Korolev following his viewing of the Allied A-4 launches at Cuxhaven in October 1945. He himself received official recognition for his work in Germany in February, when he was briefly recalled to Moscow and promoted to the rank of colonel—the same as such other prominent engineers of OTK as Pobedonostsev, Glushko, and Pilyugin.[40] During the visit, he also met with Georgiy M. Malenkov, Stalin's right-hand man, and reported on the general state of OTK's investigations. Arriving back in Berlin in early March, Korolev was in an unusually cheerful mood, no doubt because he had been told back in Moscow that his name was one of those under consideration as possible engineering head of a central organization for the design of Soviet ballistic missiles.[41] Soon after Korolev's return to Germany, Gaydukov officially announced that all of OTK's operations would now be further coordinated by the new Institute Nordhausen, which would replace the old Institute Rabe. He also revealed that he himself had been appointed the director of the institute and that Korolev would now be the first deputy director and chief engineer.[42]

40. *Ibid.*, p. 162; Tyulin, "The 'Seven'."
41. Mozzhorin, *et al.*, eds., *Dorogi v kosmos: I*, p. 118.
42. *Ibid.*, p. 137; Chertok, *Rakety i lyudi*, pp. 162–63. Note that the first source states that the reorganization was in May and not in March 1946.

The reorganization in March 1946 led to the formal establishment of the following divisions of OTK, all led by the Institute Nordhausen:

- Plant No. 1 (also known as the Design Bureau Olimpiya) at Sommerda, about fifty kilometers east of Leipzig, set up at the premises of the Rheinmetall-Borzig firm and headed initially by Budnik and then by Mishin, for the collating of all technical documentation on the A-4
- Plant No. 2 (also known as the Montania Plant) at Lehesten, designated for the assembly, production, and testing of all rocket engines and headed by Glushko and Shabranskiy
- Plant No. 3 (also known as Zentralwerke) at Klein Bodungen, for pilot production of A-4s and headed by Kurilo
- Plant No. 4 at Sonderhausen, for the preparation of A-4 guidance systems and other electrical equipment, staffed by those who were formerly at the Institute Rabe, including Boguslavskiy, Chertok, Pilyugin, and Ryazanskiy
- The *Schparkasse* group, headed initially by Mishin and then by Lt. Colonel Tyulin and staffed by several artillery officers, for theoretical problems, including ballistics
- A special Soviet-German bureau, headed by the German Grottrup, which was given the task of preparing a detailed history of the A-4 development program with a focus on guidance systems, radiotechnical elements, and the selection of propellants
- The *Vystrel* group, headed by Voskresenskiy and Rudnitskiy and including Institute Berlin Chief Engineer Barmin, for mastering launch and testing procedures[43]

The primary goal of the entire operation was to restore production of the A-4 missiles sufficiently to manufacture several dozen of the vehicles for flight testing. This goal gradually became the primary objective for OTK in Germany as Korolev delegated the responsibility for launch operations to Voskresenskiy. The German engineers under Grottrup were indispensable in this effort, filling in gaps in the information whenever there were problems. In addition, because of the geographically scattered nature of the original wartime German production facilities for the A-4s, many of the parts for the missiles were no longer available, because the manufacturing entities now resided in either British or U.S. territory. Resourceful Germans under Grottrup were, however, able to obtain many components from the Allies by bartering with food, tobacco, or alcohol.[44] The sights of abandon and wreckage at Peenemünde and Nordhausen in the early summer of 1945 had prompted feelings of pessimism among Soviet officials and engineers. Yet, only a year later, the commission was close to assembling a limited number of full-scale A-4 missiles from Mittelwerk.

Cooperation between the Germans and the Soviets was for the most part harmonious and to a degree a function of the Soviet engineer who had responsibility for a particular area. For example, rocket engine firings at Lehesten were evidently conducted at first under the direction of Dr. Umpfenbach, but were taken over by Glushko once the exact processes had been mastered. While the intensity of the joint activities between the Soviets and the Germans may have varied, the work of OTK did for the first time bring together scores of Soviet engineers and military officers under a single umbrella organization. Almost all of the major chief designers of the Soviet space program up until the late 1980s were members of this commission in Germany, an astonishing historical precedent that has no parallel in the U.S. space program. Many of the Soviet individuals in fact made their first acquaintance with each other in Germany in the immediate postwar period.

43. Chertok, *Rakety i lyudi*, pp. 163–64; Mozzhorin, *et al.*, eds., *Dorogi v kosmos: I*, pp. 137–38; Ordway and Sharpe, *The Rocket Team*, pp. 320–21.
44. Ordway and Sharpe, *The Rocket Team*, p. 321.

The pivotal nature of the work in Germany in 1945–46 eventually gave rise to the important question of the elaboration of a national agenda with respect to ballistic missiles. The question of defending the territory of the Soviet Union after a devastating war was clearly on the minds of Soviet leaders. At the end of World War II, the Soviet Union may have had the most powerful land force in the world, but this power had suddenly become secondary following the events of August 1945. With the destruction of Hiroshima and Nagasaki by atomic bombs, the United States had revealed its absolute military superiority over any other country in the world. For Stalin in particular, this was unacceptable. While work on the development of nuclear weapons had been conducted during the war, the bombings in Japan prompted Stalin to move this work to an urgent footing. Just eighteen days after Potsdam and fourteen days after Hiroshima, on August 20, 1945, a secret decree of the Central Committee and the Council of Ministers called for the formation of the Special Committee on the Atomic Bomb to direct and coordinate all efforts on the rapid development of operational nuclear weapons.[45] This committee was headed by secret police head Beriya himself, and its work was kept concealed even from some members of the Politburo. Acutely aware that having a nuclear weapon was only one-half of the solution, efforts were simultaneously focused on a delivery system for these explosives. Taking a cue from the magnificent American B-29 bomber, the Soviet leadership began to explore the possibility of creating analogous aircraft for the delivery of nuclear weapons. This effort was in fact taken to pathological extremes with the construction of carbon copies of a captured B-29 in the postwar years.[46] Unwilling to rule out even the most unlikely of propositions, it also seems that Stalin had been keenly interested in missiles as weapons of war. The impressive performance of the German A-4 undoubtedly attracted his attentions, and the possibility of using such vehicles with nuclear weapons was not an avenue of research he was about to ignore.

On March 18, 1946 at the first session of the Supreme Soviet of the USSR, the rubber-stamp parliament of the country, a decree was adopted recommending the development of new technologies as part of the Soviet Union's rebuilding. In particular, the decree clearly called for "efforts towards ensuring further increases in the defensive capabilities of the USSR and ensuring the equipping of the armed forces of the Soviet Union with the latest military technology."[47] This first decree set the stage for an official visit by a commission of high industrial and military leaders to Germany to investigate and assess the work of OTK. The chairman of the visiting commission was Marshal Nikolay D. Yakovlev, the commander of the Chief Artillery Directorate, the military organ that had legal control over most of the artillery officers within OTK. Other members were: the Commander-in-Chief of Artillery Forces of the Red Army, Nikolay N. Voronov; the current Chief of Staff of the Southern Forces Group of the Red Army, Col. General Mitrofan I. Nedelin; and People's Commissar of Armaments Ustinov, the defense industrialist appointed by Stalin to lead the new rocketry sector in the Soviet Union.[48] Nedelin, at the time forty-three years old, was one of the brightest and most accomplished officers in

45. Yu. P. Maksimov, ed., *Raketnyye voyska strategicheskogo naznacheniya* (Moscow: RVSN, 1992), pp. 32–33; David Holloway, *Stalin and the Bomb: The Soviet Union and Atomic Energy: 1939–1956* (New Haven, CT: Yale University Press, 1994), p. 129; G. A. Goncharov, N. I. Komov, and A. S. Stepanov, "The Russian Nuclear Declassification Project: Setting Up the A-Bomb Effort, 1946," *Cold War International History Project Bulletin* 8–9 (Winter 1996/1997): 410–16.

46. Zaloga, *Target America*, pp. 70–72.

47. A. P. Romanov and V. S. Gubarev, *Konstruktory* (Moscow: Politicheskoy Literatury, 1989), p. 60.

48. Tyulin, "The 'Seven'"; Mozzhorin, *et al.*, eds., *Dorogi v kosmos: I*, p. 118. Note that according to Chertok, *Rakety i lyudi*, p. 233, the commission's visit was in February 1946. Another person on the visiting commission may have been B. L. Vannikov, the former People's Commissar for Agricultural Machine Building, who was currently involved in leading industrial aspects of the nuclear weapons development program. See David Holloway, "Military Technology," in Ronald Amann, Julian Cooper, and R. W. Davies, eds., *The Technological Level of Soviet Industry* (New Haven, CT: Yale University Press, 1977), p. 455.

the artillery sector and had extensive experience in using the solid-fuel Katyusha rockets in wartime conditions.

The commission's visit in May 1946 was instrumental in introducing the role of the defense industrialist, the third major player in the Soviet space program after the aviation engineers and artillery experts. Represented by such individuals as Ustinov and Ryabikov, these defense industrialists would lay their indelible stamp on the rocketry and space sector, molding its activities for the next forty years. Ustinov met Korolev for the first time on this trip and was apparently very impressed with the latter's capabilities. It may have been during this visit that representatives of the commission first informed Korolev that he would be appointed chief designer of all long-range missile development.[49] OTK Chairman Maj. General Gaydukov's high evaluation of Korolev's work clearly played a critical role in this decision. Korolev himself chose his principal deputy, a man who would figure prominently in the Soviet reach for the Moon. In early 1946, after his short trip to Moscow, Korolev had asked OTK engineer Mishin if he would agree to serve with him back in the Soviet Union. Mishin had declined, at first choosing to return to spend time with his wife and two daughters. Following the May 1946 visit by the Yakovlev commission, Korolev made a second offer, asking Mishin to head a joint Soviet-German design bureau as his deputy, the goal of which would be to create a complete set of technical blueprints for the A-4 based on the drawings captured in Czechoslovakia. By this time, Mishin's family was with him in Germany, and he agreed.[50] As the head of Plant No. 1 at Sommerda, Mishin assumed one of the leading roles in OTK, and as later events would attest, he clearly impressed Korolev with his assertive nature.

Upon the completion of the Yakovlev commission's short visit in May, the members prepared what would become without doubt the most important decree in the history of the Soviet rocketry and space programs. This decree, the Council of Ministers decree no. 1017-419ss, titled "Questions of Reactive Armaments," was formally signed into law by Stalin on May 13, 1946. The primary effect of the decree was to establish a coordinated governmental mechanism for handling the issue of ballistic and cruise missiles.[51] First and foremost, Stalin sanctioned the formation of a top-secret nine-member Special Committee for Reactive Technology, much like the one for the atomic bomb. The Soviet leader's choice for chairman of the new committee was somewhat of a surprise: Georgiy M. Malenkov, forty-four, who had headed the secret Council on Radar since June 1943, but who had very little experience in dealing with any rocketry or artillery matters.[52] More curiously, it seems that Malenkov had not been one of the major power brokers in the postwar Stalin leadership, such as Beriya, Molotov, or Voroshilov. As future events would attest, he would eventually become a leading player in upper echelons of the Kremlin, although it would at best be an extremely uneven career ahead. A natural choice for one of the two deputy chairmen of the committee was the thirty-seven-year-old Ustinov, who concurrently served as the head of the Commissariat of Armaments. In 1946, the Commissariat of Armaments was reorganized as part of a general restructuring in the Soviet defense industry, absorbing the military production of the wartime Commissariats (Munitions, Mortars, Medium Machine Building, and Tank Industry), and redesignated the new

49. Konovalov, "From Germany—To Kapustin Yar."

50. Mozzhorin, *et al.*, eds., *Dorogi v kosmos: I*, p. 118. Mishin had met Korolev for the first time in Prague in November 1945. See A. Tarasov, "Missions in Dreams and Reality" (English title), *Pravda*, October 20, 1989, p. 4.

51. The complete text of the important decree is reproduced in I. D. Sergeyev, ed., *Khronika osnovnykh sobytiy istorii raketnykh voysk strategicheskogo naznacheniya* (Moscow: TsIPK, 1994), pp. 227–33. The actual Russian word "reaktivniy" is alternately translated as "reactive," "jet," or "rocket." The word is most commonly used to mean "jet-propelled" as in the Group for Study of Jet Propulsion (GIRD), but in this particular case, "rocket" or "reactive" may be a more appropriate choice.

52. Chertok, *Rakety i lyudi*, pp. 228, 233.

Ministry of Armaments.[53] The other deputy chairman of the committee was Ivan G. Zubovich, forty-five, an expert in electronics who until his new appointment had served as the First Deputy People's Commissar of the Electronics Industry.

Of the other members, certainly the most important was Ivan A. Serov, forty, the Deputy Minister of Internal Security and Beriya's right-hand man. Given the pervasive influence of the state security apparatus in every level of Soviet society and government, it seems that Serov may have actually been the most influential, if not powerful, member of the special committee, serving as Beriya's direct contact on missile issues. Beriya at the time personally kept tabs on the much more important atomic bomb development effort, and it is very unlikely that he would have allowed someone such as Malenkov to have oversight over the rocketry sector. Although official governmental documents of this period give little hint of Beriya's control over *both* the nuclear and rocketry sectors, personal recollections of participants and observers of the early Soviet rocketry program give a different view, emphasizing the direct control that both Beriya and Serov exercised over the missile sector, despite the apparent lack of any formal institutional mechanism.[54] The only military person on the committee was Marshal Yakovlev, who had headed the visiting commission to Germany in May 1946.[55]

In addition to giving the special committee jurisdiction for overseeing all ballistic and cruise missile efforts, the decree had several other important repercussions. The document specifically called for scientific research and test work, dedicated to the reproduction of the German A-4 guided ballistic missile and the Wasserfall surface-to-air missile, using Soviet materials in the period 1946–48. It appointed Ustinov's Ministry of Armaments as the leading industrial sector to manufacture these vehicles. Several other ministries were tapped to develop and produce such important parts as guidance systems (Ministry of Electronics Industries), gyroscopes (Ministry of Ship Building Industries), liquid propellants (Ministry of Chemical Industries), rocket engines (Ministry of Aviation Industries), and launch complexes (Ministry of Machine Building and Instrument Building).[56]

Given the fact that the Ministry of Armaments was responsible for developing a variety of weapons systems, a special subsection of the ministry, the Seventh Chief Directorate, was established to handle all ballistic missile research. Ustinov appointed one of his wartime lieutenants, Sergey I. Vetoshkin, forty, to head this directorate.[57] In the interest of providing a large facility from which to direct ballistic missile development, the special committee set aside a factory in Kaliningrad, the M. I. Kalinin Plant No. 88, which had originally been founded in 1866 in St. Petersburg but was transferred to the suburbs of Moscow in 1918.[58] Throughout the war, the factory had been used for manufacturing artillery weapons and tanks. By an order from Ustinov on May 16, the plant was turned over to form the base of operations for the new Scientific Research Institute No. 88, the central entity in the Soviet Union working on the development of long-range ballistic missiles. Known more commonly as NII-88 (pronounced

53. John McDonnell, "The Soviet Defense Industry as a Pressure Group," in Michael McGwire, Ken Booth, and John McDonnell, eds., *Soviet Naval Policy: Objectives and Constraints* (Halifax, NS: Centre for Foreign Policy Studies, 1975), p. 114.

54. See, for example, Col. Gen. A. Maksimov, "White Crow" (English title), *Krasnaya zvezda*, January 12, 1990, p. 4; Sergey Khrushchev, *Nikita Khrushchev: krizisy i rakety: vzglyad iznutri: tom 1* (Moscow: Novosti, 1994), pp. 13, 143. Both sources state that Beriya had been responsible for controlling the rocketry sector.

55. The remaining original four members of the special committee were: Aksel I. Berg (director of the Institute of Radiotechnology and Electronics), Petr N. Goremkyn (minister of Agricultural Machine Building), Petr I. Kirpichnikov (deputy chairman of Gosplan), and Naum E. Nosovskiy (head of the First Chief Directorate of the Ministry of Armaments). See Sergeyev, ed., *Khronika osnovnykh sobytiy*, p. 227.

56. *Ibid.*, pp. 228–29.

57. Yu. Mozzhorin and A. Yeremenko, "From the History of Space Science: From the First Ballistics to . . . : II" (English title), *Aviatsiya i kosmonavtika* no. 8 (August 1991): 34–35.

58. Lardier, *L'Astronautique Soviétique*, p. 72.

"nee-88"), all long-range rocketry for the next ten years was directed from this institution. Maj. General Lev R. Gonor, the forty-year-old wartime head of the famous Barrikady Plant at Stalingrad, was appointed director of NII-88 on August 16, 1946.[59]

Maj. General Lev Gonor was the first director of the famous NII-88 institute, which was the focus of all early long-range ballistic missile development in the Soviet Union. (files of Peter Gorin)

At the same time, the primary client for these weapons, the Ministry of Armed Forces, established the Fourth Directorate within its Chief Artillery Directorate. This directorate was heretofore used as the branch of the armed forces handling all procurement, testing, operations, specifications requests, and basic research issues dealing with long-range ballistic missiles. The first chief of the directorate was thirty-five-year-old Maj. General Sokolov, who had led the initial inspection teams into Peenemünde the previous year. Maj. General Gaydukov, the chairman of OTK back in Germany, would serve as Sokolov's deputy.[60] In June, Sokolov and Gaydukov were instrumental in creating the Scientific Research Institute No. 4 (NII-4) within the Fourth Directorate to investigate "the development of methods of testing, acceptance, storage and combat application of missile weaponry."[61] Known secretly as "unit 25840" and located at Bolshevo near Moscow, the first director of the institute was Lt. General Aleksey I. Nesterenko, thirty-eight, yet another of the Katyusha veterans from World War II. Nesterenko was evidently picked for the post in part because of a definitive scholarly work on missile-artillery operations during the war.

The Fourth Directorate was also tasked with two other jobs: proposing a site from which the A-4 and other missiles could be tested and forming a unit of troops specifically for acquiring expertise in preparing and launching these large rockets. For the latter goal, on August 15, 1946, the so-called Special Purpose Brigade of the Supreme High Command Reserve was created within the Fourth Directorate to master the required expertise to use the A-4 ballistic missiles for training and wartime situations. Maj. General Aleksandr F. Tveretskiy, an officer who had served with the ubiquitous Lt. Colonel Tyulin, was appointed the brigade's first commander. Tveretskiy was a curious choice for the post; he had been excluded from membership in the Communist Party because of an incident during the war. When in a rage, he had shot his personal chauffeur. The core brigade was established at Sonderhausen in Germany, where they were sent to first study all available technical documentation on the A-4 to have a thorough knowledge of its capabilities and operational characteristics. Korolev, Pilyugin, and other senior

59. Yu. Mozzhorin and A. Yeremenko, "From the History of Space Science: From the First Ballistics to . . ." (English title), *Aviatsiya i kosmonavtika* no. 7 (July 1991): 40–41; Chertok, *Rakety i lyudi*, p. 234. For a wartime account of Gonor's role in the armaments industry, see D. F. Ustinov, *Vo imya pobedi: zapisky narkoma vooruzheniya* (Moscow: Voennoye izdatelstvo, 1988).

60. Mozzhorin, *et al.*, eds., *Dorogi v kosmos: II*, pp. 22, 88.

61. Mozzhorin and Yeremenko, "From the History of Space Science"; Sergeyev, ed., *Khronika osnovnykh sobytiy*, p. 20. The order for the creation of NII-4 was signed by the Council of Ministers on May 13, 1946, and by the Ministry of Armed Forces on May 24, 1946. The institute formally came into existence on June 21, 1946.

engineers of OTK were instrumental in coordinating all work with the brigade troops, some of whom later became full-time engineers with different design bureaus. For the most part, the brigade, composed of officers from the Mortar Guards Unit, Artillery, Air Force, and Navy, traveled to and from the major A-4 locations in Germany, learning operating and handling techniques from both the Soviet *Vystrel* group and the Germans themselves.[62]

The May 1946 decree also had important repercussions for the work in Germany. The writing clearly stressed the need to completely master aspects of design, production, and testing of the major German missiles, such as the A-4, Wasserfall, Rheintochter, and Schmetterling. A formal plan of action for further work in Germany was requested on the basis of a visit by Ustinov, Yakovlev, and others in the coming weeks. Most importantly, the decree formally stated that the work of OTK in Germany would end in late 1946 with the transfer of *all* German and Soviet personnel to Soviet territory, primarily to NII-88. At the time, the Special Committee for Reactive Technology concealed this order from the Germans and many of the Soviet engineers working in OTK. Originally, since about late 1945, a major portion of the work in Germany had been focused toward conducting a similar operation to the one the Allies had conducted at Cuxhaven, but by the spring of 1946, all such efforts were discontinued in anticipation of the move to Kaliningrad.[63]

It is clear both from the language of the decree and concurrent events that the entire operation was subsumed under a cover of secrecy. This was no doubt partly a result of Beriya's control of the sector but also stemmed from the ultimately military nature of the program. Even at this early point, the ultimate purpose of the Soviet effort in Germany was far from clear to the Allies, who were in some cases only kilometers away from the Soviets.

In early August 1946, members of the Special Committee for Reactive Technology officially visited Germany to make a second assessment of the A-4 effort. Arriving at Bleicherode were Marshal Yakovlev, Ustinov, Gonor, Vetoshkin, and two new members of the committee. One of them was Georgiy N. Pashkov, thirty-five, the chief of the rocket technology sector (the "2nd Department") at Gosplan, who had been recently appointed to this new position to serve as a senior advisor to the Communist Party on rocketry management issues.[64] It was evidently clear to most of the hosts at the Institute Nordhausen that Ustinov and Pashkov were both the most powerful and influential members of the visiting commission. On August 9, Ustinov officially appointed the thirty-eight-year-old Korolev as the new "chief designer" of all long-range Soviet ballistic missiles, to dispense his duties as the head of a special department in NII-88.[65] Korolev's selection for this important position did not come without resistance. Given his time as a Kolyma inmate and the fact that he was for all intents and purposes still an "enemy of the state," there were many in the upper Communist Party ranks who were unwilling to allow him to play such an important role in a top-secret national security program. The first choice to head ballistic missile development was in fact another OTK engineer named Yevgeniy V. Sinilshchikov, whose main focus had been work on the German Wasserfall surface-to-air missiles.[66] It is clear, however, that Ustinov was quite impressed by Korolev's work in Germany, and the recommendation from Gaydukov no doubt sealed his appointment. One of the new chief

62. Tyulin, "The 'Seven'"; Sergeyev, ed., *Khronika osnovnykh sobytiy*, p. 5; Holloway, *Stalin and the Bomb*, p. 457; Maksimov, ed., *Raketnyye voyska strategicheskogo naznacheniya*, p. 38.

63. Tyulin, "The 'Seven'"; Sergeyev, ed., *Khronika osnovnykh sobytiy*, p. 231.

64. Chertok, *Rakety i lyudi*, pp. 171–73. By his own account, Pashkov was appointed in "March or April of 1946." See Mozzhorin, *et al.*, eds., *Dorogi v kosmos: II*, p. 57. The other visiting member was N. I. Vorontsov, a deputy minister of the Communications Equipment Industry.

65. Tyulin, "The 'Seven'." Order No. 83-K called for: "The Appointment of Comrade Sergey Pavlovich Korolev as Chief Designer of 'Article No. 1' at the NII-88." "Article No. 1" was the R-1 missile.

66. Konovalov, "From Germany—To Kapustin Yar."

designer's first decisions was to appoint Mishin, then only twenty-nine years old, as his "first deputy," a common Russian term for "first among the deputies." On the same day as Korolev's new appointment, Mishin and several others from OTK flew back to Moscow to lay the groundwork for "transferring the set of scientific and technical documentation on the [A-4] rocket into Russian."[67] Mishin served as acting head of the ballistic missiles department at Kaliningrad until Korolev's return from Germany.

For Korolev, his quick reemergence from obscurity and hardship was a vindication of sorts, although it hardly compensated for the trials of the GULag. Most recent accounts do suggest, however, that he had a very positive attitude about life during his stay in Germany. In May 1946, a few months prior to his new appointment, his wife and daughter had arrived in Germany to visit him, staying through the summer. Korolev relished his newfound freedom, and he tried to make his tour in Germany a holiday of sorts. Between work schedules, he would take the time to drive around the countryside with his family in a state-sanctioned Opel automobile.[68] By this time, his reputation and the idiosyncrasies of his personality had made a great impression on the other members of the Soviet team. Later accounts from his subordinates and peers consistently underline his excellent managerial skills and his insistent emphasis on personal responsibility. Over the years, the latter aspect of his character, while assuming almost mythical proportions, also fostered a genuine feeling of professional workmanship among the engineers in his department. His strong personality and stubborn character also generated fear, not often unfounded. An engineer working under him later recalled that "Korolev was never lenient. He was harsh and hot-tempered. All of us who worked at his design office knew that he was merciless when he saw someone being careless or inattentive."[69] At the same time, he was also known as being extremely kind and giving. Most recollections suggest that he had no hesitation in sharing or giving credit to those who actually deserved it—a precedent that he established during these initial months in Germany during the postwar period. As the weeks wore on, there was almost unanimous belief among Soviet engineers that Korolev was the best man for the job.

New Organizations

The efforts in Germany in 1946 eventually began to split into two different paths. The first of these roads was the cooperative Soviet-German work to prepare several A-4s from parts that had been recovered at Nordhausen and elsewhere. By mid-1946, it was clear that only about a dozen A-4 articles could be produced given the relatively meager leftovers discovered. To extend the potential of using these vehicles both as training missiles and as formal armaments of the armed forces, Korolev at the time was ordered to commence work on a Soviet copy of the A-4, designated the R-1.[70] The primary difference between the two vehicles was a redesigned tail and instrument compartment to increase the range of the Soviet version. Engineers also used a modified guidance and control system designed not only to nominally increase operational characteristics of the vehicle but also to adhere to production processes in Soviet industry. It was clear, however, to Korolev and the other leading engineers of OTK that creating a Soviet copy of the A-4 would only serve as an interim measure. In fact, Korolev had very little enthusiasm for working on the R-1 project, and this issue may have caused some friction with his superiors. Even at that early stage, he had some major reservations about the

67. Mozzhorin, *et al.*, eds., *Dorogi v kosmos: I*, p. 118.
68. Romanov, *Korolev*, p. 213.
69. V. Lysenko, ed., *Three Paces Beyond the Horizon* (Moscow: Mir Publishers, 1989), p. 45.
70. The "R" stood for "raketa," the Russian word for "missile."

limited capabilities and cumbersome operational characteristics of the A-4 rocket, and he considered merely duplicating the missile a waste of time. Prompted by these considerations, in early 1946 at Sonderhausen, Mishin and Budnik had begun early work on an uprated A-4 with a range more than twice as much as its predecessor—that is, 600 kilometers. By the second half of 1946, Korolev and Glushko had already performed "a critical analysis of the missile."[71] Designated the R-2 (and K-1 by British intelligence), the new missile was essentially a stretched A-4 with a new engine designed under Glushko.

It seems that there had been some major German input into these early R-2 studies. In the summer of 1946, Gaydukov had asked the Germans to suggest technical improvements to the A-4 by mid-September. The Germans under Grottrup submitted about 150 recommendations, most of them based on ideas that had been considered by the original Peenemünde team during the war. The Soviet side accepted only half of the list and asked that the rest be studied in more detail prior to a resubmittal. According to the recollections of German engineers, it seems that Korolev had made "as little use as he could of the Germans at Zentralwerke."[72] Despite the coolness in terms of collaboration, the Germans themselves were apparently very impressed with Korolev's professionalism and courtesy. The latter was reportedly sympathetic to the needs of the German engineers; on one occasion, Korolev himself helped rebuff the Soviet secret police's attempts to harass Grottrup's secretary.

For the Germans, the underlying fear that they would be taken back to the Soviet Union was confirmed in October 1946. On the 21st, Grottrup and several of the leading Germans attended a meeting on possible improvements to the A-4. There was a party for the attendees afterwards, which was rudely interrupted at 4:00 a.m. when the Soviets began their massive operation to transport about 6,000 Germans from various technical industries to the USSR. Each individual was handed a document containing the following passage:

> *As the works in which you are employed are being transferred to the USSR, you and your entire family will have to be ready to leave for the USSR. You and your family will entrain in passenger coaches. The freight car is available for your household chattels. Soldiers will assist you in loading. You will receive a new contract after your arrival in the USSR. Conditions under the contract will be the same as apply to skilled workers in the USSR. For the time being, your contract will be to work in the Soviet Union for five years. You will be provided with food and clothing for the journey which you must expect to last three or four weeks.*[73]

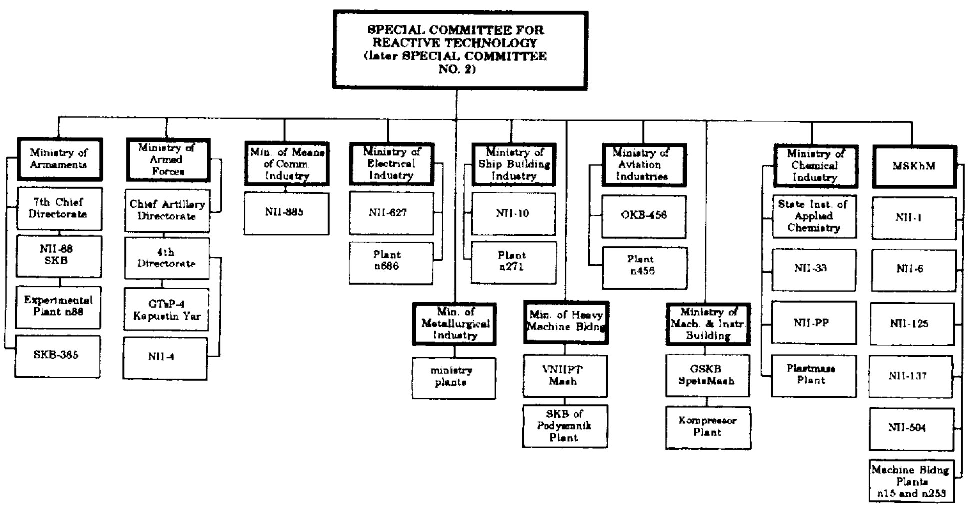
The entire operation was prepared and coordinated by Ivan A. Serov, the Deputy Commissioner of the Soviet Military Administration in Germany and Beriya's point man in the rocketry program. Some engineers, even from the Soviet side, expressed reservations about taking the Germans wholesale back to the USSR. Korolev himself reportedly remarked that "we [the Soviets] must have a little more self-respect."[74] In the end, the words of Beriya and Serov were final. In the months preceding the transfer, Serov had requested from Gaydukov a list of the most capable German rocketry specialists. Gaydukov returned with 152 names, all of whom, including their families (a total of 495 people), boarded trains for the Soviet Union on October 22 and 23.

71. Tyulin, "The 'Seven'"; Chertok, *Rakety i lyudi*, p. 165.
72. Ordway and Sharpe, *The Rocket Team*, pp. 321–23.
73. *Ibid.*, pp. 323–24; Chertok, *Rakety i lyudi*, p. 178.
74. Tokaty, "Foundations of Soviet Cosmonautics"; Chertok, *Rakety i lyudi*, p. 177.

By the time the Germans arrived in Moscow, a vast network of institutions was forming around the nerve center of NII-88 at Kaliningrad, about sixteen kilometers north of Moscow. The institute itself, headed by Maj. General Gonor, was divided into three formal structural units:

- A specialized design bureau to design long-range ballistic missiles
- A scientific branch with subdepartments for materials science, stress, aerodynamics, engines, fuels, control, testing, and telemetry
- An experimental plant to manufacture the missiles[75]

The design bureau was headed by Karl I. Tritko, who had formerly served as the chief engineer of the Barrikady Plant during the war. Tritko was assigned jurisdiction over at least eight departments in the design bureau, each focusing on a particular thematic direction. As the new chief designer of long-range ballistic missiles, Korolev headed Department No. 3, tasked initially with restoring A-4 production.[76] Vasiliy P. Mishin served as Korolev's *first* deputy, while two other engineers, Vasiliy S. Budnik and Leonid A. Voskresenskiy, also served as deputies. Konstantin D. Bushuyev, who would go on to direct the Soviet portion of the Apollo-Soyuz Test Project, joined in November 1946 and served as head of the planning sector of the



The organization of the Soviet ballistic missile program under the Special Committee for Reactive Technology in the late 1940s. (copyright Asif Siddiqi)

75. Mozzhorin and Yeremenko, "From the History of Space Science." The structure of NII-88 was established by Ustinov's order on August 26, 1946.

76. Mozzhorin, *et al.*, eds., *Dorogi v kosmos: I*, pp. 67–68. The other known departments were: Department No. 4 (to develop an anti-aircraft missile based on the German Wasserfall) headed by Ye. V. Sinilshchikov; Department No. 5 (to develop an anti-aircraft missile based on the German Schmetterling) headed by S. Yu. Rashkov; Department No. 6 (to develop an anti-aircraft missile based on the German Typhoon) headed by P. I. Kostin; and Department No. 8 (to develop liquid-propellant rocket engines for the Soviet versions of the Wasserfall and Schmetterling) headed by N. L. Umanskiy. It is clearly evident that at least half of the work at NII-88 was dedicated to efforts other than surface-to-surface long-range ballistic missiles. Korolev was officially appointed chief of Department No. 3 on August 30, 1946.

department responsible for all long-range projects.[77] Many of the other engineers who were employed at Department No. 3 went on to head their own design bureaus as chief designers of the Soviet space program in the 1960s and 1970s. Among the major individuals who joined in 1946–47 were Refat F. Appazov, Viktor F. Gladkiy, Aleksandr S. Kasho, Vyecheslav M. Kovtunenko, Dmitriy I. Kozlov, Sergey S. Kryukov, Svyastoslav S. Lavrov, Arkadiy I. Ostashev, Ivan S. Prudnikov, Yevgeniy V. Shabarov, and Georgiy S. Vetrov. At the time of its formation, this department employed sixty engineers, fifty-five technicians, and twenty-five workers.[78] The successor organization to this small section is known today as the Energiya–Rocket Space Corporation ("RKK Energiya").

The scientific branch of NII-88 was headed officially by the new chief engineer of the institute, Yuriy A. Pobedonostsev, who was Korolev's prewar colleague from the GIRD and NII-3 days.[79] Pobedonostsev oversaw at least five separate departments that focused on specific engineering areas in support of actual design work at the design bureau. Boris Ye. Chertok, the head of department U for guidance systems, served as Pobedonostsev's immediate deputy.[80] There was clearly a visible trend in hiring those who had performed admirably in Germany to important positions in the NII-88 hierarchy, as evidenced by the new posts for not only Korolev, but also Mishin, Pobedonostsev, and Chertok. In spite of Korolev's appointment as chief designer, he was, however, still buried under several levels of the bureaucratic chain. Officially, he was responsible to Chief Engineer Pobedonostsev and then to NII-88 Director Gonor, which naturally set limits as to his influence in institute decisions. These multiple levels of leadership proved to be difficult for Korolev to adjust to, given that back in Germany he had essentially assumed a coordinating role for the entire recovery operation by mid-1946.

The living conditions for those at NII-88 in 1946 were not very conducive to comfort. Even the more senior engineers had to live in "communal apartments" because of the lack of housing. At least half of the employees of the specialized design bureau were in fact on a waiting list for a *single* room for their families. Most of the workers simply lived in overcrowded barracks and tents, working often through weekends in hastily constructed hangars and "auxiliary structures" at an experimental airfield, which had been given to the institute upon its formation.[81] Instead of working tables, the engineers used equipment boxes for drawings. Manufacturing buildings were in poor conditions, with leaking roofs and puddles on the floor after rainstorms. One engineer remembers that "the heating didn't work, so it was colder inside the shops than outside."[82] Disease was widespread, and hospital facilities were severely lacking. In addition to their primary job of missile engineering and development, all the engineers had to participate in the building of work facilities, test installations, and even housing. Additional duties involved gardening and assisting the *kolkhozes* they sponsored. During 1946, at least 1,832 people quit

77. S. S. Kryukov, "K. D. Bushuyev—Scholar, Designer, Technical Director of the 'Soyuz-Apollo' Program" (English title), in B. V. Raushenbakh, ed., *Issledovaniye tvorchestva osnovopolozhnikov kosmonavtiki i yeye sovremennye problemy* (Moscow: Nauka, 1989), pp. 38–39; Mozzhorin and Yeremenko, "From the History of Space Science."

78. Yu. Ishlinskiy, ed., *Akademik S. P. Korolev: ucheniy, inzhener, chelovek* (Moscow: Nauka, 1986), pp. 514–16; Lardier, *L'Astronautique Soviétique*, p. 73; Mozzhorin, *et al.*, eds., *Dorogi v kosmos: I*, p. 170.

79. Pobedonostsev was appointed to his new position at the same time as Korolev in August 1946. See Chertok, *Rakety i lyudi*, p. 175. He returned from Germany to take up his post on December 21, 1946.

80. The other departments were department M for materials (headed by V. N. Iordanskiy), department P for strength (headed by V. M. Panferov), department A for aerodynamics and gas dynamics (headed by Rakhmatulin), and department I for testing (headed by P. V. Tsybin). See *ibid.*, p. 249.

81. B. Konovalov, "Dash to the Stars" (English title), *Izvestiya*, October 1, 1987, p. 3; Mozzhorin and Yeremenko, "From the History of Space Science."

82. James Harford, *Korolev: How One Man Masterminded the Soviet Drive to Beat America to the Moon* (New York: John Wiley & Sons, Inc., 1997), p. 93.

the institute, while the volume of work was always increasing. It was a pace and level of labor that were quite unusual for civilians, even given the poor postwar economic conditions in the Soviet Union. Most of the engineers were in their late twenties or early thirties, fresh from graduation, although in time Korolev managed to recruit some of his old prewar colleagues from NII-3 and even GIRD.

The transfer of the Germans in late 1946 significantly augmented the work at NII-88. On arrival in Moscow on October 28, the 150 or so German rocketry specialists were split into two groups. One group ended up at the new NII-88 Branch No. 1 on Gorodomlya Island in Lake Seliger, about 240 kilometers northwest of Moscow—a remote location that had been witness to some of the most bitter fighting between the Soviets and the Germans. Needless to say, the locals were not very welcoming to the Germans.[83] Dr. Waldemar Wolff and Josef Blass were appointed the German chiefs of the group. The more fortunate of the Germans were transferred to the northeastern section of Moscow to facilitate easier and direct collaboration with engineers at NII-88 in Kaliningrad. Eventually, however, the latter group dispersed; many were assigned to various industrial ministries. It became clearer to the "guests" that the only Germans the Soviets planned to use as a group were the ones at Gorodomlya. The Germans were to focus on six major themes:

- Consultation on creating a Soviet version of the A-4
- Work on "organizational schemes"
- Research in improving the A-4 main engine
- Development of a 100-ton thrust engine
- Assistance in the "layout" of plant production rooms
- Preparation of rocket assembly using German components[84]

Living conditions for the Germans depended greatly on their relative importance and their education. Grottrup's family, for example, was housed in a six-room villa outside of Moscow that had formerly been occupied by a member of the Council of Ministers, and they were provided with a chauffeured BMW automobile. Others were housed according to a system based on the number of members in their families and their academic seniority. The latter criterion in fact determined their pay scales. Those with the equivalent of a Ph.D. degree, such as Magnus, Schmidt, and Umpfenbach, were paid 6,000 rubles a month. Those with engineering diplomas, such as Grottrup and Schwartz, were paid 4,500 rubles. The rest received 4,000 rubles a month. By comparison, most of the Soviet engineers themselves were paid much less. Korolev as a chief designer and head of a department was paid 6,000 rubles a month. NII-88 Chief Engineer Pobedonostsev earned 5,000 rubles, while Korolev's first deputy Mishin was paid only 2,500 rubles a month.[85] Most other Soviet engineers were paid much less.

While NII-88 was the primary institute responsible for the design and development of long-range rockets, it was by no means the only one. Unlike the small-scale vehicles developed by GIRD and NII-3 in the 1930s, missiles on the scale of the A-4 used systems that were vastly

83. Ordway and Sharpe, *The Rocket Team*, p. 325. The German "guests" at Branch No. 1 were put under the direct command of F. G. Sukhomlinov from the Ministry of Armaments, replaced soon after by P. I. Maloletov, who had formerly headed the NII-88 experimental plant. See Chertok, *Rakety i lyudi*, p. 195. Another source suggests that the first director of Branch No. 1 was V. D. Kurganov.

84. P. Bork and G. A. Sadovoj, "On the History of Rocketry Developed in the U.S.S.R. in the First Years After the Second World War (The Participation of German Specialists in the Development of Soviet Missile Technology in the Early Post-War Period)," in J. D. Hunley, ed., *History of Rocketry and Astronautics, Vol. 19* (San Diego, CA: Univelt, 1997), pp. 143–52.

85. Chertok, *Rakety i lyudi*, pp. 196–97; Ordway and Sharpe, *The Rocket Team*, p. 325.

more complicated. In particular, the guidance systems, engines, and launch platforms were areas for which NII-88 was forced to collaborate with a number of other important institutes spread across the Soviet defense industry. As with the Ministry of Armaments and its NII-88, other design organizations were under the command of other ministries. On July 3, 1946, the Ministry of the Aviation Industry established the Special Design Bureau No. 456 (OKB-456) at its former Aviation Plant No. 84 in Khimki for the design, development, and production of high-performance rocket engines. Headed by Chief Designer Glushko, the infrastructure and materials at the new design bureau had been transferred wholesale from the Lehesten plant in Germany. Glushko was also able to assemble about 150 of his old colleagues from the wartime days at OKB-SD.[86] Much of the effort at OKB-456 was focused toward testing existing A-4 main engines and facilitating the manufacture of its Soviet-made version, the RD-100.

Guidance and control systems for long-range missiles were handled by several enterprises spread across the Soviet defense industry. The Scientific Research Institute No. 885 (NII-885), under Director Nikolay D. Maksimov in the Ministry of the Communications Equipment Industry, was tasked with the design and development of all autonomous guidance systems, radio control systems, and radiotelemetry systems.[87] Mikhail S. Ryazanskiy, thirty-seven, was appointed the chief designer of radio control systems for all Soviet ballistic missiles, while simultaneously serving as the chief engineer of the institute. With a background in developing radar instruments for naval systems, Ryazanskiy had worked at NII-20 until his arrival in Germany. In early 1947, Nikolay A. Pilyugin, thirty-eight, a veteran of the NII-1/Raketa effort, was named Ryazanskiy's principal deputy for autonomous guidance systems as the chief of the Automation Department.[88] Both these men had played major roles in the work in Germany and would have a significant influence over future events in both the rocketry and space programs of the Soviet Union.

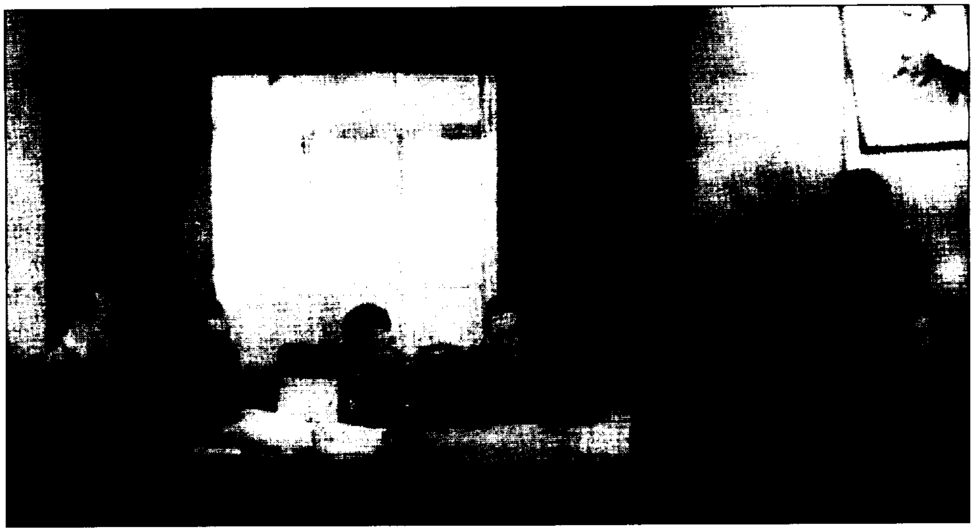
The development of all-command gyroscope instruments for the long-range ballistic missiles was entrusted to Scientific Research Institute No. 10 (NII-10), in the Ministry of the Shipbuilding Industry, under new Chief Designer Viktor I. Kuznetsov, who was thirty-three. With a background in designing gyroscope instruments during the war, Kuznetsov had also worked in Germany in 1945–46 and based much of his subsequent efforts on the results of this research. The clearly important job of designing launch pads and associated equipment for the missiles was assigned to the State Union Design Bureau of Special Machine Building (GSKB SpetsMash), within the Ministry of Machine and Instrument Building. The appointed chief designer was Vladimir P. Barmin, thirty-seven, who had headed the production of the Katyusha missile launch containers throughout the entire period of the war at the famous Kompressor Plant in Moscow.[89] During 1945–46, Barmin had also served as chief engineer of the Institute Berlin in Germany.

86. Chertok, *Rakety i lyudi*, pp. 196–97; Lardier, *L'Astronautique Soviétique*, pp. 73–74. Until Glushko's arrival, the plant had been headed by P. D. Lavrentiyev and was producing Li-2 transport aircraft under license.

87. Mozzhorin and Yeremenko, "From the History of Space Science." The NII-885 was established on February 26, 1938, to develop radio control systems. For a short time beginning May 13, 1946, this institute was subordinated to the Sixth Chief Directorate of the Ministry of the Electronics Industry and renamed the Scientific Research Institute for Special Technology (NII ST). See K. V. Gerchik, ed., *Nezabyvayemyy Baykonur* (Moscow: Interregional Council of Veterans of the Baykonur Cosmodrome, 1998), pp. 267–68; Maxim Tarasenko, "Evolution of the Soviet Space Industry," presented at the 46th International Astronautical Congress, IAA-95-IAA.2.1.01, Oslo, Norway, October 2–6, 1995.

88. Yu. A. Mozzhorin, *et al.*, eds., *Nachalo kosmicheskoy ery: vospominaniya veteranov raketno-kosmicheskoy tekhniki i kosmonavtiki, vypusk* 2 (Moscow: RNITsKD, 1994), p. 279; Lt. Gen. G. Tyulin, "Look Forward" (English title), *Krasnaya zvezda*, May 18 1988, p. 4; Chertok, *Rakety i lyudi*, pp. 235, 333. Pilyugin's Automation Department was the NII-885's Department No. 3.

89. Mozzhorin and Yeremenko, "From the History of Space Science."; Mozzhorin, *et al.*, eds., *Dorogi v kosmos: II*, pp. 50, 76.



This still from a late-1940s-era film shows the original members of the famous Council of Chief Designers. Starting second from left are Chief Designers Vladimir Barmin, Mikhail Ryazanskiy, Sergey Korolev, Viktor Kuznetsov, Nikolay Pilyugin (standing), and Valentin Glushko. At the far left is Boris Chertok, who was a deputy chief engineer responsible for guidance systems at NII-88. (copyright Christian Lardier)

Korolev, Glushko, Ryazanskiy, Pilyugin, Kuznetsov, and Barmin each represented the primary areas of development for long-range ballistic missiles. By the last few months in Germany in late 1946, the six had in fact begun to have informal meetings to coordinate overall program goals. After the major organizational changes in 1946–47, they continued these informal contacts. As the programs for missile development began to assume greater levels of complexity, Korolev developed the idea of forming a "Council of Chief Designers" consisting of the six leading chief designers. Established sometime in November 1947, the council was an informal and separate entity from the institutes and design bureaus and eventually assumed engineering control over much of the early development of the Soviet space program.

The original council consisted of Korolev (who was the chairman responsible for overall design), Glushko (rocket engines), Barmin (launch equipment), Kuznetsov (gyroscopes), Pilyugin (autonomous guidance systems), and Ryazanskiy (radio control systems).[90] One of its outstanding advantages was that it circumvented the normal chain of command in the industry and facilitated swifter and more efficient work. The standard hierarchy in the new missile industry meant that a particular design bureau or institute would be responsible to the specific ministry that had jurisdiction over it. The new council, however, managed to bring together individuals who were officially employed by several different ministries. This was clearly a novelty in the very centralized approach of the Soviet defense industry and illustrated Korolev's early pragmatism and originality in the search for more efficient work.

Apart from the central six organizations involved in the missile sector, there were at least two other major entities that played very significant roles in the formation of the space program. The first was NII-1, the institute that had served as a training ground for so many of the engineers who had ended up under Korolev. On November 29, 1946, a major reorganization in the

90. Col. M. Rebrov, "Council of Chiefs" (English title), *Krasnaya zvezda*, April 8, 1989, p. 3. Pilyugin was technically a deputy chief designer from 1946 until mid-1948, when he was appointed a chief designer.

institute was enacted as Mstislav Vsevolodovich Keldysh, a thirty-five-year-old mathematician, was appointed the new director.

Keldysh was born on February 10, 1911, in Riga, Latvia. His passion for mathematics was reinforced by his mentor, the famous Nikolay Luzin, who educated a generation of brilliant Soviet mathematicians. To Luzin's disappointment, Keldysh was more interested in applied fields rather than theory and ended up with a research position at the prestigious N. Ye. Zhukovskiy Central Aerohydrodynamics Institute (or TsAGI). His record was outstanding. In 1938, at the age of twenty-seven, he single-handedly found a solution to "flutter," the sharp increase in vibrations beyond critical flight velocity, after which aircraft would tend to simply fall apart. Later, by the end of the war, Keldysh tackled another difficult problem by discovering a way to avoid "shimmy," a phenomenon discovered by U.S. engineers that caused the front wheel of three-wheeled aircraft to oscillate from left to right upon landing. Keldysh's writings encompassed an astoundingly vast range of scientific areas, including aerodynamics, pure mathematical theory, hydromechanics, vibrations and oscillation, and thermal excitations of sounds. Based on these accomplishments, in 1946, the USSR Academy of Sciences elected the twenty-five-year-old Keldysh to be an Academician, possibly one of the youngest men ever to have such an honor.[91]

The primary goal of the reorganized NII-1, still under the jurisdiction of the Ministry of the Aviation Industry, was to examine the Sänger-Bredt antipodal bomber proposal for potential use as an "intercontinental rocket-plane."[92] A second major theme at the institute was basic research on aerodynamics, ballistics, rocket, and ramjet engines. Several divisions were established within the institute to study these problems, including an aeronautical design bureau headed by former Raketa head Viktor F. Bolkhovitinov and three engine design bureaus. Aleksey M. Isayev, the engineer who had been one of the first Soviets to enter Peenemünde in the spring of 1945, led the first of these engine design bureaus. He had returned from Germany to the Soviet Union in September 1945 to resume his work at NII-1 following a productive period at the Lehesten plant. By all accounts, Isayev was one of the most talented rocket engine designers in the country at the time, and it is more than likely that there was some level of rivalry between Glushko and Isayev at this early stage. Leonid S. Dushkin, tapped to head the second engine design bureau, also focused on rocket engines, while Mark M. Bondaryuk, appointed to the third bureau, led the development of ramjet engines for the Sänger-Bredt bomber. All three were to eventually develop propulsion systems for long-range strategic missiles.

Besides NII-88 and NII-1, NII-4 was the third organization with a major role in the early postwar rocketry sector. Unlike all the other research institutes and design bureaus, NII-4 was part of the Ministry of Armed Forces, the primary *client* for ballistic missiles. Formed at the same time as NII-88, one of those who had ended up at NII-4 was Mikhail K. Tikhonravov, Korolev's old collaborator from GIRD and the designer of the first Soviet liquid-propellant rocket. Tikhonravov had served at NII-1 throughout the war and had spent a short time as part of the inspection commission in Germany, but he was apparently not deeply involved in its activities. Instead, he took part in research on the first postwar Soviet missile dedicated to scientific purposes.

In 1943, the P. N. Lebedev Physical Institute of the USSR Academy of Sciences (FIAN) proposed the development of a rocket designed to reach an altitude of forty kilometers to conduct research on cosmic rays. In April of the following year, while Tikhonravov was still at NII-1, he established a group under Pavel I. Ivanov to develop a missile to satisfy these require-

91. V. S. Avduyevskiy and T. M. Eneyev, eds., *M. V. Keldysh: izbrannyye trudy: raketnaya tekhnika i kosmonavtika* (Moscow: Nauka, 1988), p. 7; John Turkevich, *Soviet Men of Science* (Princeton, NJ: D. van Nostrand, 1963), pp. 152–53.

92. Yu. V. Biryukov and A. A. Yeremenko, "50 Years for the Native Rocket-Space Industry. The Early Period of Development" (English title), *Novosti kosmonavtiki* 10 (May 6–19, 1996): 54–64.

ments. A plan for an eighty-seven-kilogram rocket was finished in two months and formally presented to FIAN in December 1944. The design combined several RS-132 solid-propellant Katyusha rockets together into a four-meter-long three-stage vehicle. The rocket was capable of lifting a mass of instruments (just under fifteen kilograms) to an altitude of forty kilometers.[93] Interrupted by Tikhonravov's short stint in Germany, the plan to construct the rocket took longer than expected, but finally in June 1946, Tikhonravov's team and Sergey N. Vernov, a scientist at the Lebedev Physical Institute who had developed the experiments, assembled in Leningrad to launch the so-called VR-210.[94] The first rocket exploded because of a faulty combustion chamber, the second also failed, and the third, although launched without problems, did not reach the desired altitude. The program was canceled at that point, and Vernov eventually took his experiments to a more well-equipped team, one under Korolev at NII-88.

As for Tikhonravov, when NII-1 was reorganized in November 1946, his group of twenty-three individuals from Branch No. 1 was transferred wholesale to the new military NII-4 in Bolshevo, participating in basic research on the application of long-range missiles for the USSR Ministry of Armed Forces. Staffed and headed mostly by artillery officers, it seems that Tikhonravov's group had been somewhat of an anomaly at the institute given their background in aeronautical engineering. Others who ended up at NII-4 included veterans of operations in Germany, such as Lt. Colonel Tyulin, who would also play a very significant role in the early days of the Soviet space program.

The R-1 and the Antipodal Bomber

Korolev finally returned to the Soviet Union in February 1947, formally taking over his duties as chief designer and chief of Department No. 3 at the NII-88 Specialized Design Bureau. By the time of his return, the investigations in Germany had yielded a massive thirteen-volume work authored by engineers at OTK titled "Collection of Materials for the Study of Captured Reactive Technology."[95] The Soviet authors were surprisingly cautious in their assessments of the level of advancements achieved by the Germans. While acknowledging significant accomplishments on the part of the Peenemünde team, the study also emphasized the limitations of the A-4. These shortcomings included the overall design of the frame of the missile, the design of the propellant tanks, and the warhead container. The authors did, however, recognize that they had much to learn in the field of guidance system development.[96]

Despite the limitations of the A-4, the Soviet leadership was keen to move ahead with launches of the native-built version of the missile, the R-1, to acquaint Soviet industry with the process of manufacturing and operating a long-range missile. Korolev himself was looking ahead to the much more powerful R-2 rocket based on the earlier work of Mishin and Budnik in Germany. In January 1947, in an official request to the government, he had proposed the immediate commencement of work on the latter vehicle. In response, the government declined

93. Yaroslav Golovanov, *Korolev: fakty i mify*, (Moscow: Nauka, 1994), p. 406; Peter Stache, *Soviet Rockets*, Foreign Technology Division Translation, FTD-ID(RS)T-0619-88 (from unnamed source), Wright-Patterson Air Force Base, Ohio, November 29, 1988, p. 206. This is a translation of Peter Stache, *Sowjetischer Raketen* (Berlin: Militarverlad der DDR, 1987).

94. There was an earlier test firing on March 19, 1946, to test the separation of the stages. See Igor Afanasyev, *R-12: Sandalovoye derevo* (Moscow: EksPrint NV, 1997), p. 20; Lardier, *L'Astronautique Soviétique*, p. 77. Another source suggests that the model actually launched was capable of lifting a mass of twenty kilograms to altitudes of fifteen to eighteen kilometers. See V. N. Galkovskiy, "Activities of M. K. Tikhonravov in the RNII (1934–1944)" (English title), *Iz istorii aviatsii i kosmonavtiki* 42 (1980): 23–26

95. Romanov, *Korolev*, pp. 214; M. V. Keldysh, ed., *Tvorcheskoye naslediye akademika Sergeya Pavlovicha Koroleva: izbrannyye trudy i dokumenty* (Moscow: Nauka, 1980), p. 395.

96. Stache, *Soviet Rockets*, p. 168.

to approve work on the R-2 and instead opted for a conservative approach focused on the R-1.[97] Much of the technical details of the R-2 remained in the realm of conjecture at the time, and the project would face a rather circuitous route to formal approval from the Soviet government. As for the R-1 itself, in a letter to the overseeing Special Committee for Reactive Technology, Korolev cautioned that the "creation of the native R-1 missile is not [simply a matter] of copying German technology and substituting their materials with [Soviet] materials."[98] In other words, it was a note of warning to Soviet leaders that the path to creating such a large missile, given existing conditions, would take the marshaling of a substantial amount of resources. The letter from Korolev prompted the establishment of specific schedule, beginning with launches of the A-4 and then leading into flights of the R-1. Finally, he also called for starting the formal process to create a launch test site for flying the A-4 and R-1 missiles.

In design and appearance, the R-1 was a near copy of the German A-4 missile. The 14.65-meter-long vehicle consisted of four primary elements: the tail assembly, the propellant compartment, an equipment section, and the warhead. The maximum body diameter was 1.65 meters. The lower part of the propellant section incorporated an oxidizer tank container, which carried approximately five tons of liquid oxygen. An insulated feed line was routed from the top tank for four tons of ethyl alcohol. Both containers were self-supporting, separate from the outer shell of the missile, and covered by heat insulation made of glass wool. The twenty-five-ton-thrust RD-100 engine was installed at the base of the rocket with a large turbopump assembly. The equipment section was situated on top of the propellant tanks and contained the guidance system with control and gyroscopic instruments. During flight, the system would control the air rudder at the rear of four large fins at the base of the rocket via servomotors. The explosive warhead was inserted into the nose cone, which itself was attached to the main body of the missile.[99] The total mass of the rocket was about thirteen and a half tons, approximately nine and two-tenths tons of which was propellant. The maximum flight range was about 270 kilometers, slightly higher than the A-4.

Although Korolev himself was the managerial leader of the project, he also contributed extensively to technical aspects of development. Other engineers closely involved in the effort at Korolev's Department No. 3 were Mishin, Abramov, Budnik, Bushuyev, Lavrov, Okhapkin, and Voskresenskiy. The development of the missile also brought into the forefront the operations of the Council of Chief Designers. While the Germans were not involved in any decision-making, they did, however, closely participate in assisting their "hosts" in facilitating the road to the first Soviet tests. For example, German guidance experts at Gorodomlya Island built a simulator for missile trajectories in a month's time, which was sent to NII-88 at Kaliningrad. In addition, a team of twenty German propulsion experts was dispatched to OKB-456 to work with Glushko, although the latter was evidently uninterested in using their talents. The Germans were forced to return to NII-88 soon.[100]

At this time, in early 1947, the Soviet leadership had yet to formulate a specific agenda for the new missile industry. Much of the effort in the defense industries was in fact focused on developing the first atomic bomb. A means of delivery, while important, was still clearly secondary. Without a clear idea of what system to pursue for delivery, Soviet Communist Party

97. Yu. V. Biryukov, "Materials in the Biographical Chronicles of Sergey Pavlovich Korolev" (English title), in B. V. Raushenbakh, ed., *Iz istorii sovetskoy kosmonavtiki: sbornik pamyati akademika S. P. Koroleva* (Moscow: Nauka, 1983), p. 226.

98. Chertok, *Rakety i lyudi*, pp. 205–06.

99. Stache, *Soviet Rockets*, p. 173; G. A. Sadovoy, "10 October—40 Years After the First Successful Launch of the First Soviet Guided Missile of Long Range R-1 (1948)" (English title), *Iz istorii aviatsii i kosmonavtiki* 59 (1989): 94–101.

100. Ordway and Sharpe, *The Rocket Team*, p. 327; Sadovoy, "10 October—40 Years After."

leaders—and in particular Stalin himself—were particularly interested in the old German Sänger-Bredt idea. NII-1 engineer Isayev had discovered some documents on this German intercontinental bomber project in May 1945 at Peenemünde; at that time, the projected capabilities of the piloted vehicle had astounded the Soviets.[101] The need for a 100-ton-thrust rocket engine in the vehicle no doubt gave pause to any hopes of an early development of the bomber. But caught amid the period's appropriation of German technology, the Soviets were not willing to discard even the most outlandish ideas from their German opponents. A copy of the report was first turned over to NII-1 Deputy Director Bolkhovitinov in 1945. The following year, he authored a preliminary study of the vehicle titled "Survey of Captured Technology," which was in fact published in a slim volume by the Ministry of Armed Forces.[102] Initial Soviet assessments of the plan were not encouraging: Bolkhovitinov's deputy Genrikh N. Abramovich, evaluating the proposal, speculated that it would take another decade before the Soviet Union could bring the project to fruition. This pessimistic view does not seem to have affected the aviation sector's interest, and soon after Academician Keldysh's appointment as director of NII-1 in November 1946, much of the work at the institute was devoted to the Sänger-Bredt problem. In a document prepared on April 3, 1947, Keldysh for the first time discussed the necessary technical and industrial requirements for creating a 100-ton-thrust engine to power an aircraft.[103]

As Keldysh began research work at NII-1 on the bomber, in the spring of 1947, scientists and engineers briefed Stalin on the work on the vehicle. By some accounts, the Soviet leader was unusually enamored of the Sänger-Bredt concept, and he may have in fact been personally instrumental in pushing for an analog Soviet project to produce the intercontinental bomber as a delivery system for nuclear weapons.[104] Several important officials, including representatives from the Soviet Air Force, the Ministry of the Aviation Industry, and the Ministry of Armaments, were on hand to discuss the project with Stalin in mid-April. Unconfirmed reports suggest that there were guarded attempts to caution the Soviet leader about drawbacks in the design's technical details, but that these attempts did not change Stalin's mind. A commission was allegedly established under Col. General Serov, the first deputy chairman of the state security apparatus, to seriously investigate the program.[105] The Sänger-Bredt commission, if it existed at all, may have been an adjunct to the more important Special Committee for Reactive Technology, which had been renamed Special Committee No. 2 by June 1947.[106]

Stalin's support notwithstanding, Soviet scientists were not too favorable in their opinion of the piloted antipodal bomber plan. The initial impressions of both Keldysh and Abramovich were not encouraging. Both believed that the project could not be brought to fruition in a short

101. Chertok, *Rakety i lyudi*, p. 91.

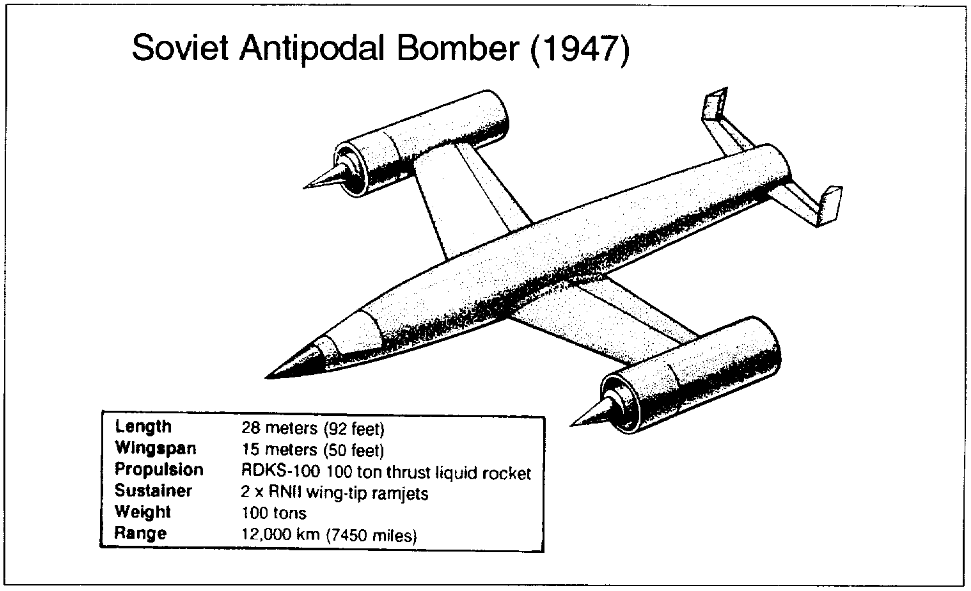
102. *Ibid.*, p. 93.

103. This document has been reproduced as M. V. Keldysh, "On the Development of Research Work on Aircraft With ZhRDs" (English title), in Avduyevskiy and Eneyev, eds., *M. V. Keldysh*, p. 20. "ZhRD" is the acronym in Russian for liquid-propellant rocket engine.

104. Zaloga, *Target America*, p. 122.

105. Tokaty, "Foundations of Soviet Cosmonautics"; Tokaty, "Soviet Space Technology." The accuracy of both these sources should be viewed with great doubt. Many of the details of the two meetings that the author discusses have serious inconsistencies and historical inaccuracies. The general nature of Stalin's policy on the Sänger-Bredt bomber and the overall tone of the meeting may, however, be fairly indicative of actual events in April 1947. For a detailed Russian analysis and refutation of Tokaty-Tokayev's accounts, see Golovanov, *Korolev*, pp. 392–95. Note that the date given in both the Tokaty sources is March 14, 1947. Based on information from recent Soviet reports, it seems that the meeting was on April 14, 1947. See Golovanov, *Korolev*, p. 396. Among those named by Tokaty-Tokayev as allegedly present were L. P. Beriya, M. V. Keldysh, G. M. Malenkov, A. I. Mikoyan, V. M. Molotov, I. A. Serov, I. V. Stalin, G. A. Tokaty-Tokayev, D. F. Ustinov, K. Ye. Voroshilov, N. A. Voznesenskiy, and A. A. Zhdanov.

106. Mozzhorin and Yeremenko, "From the History of Space Science: II."



The Soviet version of the Sänger-Bredt antipodal bomber, shown here as it was conceived in 1947 by the NII-1 institute headed by Academician Mstislav Keldysh. The rocket plane would have been launched from a special catapult. (copyright Steven Zaloga)

time period given the relatively large leap in technology required. The governmental pressure was, however, insistent enough for Keldysh to write a lengthy report on the bomber in 1947, titled "On Power Plants for a Stratospheric High-Speed Aircraft," which examined in detail the necessary requirements for the creation of an experimental system.[107] The report, prepared under Keldysh's direction at NII-1, described a vehicle clearly reminiscent of the original Sänger-Bredt concept.

The 100-ton winged spacecraft was twenty-eight meters long, with a total wingspan of fifteen meters, and it had a full operational flying range of 12,000 kilometers. The basic vehicle was equipped with three engines, two ramjet units at the tips of the wings, and one traditional liquid-propellant rocket engine at the rear end of the fuselage. As envisioned in the 1947 report, the bomber would be piloted by a single crew member in a special hermetically sealed cockpit at the front of the vehicle. In one of the more original schemes of the plan, the bomber would be launched using a special "catapult" equipped with at least five 100-ton-thrust liquid-propellant rocket engines to impart a total thrust of 500 to 600 tons, for about ten to twelve seconds, accelerating the vehicle to a velocity of about 500 meters per second. At this point, the huge ramjets at the wingtips would fire, working until the vehicle reached an altitude of twenty kilometers, then the main 100-ton-thrust engine at the rear of the bomber would ignite to literally "launch" the bomber into the upper reaches of the atmosphere. A nominal mission would have the bomber fly several "dip-and-skip" trajectories into the atmosphere before reaching the final target.[108]

107. A chapter from the report has been published as M. V. Keldysh, "On Power Plants for a Stratospheric High-Speed Aircraft" (English title), in Avduyevskiy and Eneyev, eds., *M. V. Keldysh*, pp. 22–34.

108. *Ibid.*

Active research on the ambitious project began in 1947 under Keldysh's guidance. Apart from playing the overall role of coordinating work on the project, NII-1 also contracted one of its own subdepartments to develop the kerosene-liquid oxygen rocket engine for the catapult and the bomber itself. Leonid S. Dushkin, an engineer who had been an associate of Korolev's in the 1930s, was appointed to lead a team to develop the main engine, designated the RDKS-100. Given the fact that the most powerful Soviet liquid-propellant engine in existence at the time had a thrust of only twenty-five tons, it was quite an ambitious undertaking for Dushkin. NII-1 also at the time commenced an extensive series of experiments, having established laboratories for gas dynamics, combustion, heat exchange, physical methods of measurement, on-board automatic instruments, and a special ground test stand for very high-thrust rocket engines.[109] Research on the two giant ramjet engines was tasked to the Central Institute for Aviation Motor Building in Moscow—an institution that had perhaps the most extensive experience in the Soviet Union in the design of such engines. The actual models would be built in-house at NII-1 under Bondaryuk.

Soviet officials also briefly attempted to involve the Germans in the work on the antipodal bomber. In October 1947, NII-88 Chief Engineer Pobedonostsev forwarded a copy of the original Sänger-Bredt report to the Germans at Gorodomlya. Given the earlier negative assessments from Keldysh and Abramovich, it is not surprising that the Germans had much the same impressions of the proposal. Several major problems were found with the project, including Sänger's claim that the mass ratio of the vehicle would be 0.1. In addition, the Germans postulated that each "skip" into the atmosphere would result in unforeseen gravity loads on the lone pilot and the wing structure, which were not accounted for in the design. They also found problems with the required exhaust velocity, reentry, and choice of a catapult-sled for launching the vehicle.[110] Despite the German recommendations, Keldysh and his engineers continued work on this project. In his 1947 report, Keldysh was remarkably optimistic, suggesting that based on NII-1's calculations, "it would be possible to create a combined propulsion unit with liquid rocket engines and supersonic [ramjets] ensuring a range of 12 thousand kilometers for the rocket plane."[111] Research at the institute focused on those areas in which there were inherent weaknesses in Soviet technology, such as the development of high-temperature resistant metals and high-thrust propulsion systems. Such was the interest in the bomber that Stalin reportedly dispatched an Air Force officer name Grigoriy A. Tokaty-Tokayev in 1948 to kidnap Dr. Sänger, who was at the time living in France. Unfortunately for the Soviet leader, Tokaty-Tokayev took the opportunity to defect to the West, thus providing a key source for information on the Soviet antipodal bomber effort.[112]

Kapustin Yar

Korolev's February 1947 letter to Special Committee No. 2 accelerated the process to select a missile test site for testing the A-4 and R-1 rockets. The committee, in cooperation with the General Staff of the USSR Ministry of Armed Forces, had initially settled on a location on the Azov shore, with launch routes taking the missiles over the Don steppes toward Stalingrad. Ukrainian Communist Party First Secretary Nikita S. Khrushchev was evidently opposed to such a move because of the possibility of "resettling" a large amount of people from the Ukraine. Khrushchev took the matter directly to Stalin, who asked Beriya to look elsewhere.[113] On July

109. Lardier, *L'Astronautique Soviétique*, p. 69.
110. Ordway and Sharpe, *The Rocket Team*, p. 329.
111. Keldysh, "On Power Plants for a Stratospheric High-Speed Aircraft."
112. See G. A. Tokaty-Tokayev, *Comrade X* (London: Harvill Press, 1956), for an account of his defection.
113. Khrushchev, *Nikita Khrushchev*, pp. 107–09.

27, 1947, from nine other choices, the committee selected a desolate area ninety kilometers southeast of the town of Volgograd on the banks of the Akhtuba River, a tributary of the Volga. Officially designated State Central Range No. 4 (GTsP-4), the place was informally called Kapustin Yar and covered a ninety-six-by-seventy-two-kilometer stretch of desert land. The name came from a legend that described a robber named Kapustin who had found refuge in the small village. The primary motivations for selecting Kapustin Yar were its remoteness from populated areas, its closeness to established railway tracks, and its proximity to the major industrial center of Volgograd. In addition, the railroad from Stalingrad to Kapustin Yar did not go through a single population center, thus isolating the new project from curious citizens. Apart from selecting a site, the July decree also formalized two other issues. The first launches of German and Soviet-built A-4 missiles were set for the period September–October 1947. Furthermore, Lt. General Vasiliy I. Voznyuk, a forty-year-old artillery officer who like many others in the new rocketry sector had participated in the operation of the Katyushas during the war, was appointed the first commander of the range.[114]

The construction of the modest launch facilities at the desolate area began at the height of summer in late July and early August 1947. The conditions were terrible, as Voznyuk later recalled:

> *Barren steppes. A little vermouth. Thorn bushes, occasionally some wolf's milk. Little water. Transport after transport arriving with construction worker[s] who had become famous for their efforts during the . . . war. Transports and materiél and equipment arrived. Families arrived. Where were they to be housed? As it turned out in tents and, at best, in small settlements located along a small stream whose water had too high a salt content to be used for drinking water. Sand, gravel, and bricks for building, water and food for personnel had to be brought in.*[115]

Some of the engineers from NII-88 and elsewhere were housed in special trains that served a multipurpose role. Most had live in tents or in the village houses of the local inhabitants, who were none too pleased with this sudden intrusion into their lives. The temperature in summer was as high as forty degrees Centigrade, while in winter it was known to drop to as low as minus thirty degrees. Although spring did bring a temporary respite from the extreme weather conditions, the workers then had to cope with deadly snakes and tarantulas.[116] Necessities, such as water, food, clothing, and shelter, were not by any means taken for granted, and there were several fatalities.

In anticipation of the first launches in the fall, Soviet and German engineers, artillery officers, defense industrialists, secret police representatives, and Communist Party officials poured into Kapustin Yar and were housed in rail cars and tents. Korolev and several of his leading deputies arrived in early October at the same time as a number of notable dignitaries. These included Chief of Chief Artillery Directorate Marshal Yakovlev, Minister of Armaments Ustinov, Chief of the Seventh Chief Directorate Vetoshkin, and Deputy Minister of State Security Serov.[117] For the series of launches, the Soviet government set up a temporary administrative body called a "State Commission," whose members were the leading officials involved in the tests. Entities

114 Mozzhorin, *et al.*, eds., *Dorogi v kosmos: II*, pp. 76–77; Jacques Villain, ed., *Baïkonour: la porte des étoiles* (Paris: Armand Colin, 1994), p. 44; D. V. Shatalov, "The History and Formation of the First Soviet Cosmodrome Kapustin Yar," presented at the 48th International Astronautical Congress, IAA-97-IAA.2.2.01, Turin, Italy, October 6–10, 1997.

115. Stache, *Soviet Rockets*, p. 171; Tyulin, "The 'Seven'."

116. Villain, ed., *Baïkonour*, p. 44.

117. Boris Konovalov, "Soviets Rocket Triumphs Started in Germany: II" (English title), *Izvestiya*, March 7, 1992, p. 5; Mozzhorin, *et al.*, eds., *Dorogi v kosmos: II*, p. 78.

similar to the State Commission for A-4 Launches were quite common in the Soviet defense industry, existing only temporarily to certify each stage of testing of a new weapons system, such as tanks, aircraft, and rockets. By bringing together individuals from different institutional boundaries, governmental agencies could make more effective assessments of the capabilities and limitations of weapons. Eventually, decades later, the same principle would come into use in the Soviet space program.

Marshal Yakovlev, the head of the Chief Artillery Directorate, was a natural choice for the post of chairman of the State Commission for A-4 Launches. Officially, his deputies were Ustinov and Serov, although in actuality, much like the policy-making Special Committee No. 2, Serov probably played a pivotal role in the new commission's operations.[118] Numerous German engineers, including Grottrup, Hoch, Klippel, Magnus, Meier, and Munnich, also traveled to Kapustin Yar in early fall to serve as coordinators for the launches, although they were not official members of the State Commission. They were well acquainted with most of the equipment at the range because a large amount of it had been directly collected at Lehesten and Peenemünde. The actual launch "pad" itself was served by special railcar built under the guidance of Grottrup in Kaliningrad. A "consultant" group of Germans for launch operations was headed by Fritz Viebach. Apart from the Germans, a small active Soviet launch group was also established to directly conduct the tests.[119] A total of about 2,200 personnel were present for these historic launches at Kapustin Yar.

There were two different series of A-4s prepared for launch, each comprising nine rockets. The first, designated "series N," had been built by the Germans at the Klein Bodungen plant and tested horizontally at Mittelwerk. The "series T" consisted of those built and assembled using primarily German and some Soviet parts at NII-88 plant at Kaliningrad, near Moscow. The first launch of an A-4 missile from Soviet soil took place at 1047 hours Moscow Time on October 18, 1947, more than a year after the first U.S. A-4 test. The series T rocket lifted off successfully, and as a result of clear weather, viewers saw the rocket for a few minutes. The A-4 impacted some 206.7 kilometers from the launch point, a distance of thirty kilometers to the "left" of its intended target point.[120] Initially unaware of the guidance system failure, there was almost pandemonium at the launch site when it was announced that the missile had flown the full intended range. Ustinov held Korolev in a bear hug and engaged in a celebratory dance with him. Korolev and Grottrup also hugged each other in congratulations.[121] The second launch on

118. The complete State Commission was: Marshal N. D. Yakovlev (Chief of the Chief Artillery Directorate), D. F. Ustinov (Minister of Armaments), I. A. Serov (First Deputy Minister of Interior Affairs), S. N. Shishkin (Deputy Minister of Aviation Industries), N. I. Vorontsov (Deputy Minister of Communications Equipment Industry), V. P. Terentyev (Deputy Minister of Ship Building Industry), V. I. Vinogradov (Deputy Chief of Rear Services and Chief of Staff of Rear Services of the Ministry of Armed Forces), N. I. Kochnov (Deputy Minister of Machine Building and Instrument Building), M. P. Vorobyev (Chief of Engineering Forces of the Ground Forces), M. K. Sukov (Chief of the Chief Directorate of the Oxygen Industry of the Council of Ministers), S. I. Vetoshkin (Chief of the Chief Directorate of Reactive Armaments of the Ministry of Armaments), and P. F. Zhigarev (Deputy Commander-in-Chief of the Air Force). See Vladimir Ivkin and Aleksandr Dolinin, "They Were the First" (English title), *Krasnaya zvezda*, October 31, 1997, p. 2.

119. Sergeyev, ed., *Khronika osnovnykh sobytiy*, p. 34. This team included brigade officers Major Ya. I. Tregub (chief of launch command) and Captain N. N. Smirnitskiy (launch operator), Korolev's Deputy for Testing L. A. Voskresenskiy (launch operator on behalf of the engineers), NII-88 Deputy Engineer B. Ye. Chertok, and NII-885 Deputy Chief Designer N. A. Pilyugin. Others in the group included Lieutenant A. P. Bachurin, Captain V. D. Boykov, Lieutenant G. V. Dyadin, Pilyugin's deputy A. M. Ginsburg, and Captain V. I. Menshikov. See Mozzhorin, *et al.*, eds., *Dorogi v kosmos: II*, p. 78.

120. Chertok, *Rakety i lyudi*, pp. 186–87, 192–93; Igor Yemelyanov, "This Yar Wasn't So Easy to Come by: Our First Space Launch Facility Hears the Rockets Less and Less Often" (English title), *Komsolskaya pravda*, November 26, 1993, p. 3; Tyulin, "The 'Seven'."

121. Ordway and Sharpe, *The Rocket Team*, p. 333.

October 20, also of a series T vehicle, was more of a disappointment. During the active part of the trajectory, the missile deviated sharply to the left and disappeared into the clouds. After a few seconds, an announcement came over the speakers, with some element of humor, that the missile had "fallen in the region of Saratov," a densely populated region.[122]

The State Commission immediately met, and Serov asked that all efforts be made to ascertain the possibility that the A-4 had indeed landed at Saratov. Because the request came from Serov, the rocket builders took the order correctly as a veiled threat to their jobs. Eventually, after tense minutes, investigators discovered that the rocket had actually landed not in Saratov, but elsewhere, about 180 kilometers from the intended target. Ustinov immediately decided to consult German specialists on the problem. Two of them, Magnus and Hoch, were instrumental in determining the cause of the guidance failure, allowing the tests to proceed. The last A-4s, the tenth and eleventh missiles, were successfully launched the same day, November 13, completing the historic first long-range ballistic missile launches in the Soviet Union. Of the total launched, five were built at Nordhausen and six at NII-88. The record of tests showed that all were launched successfully, although only five reached their designated targets.[123]

These first A-4 tests were also important for facilitating the first high-altitude scientific research in the Soviet Union. Scientists at the P. N. Lebedev Physical Institute of the USSR Academy of Sciences had been disappointed when the postwar VR-210 project had failed to produce any fruitful results. Aware of the R-1 effort at NII-88, Sergey N. Vernov, the nuclear physicist at the institute, was instrumental in trying to create a rapport between scientists and the engineers at NII-88, including Korolev. As a result, in 1948, the special Commission for the Study of Stratosphere, whose work had been on hold during the war, was revived. Academy President Sergey I. Vavilov met formally with Korolev that year to discuss a plan of operations for allowing scientists to design payloads for the R-1 missiles. By the fall of 1947, a modest experiment regime involving the study of cosmic rays had been prepared. The nose section of a few A-4s were equipped with an ionization chamber and a gas discharge counter with appropriate shielding; the main equipment section of the missile was modified to hold electronic instruments for the amplification, conversion, and coding of signals, which were all connected using a cable with antennae at the rear of the rocket. The actual cosmic ray detectors were attached between the rear fins of the A-4.[124] The total scientific payload mass was about 500 kilograms. The first of three of these "scientific" launches was conducted on November 2 in the presence of Dr. Vernov, the chief experimenter and at the time the deputy director of the Scientific Research Institute for Nuclear Physics. The missile reached an altitude of eighty kilometers, providing about three minutes of good data.[125]

The launches at Kapustin Yar in 1947 were clearly significant events in the history of the Soviet rocketry and space program. Having recovered only a handful of A-4s from the wreckage left behind by the Peenemünde group, it was a tribute to both the Soviet and German engineers involved that full-scale launches of these rockets, most of them successful, were resumed in such a short period after the end of the war. Unlike the U.S. military, which was able to capture 100 A-4s, the Soviets suffered from the limitation of having recovered approximately one-

122. Chertok, *Rakety i lyudi*, p. 192; Konovalov, "Soviets Rocket Triumphs Started in Germany: II."

123. Biryukov, "Materials in the Biographical Chronicles of Sergey Pavlovich Korolev," p. 226; Mozzhorin, *et al.*, eds., *Dorogi v kosmos: II*, p. 79; Chertok, *Rakety i lyudi*, pp. 192–93. An assessment of the A-4 launches is also given in Sadovoy, "10 October—40 Years After."

124. Stache, *Soviet Rockets*, p. 208; Biryukov, "Materials in the Biographical Chronicles of Sergey Pavlovich Korolev," p. 226.

125. Lardier, *L'Astronautique Soviétique*, p. 76. See also Stache, *Soviet Rockets*, p. 208. For Vernov's role, see L. L. Layko, "11 June—80 Years From the Birth of Soviet Scholar S. N. Vernov (1910)" (English title), *Iz istorii aviatsii i kosmonavtiki* 64 (1990): 48–54.

fifth of that number. Given the vast number of A-4s that were brought to the White Sands Proving Ground in New Mexico, the U.S. Army rapidly launched twenty-five of them in rapid succession in 1946 under the first phase of Project Hermes.[126] Assessing and identifying weaknesses in the A-4 design, the military was able to capitalize on the early tests and move on to more advanced programs. The Soviets, on the other hand, limited by the number of A-4s they could launch, simply opted to create their own homemade version, the R-1. Thus, the results of recovery operations by the Soviet Union and the United States in Germany in 1945 had a direct effect on the nature of immediate postwar rocketry efforts.

The Debate Over the R-2

Korolev supported the 600-kilometer-range R-2 missile project throughout 1947, but that project seems to have faced many delays from various sources. Initially proposed as early as January 1947, Stalin did not seem too keen on the project, given that the A-4s had yet to fly at the time. A meeting of the Scientific-Technical Council of NII-88 was held on April 25 to 28, 1947, at Kaliningrad in the presence of Minister of Armaments Ustinov. This allowed Korolev to formally "defend" the R-2 draft project.[127]

The R-2 missile was a significant advance over the German-based predecessor. The basic external structure of the R-2 was somewhat reminiscent of the A-4, but the new missile had a range twice that of the R-1. The corresponding increase of dry mass was only about 500 kilograms, while the increase in length was about two and a half meters. Korolev's engineers incorporated at least four major innovations into the vehicle to achieve the given performance. One of the two propellant tanks of the missile, the one carrying ethyl alcohol, was incorporated as an integral part of the overall structure of the rocket, often called a "monocoque" design. Engineers had to learn to master the complex thermal processes on the exterior of the vehicle because of such a scheme, which itself contributed to changing internal pressure in the tank. A monocoque design for the liquid oxygen tank was deemed too complex because of the uncertainties in its behavior in flight, although research was already ongoing on the means to incorporate such practices in succeeding designs. The second major design improvement was the use of a separable warhead, making it possible to have a much lighter rocket body, because thermal insulation would prove to be unnecessary for the main body after the separation of the warhead and the missile. This problem posed one of the greater challenges for Soviet engineers and required research on coordinating the separation of the two parts, elements of the trajectories, precise knowledge of engine performance, and stabilization of the nose section following separation. The R-2 also had a much improved guidance system, developed in cooperation with groups under Chertok, Pilyugin, Ryazanskiy, and Kuznetsov, which would allow increased targeting accuracy and also provide easier access during prelaunch operations to decrease the time required for preparing launches. Finally, the missile would use an uprated version of the R-1's RD-100, designated the RD-101, with a thrust of thirty-five tons, and developed at OKB-456 under Chief Designer Glushko. The new engine was achieved by increasing the concentration of ethyl alcohol and raising combustion pressure.[128] While the total length of the new missile

126. Andrew Wilson, *The Eagle Has Wings: The Story of American Space Exploration: 1945–1975* (London: BIS, 1982), p. 2; Ordway and Sharpe, *The Rocket Team*, pp. 353–54. A total of sixty-four A-4s were launched between April 16, 1946, and September 19, 1952, from White Sands.

127. Biryukov, "Materials in the Biographical Chronicles of Sergey Pavlovich Korolev," p. 226; Tyulin, "The 'Seven'." This was the first-ever meeting of the Scientific-Technical Council of NII-88. See Yu. A. Mozzhorin, "The Central Scientific-Research Institute for Machine Building—The Chief Center of the Soviet Rocket-Space Industry" (English title), *Iz istorii aviatsii i kosmonavtiki* 60 (1990): 20–40.

128. Keldysh, ed., *Tvorcheskoye naslediye akademika Sergeya Pavlovicha Koroleva*, p. 544; Stache, *Soviet Rockets*, pp. 175–77. The R-2 also had a new telemetry system named *Don*.

was 17.65 meters, the maximum body diameter was the same as the R-1, 1.65 meters. The total fueled mass was fifteen and a half tons.

The engineers froze the basic design elements of the R-2 plan by April 1947. Although the technical improvements were theoretically sound, the engineers did face serious problems translating their plans into reality. Among the major factors were the severe lack of raw materials and the absence of many important industries, such as advanced metallurgy, which had to be built from scratch. The industrial infrastructure for manufacturing the myriad of parts was almost nonexistent at the time, and engineers often had to scrounge through their own possessions for items such as springs and screws. The issue of quality control would also become a very important issue given the expenses associated with losing complete missiles because of faulty assembly. Finally, the Soviets were forced for the first time to create ground testing infrastructure for testing key elements of the missile prior to launches. One of the first dedicated engine testing facilities was established in July 1947 as Branch No. 2 of NII-88, about seventeen kilometers north of Zagorsk near Moscow, initially under the leadership of Gleb M. Tabakov.[129] The R-1's RD-100 was the first engine fired on static stands at the branch, while units for surface-to-air missiles developed at the NII-88 were also among those tested during 1947–48.

The development of the R-2 missile ran into serious problems soon after the April meeting. On June 4, 1947, NII-88 Director Maj. General Gonor hosted another meeting to discuss the long-range goals of the German specialists affiliated with the institute. At the meeting, Grottrup, the leading German rocketry specialist in the Soviet Union, proposed the development of a new missile designated the G-1 (later to be confusingly called the R-10) as a successor project to the R-1. Not surprisingly, there was a much resistance on the part of Soviet engineers to any German proposal that was competitive with their own plans. In this case, the G-1, with a range of 600 kilometers, had capabilities and design elements very similar to Korolev's R-2. The latter was particularly stubborn in his opposition to the G-1 plan. One of his closest associates, NII-88 Deputy Chief Engineer Chertok, later recalled that Korolev's resistance was based more on personal reasons than any technical considerations. Having suffered through the humiliation of the Great Purges, he had watched the Soviet rocketry effort crumble while the Germans had advanced swiftly with their ambitious A-4s. His hostility to the Germans and their designs in part contributed to his vigorous opposition to creating the R-1 copy of the A-4, a matter that resulted in significant friction with Minister of Armaments Ustinov.[130] The industrial leaders of the missile industry, in the person of not only Ustinov, but also Ryabikov, Vetoshkin, and others, were evidently in favor of allowing the German engineers a free reign in their design projects. This high level of support was crucial in ensuring that Grottrup's team could accelerate their work on the G-1 after the June meeting. To the dismay of Soviet engineers, relevant departments at the institute were subordinated to the Germans to assist them in their calculations in the ensuing months. It is quite likely that Korolev's engineers investigated the design characteristics of many of the German design characteristics for the G-1 for their relevance to the R-2 project, but ultimately the "German diversion" seems to have siphoned off resources for work on the Soviet R-2 missile, delaying its overall progress.

A preliminary draft plan for the German G-1 was discussed at a meeting of the Scientific-Technical Council of NII-88 on September 25, 1947. Present were the Germans Grottrup, Umpfenbach, Hoch, Albring, Anders, Wolff, and Sheffer, along with Chief of the Seventh Chief Directorate of the Ministry of Armaments Vetoshkin and NII-88 Chief Engineer

129. Mozzhorin, *et al.*, eds., *Dorogi v kosmos: II*, pp. 64–65. Other sources state that first head of Branch No. 2 was V. S. Shachin.

130. Chertok, *Rakety i lyudi*, pp. 199–200.

Pobedonostsev.[131] Korolev himself was not in attendance, but he was represented by two of his deputies, Mishin and Bushuyev. The design that the Grottrup team presented to the leadership of the institute had a number of similarities to the Soviet R-2, including the use of a separate payload section for the warhead and the 600-kilometer range for the missile. There were also major differences between the two vehicles. *Both* the liquid oxygen and ethyl alcohol tanks on the G-1 had a monocoque structure made of very thin aluminum or steel, unlike the R-2, which only had one monocoque tank. The Germans increased engine thrust to thirty-two tons by adopting innovative methods for regulating propellant flow rates. A mass saving of about 180 kilograms was achieved by dispensing with the high-test peroxide generator in favor of using gases diverted from the combustion chamber to turn the turbopumps. The guidance and control systems for the G-1 were also relocated at the base of the missile in contrast to the forward end on the A-4. Finally, the guidance system would use a then-sophisticated method known as "beam-riding," which essentially transferred a major portion of such systems to ground stations, thus saving mass on the rocket itself. The missile looked similar to the A-4, with a length of 14.3 meters and a total mass of 18.6 tons. According to Grottrup, the new design would allow vastly increased targeting precision, a much shorter launch preparation time, and twice as much range compared with the A-4. The payload mass would also rise from the A-4's 0.74 tons to a new peak of 0.95 tons.[132]

Grottrup made a very persuasive case to the NII-88 leadership, and he asked for formal approval of the G-1 project, shrewdly proposing that both the R-2 and the G-1 be allowed to proceed in parallel and completely independently of each other. Many of the Soviet engineers predictably put up resistance. Mishin, one of the authors of the Soviet R-2, argued that the institute had two possible roads: exploiting the current technology available and developing a missile (the R-2), which had a real possibility of being created in a short time, or developing a rocket (the G-1), which would necessitate a radical restructuring of the existing Soviet testing and manufacturing base.[133] In its final decision, the council of the institute, while mentioning the several attributes of the G-1, declined to approve a full-scale program to develop the G-1, instead asking that Grottrup's group present a formal and complete "draft plan" for the missile at a following meeting.[134] It was evidently a means to delay decisive action on the German project and, in an overall sense, a policy on the use of German expertise in the rocketry industry in the Soviet Union. The decision pleased no one and clearly indicated that the leadership of the Ministry of Armaments, in particular Ustinov and Vetoshkin, were at odds with the engineers in their view on the use of German engineers in the Soviet missile program. The matter was obviously a very sensitive issue. While most Soviet officials were reluctant to use German expertise, many were amenable to compromise on the issue to accelerate the development of ballistic missile technology in the Soviet Union. Formally establishing a mechanism for doing this was much harder. Korolev could clearly not be expected to work under Grottrup, while if the roles were reversed, Korolev would no doubt exclude Grottrup's group from all work. A third alternative was equally unpromising: allowing two parallel and independent development projects, which was well outside the capacity of funding at the Ministry of Armaments.

131. Among the others present were V. I. Kuznetsov (NII-10 Chief Designer), M. S. Ryazanskiy (NII-885 Chief Designer), B. Ye. Chertok (NII-88 Deputy Chief Engineer), A. M. Isayev (NII-1 Chief Designer), M. K. Tikhonravov (NII-4 Deputy Director), V. A. Trapeznikov (Automation Institute of the USSR Academy of Sciences Director), A. A. Kosmodemyanskiy (N. Ye. Zhukovskiy Engineering Academy Professor and Special Committee No. 2), and G. A. Nikolayev (Rector of the Bauman MVTU). See *ibid.*, p. 202.

132. CIA Office of Scientific Intelligence, *Scientific Research Institute and Experimental Factory 88 for Guided Missile Development, Moskva/Kaliningrad*, OSI C-RA/60-2, March 4, 1960, p. 7; Ordway and Sharpe, *The Rocket Team*, pp. 329–31; Chertok, *Rakety i lyudi*, pp. 202–04; Bork and Sadovoj, "On the History of Rocketry."

133. Chertok, *Rakety i lyudi*, p. 204.

134. An excerpt from the original document is reproduced in *ibid.*, p. 207.

Immediately after the September 1947 meeting, the Germans were given a temporary lift; there was a subtle shift in favor of their G-1 plan. It was to be a relatively short time to celebrate victory. Although the Germans spent the better part of 1948 working on the G-1 project, there were some unexpected institutional changes. Beginning in the early months of the year, the Soviets began relocating all of the remaining Germans to Gorodomlya Island in Lake Seliger. Grottrup himself left Moscow to join NII-88's Branch No. 1 in February. By May, almost all of the Germans had departed the main institute offices at Kaliningrad, and few were ever to visit again. The Germans also later reported that their pay rates were significantly reduced. In addition, Grottrup's position in the German hierarchy was called into doubt by a combination of Soviet hostility and internal struggle among the Germans themselves. The pace of work on the G-1 dramatically decreased in 1948, as Grottrup began to raise formal complaints with his Soviet bosses, arguing that only a few of the planned experiments on the project had been allowed to proceed.[135]

The Germans may have lost their access to Kaliningrad, but this did not accelerate a final definitive decision between the Soviet R-2 and the German G-1. Korolev's long battle over the R-2 had actually begun more than a year before when he had taken the matter to Stalin himself. On April 14, 1947, he was escorted into the Kremlin to meet the Soviet leader in person for the first time.[136] Over the years, Korolev gave wildly contradictory accounts of that meeting. In a rare interview with a Soviet journalist in 1963, he remembered:

> *I had been given the assignment to report to Stalin about the development of the new rocket. . . . He listened silently at first, hardly taking his pipe out of his mouth. Sometimes he interrupted me, asking terse questions. I can't recount all the details. . . . I had a short . . . synopsis report which I was not allowed to take with myself. Stalin replied with a greeting but did not offer his hand. Stalin was outwardly restrained. I could not tell whether he approved of what I was saying or not. [He] said "no" enough times that these "no's" became the law for the moment. These were the conditions [of the meeting].*[137]

In a letter to his wife written after Stalin's death in 1953, Korolev recalled that he was very nervous at the meeting, which was attended by many others, including Minister of Armaments Ustinov. Stalin apparently paced around his office during the entire hour, asking many pointed and pertinent questions about the state of the missile program.[138] One of those attending was Korolev's first deputy, Vasiliy P. Mishin, who remembers:

135. *Ibid.*, pp. 210–11; Ordway and Sharpe, *The Rocket Team*, p. 335.

136. The actual date of Korolev's meeting with Stalin has been the subject of some speculation. An in-depth analysis is included in Golovanov, *Korolev*, pp. 390–98, in which the author concludes that the meeting took place in 1949. The evidence for 1947, 1948, and 1949 is equally compelling. In an interview in 1963, Korolev mentioned 1947 as the year, whereas Tyulin's recollections set it in 1948. See Tyulin, "The 'Seven'." Finally, Golovanov argues, based on the remembrances of Chief Designer Kuznetsov, that it was in 1949. In a letter to his wife from 1953, Korolev remembered the exact date as March 9 without naming a year.

137. Romanov, *Korolev*, pp. 10–11. This interview was held on November 30, 1963, by TASS correspondent A. P. Romanov. Many censored and altered versions of the interview were published over the years in different publications. The complete unexpurgated text was finally allowed to be published in 1996 in Romanov, *Korolev*, pp. 5–20. For one "censored" version of the interview, see Ivan Borisenko and Alexander Romanov, *Where All Roads Lead to Space Begin* (Moscow: Progress Publishers, 1982), pp. 40–43.

138. Golovanov, *Korolev*, p. 391–92.

I can remember that [Stalin] walked around the room smoking his pipe, breaking papyrosi [cigarettes] and putting tobacco in. There were about a hundred people there—marshals, ministers, officials of the Party. It was in the building of the Central Committee and the subject was liquid rockets. Stalin was a strong supporter of their development. The U.S. had naval bases in Europe, owned the A-bomb. They didn't really need the ICBM. They could reach the USSR with bombers.[139]

The Soviet leader asked Korolev about his impressions on the comparative uses of rockets versus bombers in wartime situations, to which Korolev summarized the possible advantages of the former. After the end of the meeting, Korolev, on request from Stalin, wrote up a short report on the spot on the rockets-versus-bombers discussion and departed.[140] The influence of Korolev's report is still open to interpretation. The chief designer himself recalled somewhat ambiguously:

This meeting played its positive role. Apparently Stalin and his military advisers seemed to understand that the first experiments at designing jet aircraft, artillery units, and other things could in the future produce far-reaching positive results.[141]

One of Korolev's goals at the meeting had evidently been to convince Stalin of the need to move ahead with the longer range R-2 missile. The Soviet leader declined to approve such a strategy, electing to maintain focus on the Soviet copy of the German A-4 missile. It would be exactly a year before the Council of Ministers formally adopted a decree on the future of the missile program. Dated April 14, 1948, the resolution called for the development, testing, and use of the R-1 missile in the Soviet Union. The same document sanctioned "scientific and experimental work" for the eventual creation of the 600-kilometer-range R-2 missile.[142]

Stalin's decision no doubt gave some impetus to Korolev's arguments against the G-1. The continuing battle between the German and Soviet proposals continued throughout the year as the Germans prepared a huge and detailed draft plan for the their missile. The conflict between the R-2 and the G-1, however, took a hiatus in the fall of 1948 as Soviet engineers once again trekked to the steppes at Kapustin Yar for the very first launches of a Soviet-made long-range ballistic missile. Unlike the earlier A-4 tests in 1947, this time none of the Germans were invited, a clear indication of their isolation from the mainstream Soviet program. The test program for the R-1 envisaged two separate series of launches, the first consisting of about a dozen vehicles primarily to verify the correctness of the newly introduced industrial design and manufacturing methods in the Soviet Union. The second series, to consist of about twenty missiles, would be flown to increase reliability and eliminate defects that would show up in the first series.[143] The construction of the first flight articles began in May 1948. While the missiles were officially referred to as R-1, in all technical documentation, the vehicle was designated "product 8K11," a style of nomenclature, using a number-letter-number system, that would be continued into the space era.

The State Commission for testing the R-1 missiles was chaired by Chief of the Seventh Chief Directorate of the Ministry of Armaments Vetoshkin. His deputy on the commission was Maj. General Sokolov, the head of the Fourth Directorate of the Chief Artillery Directorate, who

139. Harford, *Korolev*, p. 234.
140. Golovanov, *Korolev*, p. 396; Tyulin, "The 'Seven'."
141. Romanov, *Korolev*, p. 11; Nicholas Daniloff, *The Kremlin and the Cosmos* (New York: Alfred A. Knopf, 1972), p. 97; A. Romanov, *Spacecraft Designer: The Story of Sergei Korolev* (Moscow: Novosti Press Agency, 1976), p. 27.
142. Chertok, *Rakety i lyudi*, p. 310; Sadovoy, "10 October—40 Years After."
143. Sadovoy, "10 October—40 Years After."

was responsible for the hundreds of artillery personnel involved in the program. Korolev was the only engineer who was a formal member of the commission, although the five other individuals in the Council of Chief Designers served as technical advisors.[144] The first two launch attempts in mid-September had to be postponed because of equipment failures. The third vehicle, the first to get off the launch pad, flew into the skies on September 17, but suffered a major control systems failure.[145] Almost immediately following liftoff, the R-1 veered fifty-one degrees off its main trajectory, flew nearly horizontal to the ground, and landed only ten kilometers from the launch site. The engineers apparently quickly determined the cause of the malfunction, for a second R-1 was launched soon after. This one also failed, this time because of a malfunction in an oxygen valve in the engine's combustion chamber. The R-1 finally lifted off on its first successful flight on October 10, 1948, traveling a full range of 288 kilometers and attaining a top velocity of 1,530 kilometers per second. A second partially successful launch took place three days later. After these tests, Ustinov and Marshals Yakovlev and Voronov arrived at Kapustin Yar as observers, lending an unusual importance to the tests.[146] As with the A-4 launches in 1947, agents from the state security apparatus sent by Col. General Serov were on hand at the testing ground, providing a general feeling of uneasiness to all the proceedings. Weather was also a problem and at least one of the launches, on November 1, had to be postponed because of heavy fog. In addition, a technician was killed while checking a newly designed gangway to the missile. The final R-1 vehicle was launched on November 5, the ninth successful flight out of twelve launches.[147]

The nine launches that were deemed successful were classified on the basis of the achieved range, about 300 kilometers on each flight. The accuracy of the missiles, however, left much to be desired. Only *one* of the vehicles impacted in the designated sixteen-by-eight-kilometer target area, raising serious concerns about the missile's possible use in battle. The poor record of the launches instigated a minor altercation between Ustinov and Marshal Yakovlev, representing different interests of the Soviet government.[148] The latter, speaking for those that would eventually use the missile as a weapon, was not pleased about the outcome of the launches. It was a debate that would continue for several years until the Soviet missile finally outgrew its connection to the German A-4 missile. In retrospect, these launches comprised a critical period in the development of the future Soviet missile and space industry; many new technologies were introduced in the production process. New techniques, such as those for the manufacture of large sheets of special magnesium steels and magnesium alloys, and new types of cables, relays and sensors, and materials-handling machinery were developed for the R-1. In addition, the Ministry of Armaments concurrently created assemblies for the storage and transporting of liquid oxygen with refueling equipment, and it also developed new methods for welding and protective coatings for the R-1 warheads.[149] These industries, a total of thirty-five Scientific

144. The other members of the State Commission for the R-1 were: Lt. Colonel V. I. Voznyuk (Commander of the GTsP-4), Maj. General L. R. Gonor (Director of the NII-88), and industrial representatives G. I. Muravyev, V. N. Tretyakov, S. M. Vladimirskiy, and Yeremeyev. Additional technical advisors were G. I. Degtyarenko and M. I. Likhnitskiy. See *ibid.*; Chertok, *Rakety i lyudi*, p. 313.

145. Biryukov, "Materials in the Biographical Chronicles of Sergey Pavlovich Korolev," p. 227; G. A. Kustova, ed., *Ot pervogo Sputnika do "Energii"-"Burana" i "Mira"* (Moscow: RKK Energiya, 1994), p. 6.

146. Biryukov, "Materials in the Biographical Chronicles of Sergey Pavlovich Korolev," p. 227; Lardier, *L'Astronautique Soviétique*, p. 80; Chertok, *Rakety i lyudi*, pp. 317–19.

147. Konovalov, "Soviets Rocket Triumphs Started in Germany: II." Note that another source suggests that there were nine launches, of which only one (on October 10) reached its target. See Yu. P. Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya "Energiya" imeni S. P. Koroleva* (Moscow: RKK Energiya, 1996), p. 32.

148. Golovanov, *Korolev*, pp. 402–03; Sadovoy, "10 October—40 Years After."

149. Mozzhorin and Yeremenko, "From the History of Space Science"; Mozzhorin and Yeremenko, "From the History of Space Science: II."

Research Institutes, and eighteen manufacturing plants later facilitated the relatively quick and efficient production of larger and more powerful missiles.

Korolev and his engineers returned from Kapustin Yar to Kaliningrad in time to hear the revised report by the German engineers on their G-1 study. On December 18, 1948, the members of the Scientific-Technical Council of NII-88 gathered to make a final decision on the German proposal. Sitting in for the absent NII-88 director was Maj. General Aleksey S. Spiridinov, an artillery officer who had hitherto served as a liaison contact between the Germans and the Soviets. The entire German "high command," including Grottrup, Albring, Blass, Hoch, Muller, Rudolf, Umpfenbach, and Wolff, were in attendance. Representing the Soviet assessment team were Bushuyev, Isayev, and Lapshin from NII-88 and Chief Designer Glushko from OKB-456. Once again, Korolev was absent, perhaps to preclude the Germans from acquiring information on the real power behind the ballistic missile program. In his report, Grottrup announced that his group, over the course of the past year, had managed to increase the design range of the G-1 from 600 kilometers to 810 kilometers and had also dramatically increased targeting accuracy. Dr. Hoch, the author of the new guidance system, also expounded on the advantages of the new redesigned missile. After a long and sometimes acrimonious session, punctuated for the first time by a discussion of the political implications of using German expertise, the council formally terminated the parallel approach of work on the R-2 and the G-1, which had been continuing for close to two years by then. Instead, taking what was considered "decisive" action, the institute leadership did not approve creation of the G-1, although Spiridinov explained that the Germans would be allowed to continue work on their coveted missile.[150]

It was an extremely significant decision that had a profound effect on the role of the German group on the further development of long-range ballistic missiles in the Soviet Union. The Germans continued to work on several more major rocketry projects, but none played as major a role in Soviet planning as the G-1. Work on that effort was continued into 1949 as Grottrup's group focused on structural aspects and the Doppler radio system of the missile.[151] By then, however, it was increasingly clear that the future did not hold much promise. As the Germans settled into studying further missile projects in the ensuing years, each one raised hopes that the Soviet side would finally give them the green light to create their first rocket in metal.

Stratonauts and Multistage Rockets

Mikhail K. Tikhonravov, the man who had designed the first Soviet liquid-propellant rocket, the *09*, had, as with many of the other engineers of NII-3, moved from project to project, first because of the Purges and then as a result of the war. After Korolev's arrest in 1938, the two did not work together in any capacity, and their efforts moved in different paths. The older of the two—he was forty-five years old at the end of the war—Tikhonravov had established a group at NII-1's Branch No. 2 during the last years of the war to develop a solid-propellant rocket for scientific experiments. When this project, the VR-210, failed to yield any positive results, he threw his lot into a much more ambitious plan, one with which he had been toying since at least the late 1930s.

In early 1945, Tikhonravov brought together a group of engineers at the institute to work on a design for developing a high-altitude rocket for carrying two passengers to an altitude of

150. Chertok, *Rakety i lyudi*, pp. 212, 218; CIA Office of Scientific Intelligence, *Scientific Research Institute*, p. 7.

151. Ordway and Sharpe, *The Rocket Team*, p. 335.

190 kilometers.[152] Designated the VR-190 proposal, it was the very first concrete project in the Soviet Union for launching humans into space. Tikhonravov's plan envisioned the use of a modified A-4 rocket with a recoverable nose cone containing a pressurized cockpit for carrying two "stratonauts."[153] The passengers would remain in an upright position in the capsule from launch until touchdown in two custom-made couches. Tikhonravov formulated four primary goals for the project:

- To conduct research on the effects of the temporary weightlessness on humans during free-fall
- To carry out investigations on shifts in the center of gravity in the cabin and the movement of the center of gravity subsequent to the separation of the nose cone from the main rocket
- To acquire information on the density, pressure, and temperature of the upper atmosphere
- To test the operational reliability of instruments for separation, descent, stabilization, and landing of the cockpit

Tikhonravov even went so far as to contract out the development of the special two-passenger cabin for the VR-190 to a designer, A. V. Afanasyev, at OKB-115, an organization led by the famous Soviet aviation designer Aleksandr S. Yakovlev. Work on a parachute system for the recovery capsule began simultaneously in May 1946.

Many of the design aspects of the VR-190 were remarkably advanced for the time. In his conception of the spacecraft, Tikhonravov proposed the use of the following:

- A parachute system for returning to Earth
- A braking rocket engine for soft landing the cabin on the ground
- A system using explosive bolts to separate the cabin from the launcher
- A special probe extended downward beneath the cabin to serve as a sensor to trigger the soft-landing engines
- A pressurized cockpit with fully equipped life-support systems, thus bypassing the need for a catapult or ejection seats
- A system of low-thrust attitude control engines to maneuver the vehicle during its vertical trajectory beyond the atmosphere

Remarkably, all six of these design elements would be adopted for Soviet piloted spacecraft by the early 1960s. More impressively, Tikhonravov proposed the use of an "arched" protective heat shield, a design not unlike the one used today on the Soyuz spacecraft.[154]

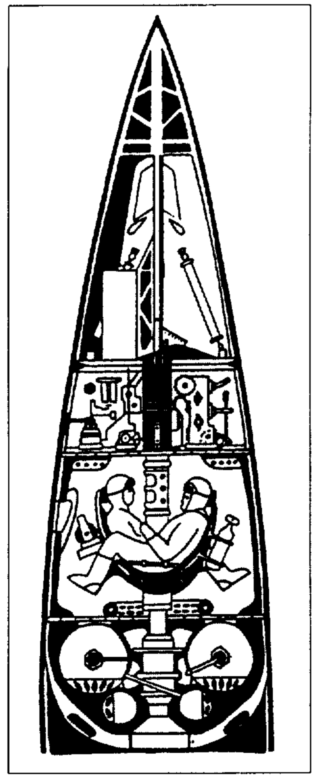
Not wanting his idea to languish from a lack of interest, Tikhonravov tried to elicit interest from authorities all the way at the top of the Soviet leadership. In June 1946, he and his deputy, Nikolay G. Chernyshov, authored a letter to Stalin on the VR-190:

152. This group included N. G. Chernyshov, V. N. Galkovskiy, P. I. Ivanov, A. F. Krutov, G. M. Moskalenko, and V. A. Shtokolov.

153. V. N. Galkovskiy and G. M. Moskalenko, "The VR-190 Project—A Step in the Road to the Creation of Space Ships" (English title), *Iz istorii aviatsii i kosmonavtiki* 42 (1980): 28–30; Yevgeniy Ryabchikov, "A Russian Story. In One Moment Sputnik Became Part of the Vocabulary of Mankind. The Beginning of the Space Era Revealed" (English title), *Ogonek* 40 (October 3–10, 1987): 1–3; Stache, *Soviet Rockets*, pp. 257–58.

154. *Ibid.*

Dear Comrade Stalin! We have developed a plan for a high-altitude Soviet rocket for lifting two humans and scientific apparatus to an altitude of 190 kilometers. The plan is based on using equipment from the captured V-2 missile, and allows for realization in the shortest time . . . for returning, the cabin has load-bearing parachutes, [and] a braking unit in the form of [liquid propellant rocket engines], installed together with its propellant tanks at the base of the cabin. . . . The practical realization of the project would be possible, given the creation of the required conditions, in close to a year's time! . . .[155]



A drawing of the VR-190, the very first Soviet conception of a piloted spacecraft in the postwar era. Conceived by Mikhail Tikhonravov at NII-1 in 1945, the VR-190 would carry two "stratonauts" strapped in an upright position on a 200-kilometer "hop" into the upper atmosphere. Many design innovations from the project were later used in the 1960s-era spacecraft, such as Voskhod and Soyuz.
(files of Asif Siddiqi)

At the same time, Tikhonravov also collated his group's research and presented the results to the Collegium of the Ministry of the Aviation Industry, the supervising authority over NII-1. Reactions from both Stalin and the ministry were remarkably positive. The bureaucrats all nodded with approval at the plan and gave the project "a positive review and recommendation," while Stalin himself wrote back that "the proposal is interesting—please examine for its realization."[156] Unfortunately, it seems that bureaucratic gridlock killed the effort. Because of "a number of organizational difficulties," the Ministry of the Aviation Industry never set about funding the idea, and Tikhonravov's report ended up in the ministry's library "gathering dust."[157] One can imagine aviation minister Shakhurin's views on piloted spaceflight given his complete and total noninterest in rocketry in general.

In late 1946, NII-1 was reorganized to carry out dedicated work on the Sänger-Bredt antipodal bomber, and consequently Tikhonravov's group at its Branch No. 2 was transferred out to another military institute, NII-4, at which scientific research was geared completely for purposes of defense. NII-4 itself was soon brought under the umbrella of a new entity, the USSR Academy of Artillery Sciences. Established on October 11, 1946, this academy, under Lt. General Anatoliy A. Blagonravov, was formed to provide an institutional setting for educating a new generation of artillery experts in the technical theories of long-range ballistic missiles.[158] For the Tikhonravov group, work at NII-4 was initially focused on other unrelated areas, and they were forced to follow up engineering work on the VR-190 plan in their own spare time.[159] Surprisingly, it seems that this first

155. Valeriy Baberdin, "Military Space Started Here and Not Only Military" (English title), *Krasnaya zvezda*, April 30, 1994, p. 4.

156. *Ibid.*; Anatoliy Shiryayev and Valeriy Baberdin, "Before the First Leap Into Space" (English title), *Krasnaya zvezda*, April 27, 1996, p. 5; Galkovskiy and Moskalenko, "The VR-190 Project."

157. Shiryayev and Baberdin, 1996; Galkovskiy and Moskalenko, "The VR-190 Project."

158. CIA, *Soviet Capabilities and Probable Programs in the Guided Missile Field*, NIE-11-6-54, October 5, 1954, p. 29; Mozzhorin, *et al.*, eds., *Dorogi v kosmos: II*, p. 91.

159. Stache, *Soviet Rockets*, p. 258; Lardier, *L'Astronautique Soviétique*, p. 77.

piloted space effort had not been coordinated with NII-88 and in particular Korolev's group. The two had evidently discussed the project in mid-1945, but Korolev was clearly engaged in more earthly pursuits at the time, and he was not about to set off on a somewhat farfetched adventure only one year after his release from confinement. In addition, Korolev was a little more hesitant than Tikhonravov in believing that piloted spaceflight would be facilitated by ballistic missiles. Given Korolev's interest in rocket-powered airplanes, this is not so surprising. From the early 1930s on, he had preferred the rocket airplane as a means to explore the upper atmosphere. It was only in the immediate postwar years that there was a fundamental shift in his strategy, perhaps prompted by the successes of the German A-4 missile.

The changes with NII-1 and NII-4 slowed down the VR-190 project, and by early 1947, much of the early momentum had been lost. That same year, Tikhonravov withdrew from work on the project, and the program was delegated to a different subdivision in the institute. Redesignated a "rocket probe" and given a "different tenor," the VR-190 plan was pursued further by others, and in 1948, a preliminary plan for the project was presented for tentative approval by the Scientific-Technical Council of NII-4.[160] The council allowed further work on the project with one modification—the launch of humans in the plan was dropped in favor of using dogs. The following year, the institute finally terminated the project, possibly motivated by Korolev's own plans to modify the R-1 into a missile for scientific purposes. Thus ended the first serious investigations in the Soviet Union in the interest of piloted spaceflight. The issue would not be taken up again for several years.

Tikhonravov's move to a new sector of NII-4 in 1947 (the "first sector") as a deputy director of institute precipitated a second major first for the Soviet rocketry program: serious investigations into the possibility of designing very powerful ballistic missiles that could be used to potentially launch artificial satellites. The same year, on September 16, he established a small group under Pavel I. Ivanov at the institute to conduct research on the development of multistage rockets. Although not specifically stated as such, the rationale for conducting the study, at least on Tikhonravov's part, was to develop a satellite launch vehicle in the near future using available Soviet technology. The responsibility of exploring the details of various possible configurations of multistage long-range ballistic missiles was assigned to Vladimir A. Shtokolov and Igor M. Yatsunskiy, two young engineers in Tikhonravov's employ who had both worked on the VR-190. In December 1947, the group produced a preliminary report, which included analyses of several different variants of so-called "composite" missiles, in which stages would be discarded following the depletion of propellant, the overall mass of the booster would be lightened, and consequently velocity would be increased.[161]

Utilizing the ground-breaking theories of Tsiolkovskiy, Ivanov's group under Tikhonravov's direction studied two possible variants of combining stages into one multistage booster. The first was a "tandem" arrangement, with two stages attached successively, and the second was the "cluster" scheme, with various stages connected in parallel. Despite the apparent simplicity and elegance of the tandem scheme, the engineers saw at least two major drawbacks in that variant. First, Tikhonravov believed that the problems of developing a rocket engine to fire in vacuum, as would be required for a tandem configuration, might prove to be insurmountable

160. I. M. Yatsunskiy, "On the Activities of M. K. Tikhonravov in the Period From 1947 to 1953 on Substantiating the Possibility of Creation of Composite Missiles" (English title), *Iz istorii aviatsii i kosmonavtiki* 42 (1980): 31–38. An English title of this is available as I. M. Yatsunsky, "The Role of Mikhail Klavdiyevich Tikhonravov in Creating Stage Rockets, 1947–1953," in John Becklake, ed., *History of Rocketry and Astronautics: Vol. 17* (San Diego: American Astronautical Society, 1995), pp. 451–56. See also Stache, *Soviet Rockets*, pp. 258–59.

161. B. N. Kantemirov, "15 July—40 Years From the Report of M. K. Tikhonravov on the Possibility of Achieving Cosmic Velocity Using the Current Level of Technology" (English title), *Iz istorii aviatsii i kosmonavtiki* 59 (1989): 65–76; Yu. V. Biryukov, "Memorable Dates" (English title), *Novosti kosmonavtiki* 13 (June 16–29, 1997): 68–70.

in the coming years. Second, the extra length of a tandem arrangement of stages would also pose complicated manufacturing problems. These factors prompted Ivanov's group to focus on cluster-staged rockets in which all the stages would fire at liftoff. In such a design, the length of the missile would be much less than a tandem variant, in fact being equal to the longest rocket forming the cluster. Several variations of the cluster arrangement were studied, including one with identical boosters linked together and one with differently sized rockets connected together in parallel. A further design, called "missile complexes," envisioned the use of several boosters connected together in parallel, each of them being a multistage vehicle itself.[162] Because of the absence of electronic computers, the team performed all the mathematical calculations by hand, although this apparently did not slow down the group's work.

In December 1947, Tikhonravov produced a preliminary report on the topic, which specified configurations and capabilities of both tandem- and cluster-type long-range missiles. In the following months, Shtokolov and Yatsunskiy carried out hundreds of calculations that began to show the advantages of the cluster scheme, which by this time was given the name "packet." In their work, the two engineers examined a broad range of topics, including the means to link up the various rockets in parallel, possible ways to separate the strap-ons, and also ballistics for the active part of the trajectory. In their formal documentation, the researchers made no mention of a satellite launch vehicle, although the work was clearly aimed at achieving orbital velocity. Tikhonravov's engineers were not the only individuals at NII-4 involved in space-related themes. The institute's deputy director for science, Maj. General Yakov B. Shor, focused on a traditional successively staged missile, while institute Director Maj. General Nesterenko, Chernyshov, and others were also participants in "discussions" on space themes.[163]

In early 1948, despite the fact that the results of the study on packets were still somewhat preliminary, Tikhonravov orally presented a summary of the investigations to the Scientific-Technical Council of the institute.[164] The reception of his proposal was divided. The less than supportive response did not deter Tikhonravov, and he decided to present the paper, now titled "Paths to Accomplishing Great Ranges by Firing Missiles," at the annual meeting of the Academy of Artillery Sciences, the overseeing authority over NII-4. Despite Nesterenko's apparent support, Academy President Blagonravov was not easily convinced of the propitiousness of allowing a presentation of the paper. Fully aware of Tikhonravov's ideas of a satellite launch vehicle, Blagonravov told Tikhonravov: "The topic is interesting. But we cannot include your report. Nobody would understand why. . . . They would accuse us of getting involved in things we do not need to get involved in. . . ."[165] Tikhonravov was not easily discouraged and requested a follow-up meeting with Blagonravov the next day. This time, the Blagonravov agreed to the request, warning Tikhonravov: "Be prepared—we will blush together."[166]

On July 14, 1948, Tikhonravov read his report at the Academy of Artillery Sciences in the presence of a large group of prominent dignitaries from the military.[167] Apart from Blagonravov and Nesterenko, Chief Designer Korolev was also present, on visit from NII-88. The audience listened in pin-drop silence to Tikhonravov's speech "with tremendous attention" as he argued persuasively that the design of rockets capable of reaching very high altitudes and velocities was technologically feasible. Not surprisingly, the reaction of most of the audience was negative. One high-ranking military official reportedly said, "The institute must not have [had] much to

162. Kantemirov, "15 July—40 Years"; Yatsunskiy, "On the Activities of M. K. Tikhonravov."

163. Mozzhorin, *et al.*, eds., *Dorogi v kosmos: II*, p. 91.

164. Kantemirov, "15 July—40 Years."

165. Yaroslav Golovanov, "The Beginning of the Space Era" (English title), *Pravda*, October 4, 1987, p. 3.

166. *Ibid.*

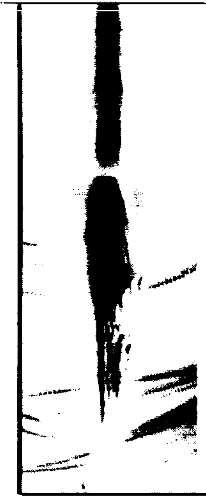
167. Yatsunskiy, "On the Activities of M. K. Tikhonravov." For a complete reproduction of Tikhonravov's paper, see M. K. Tikhonravov, "Paths to Accomplishing Great Ranges by Firing Missiles" (English title), *Iz istorii i kosmonavtiki* 67 (1995): 3–26.

do and decided to switch to the realm of fantasy?"[168] Korolev was one of the very few who reacted positively, telling Tikhonravov after his presentation: "We have some serious things to talk about. . . ."[169] For Korolev, it was a small opening for his own nascent dreams of space exploration. As plans for new longer range missiles to follow the R-2 were beginning to emerge at NII-88, Tikhonravov's bold report clearly served as a catalyst for combining the disparate efforts at the two different institutions.

The political climate, and especially the fear of the secret police in the late Stalin era, no doubt also played a major role in any decision on the part of Tikhonravov or Korolev. Given the job of creating a long-range ballistic missile for the Soviet armed forces, Korolev was not about to jeopardize his job and perhaps even his life by making hasty diversions into what the secret police no doubt considered a pointless endeavor. In Tikhonravov's case, his work on packet-based long-range rockets was continued into the following year only to face near cancellation. For reasons still unclear, the leadership of NII-4 disbanded Ivanov's subdivision in early 1949. Put into a difficult position, Tikhonravov entrusted one member of his team, Yatsunskiy, to persevere with this theme.[170] The latter by this time was employed in a different sector of the institute, thus considerably slowing down work on Tikhonravov's project because of institutional barriers.

Despite the sudden shutdown of this important work, Tikhonravov's landmark July 1948 speech served as a catalyst for intensive cooperation between himself and Korolev. The two had known each other since 1927, when they had met as young glider pilots, working together through the 1930s at GIRD and NII-3. In the postwar years, although officially at two different organizations, they reestablished an informal but pivotal communication between each other. Prompted by the initial satellite launch vehicle studies at NII-4, it seems that Korolev had decided to take the matter in his own hands and approach the Soviet leadership with a proposal to fund the launch of an artificial satellite in the near future. It was probably clear to him that neither Blagonravov nor Nesterenko had the political clout to handle such a request, and he opted to instead appeal to Soviet leader Stalin himself. It was a risky decision to take, but clearly underlines Korolev's true interests. His group at NII-88 may have been officially working on military rockets, but it is apparent from the many descriptions of Korolev's life in those years that he never lost sight of the ultimate objective of space exploration. As it turned out, Tikhonravov's early but ambitious studies at NII-4 on launch vehicles, artificial satellites, and human spaceflight laid the basis for unexpected opportunities of which Korolev would soon take advantage to realize his dream of space exploration.

168. Golovanov, "The Beginning of the Space Era."
169. *Ibid.*
170. Yatsunskiy, "On the Activities of M. K. Tikhonravov."



Chapter Three
Stalin and the Rocket

The first long-range ballistic missile launches during 1947–48 served as watershed events in the early history of the Soviet rocketry program. Within three years of the end of the war, the Soviets had managed to establish a level of capability at least equivalent to wartime German accomplishments, while at the same time initiating ambitious studies on artificial satellites, launch vehicles, and even a short-lived program to lob humans on vertical trajectories. The problems, both technical and institutional, remained paramount, but allowed the engineering faction, led primarily by NII-88, to identify several useful avenues for further investigation. The ensuing years, between 1949 and 1953, would prove to be even more critical; research was focused on a number of important studies dedicated to advancing the capabilities of the A-4–derived Soviet missiles. The rate of progress in the rocketry program was astonishing; by the end of that four-year period, the Soviets had almost completely left behind the German antecedents of their missile program and moved into the realm of intercontinental ballistic missile (ICBM) development, effectively laying the foundation for the birth of the Soviet space program.

Testing at Kapustin Yar

The overriding motivation for the new Soviet ballistic missile program was obviously military, but over the years, a small but vigorous scientific element of high-altitude rocketry research began to emerge. Primarily because of the efforts of nuclear physicist Sergey N. Vernov, Deputy Director of the Scientific Research Institute for Nuclear Physics, the work of the Commission for the Study of the Stratosphere had been revived in the postwar years. To facilitate the design and development of instruments for flight on board A-4–derived missiles, NII-88 Chief Designer Korolev met with USSR Academy of Sciences President Sergey I. Vavilov in 1949 to coordinate this effort. Following their consultations, Vavilov entrusted the organizational problems of this field of research to Academician Keldysh, who, in turn, used the existing Stratosphere Commission to establish in late 1949 the new Commission for the Investigation of the Upper Atmosphere.[1] He appointed Academician Blagonravov, the President of the USSR Academy of Artillery Sciences, as this commission's chair and assigned to him all

1. Yu. V. Biryukov, "Materials in the Biographical Chronicles of Sergey Pavlovich Korolev" (English title), in B. V. Raushenbakh, ed., *Iz istorii sovetskoy kosmonavtiki: sbornik pamyati akademika S. P. Koroleva* (Moscow: Nauka, 1983), p. 229. According to one source, the Commission for the Coordination of Work for the Research of the Upper Layers of the Atmosphere was established on February 18, 1953. See L. A. Vedeshin, "18 February—25 Years From the Day of Creation of the Commission of the USSR Academy of Sciences for the Coordination of Work on Research on the Upper Atmosphere (1953)" (English title), *Iz istorii aviatsii i kosmonavtiki* 35 (1978): 24–26.

duties concerning the coordination of a formal scientific offshoot of the Soviet ballistic missile program. By that time, under Korolev's leadership, Department No. 3 at NII-88 had already begun the first tests of the new version of the R-1 missile, designated the R-1A.[2]

The modification effort to create the R-1A, led by Korolev's assistant Konstantin D. Bushuyev, was in many ways related to the work on the still-to-be-flown R-2 missile. In particular, in 1949, a series of experimental R-1 rockets was earmarked specifically to test the separation of the payload during flight. The first of these test missiles was launched into a ballistic trajectory from Kapustin Yar on May 7, 1949, equipped for the first time with a nonrecoverable nose cone container, as well as two simulated instrument packages, each with a mass of sixty-five kilograms mounted at the rear of the missile between the stabilizer fins.[3] At least three more of these R-1A tests were conducted in May under Korolev's direction, essentially confirming the basic design elements of the separating payload section.

The first vehicle with actual scientific instruments was prepared for its first launch in the third week of May. The instruments designed to measure air pressure and air composition were developed at the Geophysical Institute of the Academy of Sciences (GeoFIAN) under the leadership of B. L. Dzerdzyevskiy and Ye. M. Reikhrudol. Vernov himself was involved in the test preparations. Just prior to launch, special glass containers were emptied of air, hermetically sealed, and installed in the payload packages. Following the launch of the R-1A missile and engine cutoff, a mechanism would remove the containers from their host, followed by the breaking of the glass support, enabling air to enter the containers. This would be preceded by the ejection of the complete packages from the rocket into a path ahead of the missile's trajectory so as not to collect air contaminated by the exhaust of the R-1A. Newly developed parachutes were then to bring the scientific instruments safely back to Earth.[4] With the exception of the design of the separable payload, the R-1A was not much different from the military R-1. The vehicle was just under fifteen meters in length and had a fueled mass of 13,910 kilograms.

The very first R-1A with operational scientific packages, officially designated FIAR-1, was launched into a vertical trajectory at 0440 hours local time on May 24, 1949.[5] The initial phases of the launch were successful, and the FIAR-1 packages were ejected without problem, having reached an altitude of about 100 kilometers. Seventeen seconds following ejection, at which point the containers had dropped twenty kilometers in free flight, the parachute deployed on schedule, but the shock of its unfurling resulted in damage to the canopy. The landing was much harder than expected, and both the containers were deformed, thus terminating any hope of scientific data. An inspection of the recovered capsules showed, however, that the instruments had operated as planned. In the ensuing days, engineers quickly designed a modified parachute system, while improving the shock-absorption capabilities of the FIAR-1 containers.

2. The report on the "new" missile was titled "Plan for the V-1A Experimental Geophysical Missile With a Separable Payload." See Biryukov, "Materials in the Biographical Chronicles," p. 227. See also Yu. P. Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya "Energiya" imeni S. P. Koroleva* (Korolev: RKK Energiya, named after S. P. Korolev, 1996), p. 34.

3. Biryukov, "Materials in the Biographical Chronicles," p. 228. Peter Stache, *Soviet Rockets*, Foreign Technology Division Translation, FTD-ID(RS)T-0619-88 (from unnamed source), Wright-Patterson Air Force Base, Ohio, November 29, 1988, p. 209. This is a translation of Peter Stache, *Sowjetischer Raketen* (Berlin: Militarverlad der DDR, 1987). A more recent report suggests that the first launch may have been on April 21, 1949. See G. A. Kustova, ed., *Ot pervogo Sputnika do "Energii"-"Burana" i "Mira"* (Moscow: RKK Energiya, 1994), pp. 6, 125.

4. Stache, *Soviet Rockets*, p. 209.

5. Biryukov, "Materials in the Biographical Chronicles," p. 228. "FIAR" was the Russian acronym for "Physical Research of the Atmosphere by Means of Missiles." Soviet sources have variously referred to the containers as both FIAR-1 and FIAN-1. For the latter, see, for example, M. I. Gerasimova, "Embodiment of a Dream" (English title), in M. I. Gerasimova and A. G. Ivanov, eds., *Zvezdniy put* (Moscow: Politicheskoy Literatury, 1986), p. 18.

A second launch, the last and sixth of the R-1A type, took place on May 28.[6] This time, the missile reached an altitude of 102 kilometers, and both containers were recovered without incident. Unfortunately for the scientists from GeoFIAN, the measuring equipment worked poorly, thus affecting the quality of information gathered.[7] Clearly, the scientific results from the two launches were meager, but the overall outcome of the series was considered satisfactory. Korolev, summarizing the launches a few years later, recalled that:

> *1) We were able to experimentally show that it was possible to transport equipment for the investigation of the upper layers of the atmosphere by rocket to altitudes of 100 kilometers, to eject the equipment-filled container, and to safely bring it back to Earth; 2) it was found that devices for measurement of the high temperature operated normally during ascent, ejection, and freefall; 3) for the first time it was possible to make direct measurements of air pressure at an altitude of approximately 100 kilometers and to take air samples. Despite the modest results of these first launches and numerous serious technical and methodological deficiencies, as well as serious defects in equipment, these flights awoke the enthusiasm of all involved and awakened the interest of institutes and organizations of the USSR Academy of Sciences as well as of the industry.*[8]

The launches of the R-1A missiles were only one of numerous rockets conducted at Kapustin Yar during that period. Perhaps the most important tests at the range were those of the second series of R-1 rockets, designed to incorporate improvements following the poor performance of the first series in late 1948. The initial manufacture of the basic frames of the second group of about twenty missiles had begun as early as August–September 1948 at the NII-88 plant in Kaliningrad. The launches were carried out between September 10 and October 23, 1949, once again under Korolev's leadership. In contrast to the first series, which had raised serious doubts among military commanders on the effectiveness of the missiles, these tests were far more successful and restored confidence in the new rocketry industry. Of the total of twenty missiles launched, seventeen reached their designated sixteen- by eight-kilometer target area, while only two were complete failures.[9] A third series of ten launches of the R-1, called the "P" series, was also apparently conducted soon after, with seven reaching the target.[10]

These launches were critical to the training of the first Soviet rocket troops, and the high number of manufactured rockets and test launches suggests an unusually important emphasis on improving the operational characteristics of the rocket as a weapon of war. The path to actual deployment in the armed forces proved to be longer than expected. It was a further year of

6. Biryukov, "Materials in the Biographical Chronicles," p. 228; M. V. Keldysh, ed., *Tvorcheskoye naslediye akademika Sergeya Pavlovicha Koroleva: izbrannyye trudy i dokumenty* (Moscow: Nauka, 1980), p. 348.

7. Some of the results are compiled in B. A. Mirtov and L. A. Vedeshin, "Research of the Upper Atmosphere—First Rocket Experiments in the USSR" (English title), International Astronautical Federation, 1975. A translation of this document is available in the folder on Soviet suborbital launches, translation no. TT 76-53470 by Saad Publications, NASA History Reference Collection, NASA History Office, NASA Headquarters, Washington, DC.

8. Keldysh, ed., *Tvorcheskoye naslediye akademika Sergeya Pavlovicha Koroleva*, p. 349. These comments are part of Korolev's speech titled "Investigation of the Upper Atmosphere with Powerful Long-Range Missiles," given at the All-Union Conference on Missile Investigations of the Upper Atmosphere, held in April 1956, part of which is reproduced in Keldysh, ed., *Tvorcheskoye naslediye akademika Sergeya Pavlovicha Koroleva*, pp. 348–61. The six launches of the R-1A were carried out on May 7, 10, 15, 17, 24, and 28, 1949.

9. Biryukov, "Materials in the Biographical Chronicles," p. 229; B. Ye. Chertok, *Rakety i lyudi* (Moscow: Mashinostroyeniye, 1994), p. 326. Another authoritative source suggests that 45 percent—that is, nine of the twenty—reached the target, which, if true, was still a vast improvement over the first series. See G. A. Sadovoy, "10 October—40 Years After the First Successful Launch of the First Soviet Guided Missile of Long Range R-1 (1948)" (English title), *Iz istorii aviatsii i kosmonavtiki* 59 (1989): 94–101.

10. Sadovoy, "10 October—40 Years After."

industrial and engineering efforts before a final order was issued on November 28, 1950, formally adopting the R-1 missile as armament of the Soviet armed forces.[11] The following month, a new division of soldiers, the 23rd Special Purpose Engineer Brigade of the Rocket Troops of the High Command, was formed at Kapustin Yar to receive the first operational batch of R-1 missiles as effective components of Soviet military power.[12] The brigade, headed by Col. Mikhail G. Grigoryev, served as the original core of what would later become the famous USSR Strategic Missile Forces. Like many of the other artillery officers of the period, Grigoryev would go on to play a leading role in the Soviet space program as the first commander-in-chief of the Plesetsk launch site.

At the time that the R-1 was moving ahead with its own road to official deployment, Korolev was already advancing with work on his coveted R-2, which had faced such a hard road to approval. Coinciding with the second series of R-1 test launches, he was on hand at Kapustin Yar to direct the first launches of an experimental version of the R-2, designated the R-2E. The purpose was to primarily test the flight results of a separable warhead container so important for the further improvement of characteristics of Soviet ballistic missiles. With an appearance very similar to the planned R-2, the R-2E was just under seventeen meters in length, about a half a meter shorter than its ultimate successor. The first of five of these experimental missiles lifted off from Kapustin Yar on September 25, 1949, at the very same time that the second series of R-1 tests was in progress.[13] The warhead container tests were not completely successful, due to malfunctions in the automatic stabilization system at the time of separation. These problems were traced to the use of new and advanced gyro-stabilization systems developed at NII-10 under Chief Designer Kuznetsov. The obstacles took a considerable time to overcome. The three successes did, however, instill sufficient confidence in Soviet capabilities to eliminate any doubt about terminating work on the German G-1 concept, with which the R-2E shared many performance characteristics.

The first full-scale launch of an R-2 took place on October 21, 1950, a full year after the R-2E tests. The attempt was a failure and prompted lengthy discussions, which ended up in conflicts between engineers responsible for the suspected malfunctioning part. Partly as a result of these discussions, Pilyugin later developed a special electronic dynamic modeling unit to simulate "steering" effects on the R-2, based directly on the work of Dr. Hoch, one of the German engineers who ironically had no knowledge of the R-2 tests at the time. The second attempt on October 26 was a partial success and deposited the payload 600 kilometers from the launch site.[14] The initial troubles with the missile, however, continued to worry the engineers, and the test series was extended far beyond the initial planned schedule. After one of the longest series of launches in recent memory, the final R-2 finally lifted off on December 20. It was also one of the most disappointing series, quite possibly, in the history of the Soviet ballistic missile program. All twelve missiles launched failed to achieve their primary objectives; there were engine failures, guidance system malfunctions, and warhead trajectory errors.

11. I. D. Sergeyev, ed., *Khronika osnovnykh sobytiy istorii raketnykh voysk strategicheskogo naznacheniya* (Moscow: TsIPK, 1994), p. 34. Even after formal adoption by the armed forces, further testing of the R-1 was continued at Kapustin Yar. Controlled winter launches in temperatures as low as minus twenty-six degrees Centigrade were carried out between January 29 and February 2, 1951. A further series occurred between June 13 and 27, 1951. These launches had a 100-percent success rate in reaching the assigned targets.

12. Col. A. Belousov, "They Were Conceived at Kapustin Yar" (English title), *Krasnaya zvezda*, January 3, 1991, p. 2.

13. Biryukov, "Materials in the Biographical Chronicles," p. 229; Chertok, *Rakety i lyudi*, p. 336. The five R-2E missiles were launched on September 25 and 30 and October, 2, 8, and 11, 1949. Of these, three were considered successes.

14. Biryukov, "Materials in the Biographical Chronicles," p. 230.

Despite the failures, the R-2 launches contributed significantly to the expertise and knowledge of long-range ballistic missiles. It was the first minor step forward from the German origins of postwar Soviet ballistic missiles. The development of the R-2 missile also represented a marked level of maturation of the Soviet rocket-building industry. The effort to produce a replica of the A-4, in the late 1940s, finally paid off in a swifter and more efficient exchange of information between engineers and production managers. At least twenty-four scientific research institutes and ninety industrial enterprises coordinated their efforts to produce the vehicle.[15]

With such an intensive series of launches at Kapustin Yar, the range remained continually busy as hundreds of engineers, military officers, and secret police officials traveled to and from the site, all dealing with the major climactic hazards at GTsP-4. The winter of 1950 was particularly harsh as at least two meters of snow was deposited on the launch site. The following spring, personnel discovered the thawed body of a soldier who had been frozen to death. Searchers also found a herd of horses who had met the same fate. For the most part, sleeping quarters remained either tents or trucks; the concrete buildings were still in the process of construction.[16] Roads were almost nonexistent at the time, while mail was intermittent at best. Recollections of the time all describe the area as one of the toughest and demanding for those involved. For the mostly military personnel who were stationed there permanently, the majority of whom had survived the turmoil of World War II, it was another excursion into incredible hardship.

The R-3 Missile

The R-1 and R-2 missiles served as the beginning point for Soviet postwar ballistic missile programs. Given the ultimate military needs of the Stalin leadership, both were, however, woefully inadequate. The need for a "transatlantic" missile had been formally tabled as early as 1947, at a Kremlin meeting attended by Stalin and then chair of the Special Committee No. 2, Georgiy M. Malenkov. The latter was one of those who argued vociferously in favor of such missiles, and according to one recollection, "no limits were to be placed on available funding."[17] At the time, the focus was clearly divided between winged missiles, such as the Sänger-Bredt bomber, and traditional ballistic missiles, which were developed at the NII-88. As a starting point to fulfill Stalin's request, in late 1947, Korolev had begun low-level studies to produce a ballistic missile with a range of 3,000 kilometers, over ten times more than the German A-4. Even the resident Germans at Kaliningrad and Gorodomlya were concerned with the relatively modest G-1 with its range of 600 kilometers. The concept was evidently discussed at high levels within the Soviet government, for on April 14, 1948, the USSR Council of Ministers issued a decree sanctioning exploratory work on such a missile, designated the R-3 or "product 8A67."[18] Over the following year and a half, a group of Korolev's engineers slowly established the design specifications of the missile and incorporated them into a twenty-volume technical document called a draft plan, co-authored by Korolev and completed in June 1949.[19] The other principal authors were Korolev's first deputy Mishin and engineers Bushuyev, Kryukov, Okhapkin, and Svyatoslav S. Lavrov, a ballistics expert.

15. Yaroslav Golovanov, *Korolev: fakty i mify* (Moscow: Nauka, 1994), p. 420.

16. Col. M. Rebrov, "Where the Cranes Fly" (English title), *Krasnaya zvezda*, September 19, 1987, pp. 3–4; Belousov, "They Were Conceived at Kapustin Yar"; Yu. A. Mozzhorin, *et al.*, eds., *Dorogi v kosmos: I* (Moscow: MAI, 1992), p. 94.

17. Yu. A. Mozzhorin, *et al.*, eds., *Nachalo kosmicheskoy ery: vospominaniya veteranov raketno-kosmicheskoy tekhniki i kosmonavtiki: vypusk vtoroy* (Moscow: RNITsKD, 1994), p. 71.

18. Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p. 629.

19. Biryukov, "Materials in the Biographical Chronicles," p. 227; A. Yu. Ishlinskiy, ed., *Akademik S. P. Korolev: ucheniy, inzhener, chelovek* (Moscow: Nauka, 1986), p. 300; Chertok, *Rakety i lyudi*, pp. 219–20.

Unlike draft plans for other missiles, Korolev structured this particular work in such a way that it would serve as a reference work for future efforts in the design of long-range missiles. The first volume, titled "Principles and Methods of Designing a Missile of Great Range," was a 282-page type-written document that was a detailed theoretical treatise on missile design that went far beyond the modest German-derived R-1 and R-2 missiles.[20] While focusing loosely on the new R-3, it was also in essence a "how-to manual" for very long-range missiles—that is, a solid reference work for future efforts that would eventually lead to the creation of the first Soviet ICBM. The report examined six specific areas of investigation:

- Research on flight characteristics of three variants of single and multistage long-range ballistic missiles
- Preliminary research on flight characteristics of winged (or cruise) missiles with various types of separable winged warheads
- Research into the principles of separable warheads for long-range missiles
- Research on standard cruise missiles with separable winged warheads both with and without sustainer rocket engines
- Preliminary research on the aerodynamic characteristics of cruise missiles
- The problems of dynamic flight of long-range cruise missiles[21]

A major portion of the study was clearly focused on cruise missile concepts, perhaps indicative of Korolev's personal vision of rocketry, which for most of his life had been connected to winged rather than ballistic missiles. Stalin's own interest in cruise missiles may have also played a factor in the relative emphasis of the two competing roads, as evidenced by his continuing support for the Sänger-Bredt concept.

In terms of the future of Soviet rocketry, it was the portion dedicated to the ballistic missile that had the most relevance. In examining the possible ballistic configurations, Korolev advanced three possible ballistic "composite" (BS) or multistage schemes for the next generation of Soviet missiles:

- BS no. 1 envisioned a classic multistage vehicle with several stages connected together in tandem, each stage falling off as its propellant was exhausted.
- BS no. 2 examined the use of exterior fuel tanks, which would serve the engine on the core stage and be jettisoned following propellant depletion.
- BS no. 3, harking back to Tsiolkovskiy's theories, used a parallel arrangement of all the stages, all firing at liftoff, followed by discarding the strap-ons, after which the core would continue to fire as the "second stage."[22]

Although the study was focused primarily on the creation of a 3,000-kilometer range missile, throughout the document at key points, Korolev mentioned the possibility of designing an even more powerful rocket with an intercontinental range. In his introduction, he stated:

20. An edited version of this first volume has been published in Keldysh, ed., *Tvorcheskoye naslediye akademika Sergeya Pavlovicha Koroleva*, pp. 291–318. Korolev himself co-authored volumes I, II, IV, V, VI, and XIV. See p. 396.

21. *Ibid.*, pp. 291–92.

22. *Ibid.*, pp. 298–99.

> *A range equal to 3,000 km can be viewed only as the first stage that makes it possible to solve certain problems envisaged in the requirement for the R-3. The costs and the whole complex of technical measures necessary for attaining the range of 3,000 km are so great that it would be unacceptable to isolate this work from the prospects of further development. Therefore, for the following stage, for solving significantly greater tasks, a range on the order of 8,000 km was projected with an increased payload.*[23]

In looking at future intercontinental range missiles, Korolev argued that the "most prospective choice" was the cluster concept of BS no. 3, a decision that was to a great degree based on his friend Tikhonravov's studies on a satellite launch vehicle at NII-4. Tikhonravov's work in 1947–48 clearly pointed in the direction of what he called the "packet" scheme, a euphemism for using clusters of stages linked together in a parallel arrangement at liftoff. For many of the same reasons that Tikhonravov had rejected a successive-staged vehicle for the present time, Korolev himself had begun to accept that a packet scheme would allow for an easier creation of an ICBM. In conducting his studies, Korolev had also studied the German A-9/A-10 concept proposed initially at Peenemünde during the war. That design used the A-10 rocket as a first stage, which would boost the A-9 second stage, essentially a modified A-4, into an intercontinental trajectory. The range was about 5,200 kilometers.[24] Tikhonravov's original recommendations for using a packet scheme precluded any serious work on the German plan.

Assessing the level of Soviet technology, and in particular the envelope of high-thrust engine development, Korolev settled on a standard single-stage ballistic design scheme for the R-3, its classic cylindrical shape a distinct step away from the German A-4. On December 7, 1949, Korolev formally presented the R-3 draft plan at a meeting of the Scientific-Technical Council of NII-88. A specially established council of experts enthusiastically approved the full-scale development of the missile, emphasizing the "extraordinary" scale of the effort.[25]

The R-3 program was without doubt the largest and most expensive ballistic missile effort in the Soviet Union to date. The lead organization for the missile's design was Department No. 3 of NII-88's Specialized Design Bureau under Korolev. For the first time, there was significant cooperation with other organizations, including the Department of Applied Mathematics in the V. A. Steklov Mathematics Institute of the USSR Academy of Sciences. Led by the ubiquitous Keldysh, this small department had been established in 1944, and in 1948, it began serious scientific research into such areas as rocket dynamics and applied celestial mechanics.[26]

There were two primary design features of the R-3 that represented deviations from A-4–derived Soviet ballistic missiles, such as the R-1 and R-2. To reduce the lifting mass of postwar rockets, Korolev had partially incorporated the concept of load-bearing tanks into the R-2 missile, a configuration that allowed the propellant tanks themselves to serve as the main frame of the missile. On the R-2, only one tank, the one carrying ethyl alcohol was load bearing. With the R-3, engineers worked to develop a new missile in which *both* propellant tanks were load bearing. Second, engineers dispensed with the heavy and large stabilizing fins made

23. *Ibid.*, p. 292. See also David Holloway, *Stalin and the Bomb: The Soviet Union and Atomic Energy: 1939–1956* (New Haven, CT: Yale University Press, 1994), p. 249, for a similar English translation of the same passage.

24. Frederick I. Ordway III and Michael R. Sharpe, *The Rocket Team* (New York: Thomas Y. Cromwell, 1979), pp. 56–57.

25. The expert panel included A. A. Kosmodemianskiy (Special Committee No. 2), A. I. Makarevskiy (TsAGI), Yu. A. Pobedonostsev (NII-88), Kh. A. Rakhmatulin (MVTU), and M. K. Tikhonravov (NII-4). See also Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p. 40; Biryukov, "Materials in the Biographical Chronicles," p. 229; Chertok, *Rakety i lyudi*, p. 220.

26. V. S. Avduyevskiy and T. M. Eneyev, eds., *M. V. Keldysh: izbrannyye trudy: raketnaya i kosmonavtika* (Moscow: Nauka, 1988), p. 7.

of graphite, which were a standard on the R-1 and R-2 vehicles and significantly reduced lifting capacity.[27] The fins were retained on the R-2 so as not to introduce too many changes into the original A-4 design, but during flight testing, they were responsible for unnecessary aerodynamic resistance and stress on the missile.

Technically speaking, there was a direct connection of lineage from the experimental R-2E missile to the new R-3 model. The R-2E had tested some new design features that would end up in the R-3, in particular the integral fuel tank and the separating warhead. These technical innovations had been largely responsible for the twofold increase in range of the R-2E over the R-1 missile. For the R-3, Korolev's engineers would need to make more departures from the German antecedents of postwar Soviet rocketry. Perhaps the most risky proposition of the whole venture was the design of the main engine for the rocket. Korolev's engineers switched from the tried and tested liquid oxygen-alcohol combination so preferred by the von Braun team to the more efficient liquid oxygen-kerosene pairing, which allowed an increase in specific impulse of about 20 percent. To reduce the risk of failure, NII-88 contracted two different engine design teams to create the main 120-ton thrust engine for the R-3. These were Glushko's OKB-456 based at Khimki and a department at NII-1 under Chief Designer Aleksandr P. Polyarniy, an old prewar associate of Korolev's from GIRD.[28] Each group was to offer its own competitive design. In a direct link to the Soviet version of the Sänger-Bredt bomber, both these engines were also earmarked for use on the latter vehicle, a decision that no doubt reduced significant duplication of work.

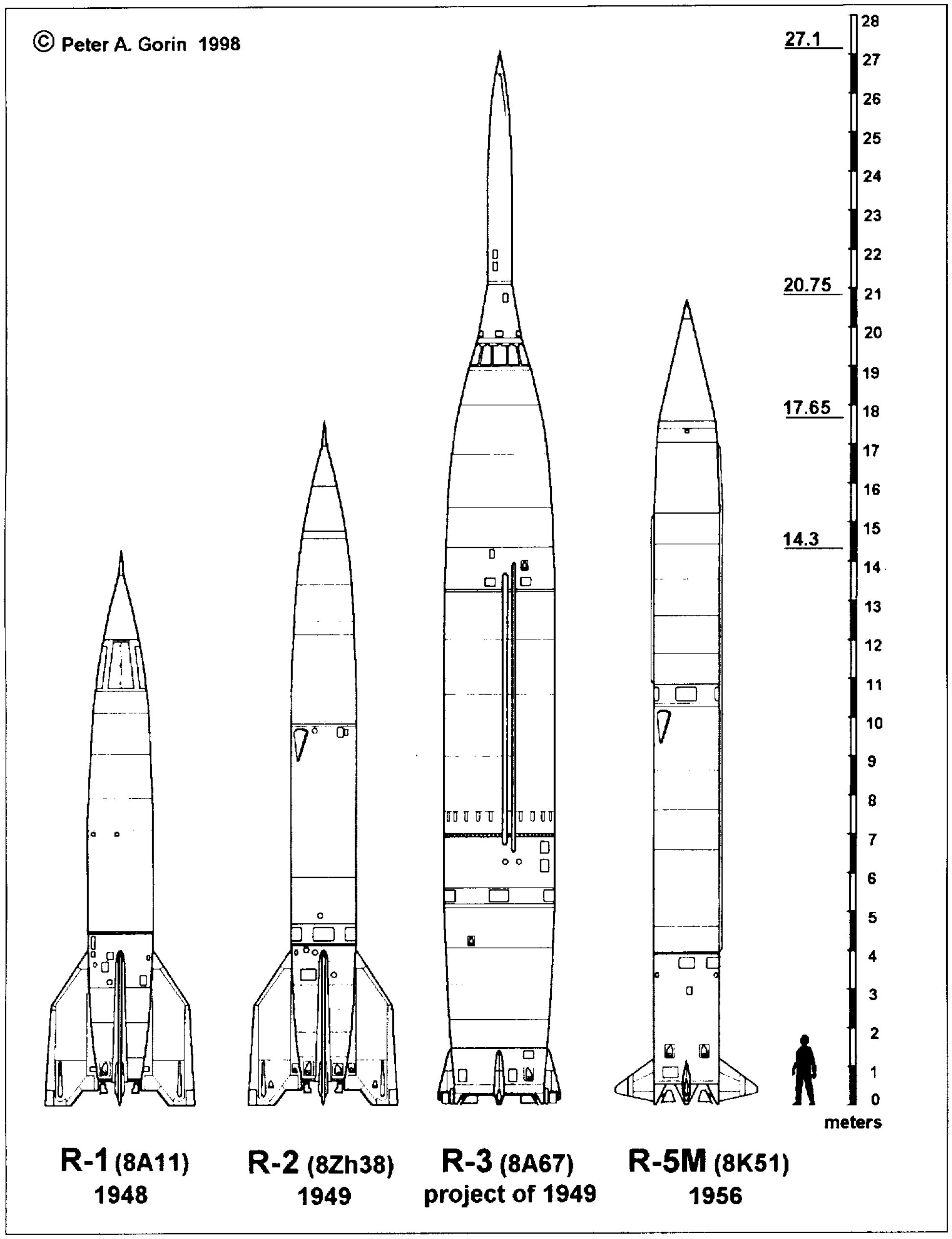
The Glushko engine, designated the RD-110, was the very first high-thrust liquid oxygen engine to be designed under his direction during his twenty-year career. Traditionally, Glushko had been reluctant to use liquid oxygen because of technical obstacles related to vibration, and preferred nitrogen-based oxidizers. In his initial conception of the new engine, Glushko, unlike Korolev, did not choose to adopt any radically new design approach. Instead, he used the old A-4 engine combustion chamber and scaled it up to match the required performance characteristics needed for the R-3. Polyarniy evidently preferred to use an alternative approach for his D-2 engine, also with 120 tons of thrust.

In looking at future variants of long-range missiles, Korolev's engineers had proposed the use of multistage rockets, but for the R-3's range of 3,000 kilometers, they believed that a single-stage missile would have significant advantages in mass and other parameters over a multistage one. The R-3 design included the use of a separable warhead and a new aluminum-magnesium alloy as the main structural material. The propellant tanks would be pressurized with liquid gas vapor rather than compressed air, as had been the practice before. Engineers improved the missile's mass efficiency by compacting its configuration as much as possible. They eliminated intertank structures with instrument sections and instead placed control and service devices in previously unoccupied spaces at the rear section of the rocket. In addition, bolted joints were replaced by welded ones, and the engine's proportional length was reduced by increasing combustion chamber pressure and adopting a contoured nozzle.[29] These were all significant innovations in the Soviet rocketry industry that in some cases served to give birth to new manufacturing technologies that would become common practice in the early Soviet space program.

27. Mozzhorin, *et al.*, eds., *Nachalo kosmicheskoy ery*, p. 261; Yu. Biryukov and A. A. Yeremenko, "50 Years for the Native Rocket-Space Industry. The Early Period of Development" (English title), *Novosti kosmonavtiki* 10 (May 6–19, 1996): 54–64.

28. J. V. Biriukov, "The R-3 Rocket Project Developed in the U.S.S.R. in 1947–1959 as a Basis for the First Soviet Space Launchers," in J. D. Hunley, ed., *History of Rocketry and Astronautics, Vol. 19* (San Diego, CA: Univelt, 1997), pp. 193–99.

29. Biriukov, "The R-3 Rocket Project Developed in the U.S.S.R."



Soviet ballistic missile development between 1946 and 1956. The R-3 missile was a significant leap in capabilities from the German antecedents of the Soviet ballistic missile program. Incorporating many new technical innovations, the R-3 would have a range of 3,000 kilometers, ten times more than the German A-4. The missile was approved for development in December 1949. (copyright Peter Gorin)

As with the engines, Korolev initially contracted the development of the R-3's guidance system to two competitive groups. A traditional autonomous system would be developed by NII-885 under Chief Designers Ryazanskiy and Pilyugin, both of whom had worked on the R-1 and R-2. A second team, under an ambitious and talented guidance specialist named Boris M. Konoplev at NII-20 (for radio systems) and A. I. Charin at NII-49 (for gyroscope units), was invited to participate for the first time in the ballistic missile program.[30]

The guidance system for the R-3 missile was selected using the extensive experience from the German designs on the A-4 and the successor Soviet modifications on the R-1 and R-2 vehicles. The results of the A-4 flight test program had, in particular, allowed the testing of several different guidance systems, including an autonomous system developed by Chief Designer Pilyugin, a German system for lateral radio control designated Hawaii-Viktoria, improved by Deputy Chief Designer Mikhail I. Borisenko, and a second German telemetry system called Messina-1, reproduced by the Soviets under Deputy Chief Designer Yevgeniy Ya. Boguslavskiy. All three individuals were prominent members of NII-885, the leading missile guidance organization in the Soviet Union at the time. The tests with the A-4 and the R-1 had also, however, showed some limitations. Given the need to achieve increased accuracy in a very short time period, it had become clear to some engineers that autonomous guidance and control systems did not offer a quick solution. With this in mind, Korolev turned to the short-term solution of using active guidance by remote control from the ground—that is, a purely radio-controlled guidance system. The Germans had already conducted research in this area (on the Hawaii-Viktoria system), and Chief Designer Konoplev at NII-20 was contracted to develop a new radio-controlled system for the R-3 designated Topaz.[31] The Topaz project using "variable system architecture" was important for the Soviet missile industry in general because it established the groundwork for a new engineering discipline called radio ballistics. The decision to use the Topaz design was also significant for it was opposed by Chief Designer Pilyugin, who by then had not only become Korolev's most important associate on guidance issues, but who was also firmly in favor of an autonomous system for the R-3.

The R-3 missile, as envisioned in the December 1949 plan, was a single-stage rocket that was just over twenty-seven meters long with a base diameter just under three meters and made of a new aluminum-magnesium alloy. The total fueled launch mass was seventy-one tons, while sea-level launch thrust was about 120 tons. The vehicle was designed to lob a three-ton separable warhead a distance of 3,000 kilometers.[32] Launches would be conducted from mobile platforms, much like those of the R-1 and the R-2. Given its proposed range, the R-3 would be the first Soviet ballistic missile capable of reaching Great Britain and Japan, giving the Soviets their first true strategic missile. A stunning qualitative and quantitative leap over any previous missile in the Soviet Union, the new rocket project was a watershed milestone in the development of Soviet rocketry. To give some indication of Korolev's ambition, it may be instructive to note that in 1949, the Soviet copy of the German A-4 had yet to be declared operational by the Soviet armed forces, while the R-3 had a flight range ten times more than that missile.

Because the R-3 represented such a leap in capabilities for the new Soviet rocketry industry, the Scientific-Technical Council of NII-88 recommended that some of the new technologies adopted for the R-3 be tested on a smaller experimental rocket known as the R-3A. The latter rocket, based in design on the much smaller R-2, used an integral oxygen tank as well as a finless rear section. Models of the experimental missile would also be used to prove out such innovations as high boiling oxidizers, high calorific fuel, and test technologies earmarked for future

30. Chertok, *Rakety i lyudi*, p. 220.
31. Mozzhorin, *et al.*, eds., *Nachalo kosmicheskoy ery*, p. 278–80.
32. Stache, *Soviet Rockets*, p. 179; Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p. 40.

rockets such as strap-on boosters and winged warheads. With the two basic improvements—that is, the integral tank and the omission of the rear rudders—the R-3A displayed significantly improved flight characteristics over its antecedent, the R-2. The missile had a mass of almost twenty-three and a half tons and main engine thrust of forty tons—values comparable to the R-2—but a range that was one and a half times more than the R-2, about 935 kilometers.[33] Flight testing of the R-3A was planned for 1951, with launches of the R-3 commencing in 1952 or 1953 at the earliest.

At about the same time that work on the R-3 was emerging as the primary thematic goal of Korolev's team, Academician Keldysh's team was winding down work on the Sänger-Bredt antipodal bomber. Since research on the program had begun in 1946, a variety of technical obstacles had plagued engineers. In 1948, Keldysh's NII-1 was institutionally subordinated to the Central Institute of Aviation Motor Building (TsIAM), one of the most prestigious Soviet scientific institutions, which focused research on aeronautical propulsion. As head of the TsIAM section on ramjet engines, Keldysh continued to work on the Sänger-Bredt project, but by 1950, technological complexities, in particular with the propulsion systems, seem to have overwhelmed any attempt at a full-scale project. Keldysh instead redirected some of the team's work in December 1950 to a more modest automated intercontinental cruise missile—one that would use tried and tested technologies. He wrote in his report on the new conception that research had "confirmed the possibility and advisability of using in the capacity of launch accelerators, [RD-100] engines from long-range missiles of the R-1 type."[34] The vehicle could use the same launch facilities as those for the R-1. After initial launch by these engines, flight at altitude would be handled by a set of supersonic ramjet engines. The aircraft-cum-missile would be able to carry a three-ton warhead a distance of 6,000 to 7,000 kilometers, flying most of the way at an altitude of fifteen to twenty-five kilometers at speeds of 3,000 to 3,500 kilometers per hour.

It seems that TsIAM was conducting extensive research during this period on the development of ramjet engines for use on such intercontinental designs. Between 1947 and 1950, efforts at the institute encompassed work on a supersonic "diffuser," which was tested at the institute at velocities of up to Mach 4. In addition, scientists built and tested an experimental combustion chamber for the ramjet engine at speeds reaching Mach 2.6. Such a motor, with a thrust of almost twenty-one tons, was also successfully tested at the institute simulating flight at an altitude of 8,000 meters. Georgiy I. Petrov, a brilliant scientist in his late thirties under the employ of Keldysh led most of these early groundbreaking studies. Awarded the USSR State Prize for his work on diffusers in 1949, two years later, Petrov was personally responsible for the design of the first Soviet aerodynamic wind tunnel capable of testing speeds of up to Mach 10.[35] The work on ramjet engines was not without problems. Although Soviet scientists had a long history of ramjet development beginning the 1930s, the leap to supersonic speeds proved to be a very difficult transition. In a document from November 1951, Keldysh lists a litany of technical obstacles that had plagued the supersonic ramjet program during 1948–51, including the inability to model the working processes of such engines on the ground and the problems in creating stabilization systems for combustion chambers.[36]

33. Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p. 40; Biryukov and Yeremenko, "50 Years for the Native Rocket-Space Industry."

34. Keldysh's document, dated December 11, 1950, is reproduced in full as M. V. Keldysh, "On the Composition of Work on PVRDs and Their Applications" (English title), in Avduyevskiy and Eneyev, eds., *M. V. Keldysh*, p. 35–38.

35. M. V. Keldysh, "On the Scientific Activities of G. I. Petrov" (English title), in *ibid.*, pp. 140–42. The document is dated September 21, 1952.

36. M. V. Keldysh, "On the Development of Work on Research on PVRDs in Flight" (English title), in *ibid.*, pp. 38–39. The document is dated November 4, 1951.

The work on the Sänger-Bredt antipodal bomber in 1946 and 1950, and the subsequent research on ramjet engines and high-speed aerodynamics, had a profound impact on the future thematic direction of the Soviet efforts to develop a transatlantic missile. The 1947 directive to develop such a vehicle led to two different but parallel options: a ballistic missile that would travel above the atmosphere for part of its trajectory and a winged cruise missile that would fly within the atmosphere during its entire flight. There was a considerable amount of emphasis on both fronts, and confidence in one road was often inversely proportional to the level of difficulties faced in the alternate path. By the turn of the decade, with the advent of the R-3, the overseers of the Soviet missile program, the omnipotent Special Committee No. 2, seem to have been favoring the ballistic missile option. Difficulties with the development of ramjet engines no doubt contributed to such a climate. At the same time, the ballistic R-3 was itself a risky endeavor. Looking to reduce risk, the Special Committee was unable to firmly decide in favor of one particular approach for an intercontinental delivery system. For almost another decade, engineers and policy makers would continue to debate over the propitiousness of one option over the other.

The End of the Road for the Germans

The abortive G-1 missile effort did not instill much hope for the Germans at Gorodomlya. As far as they were concerned, the months of intensive effort on the project effectively turned out to be a waste of time when the program was terminated in 1949. By then, almost all the Germans had been transferred to NII-88's Branch No. 1 at Gorodomlya in Lake Seliger, where the living conditions continued to be a major obstacle to fruitful engineering work. More than two years after the formation of the branch, the Germans were still, for the most part, living in huts, with no effective sewage or sanitation systems. Morale was a serious problem among the group, compounded by bitter infighting among the Germans and problems of alcoholism and marital infidelity.[37] Only on rare occasions were they allowed to leave the island to visit Moscow. Under these conditions, the group worked on a series of successor missile projects to the G-1, all of which were viewed very favorably by Grottrup's men as ways to divert their attentions from their more earthly problems. This work was performed on request by their Soviet bosses; at no point were the Germans informed of the ultimate fate of their efforts.

The winding down of work on the G-1 was followed by work on the more capable G-2 (or R-12) missile. In 1948–49, a preliminary draft plan for the vehicle was developed that envisioned the use of a missile with a range of 2,500 kilometers—far in excess of the G-1 and in fact much closer to the Soviet R-3. The Germans designed a booster that incorporated a variation of the so-called cluster scheme, in which three engines would fire at liftoff and two of the engines would be jettisoned. A similar one-and-a-half-stage configuration was used many years later in the U.S. Atlas ICBM. The total launch thrust of the missile was 100 tons, achieved by using engines from the abandoned G-1 missile. Some of the design elements incorporated into the vehicle elicited much interest from the Soviet side. For example, the G-2 was the first post–A-4 missile that rejected the traditional use of gas vanes to steer the rocket. Such a concept was still a novelty for Korolev's engineers, and the Soviets themselves would not in fact completely dispense with the concept until development of their first ICBM in the mid-1950s. Furthermore, the Germans introduced a means of regulating total thrust by using a peripheral group of three engines at the base of the rocket 120 degrees apart. A similar concept would later be used in the Soviet N1 lunar booster in the 1960s.[38] Despite its technical advancements, work on the G-2 was shut down in 1949.

37. Ordway and Sharpe, *The Rocket Team*, pp. 336, 340.

38. Chertok, *Rakety i lyudi*, pp. 218–19; CIA Office of Scientific Intelligence, "Scientific Research Institute and Experimental Factory 88 for Guided Missile Development, Moskva/Kaliningrad," OSI C-RA/60-2, March 4, 1960, pp. 7–8.

A third project during the same period served to marginally raise the spirits of the Germans. On April 4, 1949, Minister of Armaments Ustinov personally visited the Gorodomlya facility with a proposal to the Germans to design a missile that could carry a three-ton warhead a distance of 3,000 kilometers.[39] The specifications were identical to those for the Soviet R-3 missile, and Ustinov's proposal was quite likely a means to augment the R-3 effort by absorbing as many technical innovations as possible from all sources. This new German missile project, called the G-4 (or R-14), reinvigorated the energies of Grottrup's team, which was given only three months to complete a preliminary draft plan on the missile. Given the circumstances, what they came up with was no less than astounding.

The G-4 was a single-stage, cone-shaped, twenty-five-meter-long vehicle with a single 100-ton-thrust engine. The Germans completely dispensed with fins and aerodynamic control surfaces and also incorporated a full monocoque structure, much like the Soviets did with the R-3. Perhaps the major difference with the R-3 was the G-4's use of the traditional combination of liquid oxygen and alcohol—a combination that the Germans, both in the Soviet Union and the United States had favored over other mixtures. The main engine would have its combustion chamber cooled by circulating alcohol through its walls, while the turbopumps for the propellants would be driven by hot gases "bootstrapped" from the combustion chamber of the main engine. For roll control, the Germans introduced the idea of using exhaust gases from the turbopumps diverted through a nozzle that could be swiveled. A similar scheme was in fact used in the 1950s on the U.S. Jupiter missile by von Braun's team. As was standard in all post–A-4 missiles, the warhead was to fly separately from the main body of the missile after a certain point in the trajectory. One of the most impressive elements of the G-4 design was the plan for a massive underground factory, designed by Heinz Jaffke and Anton Narr, from which the missiles could be built and launched. Systems were designed that could also extract oxygen from the air to manufacture liquid oxygen.

On October 1, 1949, Ustinov sent NII-88 Director Maj. General Gonor, Chief Engineer Pobedonostsev, and Chief Designer Korolev to Gorodomlya to be briefed on the G-4 missile. It was a rare interaction between the latter and the Germans, and it was probably Korolev's last visit to the island. The Soviets returned to Kaliningrad with the product of the German team's work; the Germans themselves were given no explanation and heard little about the project ever again. Some minor redesign effort on the G-4 was continued until February 1950, but by that time, a formal decision on the R-3 had already been taken by NII-88, and presumably the Soviets saw little use in having the Germans continue with their parallel project. It was another case of German expertise compromised by a variety of factors, including perhaps most importantly an unwillingness to properly make use of their contributions.

Several more abortive projects came the way of the Gorodomlya group during the same period. The G-1M (or R-13) in the summer of 1949 involved a 1,100-kilometer-range missile using the same frame as the G-1 but with improved A-4–type engines. The G-5 (or R-15) effort led by Werner Albring was essentially a winged competitor to the ballistic G-4, at a time when the Soviets themselves were involved in intense debate over the utility of winged versus ballistic configurations. A final project, designated the G-3, with an intercontinental range of 8,000 to 10,000 kilometers and a payload of three to five tons, was also studied in 1949 and

39. Ordway and Sharpe, *The Rocket Team*, p. 337.

1950, but details are still lacking. All these later projects were limited to their initial design, comprising only diagrams and main parameter calculations.[40]

Work on the G-4 and G-5 projects coincided with a marked decrease in work among the Germans. In April 1950, the Ministry of Armaments formally decided to terminate further work on long-range missiles at Branch No. 1 at Gorodomlya. Also, by order of the ministry, on March 29 of that year, all access to classified materials was denied to the Germans.[41] Despite the order, the Soviets continued to ask advice on technical matters well into 1951, by which time Grottrup had been replaced as technical leader of the Germans by Johannes Hoch, who died soon after from appendicitis. Despite the poor living conditions at Gorodomlya, the NII-88 leadership operated a well-maintained set of technical facilities at the island that were regularly used by the Soviets. In early 1951, groups of young Soviet engineers migrated to Gorodomlya ostensibly to be taught by the experienced Germans at these excellent facilities.[42] It was the last time that the Soviets would make active use of German expertise in the postwar years. By this time, the Germans were spending most of their time playing sports, gardening, or reading available technical monographs to pass the time.

Already by August 1950, the Soviet government had decided to begin the repatriation of the Germans back to the German Democratic Republic. The group of several hundred departed Gorodomlya to return to their homeland in three waves, beginning in December 1951 and June 1952. The last remaining eight German scientists, including Grottrup, were given permission to leave the Soviet Union on November 22, 1953. Within a week, they were all gone, ending the seven-year existence of NII-88's Branch No. 1. The few who remained were moved back to Moscow under a Dr. Faulstich, and they were provided good salaries and five-year-long contracts in industries unrelated to missile development.

The fate of the Germans after their residency in the Soviet Union was varied. Grottrup returned at first to East Germany and then eventually to West Germany. Extensively interrogated by U.S. intelligence services in Hamburg, he was offered a chance to move to the United States to work on the Army's ballistic missile program. His wife Irmgard, however, refused to ever leave Germany again, and U.S. authorities were reportedly not very pleased with the decision. Grottrup remained in Germany until his death from cancer in 1980, while his wife authored a revealing memoir of their time at Kaliningrad and Gorodomlya.[43] Dr. Waldemar

40. P. Bork and G. A. Sadovoj, "On the History of Rocketry Developed in the U.S.S.R. in the First Years After the Second World War (The Participation of German Specialists in the Development of Soviet Missile Technology in the Early Post-War Period)," in J. D. Hunley, ed., *History of Rocketry and Astronautics, Vol. 19* (San Diego: Univelt, 1997), pp. 143–52; Chertok, *Rakety i lyudi*, p. 219. The G-5, essentially a smaller automated version of the Sänger-Bredt antipodal bomber, was to constitute a G-1 vehicle as the first stage, which would accelerate a small bomber with a wingspan of just over five meters using ramjet engines to thirteen kilometers altitude before diving down on its target. The G-5 plans were also submitted to the Scientific-Technical Council of NII-88 in December 1950, following which the Germans heard little from the Soviets. In 1951–52, Joachim Umpfenbach, one of the leaders of the German group, was assigned some tasks that may have been related to the G-5 cruise missile, but these were isolated jobs that did little to raise the morale of the personnel at Branch No. 1.

41. CIA Office of Scientific Intelligence, "Scientific Research Institute," p. 5. Russian sources claim that this happened in October 1950. See also Bork and Sadovoj, "On the History of Rocketry Developed in the U.S.S.R."; Chertok, *Rakety i lyudi*, p. 221. The Council of Ministers issued a decree (no. 3456-1446) on August 13, 1950, on the fate of German rocketry specialists in the Soviet Union that called for their repatriation. See V. F. Rakhmanin and L. Ye. Sterpin, eds., *Odnazhdy i navsegda . . .: dokumenty i lyudi o sozdatelye raketnykh dvigateley i kosmicheskikh sistem akademikye Valentinye Petrovichye Glushko* (Moscow: Mashinostroyeniye, 1998), p. 447.

42. Ordway and Sharpe, *The Rocket Team*, p. 341.

43. Peter Smolders, "I Meet the Man Who Brought the V-2 to Russia," *Spaceflight* 37 (July 1995): 218–20. For Mrs. Grottrup's book, see Irmgard Grottrup, *Rocket Wife* (London: Andre Deutch, 1969). Another personal memoir, by gyroscope specialist Kurt Magnus, has also been published. See Kurt Magnus, *Raketenskaven* (Stuttgart: Deutschen Verlags-Anstalt, 1993).

Wolf, one of the few who remained behind in the Soviet Union after 1953, lived in Moscow for many years before also returning to Germany. In his remaining years in the Soviet Union, he had no contact with the ballistic missile program.

The almost eight years of involvement of the German scientists in the Soviet rocketry program clearly proved to be an essential catalyst to its further advancement. During the existence of the USSR, Soviet historians rarely, if ever, mentioned the use of German expertise in the postwar years, but the collaboration was real and extremely pivotal in furthering Soviet goals. German expertise was invaluable in 1945 and 1946 in setting up and restoring A-4 production in the Soviet Union in the form of the R-1. Without the help of the Germans, the Soviets—and in particular NII-88—would have clearly lagged in their efforts, and it might even be argued that the twelve years from 1945 to the launch of the first Soviet artificial satellite would have been far longer. This is not to take away from the intrinsic talents and dedication of the Soviet Union's own scientists. In fact, a similar argument might be made for the launch of the American Explorer 1 in 1958. For the Soviets, their missile programs were in a state of total disarray by the end of World War II. Decimated by the Purges and then World War II, Soviet achievements in missile building paled in comparison to the products of the Peenemünde group. Grottrup's team was indispensable in quickly transferring the database of German achievements to the Soviets, thus providing a strong foundation from which to proceed. Even in more specific areas, the Germans were instrumental in reducing the amount of time needed to attain an A-4 capability. For example, Grottrup was responsible for building the mobile launch trains for the A-4s, while Heinz Jaffke helped set up NII-88's Branch No. 2 testing stands at Zagorsk.

There are, however, key differences in the role of Germans in the United States versus that of those in the Soviet Union. The Germans in the Soviet Union never participated in the mainstream rocketry program. In fact, after the restoration of A-4 production and the G-1 debacle, they worked completely independently and without much influence on Soviet plans. Not a single one of the German missiles designed in 1947 through 1950 was ever built. Following the significant events of 1946–47, the Germans essentially played a peripheral role, proposing a number of important technical innovations, only some of which were adopted by the Soviets. Compounding Korolev's personal resistance toward cooperation with the Germans was a much more imposing political imperative—one that was grounded in xenophobia and distrust. While some Soviet engineers may have realized the extremely important value of potential German contributions to the rocketry program, there was never any concerted effort to make maximum use of Grottrup's team.

Western historians have debated much on the role of the "German factor" in the postwar development of ballistic missiles in the Soviet Union. The most common interpretation has been one very generous to the Germans—that is, that they had a significant influence over early Soviet developments. One author, writing in 1995, argued:

> *For years Soviet space leaders put down the contribution that captured Germans and their V-2 technology made to the Soviet ballistic missile and space programs. "Not significant," they would say, "we got mostly the technicians. The Americans got von Braun and his top team. We sent our Germans back after a few years." That explanation is no longer the Party line. In fact, it is now acknowledged that German rocket technology was bedrock to the USSR, just as it was to the US.*[44]

44. James Harford, "What the Russians Learned from German V-2 Technology," presented at the 46th International Astronautical Congress, Oslo, Norway, October 2–6, 1995. See also James Harford, *Korolev: How One Man Masterminded the Soviet Drive to Beat America to the Moon* (New York: John Wiley & Sons, 1997), p. 64.

Such an argument conflates two clearly distinct issues: the use of recovered German technology and the use of the actual German scientists. There is no doubt that the Soviet Union benefited from A-4 technology in developing its early ballistic missiles. There is compelling reason to believe that the USSR might have floundered for years before moving ahead to such ambitious concepts as the R-3 had it not been for mastering the design and manufacturing technologies of the A-4 rocket. On the other hand, the available evidence suggests that Korolev and his team made very little use of German *expertise*, at least after 1947. Their influence over the direction of the Soviet ballistic missile program was marginal at best. Thus, if the parameters of the debate are limited to "the Germans," their contribution to the rocketry program in the Soviet Union was far less than that in the United States. In purely technical terms, the gains to the Soviets were in such areas as the design of guidance systems and the test and launch equipment. Perhaps some of the more advanced managerial techniques among the Germans may also have found their ways into Soviet institutions. A CIA report, authored in 1960 and declassified in 1980, summed up the total German contribution:

> *The German scientists made a very valuable contribution to the Soviet missile program[;] however, it cannot be said that without the Germans the Soviet Union would have had no significant missile program. . . . There is no doubt that it took the German wartime success with guided missiles to cause Stalin and his colleagues to devote large scale support to the Soviet effort in this field. Once this support was forthcoming the use of German scientists permitted the Soviets to achieve results in a much shorter time than it would have taken them along but there is no reason to believe that the Soviets could not have eventually done the job by themselves.*[45]

Satellites

One of the consistent themes running through most commentaries of Korolev's first years as a chief designer is an undeterred interest in space exploration. In the minds of most engineers in the rocketry sector, these dreams were tolerated as one of the many idiosyncrasies of his character. At the time he first became acquainted with the Germans in 1945, when the Soviets had no long-range ballistic missiles, let alone intercontinental rockets, Korolev tried to stimulate work by telling the Germans about working together to reach the Moon. Such ideas were clearly anomalies and were not shared by most of the other leading designers. There were, in fact, many in the government who suspected that Korolev's "real" objective was space travel, and the development of weaponry for the Soviet defense forces was merely a "Trojan horse" for his intentions. Given the paranoia and terror inflicted by the Soviet secret police at that time, Korolev was insightful enough to keep his hopes and plans to himself or his closest friends.

Mikhail K. Tikhonravov, at work at the Academy of Artillery Science's NII-4 organization, may have been one of the few prominent engineers who shared Korolev's vision. With a reputation for indefatigable curiosity, Tikhonravov was an unusually talented man. In his free time, he painted oil landscapes, collected wood-eating beetles, and even studied the characteristics of insects in flight, hoping to extract some insight into the dynamics of flying.[46] Interested for a long time in ascertaining the feasibility of launching an artificial satellite, the first steps in that direction had been taken in 1947, when he had initiated studies on possible configurations for a powerful multistage ballistic missile capable of reaching orbital velocity. For reasons still not

45. CIA Office of Scientific Intelligence, "Scientific Research Institute," pp. 10–11.
46. Yaroslav Golovanov, "The Beginning of the Space Era" (English title), *Pravda*, October 4, 1987, p. 3.

clear, his study group at the institute had been disbanded in early 1949. Only one person, Igor M. Yatsunskiy, was kept on by Tikhonravov to continue his explorations into possible configurations for the booster. In mid-1949, Yatsunskiy finished a series of calculations determining the relative mass of a three-stage rocket optimized with the specific goal of achieving orbital velocity.[47] Upon seeing the computations, Tikhonravov requested that Yatsunskiy apply his work specifically to the missiles being developed currently at NII-88 under Korolev—in particular, the still-to-be-built R-3. To coordinate the work more efficiently, Tikhonravov invited Korolev to meet him at NII-4's premises at Bolshevo in July 1949. Korolev was clearly impressed with Yatsunskiy's work, which focused on a launch vehicle composed of three R-3 missiles attached in parallel like a "packet."[48] Seeing the report, Korolev encouraged Tikhonravov to prepare a formal report addressing the issue of launching a satellite to be presented at the next session of the Academy of Artillery Sciences.

Boosted by Korolev's support, Tikhonravov reestablished a group to study packet-based satellite launch vehicles. The original group with A. V. Brykov, Ya. I. Koltunov, G. Yu. Maksimov, and L. N. Soldatova was set up in late 1949; it was augmented by G. M. Moskalenko and B. S. Razumikhin in 1950 and by I. K. Bazhinov and O. V. Gurko in 1951. All were recent graduates of the N. E. Bauman Moscow Higher Technical School, where special advanced engineering courses on missile design, construction, and engineering had been instituted and taught by such luminaries of the Soviet ballistic missile program as Korolev (1947–49), Glushko (1947–53), Tikhonravov (1947–52), Pobedonostsev, and others.[49] The lectures themselves were surprisingly interconnected with actual developments within the Soviet rocketry industry. For example, Korolev's own lectures incorporated details of the R-1, R-2, and R-3 missiles, albeit with disguised designations. The courses from this time period were instrumental in training a new generation of young engineers who would join major design bureaus and research institutes and make important contributions to the Soviet space program. Thus, by the time that Brykov, Koltunov, Maksimov, and the others joined Tikhonravov's team during 1949–51, they had solid training in actual and proposed Soviet ballistic missiles, providing a key connection between Korolev's work at NII-88 and Tikhonravov's efforts at NII-4.

The work of the original members of Tikhonravov's newly established group culminated in 1950 with the authorship of what may have been the very first detailed Soviet exposition on the technical prospects and requirements of launching an artificial satellite of Earth. Titled "On the Possibility of Achieving First Cosmic Velocity and Creating an Artificial Satellite with the Aid of a Multi-Stage Missile Using the Current Level of Technology," the paper was formally presented by Tikhonravov at a special session of the Academy of Artillery Sciences on March 15, 1950.[50] Along with many important military representatives, three engineers from NII-88 were present to hear his speech: designer Korolev, his first deputy Mishin, and planning department chief Bushuyev. Technically based around the idea of using the R-3 missile, Tikhonravov detailed a plan on using a packet-type multistage vehicle capable of launching a

47. I. M. Yatsunskiy, "On the Activities of M. K. Tikhonravov in the Period From 1947 to 1953 on Substantiating the Possibility of Creation of Composite Missiles" (English title), *Iz istorii aviatsii i kosmonavtiki* 42 (1980): 31–38. An English translation of this article is available as I. M. Yatsunsky, "The Role of Mikhail Klavdiyevich Tikhonravov in Creating Stage Rockets, 1947–1953," in John Becklake, ed., *History of Rocketry and Astronautics: Vol. 17* (San Diego, CA: American Astronautical Society, 1995), pp. 451–56.

48. Biryukov, "Materials in the Biographical Chronicles," p. 228.

49. Lardier, *L'Astronautique Soviétique*, p. 79; Yatsunskiy, "On The Activities of M. K. Tikhonravov."

50. B. N. Kantemirov, "15 July—40 Years From the Report of M. K. Tikhonravov on the Possibility of Achieving Cosmic Velocity Using the Current Level of Technology" (English title), *Iz istorii aviatsii i kosmonavtiki* 59 (1989): 65–76. With the phrase "first cosmic velocity," the Russians refer to the velocity required to attain orbit around Earth. The title of the paper has also been reported as "Rocket Packs and Their Development Prospects." See Yatsunskiy, "On the Activities of M. K. Tikhonravov."

small artificial satellite. Although he did not specifically mention a timetable, implicit in his words was the possibility of launching a satellite by the mid-1950s if given the requisite support. In an unexpected move, near the end of his monologue, Tikhonravov also raised the issue of launching humans into orbit in the near future using his proposed rocket. The reaction to this presentation was much more negative than the earlier session in 1948. Some in the audience were outwardly hostile to Tikhonravov's ideas, others were silent, and many had sarcastic reactions. Even Mishin himself expressed serious doubts of the technical feasibility of Tikhonravov's plan.[51] There was, in fact, a running joke after the conference that Tikhonravov and a monkey, in each other's arms, would fly off to the Moon.[52] Korolev was one of the few who unconditionally and publicly supported Tikhonravov's ideas.

The March 1950 report precipitated a few extremely fruitful months for Tikhonravov's group. Each participant was given a separate assignment on the development of a Soviet satellite launch vehicle, with the goal of authoring a detailed and comprehensive study on the issue. They studied various configurations of clustered and tandem missiles and devised a special mathematical model for mass analysis based on firsthand information on the R-3 missile provided by Korolev's own engineers. As a result of this work, Moskalenko subsequently authored *Engineering Methods of Designing Missile Dynamics*, while Maksimov completed a report on the ballistic trajectories of an artificial satellite launched by the booster. Advanced studies were also conducted on interorbital transfers and the deorbiting, reentry, and recovery of a satellite. In designing the launch vehicle, Tikhonravov favored a two-stage packet of three R-3s; calculations showed that this configuration would be able to insert a fairly heavy satellite into orbit. The results of all of this work was collated into a massive work consisting of three volumes and published in late 1950. Tikhonravov's own March 1950 paper was also published in a scientific journal in 1951. Despite the voluminous amount of work, Tikhonravov's group was once again disbanded at this time.[53] Although this second setback was temporary, the termination of the launch vehicle effort apparently was related to a number of institutional factors that clearly illustrated the tenuous support for scientific endeavors in a predominantly military industry.

On August 29, 1949, the Soviet Union exploded its first atomic bomb in a desert south of Semipalatinsk in Kazakhstan.[54] The balance of power abruptly shifted between the two major powers. In the immediate postwar years, Stalin's first and foremost priority was the creation of Soviet nuclear weapons. Although modest rockets were developed during the same period, the missile industry itself did not have the same kind of political imperative as atomic bombs. Always holding a second place in the top-secret armaments industry, in 1949, a missile delivery system finally began to receive a pronounced support, and this support was tied to the nuclear capability. It was painfully clear, however, that the available or planned rockets in the Soviet arsenal such as the R-1 and R-2 were inadequate to satisfy the needs of Soviet defense policy. Neither of these missiles had the capability to carry the heavy nuclear warheads available at the time, nor were they particularly efficient in terms of preparations for launch and targeting. Most critically, they had very short ranges and could only be useful in tactical battles in the European theater. Preparatory work on the R-3 program was ongoing at the time, although

51. Yu. A. Mozzhorin *et al.*, eds., *Dorogi v kosmos: II* (Moscow: MAI, 1992), pp. 91, 103; B. N. Kantemirov, "From the History of Science: Flight—His Dreams and Affairs" (English title), *Zemlya i uselennaya* no. 6 (November-December 1991): 54-56.

52. Kantemirov, "From the History of Science."

53. Kantemirov, "15 July—40 Years From the Report"; Yatsunskiy, "On the Activities of M. K. Tikhonravov."

54. Yu. P. Maksimov, *Raketnyye voyska strategicheskogo naznacheniya: voyenno-istoricheskiy trud* (Moscow: RVSN, 1992), p. 34.

even its 3,000-kilometer range was insufficient to cross the Atlantic and reach the shores of what the Soviets considered their number-one enemy.

In this context, in late July 1949, less than a month prior to the first nuclear test, Stalin summoned the top leaders of the missile industry to the Kremlin for a briefing on the state of missile delivery systems. Representing the new rocketry industry were men from both the missile industry and the artillery forces. Also present were Chief Designer Korolev and Igor V. Kurchatov, the famous nuclear physicist and scientific leader of the Soviet nuclear weapons program.[55] As the meeting dragged on into the evening, Col. General Mitrofan I. Nedelin, who headed the Chief Artillery Directorate, and Marshal Nikolay N. Voronov, the chief of Artillery Forces, gave brief reports on the status of efforts to adopt the R-1 as an armament for the Soviet Army. They were followed by Kurchatov, who reported on nuclear weapons development. Korolev was apparently a little nervous when it was his turn, but he explained to Stalin that the R-2 vehicle was almost ready for test launches. He specifically emphasized the advantages of the vehicle over the original German designs, no doubt knowing that Stalin desired something more capable of covering transatlantic distances. In a perhaps apocryphal account of the meeting, Stalin is alleged to have followed Korolev's report with the following tirade:

> *We want long, durable peace. But Churchill, well he's warmonger number one. And Truman, he fears the Soviet land as the devil's own stench. They threaten us with atomic war. But we are not Japan. That is why you, comrade Kurchatov, and you, comrade Ustinov, and you as well [turning to Korolev] must speed things up. Are there any more questions?*[56]

With the clear message that the political leadership was not happy with the rate of progress, Korolev and Nedelin departed together in silence. For Korolev, it was a double disappointment, for he had apparently intended to speak to Stalin about a "space rocket" capable of traveling the upper reaches of the atmosphere, eventually with humans on board. At the last minute, he omitted his notes on the subject, perhaps for fear that Stalin would see no interest in it. Assuming that Nedelin would be more receptive to it, Korolev briefly told him about Tikhonravov's work at NII-4 and about the level of resistance it was facing from the general scientific community.[57]

Nedelin was not too receptive to Korolev's promotion of Tikhonravov's ideas, irritating Korolev and prompting him to argue even more forcefully. In the end, Nedelin effectively ended the conversation with a warning that no doubt did not fall on deaf ears:

> *There's no need to be irritated. . . . The history of all this has been well known to me for a long time. You probably don't know this, but our higher Generals have called for the dismissal of Blagonravov from his post as the President of the Academy of Artillery Sciences. Your name has also not been left out.*[58]

55. Aleksandr Romanov, *Korolev* (Moscow: Molodaya gvardiya, 1996), p. 228. Among those present were Minister of Armaments D. F. Ustinov (who was also the deputy chair of the policy-making Special Committee No. 2), Commander-in-Chief of Artillery Forces Marshal N. N. Voronov, Deputy Minister of Armed Forces and former Commander of the Chief Artillery Directorate Marshal N. D. Yakovlev, and recently appointed Commander of the Chief Artillery Directorate Col. General M. I. Nedelin. Note that while Romanov states that Korolev was present at this meeting, another biographer of the chief designer, Ya. K. Golovanov, does not mention this meeting.

56. *Ibid.*, p. 229.

57. *Ibid.*, p. 230.

58. *Ibid.*, p. 231.

Korolev immediately grew gloomy, and the two eventually parted on an unresolved note. Nedelin's words were not only a warning about Korolev's position as chief designer, but also his life itself. The reign of Beriya's secret police had a few more years left to go, and it was with great care and tact that most of the engineers had to negotiate their activities through the innards of the military defense industry. Such was Beriya's logic that if one was not actively working to increase the defensive might of the Soviet Union, then one must be actively engaged in sabotaging it.

Clearly, Korolev's plans for a satellite launch vehicle were not in the interests of either the military or the Communist Party at this point. The tenuousness of Korolev's own position was demonstrated most acutely by a document authored by NII-4 Director Maj. General Nesterenko sometime in 1950. Although he had supported Tikhonravov's early studies, for reasons still unknown, Nesterenko sent a letter directly to the Central Committee suggesting that the work being carried out by Korolev and his engineers at NII-88 on developing A-4–based missiles was essentially a waste a time and resources. He supported his accusations based on the fact that the Germans, using untold materials, had produced about 1,500 of the A-4 missiles, making absolutely no difference to the ultimate outcome of the war. He added a number of criticisms of the A-4 missile itself, including its poor targeting accuracy. Given Nesterenko's important position, the letter might have had dire consequences, had it not been for Ustinov's efforts to "neutralize" the effects of the document.[59] For Korolev, who somehow found out about the letter, this was unforgivable; it was a grudge he held against Nesterenko to the end of his days.

Whether this event had any influence on Korolev's curiously cool attitude toward NII-4 is unclear, but in 1950, there were some dramatic changes at that institute. The same year, several scholars at NII-4, including Nesterenko, were awarded the USSR State Prize in recognition of their role in developing a system for soft-landing scientific apparatus from a high-altitude missile using parachutes.[60] Korolev was apparently displeased that NII-4 had received such an honor when his own institute had yet to be recognized for *its* achievements. By pulling strings, he was able to significantly reduce such work at NII-4. At the same time, cooperation between the institute and other institutions in the military industry were dramatically curtailed. Several important people lost their jobs in this massive reshuffle. Nesterenko was dismissed from his post as NII-4 director, while the president of the Academy of Artillery Sciences, Academician Blagonravov, was demoted to vice president at about the same time in December 1950.[61] Whether Nedelin's warnings about the military's displeasure over Blagonravov's work or Korolev's own offensive against NII-4 was a bigger factor in these dismissals is unclear. Many of the details of the incident still remain obscure. Given Blagonravov's visibly strong support for Tikhonravov's launch vehicle studies, it would seem completely irrational for Korolev to actively lobby for his removal. It is more likely that the changes at the institute were an unlikely and peculiar combination of Korolev's dislike of Nesterenko and the military's displeasure of Blagonravov.

59. Mozzhorin, *et al.*, eds., *Dorogi v kosmos: I*, p. 113. A. A. Maksimov, who gives this account, recalls that the incident occurred sometime in "1951 or perhaps 1949." Curiously, Nesterenko, in his own account of the same period, does not mention the letter. Instead, he writes, ""Looking back, I would suggest that if I had not offered Mikhail Klavdiyevich [Tikhonravov] a place to work at my institute, and if I had not supported his favorite theme, the launch of the first artificial satellite of the Earth may have been delayed for some years." See Mozzhorin, *et al.*, eds., *Nachalo kosmicheskoy ery*, p. 145.

60. Mozzhorin, *et al.*, eds., *Dorogi v kosmos: II*, p. 91.

61. K. V. Frolov, A. A. Parkhomenko, and M. K. Usokov, *Anatoli Arkadyevich Blagonravov: Outstanding Soviet Scientists* (Moscow: Mir Publishers, 1986), p. 71. Blagonravov was replaced by Commander-in-Chief of Artillery Forces Marshal N. N. Voronov.

Tikhonravov was the third person to feel the brunt of the changes. During "a routine check," the Chief Inspectorate of the Ministry of Defense was surprised to find that NII-4 was involving itself in "wholly non-military affairs in an initiatory fashion." The inspectors recommended that Tikhonravov's group be disbanded.[62] Tikhonravov was demoted from his position as deputy director to that of a scientific consultant, a position one of his associates recalls as being like an "honorary banishment."[63] In the ensuing two years, he and his old staff continued to conduct numerical investigations on different variations of multistage missiles and trajectories of artificial satellites, but the impetus that had driven the group from 1949 to 1950 was lost because of these institutional changes. The early efforts of the group did, however, serve as an extremely important base from which the Soviet Union embarked on the creation of an ICBM capable of reaching orbital velocity.

In a curious departure from the pervasive security regarding high-technology efforts, an article authored by Tikhonravov titled "Flight to the Moon" was published in the newspaper *Pionerskaya pravda* in October 1951.[64] Prominently mentioning the works of Tsiolkovskiy, Tikhonravov adeptly described a two-person interplanetary spaceship of the future and the industrial and technological processes required to create it. He ended the short article, written for young readers, with a clear forecast of the future: "We do not have long to wait. We can assume that the bold dream of [Tsiolkovskiy] will be realized within the next 10 to 15 years. All of you will become witnesses to this, and some of you may even be participants in as yet unprecedented journeys."[65] In perhaps the very first reporting in the West of Soviet space plans, Tikhonravov's article apparently caused quite a stir. It was the subject of a prominent write-up in *The New York Times* two days after the original publication, which explained that:

> *Dr. Tikhonravov left no doubt that Soviet scientific development in the field of jet propulsion and rockets was advancing rapidly. He suggested that this science in the Soviet Union had reached the level at least equaling if not exceeding that in Western countries.*[66]

It was a rare peek into the shrouded world of Soviet rocketry. The fact that Tikhonravov was allowed to write under his own name on a potentially sensitive topic indicates that the censors viewed the article as of no importance or relevance to national security.

Organizational restructuring was not unique to NII-4. Symptomatic of a broader evolution and maturity in the missile industry, Korolev's home institute, NII-88, was also the center of some dramatic changes. Since his appointment as chief designer of long-range ballistic missiles in 1946, Korolev had continually felt a certain sense of powerlessness in the Ministry of Armaments. At Kapustin Yar, as the technical director of the state commissions, his word was law, and deputy ministers, chiefs of directorates, and other chief designers would literally subordinate themselves in the face of his incredibly assertive personality. On his return to Kaliningrad, however, he would come face to face with an overtly complex bureaucracy comprising several layers in the chains-of-command, which gave him very little in terms of legal and

62. Anatoliy Shiryayev and Valeriy Baberdin, "Before the First Leap into Space" (English title), *Krasnaya zvezda*, April 27, 1996, p. 5.

63. Kantemirov, "From the History of Science"; Mozzhorin, *et al.*, eds., *Dorogi v kosmos: II*, p. 94; Kantemirov, "15 July—40 Years From the Report."

64. M. K. Tikhonravov, "Flight to the Moon" (English title), *Pionerskaya pravda*, October 2, 1951, p. 2. An English translation of the article can be found in F. J. Krieger, *A Casebook on Soviet Astronautics* (Santa Monica, CA: RAND, 1956), pp. 45–48.

65. *Ibid.*

66. "Flights to Planets Forecast in Soviet," *The New York Times*, October 4, 1951.

institutional authority. He became another one of several chief designers, often with less ministerial capacity than his other colleagues because he was officially the head of a department *within* a design bureau, while his contemporaries on the Council of Chief Designers all headed their *own* bureaus.

For the most part, Korolev's predicament was a result of the institutional peculiarities of the armaments industry, which had essentially been modeled along the lines of the aviation sector. There was a four-step process in project implementation in the creation of aircraft: the scientific research institutes conducted the basic research on a weapon; the design bureaus carried out the engineering work; departments in the military subjected the particular vehicle through a thorough testing regime; and then the product would be declared operational and be formally handed over to the Air Force. In the case of rockets, Korolev believed that such a chain-of-command was not optimal. On many occasions, he had attempted to convince Minister of Armaments Ustinov on the need for *total* control of the entire process from one centralized entity—that is, his own organization. During one heated conversation, Korolev was particularly explicit:

> *Dmitriy Fedorovich, you and your deputies are trying to make me a designer of just a missile. Not even a missile, but a very large automated cannon shell, to be more precise. Listen, if I work as the aircraft designers do, our whole business would collapse very soon. You need to understand: I have to be Chief Designer of the whole system. . . .*[67]

The disillusionment expressed by both Korolev and his first deputy Mishin was compounded by the fact that the primary thematic direction at the institute was represented by Korolev's department, although its powers were officially limited to the level of that of the several other minor departments at NII-88's Specialized Design Bureau. The bureau's Department No. 3 had clearly outgrown its original mandate by 1950.

The first major change at the institute was precipitated by the departure in the autumn of 1949 of NII-88 Chief Engineer Yuriy A. Pobedonostsev. Ending his extremely fruitful participation in the formation of the postwar ballistic missile programs, in May 1950, he was appointed the rector at the Academy of Armaments Industry.[68] It was the effective end of a twenty-year career, during which he had played major roles in GIRD, in NII-3, on the recovery teams in Germany, and finally in NII-88. In later years, he participated in the development of early Soviet solid-propellant ICBMs at NII-125. He was a professor at the Moscow Aviation Institute at the time of his death in 1973 at the age of 66. Following Pobedonostsev's resignation, in 1950, at the behest of Korolev, Minister Ustinov agreed to hold a meeting to discuss a complete restructuring of the institute. Attended by Korolev, Ustinov, institute Director Gonor, Chief Engineer Tritko (who had temporarily replaced Pobedonostsev), and his Deputy Chertok, the session was held at an all-night restaurant in Moscow, during which the men hammered out the details of the changes. Ustinov agreed to merge several sectors at NII-88 that were dedicated to anti-aircraft missiles, partly because of their poor performance in the postwar years. At the same time, on April 26, 1950, a number of other departments at the institute were consolidated to create the new Special Design Bureau No. 1 (more commonly known as OKB-1) of NII-88.

67. Golovanov, *Korolev*, pp. 376–77.

68. Valeriy Zharkov, "Pobedonostsev's Criteria" (English title), in V. Shcherbakov, *Zagadki zvezdnykh ostrovov* (Moscow: Molodaya gvardiya, 1989), p. 95; Chertok, *Rakety i lyudi*, p. 344.

Korolev was formally named the chief and chief designer of OKB-1, an organization dedicated exclusively to the development of long-range ballistic missiles.[69] Ustinov formally named the thirty-three-year-old Mishin as Korolev's first deputy chief designer, who then was already famous for being a "generator of ideas." Vasiliy S. Budnik, a thirty-seven-year-old engineer who was responsible for the missile production programs, was appointed the sole deputy chief designer.[70]

Ustinov enacted further changes in the overall leadership of the institute. Maj. General Lev R. Gonor, who had served as director of NII-88 since its inception in 1946, was relieved of his duties in June 1950.[71] A very opinionated and assertive individual, Gonor had continually clashed with both Korolev and Mishin in the previous years over a variety of technical and thematic issues. There is no doubt that Korolev, with his unpredictable temper and aggressive nature, was responsible for most of these conflicts. Unable to accept subordination to a number of officials such as Tritko, Gonor, Vetoshkin, Ryabikov, and Ustinov, the chief designer was prone to be resistant to any efforts originating from Gonor. The artillery general also had the misfortune of being one of the very few high-ranking Jewish individuals in the rocketry industry. Although there is no evidence to suggest that anti-Semitism played any role in his dismissal, there was clearly a certain degree of prejudice with which he had to deal as director. Without Ustinov's strong support for his candidacy in 1946, Gonor probably would not have been appointed director of such an important institution. Leaving NII-88, Gonor moved to head an artillery plant in Krasnoyarsk. In January 1953, he and many others were arrested during the so-called "Doctors' Plot" and thrown into prison. Other missile men among the incarcerated were several officers from the Chief Artillery Directorate, including its former head Marshal Yakovlev, who had been instrumental in restoring A-4 production in the Soviet Union. Fortunately for those affected, Stalin died only two months later, and Gonor, Yakovlev, and the others were released. Formally rehabilitated, Gonor went on to become the chief of a branch at the Central Institute of Aviation Motor Building at Turayevo, near Moscow. He led a very successful career in the aviation industry, which was unexpectedly cut short by the development of gangrene in one of his limbs. He died on November 13, 1969, at the age of sixty-three.[72]

Gonor's replacement at the NII-88 arrived in his office on August 18, 1950, in the person of Konstantin N. Rudnev, a thirty-nine-year-old graduate of the Tula Mechanics Institute. During the war, the soft-spoken Rudnev had served as director of a famous munitions plant. He was received by some apprehension by the engineers at NII-88, but Rudnev's intelligence and modesty apparently soon won over most of the institute's employees. Much less stubborn than Gonor, Rudnev developed a good working relationship with Korolev, Mishin, and others, helped no doubt by his inexhaustible sense of humor. At the time of Rudnev's appointment, there were rumors abounding in the Ministry of Armaments that Korolev would not only head the new OKB-1 but also be named the chief engineer of the *entire* institute. Fearful about allowing Korolev too much power at NII-88, Minister Ustinov instead invited NII-885 Chief Designer

69. Biryukov, "Materials in the Biographical Chronicles," p. 230. Another bureau, OKB-2, was also established to consolidate all work on anti-aircraft missiles. It was originally headed by Chief Designer Ye. V. Sinilshchikov and later by K. I. Tritko. OKB-2, in its original form, was dissolved shortly after, on August 27, 1951, when all anti-aircraft missile development was transferred from the armaments industry to the aviation industry.

70. Golovanov, *Korolev*, p. 436. Mishin and Budnik's appointment order was signed on June 16, 1950.

71. Chertok, *Rakety i lyudi*, p. 47.

72. *Ibid.*, pp. 245–46; Mikhail Rebrov, "Return to the Loss of God, or the History of a Man About Whom We Know Almost Nothing About" (English title), *Krasnaya zvezda*, June 21, 1997, p. 6.

Mikhail S. Ryazanskiy to give up his engineering job developing radio-controlled guidance systems to serve as chief engineer of NII-88. It was a peculiar situation because originally Ryazanskiy had been one of Korolev's associates on the Council of Chief Designers. After his formal appointment in January 1951, he effectively served as Korolev's superior as the chief engineer and first deputy director of the institute.[73]

Dogs in Space

It was Korolev himself who served as the chief driving force behind formulating a dedicated plan to loft animals on short vertical flights into the upper atmosphere—a program that directly cleared the way to launch the first human being into orbit. As early as 1948, he began to informally consider ways of lifting human passengers into space using available technology. Inspired by U.S. programs using A-4 and Aerobee missiles for launching animals into space, Korolev mentioned his plans for human spaceflight to famous aviation designer Andrey N. Tupolev during a conversation in late 1948.[74] In response, Tupolev gave Korolev the name of Vladimir A. Yazdovskiy, a young physician employed at the Air Force's Institute of Aviation Medicine in Moscow.

The thirty-five-year-old Lt. Colonel Yazdovskiy had graduated from the Tashkent Medical Institute before spending the war as an Army physician. Moving to aviation medicine after 1945, he evidently made quite a name for himself as a bright and resourceful researcher. In January 1949, Korolev telephoned Yazdovskiy, introducing himself as a builder of "special equipment" (it was illegal to make references to military weapons such as missiles over the phone), and arranged a meeting at the

Sergey Korolev in July 1954 is with a dog that just returned to Earth after a lob to an altitude of 100 kilometers on an R-1D scientific rocket. In 1951, the Soviet Union became the first country to safely recover a living organism after a flight in space. (files of Asif Siddiqi)

73. Golovanov, *Korolev*, p. 565; Chertok, *Rakety i lyudi*, p. 349. The option of transferring M. S. Ryazanskiy from NII-885 was partly the result of a minor conflict with Chief Designer B. N. Konoplev. Both had independent engineering teams focusing on developing radio-controlled guidance systems at the institute. Konoplev had been transferred to NII-885 from NII-20 in April 1950 as a full chief designer in recognition of his role in developing the advanced systems for the new R-3 missile. Konoplev eventually took over Ryazanskiy's vacant post on the Council of Chief Designers.

74. Mozzhorin, *et al.*, eds., *Dorogi v kosmos: II*, pp. 119–20. The first U.S. program for launching animals into space used A-4 missiles. Between June 11, 1948, and August 31, 1950, five A-4s (three of them stretched) were launched from White Sands in New Mexico as part of the Albert and Blossom Albert programs. All except one carried monkeys. Despite reaching a highest altitude of 136.5 kilometers on the last launch, none of the animals were recovered alive. A second program involved Aerobee RTV A-1 missiles; three were launched between April 18, 1951, and May 21, 1952. The second flight on September 20, 1951, with a monkey and eleven mice was the first U.S. mission involving the successful recovery of animals after a high-altitude flight (just over seventy kilometers).

Petrovsko-Razumovskiy Park near the Institute of Aviation Medicine. Korolev was direct with the young physician, informing him that:

> *Andrey Nikolayevich [Tupolev] suggested I contact you about leading a biomedical program in preparation for future flights of spaceships. I would like you to lead this effort, since I don't know what's being done in this area nowadays and what has already been done. . . .*[75]

Yazdovskiy was resistant at first, but Korolev would not take no for an answer: "Oh, come on now Volodya. . . . What's in it for you in all that aviation medicine business? What I'm offering you is far more challenging." Hearing that Yazdovskiy had never seen a launch of a rocket, Korolev replied, "Well, then, if you've seen it once, it'll stay with you for the rest of your life."[76] Within a few days, Korolev personally arranged with the USSR Minister of Defense Aleksandr M. Vasiliyevskiy to have Yazdovskiy's current work transferred to others, and the physician was given a mandate to begin dedicated biomedical studies in preparation for putting a human into space at an unspecified time in the future. The short-term goals were to use small animals as test beds for gathering medical data on the effects of rocket flight on living organisms.

The director of the Institute of Aviation Medicine, Maj. General Aleksey V. Pokrovskiy, initially assigned a small group of physicians to work under Yazdovskiy, including Boris G. Buylov, Vitaliy I. Popov, and Aleksandr D. Seryapin. At the time, the literature in the Soviet Union on space medicine was almost nonexistent. Thus, the group began its efforts by studying translations of American texts on the subject in detail and identifying the major areas of focus. In designing a payload module for a small animal to fly aboard a modified R-1 missile, Yazdovskiy narrowed down three factors that would play important roles: the environment of vacuum, radiation, extreme temperatures, and meteorites in near-Earth space; the presence of parameters such as vibration, noise, and weightlessness during dynamic flight; and issues associated with the confinement of organisms in a very small space.[77]

In studying these factors, the group also addressed the question of what type of animal to use on the launches. The candidates most appropriate for medical use were initially narrowed down to apes and dogs, but by late 1950, the group began to lean more toward the use of the latter. Apes were considered to be more difficult to dress and were more likely to get colds and other diseases. Furthermore, because they were more excitable than dogs, the doctors believed that they might, for example, bite off important sensors from their bodies. The decision to use dogs was formally approved at a meeting of important scientists and physicians at a special session organized by the Academy of Medical Sciences and the Academy of Sciences in December 1950.[78] Academician Blagonravov, who had just been relieved of his post as president of the Academy of Artillery Sciences, was nominated and appointed chair of a state commission to oversee the actual biological launches. Several famous Soviet biomedicine specialists, such as Vladimir N. Chernigovskiy, Vasiliy V. Parin, and Norair M. Sisakyan, were also inducted as advisors to the commission, emphasizing the importance with which the scientific community viewed the program.

The selection of dogs as test subjects commenced a search to establish criteria for particular types of dogs. Starting with the rationale that the choice had to be satisfactory to both the rocketeers and the biologists, Yazdovskiy's group had to negotiate a number of major obstacles. At the outset, the doctors agreed that at least two dogs would have to be launched in a

75. *Ibid.*, p. 120.
76. *Ibid.*
77. *Ibid.*, pp. 122–24.
78. Golovanov, *Korolev*, pp. 545–46; Stache, *Soviet Rockets*, p. 212.

common container on each flight because the reaction of one animal would not provide objective results, given the conditions on a particular launch and the peculiarities of the dog. With the constraint of only 0.28 cubic meters of volume, the dogs had to be relatively small and light, somewhere between six and seven kilograms. Experts in dog behavior were consulted, and they reported that small dogs were not compatible with each other, further narrowing the field. The subjects also had to have a high level of resistance and be easily trainable. In addition, the dogs had to have a white or brightly colored coat because the plan was to film the behavior of the animals during flight using a system of mirrors in the poor lighting conditions inside the capsule. Finally, only female dogs were considered because the special anti-gravity suit and sanitation equipment would pose complex problems in the case of males. The requirements were so stringent that at one point one of the "dog catchers" in exasperation told one of the physicians, "Perhaps you'd like them to also have blue eyes and howl in C major?"[79]

Such aspects as the posture of the dogs in flight were carefully planned out prior to launch. Yazdovskiy's team used pairs of dogs in a special centrifuge with self-contained life support systems to ascertain that a vertical posture would probably kill the animals because of the high rates of acceleration in the initial stages of flight. Equipment for monitoring the physiological behavior of the dogs was culled from a variety of sources, including a local military college and the Krasnogorsk Mechanical Optical Plant, which manufactured a camera capable of holding 120 to 300 meters of film.[80]

At Korolev's department at NII-88, the design of modified R-1 missiles and a special container to carry the small animals had formally began on December 30, 1949, as part of a coordinated project to develop different variants of the rocket for scientific purposes. The chief of the planning sector at Korolev's section, Konstantin D. Bushuyev, was appointed to lead the team that would design two new modifications of the R-1, designated the R-1B and R-1V. The design of both the rockets and the payload evolved over 1950 and 1951, with significant interaction between Yazdovskiy's group at the Institute of Aviation Medicine. Both visually and technically, the new missiles were markedly different from their predecessor, the R-1A missile. They incorporated many of the mechanisms developed for the R-2 ballistic missile and had a much more sleek appearance than the R-1A. Each missile was 17.55 meters in length with a base diameter of 2.56 meters, dimensions significantly exceeding the R-1A. Total liftoff mass was about 14.32 tons.[81] The total mass of the experimental payload of the vehicle was set at 1,160 kilograms, of which 590 kilograms was the actual container carrying the dogs.

Engineers under Bushuyev spent a significant amount of work designing a container that could be safely recovered. They modified the original nose cone separation mechanism from the R-1A and raised the reliability of the parachute system during preflight tests. Auxiliary air brakes were introduced to decrease the rate of descent prior to the opening of the parachute, primarily to reduce deployment shock. The new rockets also incorporated improved telemetry systems because the most important aspect of the mission would be the data recorded during the flight. This in turn necessitated a more accurate orientation and stabilization system. The end result of the R-1B/R-1V design program in 1951 was the development of a standard nose cone payload section that could be used in a variety of configurations for different requirements.[82] In addition to the main payload container, the R-1B carried two eighty-five-kilogram

79. Stache, *Soviet Rockets*, pp. 212–13. Evgeny Riabchikov, *Russians in Space* (Garden City, NY: Doubleday, 1971), p. 140.

80. Mozzhorin, *et al.*, eds., *Dorogi v kosmos: II*, pp. 126–27.

81. Keldysh, ed., *Tvorcheskoye naslediye akademika Sergeya Pavlovicha Koroleva*, p. 536; Biryukov, "Materials in the Biographical Chronicles," p. 229.

82. Stache, *Soviet Rockets*, p. 213.

scientific modules that were attached longitudinally to the sides of the main body of the missile. These were designed by the Geophysical Institute of the USSR Academy of Sciences, and they contained a number of instruments for studying the upper atmosphere. The R-1V, identical in all other respects, carried a large parachute system in place of the science modules to enable engineers to recover the 4,160-kilogram main body of the rocket.

In mid-summer of 1951, the state commission, headed by Blagonravov, Yazdovskiy, and other representatives from the Institute of Aviation Medicine, and engineers from OKB-1, led by Korolev, converged at Kapustin Yar for the first Soviet attempt at launching a living organism into space. A total of nine dogs were selected to form the core pool, including Albina (Russian for White), Bobik, Dezik, Kozyavka (Gnat), Lisa, Malyshka (Little One), Smelaya (Bold), and Tsygan (Gypsy).[83] Yazdovskiy chose Dezik and Tsygan for the first flight, set for July 22, 1951. The launch, using an R-1V, was held during the early morning hours so the rocket would be illuminated by the Sun during the ascent portion. Preparations for the launch were conducted in a mood of unconcealed excitement and anxiety, and following Blagonravov's formal approval, the rocket finally lifted off in a roar amid the dust of Kapustin Yar, carrying its two canine passengers. During their flight, the animals reached a velocity of 4,200 kilometers per hour and an altitude of 101 kilometers, and they experienced four minutes of weightlessness. Approximately 188 seconds following launch, the payload section separated from the main booster and went into freefall until it dropped to an altitude of six kilometers, at which time the parachute successfully deployed. Yazdovskiy had personally asked all the members of the state commission to remain at their viewing positions until the dogs had landed, but about twenty minutes following launch, a white parachute was visible in the sky, and everyone at the launch site rushed to their cars, driving off into the desert in a cloud of sand. At the landing site, the cabin hatch was hurriedly unscrewed, and both dogs were found barking and wagging their tails. Although Dezik was in perfect condition, Tsygan had apparently sustained a minor injury on her belly when the inner compartment had curved in upon impact.[84] The dogs were the first living organisms successfully recovered after a flight into space, coming two months before the United States achieved a similar feat.

This first historical launch was followed by an unevenly successful program. The second of six total missiles, this one an R-1B, carried Dezik on her second flight with a new dog, Lisa, on July 29. Unfortunately, the pressure sensor used to trigger the parachute system had been damaged by vibration, and both dogs were killed upon impact on the steppes of Kapustin Yar. The on-board data recorders were, however, successfully salvaged.[85] Korolev himself was apparently greatly grieved by the loss. The third launch almost did not go off. One of the dogs chosen for the flight, Smelaya, unexpectedly ran loose the day before launch, causing great consternation among the specialists that she had met her fate at the jaws of jackals, which were known to roam the area. Fortunately, the next morning, Smelaya returned to the launch site, quite safe, and the launch went off on time. Both dogs survived and were recovered successfully. One of the dogs slated to fly on the sixth and final flight once again disappeared during a walk prior to launch. Yazdovskiy ordered Seryapin to search for a replacement, and the latter went to the local canteen and picked up one of the dogs that were known to frequent the place, making sure that she was suitable in size and temperament. With no previous documentation, Korolev opted to give her the name ZIB, the Russian acronym for "Substitute for Missing Dog Bobik." With minimal training, she and another dog were successfully launched on September 3 on a completely successful mission, reaching an altitude of 100 kilometers and

83. Riabchikov, *Russians in Space*, p. 141.

84. Frolov, Parkhomenko, and Usokov, *Anatoli Arkadyevich Blagonravov*, pp. 144–45; Mozzhorin, *et al.*, eds., *Dorogi v kosmos: II*, p. 127.

85. Golovanov, *Korolev*, p. 547.

finishing the program.[86] In total, nine dogs were flown on six launches, three of them flying twice.

Despite four dog fatalities, the results of the R-1B/R-1V launch program were encouraging.[87] Data gathered on a four-channel recorder included information on fluctuations of skin temperature and pulse and on cabin pressure and temperature. Film from the movie camera proved extremely useful in observing the behavior of the dogs in flight. In addition, before and after the missions, physicians obtained an electrocardiogram, an x-ray of the thorax, conditional food reflexes, and data on body mass. The flights also introduced the first fully functioning life support system for organisms in Soviet rocketry, consisting of a seven-liter globe filled with a mixture of 70 percent air and 30 percent oxygen. A soda lime cartridge was used to absorb exhaled carbon dioxide, and a silica gel cartridge was used as a desiccant. Among nonbiomedical experiments, the launch of August 15 was the first time that Soviet instruments were used to study the spectral composition of solar shortwave radiation from an altitude of 100 kilometers.[88] For Blagonravov, the launches had one important result. After the second launch, when Dezik and Lisa had been killed, Blagonravov had decided that Tsygan, who had been Dezik's partner on the first flight, should not fly again. Instead, in early September, he took the lone dog back to Moscow and adopted her as his own. Tsygan lived to a great old age, and Blagonravov and the dog would often be seen walking the streets of Moscow, both clearly very much attached to each other.[89]

The vertical dog flights of 1951 opened up the era of space biomedicine for the Soviet Union. At the same time, there was also a significant expansion of the use of ballistic missiles for the study of the upper atmosphere. Under Academician Blagonravov's chairmanship, the Commission for the Investigation of the Upper Atmosphere submitted a formal report in 1951 describing a full-scale program for high-altitude scientific research. Using available R-1–based missiles as a limiting factor, an eight-point program was put forth that encompassed the following:

- Investigations on the chemical composition of air at high altitudes
- The determination of wind velocity
- The development of methods for determining ionization density
- Investigations into the composition of primary cosmic radiation and its interaction with matter
- Spectral measurements of solar radiation
- Research on aerodynamics, boundary layer structures, and surface resistance
- Research on life functions of animals at high altitudes
- The development of integrated recovery systems[90]

86. Mozzhorin, *et al.*, eds., *Dorogi v kosmos: II*, p. 128. The launch dates and results were as follows:

Rocket	Date	Rescue of Payload	Rescue of FIAR-1	Rescue of Dogs
R-1V	July 22, 1951	yes	yes	yes
R-1B	July 29, 1951	no	no	no
R-1B	August 15, 1951	yes	yes	yes
R-1V	August 19, 1951	yes	no	yes
R-1B	August 28, 1951	no	yes	no
R-1B	September 3, 1951	yes	yes	yes

See B. V. Raushenbakh, ed., *S. P. Korolev i ego delo: svet i teni v istorii kosmonavtiki: izbrannyye trudy i dokumenty* (Moscow: Nauka, 1998), p. 547.

87. Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p. 35.

88. George Wukelic, ed., *Handbook of Soviet Space-Science Research* (New York: Gordon and Breach Science Publishers, 1968), pp. 16–17, 19–20; G. S. Ivanov-Kholodnyy and L. A. Vedeshin, "First Rocket Experiments for Research on Solar Short-wave Radiation," in Frederick I. Ordway III, ed., *History of Rocketry and Astronautics, Vol. 9* (San Diego: American Astronautical Society, 1989), p. 191.

89. Golovanov, *Korolev*, p. 547; Stache, *Soviet Rockets*, p. 216.

90. Stache, *Soviet Rockets*, p. 211.

Visits to the Kapustin Yar range were frequent for engineers at OKB-1. Although the launches of the R-1B and the R-1V were no doubt important for the scientific community, of much greater significance was the testing in support of the military ballistic missile program. An intensive effort had been expended in late 1950 during the first series of launches of the new R-2 missile. A second series, again directed by Korolev, was carried out between July 2 and 27, 1951, at the same time that dogs were being lofted into space from the same site.[91] Of the total of thirteen launches in the series, a remarkable twelve successfully reached their targets, finally allowing engineers to put the results of the dismal first series behind them. The Soviet armed forces formally adopted the R-2 missile as operational armament by an order dated November 27, 1951—a decision that emphasized the overriding needs of the military to operate a battle-ready long-range ballistic missile system.[92] The R-2 was, in fact, a vast improvement over the R-1—in particular, in areas such as ease of training and operation and the capabilities of its guidance system. With a range of 600 kilometers, it could reach twice as far as its predecessor, although it was still incapable of carrying the heavy nuclear weapons in existence at the time.

With the adoption of both the R-1 and the R-2 missiles in the armed forces, the overseeing Special Committee No. 2 addressed the need for establishing a new production facility for manufacturing the vehicles in quantity. After much discussion, the committee decided on May 9, 1951, to transfer a large factory in the Ukraine, the Dnepropetrovsk Automobile Plant, to the jurisdiction of the Ministry of Armaments. Since July 1944, the plant had been manufacturing automobiles, tractors, and other heavy machinery—at first in support of the war effort, but later for civilian purposes. After its transfer, the facility was formally named the State Union Plant No. 586 in 1952. In the interest of coordinating all manufacturing work with OKB-1, Korolev transferred one of his leading assistants, Deputy Chief Designer Budnik, to the newly reorganized plant on July 6, 1951. Budnik, the very first of many of Korolev's protégés to become chief designers in their own right, was instrumental in leading all the engineering aspects of manufacturing the R-1 and R-2 missiles.[93] Within twenty years, the plant at Dnepropetrovsk was to become the largest missile and space launch vehicle manufacturing facility in the entire world.

Themes

The R-3 project, begun in 1949, served as the starting point for preliminary studies into possible configurations for the first Soviet ICBM. As Korolev emphasized in his draft plan for the R-3, the 3,000-kilometer-range missile was seen as a stepping stone to more ambitious rockets. Concurrent with the early work on the R-3 during 1949–50, engineers at NII-88 were, in fact, engaged in formulating a long-range strategic plan for the institute—one that would dictate the general nature of work on Soviet long-range missiles for some time to come. By the end of 1950, this plan encompassed three specific areas of focus or "themes," as Soviet engineers called them:

- Theme N1 called for the design of a new one-stage missile with a range of 3,000 kilometers.
- Theme N2 called for the creation of a missile using storable propellant components.
- Theme N3 focused on exploratory research in developing a Soviet ICBM.

91. Biryukov, "Materials in the Biographical Chronicles," pp. 230–31.

92. Sergeyev, ed., *Khronika osnovnykh sobytiy*, p. 34. A final series of fourteen R-2 missiles was launched between August 8 and September 18, 1952, of which only two failed to reach their targets. By this time, the vehicle had a success rating of 86 percent.

93. V. Pappo-Korystin, V. Platonov, and V. Pashchenko, *Dneprovskiy raketno-kosmicheskiy tsentr* (Dnepropetrovsk: PO YuMZ/KBYu, 1994), pp. 52–53. Production for the R-1 and R-2 missiles was transferred to the plant by personal order of Minister of Armaments D. F. Ustinov on June 1 and November 30, 1951, respectively.

The USSR Council of Ministers formally approved this new research program under the title "Complex Research and Determination of the Basic Flight-Tactical Characteristics of [Long-Range Ballistic Missiles]" by an official governmental decree dated December 4, 1950.[94] Chief Designer Korolev was the overall scientific leader.

The N1 theme subsumed the already concurrent work on the ambitious R-3 missile, which was specifically geared toward two design innovations: the use of integral tanks for both propellants and the elimination of graphite rudders for guidance. Both of these were to be tested on the experimental R-3A missile. By 1951, NII-88 had prepared "The Plan for the R-3A Experimental Missile With an Improved Range of Flight," the final technical document containing the workshop drawings for manufacturing the rocket. The flight testing of the missile was set to begin from Kapustin Yar in October 1951.[95] The schedule for the R-3 program, however, proved to be overly optimistic. Given the technological leap required for the R-3 program, it is not surprising that Soviet engineers ran headlong into some seemingly insurmountable problems, bringing the effort to an impasse within two years of the start of the project. One official historian of NII-88 recalled later that:

> *. . . serious stumbling blocks prevented the [R-3] engines from being developed in time—when it became clear that these problems would lead to enormously delaying the production of the R-3 missile, Korolev was blamed for an unrealistic objective statement. Critics said that a range of 1,000 km ought to have been assigned, and the rocket model should have been [progressively] evolved as it had been with the R-2 rocket, which had been advanced to a preset standard through a certain number of modifications.*[96]

For his part, Korolev, put the blame squarely on Glushko's shoulders, believing, with some validity, that Glushko had erred seriously by trying to scale up the old German A-4 engine to create the RD-110 engine for the R-3.

Glushko's primary problem seems to have been due to the use of the new liquid oxygen (LOX) and kerosene combination. The new pairing, while being more efficient than the LOX-alcohol duo, resulted in a higher combustion chamber pressure, which meant that the walls of the chamber had to be thicker. This in turn would make the engine heavier. More damaging for the RD-110 were the problems in cooling the engine, the requirements for which were much more stringent than for the German A-4 engine. Cooling required thin combustion chamber walls, which would not stand up to the higher internal pressures. Put in a difficult position, Glushko had to resort to adopting an idea from another noted engine designer, Chief Designer Aleksey M. Isayev, who during his stint at NII-1 in the mid-1940s had performed some groundbreaking research on high-thrust liquid propellant rocket engines. Isayev's idea, derived from work at the Gas Dynamics Laboratory and by the German scientist Sänger in the 1930s, was to use a so-called "integrated solder-welded" design, which had thin "ribs" around each combustion chamber to allow coolant to pass around the chamber. Such a design circumvented major cumulative problems of operations at high pressures, temperatures, and heat fluxes, while generating the required high specific impulses.[97]

94. Avduyevskiy and Eneyev, eds., *M. V. Keldysh*, p. 139; Ishlinskiy, ed., *Akademik S. P. Korolev*, p. 302; Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p. 630. The title of the overall program is given in Keldysh, ed., *Tvorcheskoye naslediye akademika Sergeya Pavlovicha Koroleva*, p. 319. An alternate title, "The Prospects of the Development of Long-Range Missiles," is given on p. 328 of the same text. For general descriptions of the three themes, see Mozzhorin, *et al.*, eds., *Nachalo kosmicheskoy ery*, pp. 71, 261; Mozzhorin, *et al.*, eds., *Dorogi v kosmos: I*, pp. 107–08.

95. Biriukov, "The R-3 Rocket Project Developed in the U.S.S.R."; Biryukov, "Materials in the Biographical Chronicles," pp. 230–31; Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p. 40.

96. Biriukov, "The R-3 Rocket Project Developed in the U.S.S.R.," p. 197.

97. V. I. Prishchepa, "History of Development of First Space Rocket Engines in the USSR," in Ordway, ed., *History of Rocketry and Astronautics*, pp. 95–98.

Glushko had evidently begun work on such a design by the late 1940s. In mid-1947, he tested a technology demonstrator with a thrust of seven tons and an initial gas pressure of sixty kilograms per square centimeter. A second experimental chamber, designated the KS-50, had a thrust of fifty kilograms. Used for testing with various propellant combinations, it was fired successfully for the first time on April 26 of the same year.[98] While the new design was a positive step in Soviet rocket engine development, the goal of designing a single chamber LOX-kerosene engine with a ground thrust of 120 tons eventually proved to be "problematical" for Glushko's design bureau. Vibration-related explosions during testing continually delayed RD-110 development, and there were reasons to believe that the overall project might be delayed by as much as two years. By 1951, a full four years after work on the RD-110 had begun, Glushko had successfully carried out only hydraulic testing of its huge combustion chamber, the turbopump, the gas generator, and some subsystems. There had still been no integrated ground tests. By the end of the year, Glushko had temporarily suspended the continuing development of the RD-110. Work on the D-2 competitor engine (by Chief Designer Polyarniy at NII-1) "was also unsuccessful, due to excessive innovations introduced into the project."[99]

The problems with the engines for the R-3 forced Korolev to completely reassess his priorities. Having promised the Soviet armed forces a 3,000-kilometer missile, he was unable to provide anything more than the modest 600-kilometer-range R-2 rocket. In a typically shrewd move, in the spring of 1951, Korolev turned his attention to the experimental 900-kilometer-range R-3A missile, which was close to flight testing. Using the latter as a prototype, would it not be possible to marginally augment its systems and create a "new" missile with a range of about 1,200 kilometers? He set his engineers to work on the problem, and within months, by October 30, 1951, they completed the draft plan for the new missile, designated the R-5. It would heretofore be known as the "first Soviet strategic rocket."[100] Given that, unlike the R-3, this strategic missile was the result of incremental improvements in already existing Soviet rockets, Korolev and the military seemed to have had much more confidence in the new program than they did in the far too ambitious R-3. Because the development of the R-5 was performed as part of the original N1 theme, there was no formal approval of the program from the Soviet government. An official USSR Council of Ministers decree on February 13, 1953, for the first time mentioned the rocket in a document that specified timetables for its testing.[101]

The R-5 missile incorporated many of the design characteristics originally earmarked for the R-3 and, as such, served as a harbinger of many new innovations in the evolution of Soviet rocket design. For example, engineers developed a new set of reinforced servo components and speedier operating servomotors for the small aerodynamic rudders to compensate for the reduction in the size of the main stabilizing fins. The guidance system for the missile, developed at NII-885 under Chief Designer Pilyugin, used longitudinal acceleration integrators, which allowed improved precision to time engine cutoff, thus improving targeting accuracy. A team at NII-88 developed special thermal shielding for the warhead, which was expected to reenter the

98. V. A. Volodin, "2 September—80 Years Since the Birth of Academician V. P. Glushko (1908)" (English title), *Iz istorii aviatsii i kosmonavtiki* 59 (1989): 82–92. For a discussion of the KS-50 and the RD-110, although neither are named, see V. I. Prishchepa, "From the History of the Creation of the First Space Engines (1947–1957)" (English title), in B. V. Raushenbakh, ed., *Issledovaniya po istorii i teorii razvitiya aviatsionnoy i raketno-kosmicheskoy nauki i tekhniki* (Moscow: Nauka, 1981), pp. 128–29.

99. Biriukov, "The R-3 Rocket Project Developed in the U.S.S.R.," p. 198; Prishchepa, "From the History of the Creation," pp. 123, 129. For the D-2, see also V. Davydov, "The Contribution of N. G. Chernyshev in the Development of Rocket-Space Technology" (English title), *Novosti kosmonavtiki* 19 (September 9–22, 1996): 58–61.

100. Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, pp. 40, 46, 630; Biryukov and Yeremenko, "50 Years for the Native Rocket-Space Industry."

101. Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p. 46. The testing would be performed in three stages—the first two being experimental stages and the last being a targeting series.

upper layers of the atmosphere at a velocity of 3,000 meters per second, far in excess of anything previously built. Because both of the propellant tanks were integral components of the missile frame, the rocket had a markedly different appearance from the predecessor R-1 and R-2 vehicles. There was a one-ton reduction in design mass compared to the R-2, with a concurrent increase of 60 percent in the propellant mass. The propellant-to-mass ratio was thus increased from 4.2 to 6.6 in the new missile. The propulsion unit for the R-5 was the new RD-103 engine, a modified variant of the RD-101 used on the R-2. Developed by OKB-456 under Glushko, the new single-chamber engine had a vacuum thrust of fifty-one tons, a 60-percent increase over the earlier model. The performance parameters were at the upper limits then possible by the Soviets using LOX and alcohol. Unlike both the R-1 and R-2 vehicles, the R-5 had a sleek completely cylindrical frame and a high aspect ratio of 12.5 (as compared with 10.7 for the R-2).[102] All of these factors aided in significant improvements in the range of the missile, despite a generally similar overall size. The most advanced Soviet missile in existence at the time, the R-5 was 20.74 meters in length and 1.66 meters in base diameter. Total liftoff mass was 28.57 tons. The initial requirements specified that the missile be able to carry a one-ton explosive a distance of 1,200 kilometers.

In preparation for the first launch of the R-5 missile, Korolev flew out from Moscow on March 5, 1953. Arriving at Kapustin Yar, he was told that after almost thirty years of ruthless rule over the Soviet Union, Stalin had finally passed away in the Kremlin. It was a crushing blow for millions of Soviet citizens whose personal feelings on the Soviet leader withstood the test of the devastating Purges, the innumerable labor camps, and the breakdown of civil society. Still unaware of Stalin's personal role in the secret police's reign of terror, or perhaps unwilling to believe in it, the ensuing days were spent in shock at the uncertain prospects for the future of the Soviet Union. As a man wholly of his times, Korolev was one of those who mourned deeply over the death. In a series of letters to his wife in early March from the launch site, he wrote not only about his own personal loss, but also of the collective blow to the future of the Soviet nation.[103] As the future of the ballistic missile program was threatened by uncertainty, engineers from the various design bureaus and institutes continued to prepare for the first R-5 launch.

The first launch was initially planned for March 13, but weather reports for that day described the threat of heavy cloud cover, prompting the commander of Kapustin Yar, Maj. General Voznyuk, to postpone the launch. As on other occasions, the weather reports eventually turned out to be wrong, and Korolev directed the launch attempt on Sunday, March 15, ten days after Stalin's death. The rocket never reached its target, and the flight was deemed a failure. By this time, Korolev had caught a bad cold, culminating in a severe fever, which raised the question of postponing further launches. Korolev managed to endure through to a second launch attempt on March 18, which also failed, but by then he was in dire need of professional medical treatment. He was put on the next train back for Moscow and was visited there by Minister of Armaments Ustinov, who found him haggard and sickly looking. Spiritually, he had also been dealt a personal loss from Stalin's death. Eventually, his health returned to normal, and Korolev immediately returned to Kapustin Yar in time for the third launch attempt on April 2. For the first time, the missile successfully flew a nominal flight, thus signaling the introduction of a new generation of ballistic missiles in the Soviet arsenal. Despite minor failures, the first series of R-5 launches eventually ended formally on May 23, 1953, with the eighth

102. Stache, *Soviet Rockets*, pp. 180–82. The ballistic coefficient, the ratio of the mass of the rocket to the cross-sectional surface area of the rocket in the direction of flight, was also increased to 13,240 kilograms per square meter (as compared to 9,500 kilograms per square meter for the R-2).

103. Golovanov, *Korolev*, p. 422; Mariya Pastukhova, "Brighter Than Any Legend" (English title), *Ogonek* 49 (December 1987): 18–23.

launch. A second series of seven launches occurred between October 30 and December 9, 1953, also from Kapustin Yar. Of a total of fifteen missiles launched during the two series, only two vehicles failed to reach their final targets—an unprecedented level of success and a tribute to the rapidly accumulating engineering prowess of Soviet rocketry engineers.[104] By the end of 1953, a final test series, to debug modifications enacted as a result of the first launches, was set for the middle of 1954.

The N1 theme initially encompassed the R-3, then the R-3A, and finally the R-5. The N2 theme, carried out during the very same period at OKB-1, resulted in a new and revolutionary area of research for the Soviet rocketry industry: the use of storable propellants. By the late 1940s, armed forces officials were expressing concern over the limitations in using missiles propelled by cryogenic or supercooled propellants. Because LOX had to be maintained at extremely cold temperatures, if rockets such as the R-1 or R-2 were left on the launch pad for long periods, then propellant would begin to boil off. This made handling the missiles an extremely cumbersome and lengthy affair, as troops spent an inordinately long time in maintaining the missiles. To circumvent the problem, Korolev initiated theme N2 to develop a short-range tactical rocket with the performance characteristics of the modest R-1, but which used hypergolic (that is, self-igniting and storable) propellants.

Chief Designer Isayev at NII-1 originally conducted research in this field in the immediate postwar years. Isayev's group had studied a small eight-ton-thrust engine originally developed by German engineers for the Wasserfall surface-to-air missile. Work on developing a copy of the engine had begun in 1946 in support of the creation of a Soviet copy of the Wasserfall, designated the R-101. Ground tests of the engine, in the beginning unsuccessful, had begun at NII-1 premises in February 1948 under Isayev's direction. Unhappy with the state of support for rocket engine research at the institute, his entire twenty-two-person department was transferred to NII-88 by an order dated July 1, 1948.[105] Based in Kaliningrad, Isayev formally assumed the role of chief designer of NII-88's Department No. 9. The switch from the aviation sector (which controlled NII-1) to the armaments sector (which controlled NII-88) clearly put Korolev and Isayev into close contact, uniting them for work on the N2 theme. Testing of the Wasserfall engine continued under the new institutional arrangements as Isayev designed a modified unit composed of four motors designated the U-2000. In August 1950, he carried out its first successful ground test firing.[106] Although the R-101 program was eventually terminated in 1950, the successful performance of Isayev's engine prompted Korolev to join forces to develop a modified version as part of the N2 theme.

Isayev, forty-three years old in 1951, was one of the most talented engineers in the Soviet rocketry industry. His original claim to fame had been as one of the co-designers of the famous BI-1 aircraft, one of the first Soviet rocket-planes, which had flown its first test flight in May 1942. Through the war, he had continually set the standard for high-performance engines. Later, Isayev had been one of the first qualified engineers to scour through the remains of the A-4 facilities in Germany and had been instrumental in setting up initial production runs there, before handing that job over to the more powerful Glushko. While Isayev's appointment as the technical leader for storable engines was not a threat to Glushko, it was clearly a sign that

104. Golovanov, *Korolev*, p. 424; Biryukov, "Materials in the Biographical Chronicles," pp. 232–33; Chertok, *Rakety i lyudi*, p. 374.

105. V. K. Kupriyanov and V. V. Chernyshev, *I vechernyy start . . .: rasskaz o glavnom konstruktorye raketnykh dvigateley Alekseye Mikhaylovichye Isayevye* (Moscow: Moskovskiy rabochiy, 1988), p. 219. Another source says that the transfer occurred in May 1948. See Yu. A. Mozzhorin, "The Central Scientific-Research Institute of Machine Building—The Chief Center for the Soviet Rocket-Space Industry" (English title), *Iz istorii aviatsii i kosmonavtiki* 60 (1990): 20–40.

106. Kupriyanov and Chernyshev, *I vechernyy start*, p. 219.

industrial leaders did not want to put their faith in one designer alone. Soon after the 1950 reorganization at NII-88, in recognition of Isayev's work, his department was restructured into the Special Design Bureau No. 2 (OKB-2).

The rocket that Korolev and Isayev built as part of the N2 theme, known as the R-11, was built in a remarkably short time period. Its main engine was the S2.253, developed on the basis of the old German Wasserfall engine, which used nitric acid and a kerosene derivative as propellants. The missile was flown in three series of tests from 1953 to 1955 and formally adopted for operational use by the military on July 13, 1955.[107] In time, the R-11 completely replaced the use of the R-1 missiles in the Soviet Union. More significantly, for the first time, military commanders were alerted to the value of using hypergolic and storable propellants in missiles for combat applications instead of more high-energy components such as LOX. Isayev's experience in using these propellants also contributed significantly to the future success of the Soviet space program. His OKB-2 would be assigned to develop spacecraft engines for the first Soviet piloted spacecraft. The R-11 missile itself had an interesting future. It was extensively used in several modified versions in war conditions by many other nations, including Egypt during the 1973 war against Israel and Iraq during the Persian Gulf war in 1991. In its later incarnations, it was given the general North Atlantic Treaty Organization (NATO) designation Scud-B.[108] For Korolev, the development of the R-11 seems to have been more of a diversion than anything else. As one historian noted, "he regarded it with a reserved coldness, realizing that the Army needed it and was waiting for it, and that he himself needed it in order to reinforce the positions of the OKB, but nothing more."[109] Korolev's real dream was the creation of an ICBM—one that could reach orbital velocity—and it was theme N3 that focused on this particular issue.

Designing the ICBM

All three of the themes—N1, N2, and N3—were carried out simultaneously at three organizations: NII-88's OKB-1 under Korolev, the Ministry of Defense's NII-4 led by Nesterenko and later Chechulin, and the Department of Applied Mathematics of the V. A. Steklov Mathematics Institute (OPM MIAN) headed by Academician Keldysh. The N3 theme was officially called "Research on the Prospects of Creating [Long-Range Missiles] of Various Types With a Range Flight of 5,000–10,000 km with a Warhead with a Mass of 1–10 Tons."[110] Both winged and ballistic configurations were examined in the study.

For the ballistic option, focused on the development of an ICBM, work was specifically geared toward creating a multistage missile using LOX and kerosene with a capability of carrying a payload of three to five tons over 7,000 kilometers. The starting point for the ICBM

107. Sergeyev, ed., *Khronika osnovnykh sobytiy*, p. 35. The tests occurred between April 18 and June 3, 1953, then between April 20 and May 13, 1954, and finally between December 1954 and February 1955.

108. A nuclear-tipped version named the R-11M was also later developed by OKB-1. Testing of this version was conducted between December 30, 1955, and January 19, 1956, then between March 25 and April 11, 1957, and finally between August 8 and September 2, 1957. This vehicle was declared operational by an order dated April 1, 1958. The lead designer of the R-11M was M. F. Reshetnev, a young engineer at OKB-1 who later served as head of the one of the most prolific satellite-building organizations in the world, the NPO Prikladnoy mekhaniki at Krasnoyarsk-26.

109. Yaroslav Golovanov, "Portrait Gallery: Underwater Thunder" (English title), *Poisk* 18 (May 1990): 6.

110. This title is given in Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p. 73. A different title is given in Biryukov, "Materials in the Biographical Chronicles," p. 230. See also Boris Nikolayevich Kantemirov, "The History of the Selection of Design Principles for the First ICBM, the R-7" (English title), presented at the 10th International Symposium on the History of Astronautics and Aeronautics, Moscow State University, Moscow, Russia, June 20–27, 1995.

effort was Tikhonravov's ground-breaking research at NII-4, where he developed the so-called "packet" concept of clustering together several missiles into one unit. In examining the packet scheme, Tikhonravov's group had emerged with two particular variants: the "simple packet" and the "complex packet." The former, which was favored by Korolev, had independent systems for each separate strap-on; the boosters would only be connected mechanically. In the more sophisticated complex packet, supported by Tikhonravov, the boosters would not only be connected mechanically, but all systems, such as the propulsion and hydraulic elements, would be interconnected and function in conjunction with one another.[111]

General mathematical calculations by Tikhonravov's group proved that the simple packet, despite its elegance, would be much heavier than the more sophisticated complex packet arrangement. Korolev, however, continued to support the simpler configuration, and the NII-4 team prepared two reports in 1951 on the variant, without making any attempt to optimize the design in search of improving its mass characteristics. Tikhonravov was evidently so opposed to the simple packet that he declined to carry out this optimization for Korolev; instead, he continued to support the complex scheme. The minor rift created an obstacle for further research, and seeing a possible deadlock, Korolev requested Keldysh's team at the Department of Applied Mathematics to carry out the much-needed optimization. This department at the time was staffed by a group of young, recently graduated mathematicians who were only too eager to put their skills to work. Known informally as"Keldysh's boys," they were led by twenty-eight-year-old Dmitriy Ye. Okhotsimskiy, alumnus of the N. Ye. Zhukovskiy Central Aerohydrodynamics Institute (TsAGI), and included, among others, Timur M. Eneyev, Sergey S. Kamynin, Vasiliy A. Sarychev, Galina P. Taratynova, and Vsevolod A. Yegorov, all of whom had been recruited to work in the relatively new field of missile engineering.[112]

The young team's results were summarized in 1951 in a long report authored by Keldysh, Kamynin, and Okhotsimskiy titled "Ballistic Possibilities of Multistage Missiles." It examined a variety of configurations, including simple one-stage models and Tikhonravov's packet schemes. In inspecting the cluster scheme, the scientists carried out detailed comparisons using the R-2 or R-3 missile as the basic block of each packet. The calculations proved that the R-2-based variant would not satisfy the necessary payload and range requirements. On the other hand, in their investigation of Korolev's favored simple packets of three or five R-3s, "Keldysh's boys" established that the latter could achieve the necessary velocity of 7,500 meters per second, close to orbital velocity. Subsequently, the men examined different configurations of packets in detail, including those with so-called "feeding packets," whereby propellants would pour from tank to tank, and those consisting of independent tanks. In their synopsis, the authors concluded that a simple packet would indeed be the most efficient path of development, given the relatively minimal modifications required of a already existing "standard" missile such as the R-3. The development of such elements as guidance systems, the authors predicted, would be an easier proposition. While the report was mostly exploratory in nature, the scientists clearly stated that the most favored variant for an ICBM would be a two-stage missile using two strap-on boosters in the simple packet configuration, each based on the R-3, whose mass happened to be practically identical to more sophisticated configurations.[113]

111. Kantemirov, "15 July—40 Years From the Report."

112. Golovanov, *Korolev*, pp. 468–69. Apart from the OKB-1, the OPM MIAN, and the NII-4, other organizations involved in the N3 theme were OKB-456 (V. P. Glushko), NII-885 (M. S. Ryazanskiy and N. A. Pilyugin), NII-3 (V. K. Shebanin), TsIAM (G. P. Svishchev), TsAGI (A. A. Dorodnitsyn and V. V. Struminskiy), NII-6 (V. A. Sukhikh), NII-125 (B. P. Zhukov), NII-137 (V. A. Kostrov), NII-504 (S. I. Karpov), NII-10 (V. I. Kuznetsov), and NII-49 (A. I. Charin). See Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p. 73.

113. The complete report is reproduced in Avduyevskiy and Eneyev, eds., *M. V. Keldysh*, pp. 39–142. See also Yatsunskiy, "On the Activities of M. K. Tikhonravov."

The N3 studies carried out at Korolev's own OKB-1 proved to have essentially similar results. On December 27, 1951, he formally presented the preliminary conclusions of the effort to the Scientific-Technical Council of NII-88 as part of a report titled "Thesis Report on the Results of the Investigation of Prospective Development of a Long-Range Ballistic Missile."[114] The scope of the investigation was extremely wide, and engineers at OKB-1 explored a variety of different concepts, including single-stage and two-stage missiles. The latter included looking at tandem designs, strap-on or packet designs with the engines all firing simultaneously or sequentially, and feeding packets. They also studied missiles using multichamber engines, a first for Korolev's team, underlining an interest that would eventually play a major role in determining the final look of the ICBM. Ballistics and performance characteristics of each missile were examined in detail in the report. In making his presentation in December 1951, Korolev was able to note that his engineers had compared the flight characteristics of six specific missile designs (Table 1).

The first design would require a very powerful engine, while the second used fluorine-based technology, both of which eliminated them as serious contenders for further research. The third option, a conventional tandem two-stage design, was also excluded from further research because it would require a second-stage engine capable of firing in a vacuum. Each of the three packet variants consisted of a core and two strap-ons. The generic packet had the strap-ons firing at liftoff, with the core igniting at altitude after strap-on propellant depletion. In the load-bearing packet, all the engines on the strap-ons and the core fired at liftoff. In the final configuration, propellants would be supplied to the core from tanks on the strap-ons. At altitude, the strap-ons would be jettisoned, leaving the core to fire as a single unit.[115]

Table 1. ICBM Design Flight Characteristics

Type	Range (km)	Length	Mass (t)	Stage I Thrust (t)	Stage II Thrust (t)
1. Single-stage using LOX	5,000–7,000	46	325	500 (sl)	—
2. Single-stage using fluorine-based oxidizer	7,000		70		—
3. Two-stage tandem	7,000	39.7	110	170 (sl)	30 (v)
4. Two-stage packet	7,000	17.4	121	2 x 93 (sl)	38 (v)
5. Two-stage packet with load-bearing tanks	7,000	16.5	128	2 x 115 (sl) 1 x 34 (sl)	42 (v)
6. Two-stage packet with propellant feeding	7,000	16.5	117	2 x 70 (sl) 1 x 40 (sl)	50 (v)

114. The report is reproduced in Keldysh, ed., *Tvorcheskoye naslediye akademika Sergeya Pavlovicha Koroleva*, pp. 319–27.

115. *Ibid.*

The fifth variant—a central booster with a thirty-four-ton-thrust engine combined with two strap-ons, each having a sea-level thrust of 115 tons—apparently had been the early favorite, primarily because it was literally the simplest packet configuration. A final recommendation was left to the future, apparently because of the uncertainty concerning engine development. Korolev cautioned in his report, "It must be noted that these investigations of ballistic and long-range missiles may only serve as a basis for the establishment of primary directions to be followed by detailed elaborations of definite projects and proposals."[116]

One of the notable aspects of NII-88's work on the N3 theme that distinguished it from OPM MIAN's work was over the R-3. By the end of 1951, the R-3 program was in deep trouble, and this was clearly reflected in Korolev's work on the N3 theme. Perhaps realizing that the ambitious R-3 might be too large a step to successfully overcome, Korolev's engineers used relatively smaller boosters as components of potential clustered missiles. OPM MIAN's work, on the other hand, used the R-3, although in some cases they studied packaging five boosters into one ICBM. As the N3 theme was winding down, Korolev and his deputies combined elements from both analyses—that is, they derived a new preliminary concept of an ICBM that had a core and *four* strap-ons instead of two. Instead of the R-3 as the basis for all the boosters, they introduced much smaller boosters, each having engines with thrusts in the range of fifty to sixty tons each. Ballistics analysis clearly showed that with less powerful strap-ons but with a higher number of them, a missile could have the same if not better characteristics than that of an R-3–based rocket. The use of less powerful engines would also eliminate the bottleneck problems of developing 120-ton-thrust engines such as the one for the R-3. As a result, Korolev's First Deputy Vasiliy P. Mishin, in consultation with a leading manager at the Ministry of Armaments, emerged with a revised plan for future Soviet development: terminate all work on the R-3 and proceed immediately to the creation of a new ICBM.[117]

Like the R-3 proposal itself, the idea to jump from the R-3 directly to the ICBM was uncharacteristic of Soviet military practices because it necessitated a huge qualitative and quantitative leap in abilities. Officials in the Ministry of Armed Forces were, not surprisingly, resistant to the proposal. They had great hopes for the R-3 as the first Soviet strategic missile capable of hitting targets deep into Europe. Despite overwhelming resistance, Mishin managed to convince Korolev that NII-88 should proceed directly to the ICBM instead of wasting more time on the R-3. Korolev, after "some doubts," finally agreed. Korolev and Mishin had two prominent supporters in the government: Minister of Armaments Dmitriy F. Ustinov and his Deputy Ivan G. Zubovich.[118] Despite a formidable array of doubters, Ustinov, Zubovich, and Korolev were able to persuade leading officials in the armed forces, in particular Col. General Nedelin, the armed forces' chief person for managing the procurement of new ballistic missiles, of the change in strategy. After "some hesitancy," Special Committee No. 2 adopted Korolev's proposal. Work on the R-3 program was abandoned in 1952.

The N3 theme not only encompassed the development of ballistic missiles, but also intercontinental cruise missiles, known by Soviet engineers as "winged missiles." By 1952, there was still no firm consensus on whether ballistic or cruise missiles would offer a more efficient mode of delivering nuclear weapons across intercontinental distances. Each variant had its own disadvantages and advantages, which were the subject of intense scrutiny during the N3

116. *Ibid.*, p. 327; Stache, *Soviet Rockets*, p. 287.

117. Biryukov and Yeremenko, "50 Years for the Native Rocket-Space Industry"; Biriukov, "The R-3 Rocket Project Developed in the U.S.S.R."; V. P. Mishin, "Problems of the First Flight of a Man into Space" (English title), in *Gagarinskiye nauchnyye chteniya po kosmonavtike i aviatsii* (Moscow: Nauka, 1991), p. 22; Romanov, *Korolev*, pp. 373–74. The official at the Ministry of Armaments was A. V. Zaytsev, an employee of the Seventh Chief Directorate.

118. Mishin, "Problems of the First Flight," p. 22.

research phase. In the case of cruise missiles, the less stringent requirements for structural elements and power plants for cruise missiles and the extensive experience in aircraft construction prompted a serious look into a competitor program for the ICBM. Dedicated research on the issue had commenced on October 30, 1950, at NII-88.[119] Like the ballistic missile, Korolev had settled on a two-stage configuration. Unlike the former, however, the cruise missile was to use a traditional rocket engine on the first stage and a supersonic ramjet engine on the winged second stage. The latter had an advantage over traditional rocket engines by having a simpler technical construction and decreased mass, although it only operated within certain altitudes and velocities. Like concurrent American designs, such as the Navaho XSM-64 cruise missile, the Soviet vehicle was designed to travel its entire flight in the atmosphere, using the atmosphere itself as its oxidizer.

Korolev personally summarized NII-88's research on intercontinental cruise missiles as part of the N3 theme at a meeting of the Scientific-Technical Council of the institute on January 16, 1952, about two weeks following the similar presentation on ICBMs. The report, titled "Thesis Report on the Results of Research on the Prospects of Developing a Long-Range Winged Missile," comprised detailed analysis to determine the optimal configuration for a cruise missile.[120] Korolev's engineers believed that the best design would be a two-stage cruise missile with a mass of about ninety to 120 tons and a range of 8,000 kilometers. The first stage would accelerate the second stage to an altitude of fifteen to twenty kilometers and a velocity of 900 meters per second—that is, in the window for ignition of the ramjet engines. The second stage would then fly at about Mach 3 in horizontal fashion to its target and deposit its warhead. As with the ICBM conceptions, one of the primary problems was developing sufficiently powerful liquid-propellant rocket engines for the first stage. NII-88's analysis indicated that engines with thrusts on the order of 100 to 165 tons would be required. Ramjet engine thrusts would be limited to eight to ten tons. Engineers also examined three different launch configurations for the cruise missile: horizontal launch, air launch, and vertical launch. Given time and technological limitations, the last configuration proved to be the best option.

Given the leap in technology required to build an intercontinental cruise missile, Korolev proposed the development of an intermediate vehicle, the Experimental Winged Missile (EKR), a two-stage vehicle with an overall mass of just under six tons. The missile would have a flight range of a modest 900 to 1,300 kilometers. To reduce the time of development, engineers elected to maximize already tested hardware on the vehicle. For example, the main engine of the first stage would be the S2.253 engine from the short-range R-11 tactical missile. The thrust was just under eight tons. The second stage would use a single ramjet engine with a thrust of more than three tons.[121] The development of this particular engine benefited greatly from the considerable amount of research expended over the abandoned Sänger-Bredt proposal, as well as subsequent conceptions of intercontinental cruise missiles proposed at Keldysh's department at the Central Institute of Aviation Motor Building. The expansion of this department's role in the development of intercontinental cruise missiles prompted aviation industry officials to detach it from TsIAM and reestablish the old NII-1 as a separate entity on March 10, 1952,

119. Biryukov, "Materials in the Biographical Chronicles," p. 230.

120. An edited version of the report has been published as S. P. Korolev, *et al.*, "Thesis Report on the Results of Research on the Prospects of Developing a Long-Range Winged Missile" (English title), in Keldysh, ed., *Tvorcheskoye naslediye akademika Sergeya Pavlovicha Koroleva*, pp. 328–41.

121. These data are taken from Korolev, *et al.*, "Thesis Report on the Results of Research." Other conflicting data on the EKR are given in Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, pp. 61–62. The latter may refer to a later version of the EKR with a flight range of 730 kilometers, a first-stage thrust of more than eight tons, and a second-stage thrust of 625 kilograms (at an altitude of eighteen kilometers and Mach 3). See also I. Afanasyev, "Without the Secret 'Stamp': Halt the Work, Destroy the Materials" (English title), *Aviatsiya i kosmonavtika* no. 6 (June 1993): 42–44.

with Keldysh as its director. The focus on ramjet engines was also underscored by the establishment of the new OKB-670 in 1950 under Chief Designer Mark M. Bondaryuk, a former department head at NII-1, whose team had been conducting research to build the Sänger-Bredt ramjet. For Korolev's EKR, Bondaryuk was contracted to build the RD-040 ramjet.[122] Work on the EKR culminated with the signing of a five-volume draft plan for the vehicle on January 31, 1953, by Korolev, Keldysh, Bondaryuk, and Sergey A. Khristianovich, the Deputy Director of TsAGI, who was one of the leading aeronautical scientists in the Soviet Union.[123]

The complete work on the N3 theme was collated into a three-volume set published in 1952. The results indicated the most prospective directions for further research on the development of an intercontinental missile. Both industrial officials and engineers such as Korolev were unwilling to come out in favor of a ballistic approach as compared to a cruise missile option. There were intense discussions in late 1952 at various levels, within Special Committee No. 2, the Ministry of Armaments, the Ministry of Aviation Industries, NII-88, and NII-1. Among other things, an ICBM would require the development of a new heat shield for its warhead to protect it during atmospheric reentry. In addition, engineers would have to design a complex guidance and control system to accurately control the trajectory of the missile. On the other hand, with a cruise missile, one of the most challenging tasks would be the development of a star-sensing navigation system capable of operation during both day and night. The ICBM had the advantage of being invulnerable to defensive measures because it would be flying at altitudes of approximately 1,000 kilometers and speeds of almost 25,000 kilometers per hour. The cruise missile would, however, fly for several hours before reaching its target, at a relatively low altitude, making it vulnerable to defensive measures. Ultimately, the Soviet government opted to pursue both options, at least for the time, clearly hoping to mitigate the risk of failure if only one variant was pursued. Stalin himself took a personal interest in the matter. On February 13, 1953, less than a month prior to his death, he signed an official USSR Council of Ministers' decree that affected work on all long-range ballistic and cruise missiles in the Soviet Union. The decision officially:

- Terminated work on the R-3 missile
- Stipulated a timetable for testing the R-5 strategic missile
- Terminated work on the N1, N2, and N3 themes
- Approved two new themes—the T1 and T2

The T1 theme, called "Theoretical and Experimental Research on the Creation of a Two-Stage Ballistic Missile with a Range of 7–8 Thousand Kilometers," formally approved the development of a blueprint for a Soviet ICBM based on prior research. The T2 theme officially sanctioned initial groundwork for the creation of an intercontinental cruise missile—that is, it gave full approval to build the EKR to prove out new technologies for the program. The prime contractor for both vehicles would be Korolev's OKB-1 at NII-88 based in Kaliningrad.[124] The

122. Yevgeniy Yerokhin, "The Missiles of Bondaryuk" (English title), *Krylia rodiny* no. 11 (November 1993): 33–37. OKB-670 traced its lineage back to EKB-1 of NII GVF established in 1940. EKB-1 was absorbed by NII-1 in 1944. Bondaryuk was appointed Chief Designer of a department at NII-1 on August 30, 1947. This department became the independent OKB-670 in 1950. OKB-670 also concurrently worked on ramjet engines for other missiles and aircraft, such as the R-1 Shtorm and the Samolet 5.

123. Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p. 61.

124. German Nazarov, "You Cannot Paper Space With Rubles: How to Save Billions" (English title), *Molodaya gvardiya* no. 4 (April 1990): 192–207; Golovanov, "The Beginning of the Space Era"; Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, pp. 73, 630; Romanov, *Korolev*, p. 266. For a general description of the themes T1 and T2, see Mozzhorin, *et al.*, eds., *Nachalo kosmicheskoy ery*, pp. 71, 262. The February 1953 decree also affected other missile programs. It approved the development of the short-range R-11 missile and approved the transfer of work on a new missile, the R-12, from NII-88's OKB-1 to SKB-586 based in Dnepropetrovsk, Ukraine.

detailed design parameters and configuration of both rockets would be determined in the course of the ensuing two years.

By the time that the T1 theme began in February 1953, Korolev's engineers had sharpened their conception of the ICBM to fit specific requirements.[125] The missile would be a two-stage vehicle—that is, a core with strap-ons—capable of delivering a three-ton warhead to a distance of 7,000 to 8,000 kilometers. Overall launch mass and launch thrust would be 190 tons and 270 tons, respectively. The design had a direct link to the most preferred variant that had emerged from the N3 studies between 1950 and 1953, but it was optimized to fit less powerful engines and more strap-ons. The ICBM was had become a five-booster clustered missile with a central sustainer (called "Blok A") and four strap-on boosters (Bloks B, V, G, and D). All engines would fire simultaneously at liftoff; they would be separated at altitude, leaving the central one, serving as the second stage, firing until final cutoff. Each of the boosters would be equipped with one single-chamber LOX-kerosene engine with a thrust of about fifty to sixty tons. Apart from the number of strap-ons and the power of the engines, a third major design change from 1952 to 1953 was the shape of each booster. The configuration of the ICBM in the original N3 studies owed much to the shape of the abandoned R-3 missile, which was a classically constructed sleek cylinder. The new design incorporated tapered boosters, similar to elongated cones and superficially similar to the German A-4. Engineers at OKB-1 evidently gravitated to a conical shape for the strap-ons primarily because of the aerodynamic advantages over a standard cylindrical design. Furthermore, the size of the engines, the possibility of imparting additional thrust to the central sustainer, and the opportunity of decreasing tank wall thickness eventually prompted the engineers to drop the classic cylinder design.[126] The end result was four conical-shaped boosters attached to a central element, which widened in its diameter to meet the apexes of each of the four cones. It was a decision that froze the configuration of what would eventually become the world's most used launch vehicle, a design that remains instantly recognizable today.

Based on the N3 studies, Korolev's engineers had explored the possibility of incorporating the capability of propellant transfer between the strap-on blocks, especially in cases of failure in one or more boosters, but they rejected this design based on added complexities from the need for hydraulic connections between each strap-on. Instead, OKB-1 developed the System for Synchronization and Simultaneous Emptying of Tanks to ensure that propellant flow from all the boosters was regulated on a common timeline. Guidance for the ICBM would be effected by aerodynamic rudders and gas vanes placed in the engine outflow, a throwback to the pre–R-3 days.[127]

This first order of business for work on the new ICBM, called the R-6, was the engines. Korolev approached Chief Designer Glushko for the job, but he ran headlong into conflict. As one Russian historian wrote:

> *Glushko refused. He was bothered first of all by the fact that Korolev was violating the boundaries of his own professional competence. Glushko felt that he himself knew what kind of engines the new rocket needed. The kind of engines that Korolev was talking about had not been produced yet. Glushko was afraid of explosive detonations and*

125. The senior engineers at NII-88's OKB-1 who worked on the N3 and T1 themes included R. F. Appazov, K. D. Bushuyev, B. Ye. Chertok, V. F. Gladkiy, Ya. P. Kolyako, S. S. Kryukov, A. F. Kulyabin, S. S.Lavrov, V. P. Mishin, I. S. Prudnikov, V. F. Roshchin, Ye. F. Ryazanov, I. N. Sadovskiy, P. F. Shulgin, G. S. Vetrov, P. I. Yermolayev, and P. A. Yershov. See Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p. 73.

126. Timothy Varfolomeyev, "Soviet Rocketry," *Spaceflight* 37 (December 1995): 411. There were also several disadvantages to the conical design, which are outlined in the same source.

127. Mishin, "Problems of the First Flight," pp. 20–21.

acoustic vibrations—the probability of their occurrence increasing with the size of the combustion chamber. But even if he would have succeeded in producing such a [liquid oxygen] engine, he didn't have the necessary test rigs on which he could test it.[128]

Under severe pressure from not only Korolev, but other chief designers, Glushko eventually agreed. In 1952, his design bureau, OKB-456, began developing two new LOX-kerosene engines, the RD-105 and the RD-106. Both designs used Chief Designer Isayev's idea of the integrated solder-welded configuration, which had opened the door to more powerful single-chamber LOX engines. The RD-105, with a thrust of fifty-five tons, was intended as propulsion for each of the four strap-ons of the ICBM, while the RD-106, with a thrust of fifty-three tons (65.8 tons in a vacuum), was earmarked for the central block.[129]

The initiation of work on the T1 and T2 themes in 1953 was an indication of a remarkable maturity in the Soviet long-range missile programs. From the modest beginnings of the 300-kilometer-range R-1 in 1948, within five years, the Soviets were moving headlong into producing weapons with ranges of 8,000 kilometers. The rate of progress was tremendous, characterized more by technological leaps in capability, contradicting the traditional Western view of Soviet technology advancing incrementally over decades. Driven by strong personalities such as Korolev and Ustinov, the missile program also benefited from strong military support. By the mid-1950s, Korolev would have yet one more major factor on his side: institutional disarray in the rocketry effort, which allowed him to take advantage of loopholes to divert a portion of the ICBM program to his own ends.

Korolev and the Party

When Stalin died in March 1953, it instigated the first change of leadership in the Soviet Union in more than thirty years. It seems that the major thrust of the rocketry program changed little as the succession to Stalin stabilized over the next few months. There is evidence, however, to suggest that his successors had a less-than-clear understanding of the missile industry, especially in areas of policy, no doubt because the leadership of NII-88 had reported directly to Stalin, often bypassing high Communist Party officials. Even Politburo member Georgiy M. Malenkov, appointed the chairman of the Special Committee No. 2 in 1946, was apparently uninvolved with details of the rocketry program.[130] The management of the project remained firmly in the griphold of the Soviet intelligence services under the dreaded Beriya, who proliferated his henchmen in all layers of the Ministry of Armaments and the Council of Ministers. Policy decisions adopted by Beriya or Stalin himself eventually trickled down via secret police operatives before Minister of Armaments Ustinov, under the watchful eye of Beriya, would tackle the task of managing personnel and activities at the various institutes, design bureaus, and manufacturing plants.

While Ustinov was in general "a Party man," it seems that he was very protective of engineers such as Korolev and Glushko in cases in which Beriya's people became too threatening. For example, during the overtly anti-Semitic drive to arrest intellectuals in the last years of Stalin's life, several Jewish engineers in the rocketry program found their lives in jeopardy. One night, Ustinov telephoned Chief Designer Ryazanskiy and asked him to go for a walk with him in a nearby park. Realizing the absurdity of such a request from a minister, Ryazanskiy was

128. Golovanov, *Korolev*, p. 709.

129. Timothy Varfolomeyev, "Soviet Rocketry that Conquered Space: Part 1: From First ICBM to Sputnik Launcher," *Spaceflight* 37 (August 1995): 260–63; Prishchepa, "From the History of the Creation," p. 123; Prishchepa, "History of Development of First Space Rocket Engines," p. 99.

130. Golovanov, *Korolev*, p. 394.

quick to pick up that something was amiss. During the walk, Ustinov asked Ryazanskiy to immediately send his Deputy Yevgeniy Ya. Boguslavskiy on a trip "anywhere."[131] When Ryazanskiy objected to such an unusual order, Ustinov categorically demanded that Boguslavskiy be immediately sent away on a new mission. Ryazanskiy carried out the order, possibly saving his deputy from being a victim of Beriya's anti-Semitic pogrom. On another occasion in 1950, realizing that Beriya was targeting Jewish engineers at NII-88, Ustinov demoted talented control systems engineer Boris Ye. Chertok to deflect attention away from him and thus preclude his arrest.[132]

Upon Stalin's death, as Politburo members jockeyed to assume their niches of power, it was clear that the only ones who had significant knowledge of the rocketry program were the middle managers, such as Ustinov and Vetoshkin, and of course the secret police. Thus, the upper echelons in the government were, by some accounts, bewildered to discover a vast institutional apparatus for the development of ballistic missiles. An account from Politburo member Nikita S. Khrushchev provides a hint of the new leadership's problems:

> *. . . while Stalin was alive he completely monopolized all decisions about our defenses, including—I'd even say especially those involving nuclear weapons and their delivery systems. We were sometimes present when such matters were discussed, but weren't allowed to ask questions. Therefore when Stalin died, we weren't really prepared to carry the burden on our shoulders. Our experience with Korolev is a case in point.*[133]

In the weeks following Stalin's death, four major players emerged in the struggle to take over the leadership of the country: Beriya, Khrushchev, Malenkov, and Nikolay A. Bulganin, the newly appointed Minister of Armed Forces. Beriya, with the initial support of Malenkov, consolidated his already immense power by combining the two national security services into one entity, the Ministry of Internal Affairs. Having effectively assumed personal control over all high-technology programs in the country, his reign lasted only weeks, and Khrushchev, with the support of high military leaders, eventually had him arrested on June 26, 1953.[134] Following a quick trial later in the year, Beriya was summarily executed by gunshot on December 23. His arrest precipitated the first thaws in the indiscriminate terror that had pervaded Soviet society since the formation of the USSR nearly forty years before.

The confusion in the post-Stalin months prompted a major restructuring of advanced technology industry such as nuclear and rocket weapons. Despite Beriya's elimination from the scene, many of the managers of the nuclear weapons industry who had served under him, by default, ended up inheriting major roles in the rocketry program. The process was set off on July 1, 1953—five days after Beriya's arrest—when the Presidium (later the Politburo) created the new Ministry of Medium Machine Building based on the top-secret First Chief Directorate of the USSR Council of Ministers, the same entity that had managed the atomic weapons program since 1946 under Beriya's watchful eye. Vyecheslav A. Malyshev, a fifty-one-year-old former railroad engineer, well known for his role in managing the production of tanks during the war, was appointed to head the ministry. Unlike other ministers in the Soviet government, however,

131. *Ibid.*, p. 439; Col. M. Rebrov, "The Whiteness of Martian Seas . . .: Pages From the Life of the Chief Designer of Radio Control Devices" (English title), *Krasnaya zvezda*, March 11, 1989, p. 4.

132. Instead of Boris Chertok, Minister Ustinov appointed Mikhail K. Yangel as head of the department because Yangel was a long-time member of the Communist Party.

133. Nikita S. Khrushchev, *Khrushchev Remembers: The Last Testament* (Boston: Little & Brown, 1974), pp. 45–46.

134. Holloway, *Stalin and the Bomb*, p. 320.

Malyshev was also appointed a deputy chairman of the Council of Ministers.[135] A man aligned with the Malenkov axis in the Presidium, Malyshev was an extremely professional and intelligent individual who worked closely with Beriya on nuclear weapons development during the postwar years. As the top manager of the Soviet defense industry, Malyshev's appointment effectively made him the most influential arbiter of defense sector management at the time.

As head of the new ministry, Malyshev was responsible for the management of *all* three major top-secret weapons development programs in the Soviet Union: the atomic bomb, the air defense weapons, and the ballistic missile programs. The first two of these had been operated via three "Chief Directorates" of the Council of Ministers reporting directly to Beriya. With the formation of the Ministry of Medium Machine Building, the First (for atomic weapons), the Second (for management of the raw material base for the uranium industry), and the Third (for air defense missiles) were united into one and subsumed under this one ministry.[136] The precise fate of the mysterious Special Committee No. 2, which had directed the ballistic missile program, is not clear—it may have been disbanded as early as 1949—but there is no doubt that the new Ministry of Medium Machine Building also had final oversight over the missile effort after 1953. Management of day-to-day activities remained under the purview of Ustinov at the Ministry of Armaments.[137]

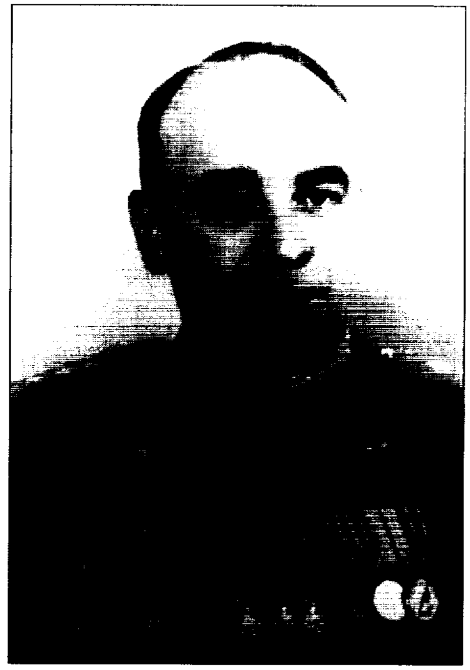
Malyshev was not a big supporter of Korolev. Unlike Ustinov, who may have listened with one ear to Korolev's interests in space exploration, Malyshev was a tried-and-true administrator, whose only goal was to produce weapons efficiently. There were, in fact, several occasions when Korolev and Malyshev went head to head. One Russian space historian, Aleksandr P. Romanov, pieced together a perhaps apocryphal account of a spat between Korolev and Malyshev over the R-3. At a high-level meeting to discuss the missile, Korolev almost casually announced to the attendees that work on the R-3 should be terminated immediately to concentrate forces on going

135. John McDonnell, "The Soviet Defense Industry as a Pressure Group," in Michael McGwire, Ken Booth, and John McDonnell, eds., *Soviet Naval Policy: Objectives and Constraints* (Halifax, NS.: Centre for Foreign Policy Studies, 1975), p. 88. A more recent Russian source suggests that the order for the formation of the Ministry of Medium Machine Building was actually issued on April 2, 1953, more than two months before Beriya's arrest. See N. S. Simonov, *Voyenno-promyshlennyy kompleks SSSR v 1920–1950-ye gody: tempy ekonomicheskogo rosta, struktura, organizatsiya proizvodstva i upravleniye* (Moscow: ROSSPEN, 1996), p. 246.

136. Simonov, *Voyenno-promyshlennyy kompleks SSSR v 1920–1950-ye gody*, p. 246. See also Andrey Sakharov, *Memoirs* (New York: Alfred A. Knopf, 1990), p. 169; Grigoriy Kisunko, *Sekretnaya zona* (Moscow: Sovremennik, 1996), p. 267. The First Chief Directorate had been established on August 20, 1945 (headed by B. L. Vannikov), the Second on December 27, 1949 (headed by V. Ya. Antropov), and the Third on February 3, 1951 (headed by V. M. Ryabikov). See Simonov, *Voyenno-promyshlennyy kompleks SSSR v 1920–1950-ye gody*, pp. 216, 225, 236. A few sources have incorrectly continued to claim that the Second Chief Directorate was a successor to the Special Committee No. 2—that is, it also oversaw the ballistic missile sector. See Vladislav Zubok and Constantine Pleshakov, *Inside The Kremlin's Cold War: From Stalin to Khrushchev* (Cambridge, MA: Harvard University Press, 1996), p. 172; B. Ye. Chertok, *Rakety i lyudi: goryachiye dni kholodnoy voyny* (Moscow: Mashinostroyeniye, 1997), p. 19; Golovanov, *Korolev*, p. 454.

137. There is some evidence to make an institutional connection between the old Special Committee No. 2, which had overseen policy aspects of the ballistic missile program from 1946, and the new Ministry of Medium Machine Building via a third government entity. This was the Third Chief Directorate of the USSR Council of Ministers established on February 3, 1951, under the leadership of V. M. Ryabikov (who until then had been D. F. Usitnov's deputy in the Ministry of Armaments). This directorate's primary duties were to oversee all research and development work on Soviet anti-aircraft and air defense missiles. When the new Ministry of Medium Machine Building was established on July 1, 1953, the Third Chief Directorate was subordinated to the ministry and renamed the Chief Directorate of Special Machine Building (GlavSpetsMash). Ryabikov remained the chief of GlavSpetsMash with the dual rank of Deputy Minister. Less than a month later, on July 29, 1953, an official governmental decree moved all ballistic missile work to the jurisdiction of GlavSpetsMash—that is, within the Ministry of Medium Machine Building under Ryabikov (Deputy Minister) and Malyshev (Minister). See Arkadiy Kruglov, *Shtab atomproma* (Moscow: TsNIIatominform, 1998), pp. 103, 106; Irina Bystrova, "The formation of the Soviet Military-Industrial Complex," Center for International Security and Arms Control, Stanford University, September 1996, p. 13.

directly to an ICBM. When Korolev finished, Malyshev looked at Korolev in bewilderment, unable to believe that the chief designer would dare to propose cancellation of a missile that was crucial to the needs of the Soviet armed forces for the next few years. When some attendees accused Korolev of using the ICBM program as a means to advance his ideas of space exploration, the chief designer did not back down, pleading that what was needed was a technological leap rather than an incremental advance. Malyshev, true to his character, severely berated Korolev in front of everyone, telling him that his proposal was out of the question. Visibly agitated, Korolev blurted out, "I refuse, Vyecheslav Aleksandrovich [Malyshev]. I repeat: this is an anti-state approach to this matter." Malyshev, not one for being intimidated, replied, "No! Really? He refuses? . . . People are not irreplaceable. Others can be found."[138] With this implicit threat on Korolev's position, there was a long moment of silence. Malyshev abruptly adjourned the meeting, saying that any more discussion on the issue was useless.



Vyecheslav Malyshev, shown here in the early 1950s, was the first manager of the entire Soviet military-industrial complex. From 1953 to 1955, as Minister of Medium Machine Building, he oversaw the rise of the hydrogen bomb and ICBM programs. (copyright Steven Zaloga)

The R-3, of course, was canceled just as Korolev had proposed. There is no record to suggest why Malyshev eventually capitulated. Perhaps Ustinov played a key role in convincing Malyshev's boss Malenkov. Certainly Beriya's arrest may have prompted Korolev to take risks he might not have previously. Clearly, however, 1953 was a pivotal year in Korolev's life. Both Stalin's and Beriya's departures had profound effects on the activities of Soviet scientists. Although formal rehabilitation for Korolev's alleged crimes in the 1930s had yet to occur, the persistently dark cloud of unexpected terror had begun to move away, and this had a marked result on his mood. Still, given the institutional arrangements of a totalitarian system, the mind-set of the Beriya years took a long time to evaporate. The history of Korolev's incarceration, in fact, significantly affected his acquirement of power in the ballistic missile program, as Communist Party officials continued to refrain from supporting an individual who was still officially a criminal of the state. With this handicap, Korolev was often forced to watch while less experienced engineers leapfrogged ahead.

One particularly important event in this respect was the rise of a talented aeronautical engineer by the name of Mikhail Kuzmich Yangel, who would go on to become the preeminent designer of strategic ballistic missiles in the Soviet Union. Born in the Ukraine on October 25, 1911, Yangel had served his apprenticeship in several major wartime aeronautical organizations led by famous designers such as Polikarpov, Mikoyan, and Myasishchev. Someone in the "higher leadership" had apparently been impressed with Yangel's activities at the Academy of

138. Romanov, *Korolev*, pp. 239–40. There is one major flaw in this account, sufficient to cast doubt on the entire anecdote. Malyshev did not become Minister of Medium Machine Building until July 1953, while the R-3 program was officially terminated in February 1953. Prior to July 1953, Malyshev had no connection whatsoever with the ballistic missile program.

Aviation Industry in the late 1940s, recommending him to Ustinov for a big promotion into NII-88. Despite Yangel's apparent lack of expertise in the area of guidance systems, in April 1950, Ustinov appointed Yangel chief of Department No. 5, the sector responsible for the development of guidance systems at the institute.[139] Yangel was a strict Party man, having joined in the early 1930s, and combined with his great technical prowess, within a year, he advanced to the post of Deputy Chief Designer at OKB-1 under Korolev.

This photo of Chief Designer Mikhail Yangel is from the mid-1960s. Although he started his career under Korolev, Yangel eventually headed an independent missile design organization in Dnepropetrovsk in the Ukraine, which produced some of the most important ICBMs in the Soviet arsenal. (files of Peter Gorin)

When NII-88 Director Rudnev was unexpectedly promoted to become a Deputy Minister of Armaments under Ustinov in May 1952, Party officials conducted a search for a suitable candidate to serve as head of the institute. It came as somewhat of a shock to most engineers when they were told that Yangel, and not Korolev, would assume the role as the director of NII-88. Clearly, Yangel's Party credentials were a significant factor in the new appointment, and Korolev was put in the awkward position of having to report to an individual who had been a subordinate for the previous two years. Both individuals had very strong personalities, and their relationship with each other was far from smooth, resulting in a very strained and stressful working environment at the institute. They essentially avoided speaking to each other, and Korolev would often use his deputies, such as Mishin or Chertok, as intermediaries.[140] The stress was apparently too much, and on October 4, 1953, Yangel was demoted to the position of Chief Engineer of NII-88.[141] Although still officially superior to Korolev, Yangel was henceforth primarily involved in the production of missiles at the manufacturing plant in Dnepropetrovsk.

The conflict between Korolev and Yangel also served to set the stage for the formation of a new organization, only the second apart from NII-88 dedicated to the development of long-range ballistic missiles. The State Union Plant No. 586 at Dnepropetrovsk had originally been involved in the manufacture of older missiles, such as the R-1 and the R-2, directed by Korolev's former protégé, Chief Designer Budnik. Although the plant primarily handled production, Korolev let Budnik set up a small design department, officially subordinate to the former, to explore modifying existing missiles. The work resulted in the development of an improved R-1 named the R-1M, distinguished by its new guidance system. At the same time, Budnik, jointly with engineers at NII-88, set about on a more ambitious project to define the concept for a new

139. Golovanov, *Korolev*, p. 439; Lardier, *L'Astronautique Soviétique*, p. 95; Chertok, *Rakety i lyudi*, p. 353.

140. Chertok, *Rakety i lyudi*, p. 354-355; Golovanov, *Korolev*, p. 440.

141. Jacques Villain, ed., *Baïkonour: la porte des étoiles* (Paris: Armand Colin, 1994), p. 136; Chertok, *Rakety i lyudi*, p. 355. Maj. General A. S. Spiridinov, who had served as liaison officer with the Germans at Gorodomlya, was appointed the new director of NII-88 at the time. A. A. Yeremenko, Chief of the Public Affairs Department of TsNIIMash, letter to the author, April 14, 1994.

strategic ballistic missile named the R-12, or "product 8A63," which would use *storable* propellants, have an autonomous guidance system, and be capable of a range of about 2,000 kilometers. The military was evidently interested in a missile that would have the modern design characteristics of the R-5 but be as easy to store for long periods as the short-range tactical R-11. Budnik was lucky to have a collaborator: Chief Designer Dominik D. Sevruk at NII-88's OKB-3 had by this time begun work on high-thrust engines using red fuming nitric acid and kerosene (storable components). Both Korolev and Glushko were lukewarm at best to the whole idea of the R-12, but on the insistence of the military, they began to take it seriously.[142] On February 13, 1953, in the same decree sanctioning the ICBM's development, the Soviet government formally transferred all draft plan work on the R-12 from NII-88 to Budnik's command in the Ukraine.[143]

Because Budnik's design bureau was essentially an entity focused on manufacturing, however, it faced serious problems in funding and staffing.[144] The problems at the factory opened the way for a solution to the conflict between Korolev and Yangel. In early 1954, Khrushchev instructed Minister Ustinov to draw up a plan to dilute Korolev's absolute monopoly in the rocket-building business. Ustinov emerged with a plan to create two completely independent groups, one in the Ukraine and one in the Urals. Korolev was called to a meeting to meet Khrushchev, who was then the First Secretary of the Communist Party, to discuss the issue. Korolev was naturally very resistant to competitors, and he suggested to Khrushchev that the most optimum plan would be to have centrally located design bureaus in the Moscow area and a number of *branches* spread across the Soviet Union. Khrushchev was adamantly opposed, instead arguing that the two new groups would be completely independent from OKB-1.[145] Thus, Korolev finally ceded his monopoly, and the foundation was laid for the expansion of the missile and space industry.

The first enterprise was the Experimental Design Bureau (OKB-586) formed at the plant in Dnepropetrovsk in the Ukraine by an order of the Council of Ministers dated April 10, 1954. Its mandate was to create a new generation of military ballistic missiles.[146] Ustinov offered the chief designer's job of the organization to Yangel, who accepted without any hesitation. The ambitious engineer had been interested for a while in heading his own design bureau and, like Korolev, had been unhappy with the situation at NII-88. Yangel was officially named to head OKB-586 on July 9 and brought with him to Dnepropetrovsk a number of able engineers from NII-88. With Budnik as his new first deputy, Yangel immediately dove into work on the R-12 missile, considered by the Soviet leadership to be a successor rocket to Korolev's R-5. Originally, Yangel's new missile would have used an engine designed by Sevruk, who had started this research in the first place, but ended up collaborating with a much more powerful individual, Chief Designer Glushko. Although Glushko had been uninterested at first in the R-12, once the program gathered steam, he had Sevruk's work on the engine transferred to his own design bureau. Thus, along with the two engines for the ICBM, in 1952, he began work on a third engine, the RD-211, for the R-12. In contrast to the other two engines, the RD-211 would have a multichamber design with four identical combustion chambers fed by one tur-

142. Biryukov and Yeremenko, "50 Years for the Native Rocket-Space Industry"; Igor Afanasyev, *R-12: Sandalovoye derevo* (Moscow: EksPrint NV, 1997), pp. 6–7.

143. Pappo-Korystin, Platonov, and Pashchenko, *Dneprovskiy raketno-kosmicheskiy tsentr*, p. 55.

144. V. F. Prisnjakov and F. P. Sanin, "To the History of Rocket-Space Technique Development in Ukraine," presented at the 45th Congress of the International Astronautical Federation, IAA-94-IAA.2.1.613, Jerusalem, Israel, October 9–14, 1994.

145. Sergey Khrushchev, *Nikita Khrushchev: krizisy i rakety: vzglyad iznutri: tom 1* (Moscow: Novosti, 1994), pp. 281–83.

146. Pappo-Korystin, Platonov, and Pashchenko, *Dneprovskiy raketno-kosmicheskiy tsentr*, p. 56.

bopump. Total thrust was about sixty-five tons.[147] The RD-211 would be Glushko's very first high-thrust liquid-propellant rocket engine using storable propellants, establishing a tradition in his design bureau that would have dramatic repercussions within ten years.

The second independent branch was opened at Zlatoust in the Urals at the former plants number 66 and 385, which had up to that time specialized in the serial manufacture of early ballistic missiles. As part of Ustinov's master plan, Serial Design Bureau No. 385 (SKB-385) was restructured, and one of Korolev's youngest protégés, apparently at the recommendation of Korolev himself, was appointed the organization's chief designer on March 11, 1955.[148] The thirty-year-old Viktor P. Makeyev was transferred from OKB-1 to the new firm to lead the development of a new generation of tactical missiles, with ranges from 200 to 300 kilometers. His experience as the lead designer of the tactical R-11 rocket no doubt played a major role in his appointment, and Makeyev's SKB-385 would soon inherit all naval rocketry development from Korolev's OKB-1, moving to become the premier developer of naval ICBMs in the world.

The conflict with Yangel and the subsequent creation of two new and independent rocket design bureaus in the Soviet Union may have temporarily diluted Korolev's powers, but his influence, both on an official and a personal level, continued to grow slowly. This was clearly in no small part because of his change of heart over the issue of membership in the Communist Party of the Soviet Union. Of the major rocketry designers, he remained one of the few who never joined the Party. The problem was compounded by the resistance of many local Party leaders in recruiting a known and convicted "enemy of the state"; Korolev, of course, had yet to be formally rehabilitated for his "crimes" of the 1930s. He attended classes at the Mitishtinskiy Evening University on Marxism-Leninism, finishing his coursework with distinctions in 1950. Unable to forget the toils of his past, he evidently remained unsure of whether to join the ranks of card-carrying communists. In 1952, at the prompting of several local Party officials at Kaliningrad, Korolev finally decided to begin the process of applying for membership. In March, he was accepted as a candidate member. The doubts about his "criminal" past were put to rest by a number of recommendations from associates such as Pobedonostsev and Kozlov. Perhaps influenced by Yangel's swift rise to the directorship of NII-88, Korolev formally applied for full membership of the Party in early June 1953, soon after his return from Kapustin Yar following a series of R-5 launches.[149] It was a critical moment in his career, for a rejection of his application would have surely necessitated his resignation as chief designer at NII-88's OKB-1, effectively ending his career. Korolev had reason to worry because it was extremely unusual for a former prisoner to become a Party member. Fortunately, at a meeting at Kaliningrad the following month, he was finally accepted as a member of the Communist Party of the Soviet Union.

The joining of the Party was an important factor in getting another distinction. The same year on October 23, Korolev and Chief Designer Glushko were elected two of approximately 300 new Corresponding Members of the USSR Academy of Sciences, the second highest ranking honor for a scientist in the nation.[150] Being the only two engineers in the entire rocketry industry who were bestowed such an honor, it was a significant recognition of the power that

147. Biryukov and Yeremenko, "50 Years for the Native Rocket-Space Industry"; Afanasyev, *R-12*, pp. 6–7; Prishchepa, "From the History of the Creation," p. 130.

148. Khrushchev, *Nikita Khrushchev*, p. 284. The SKB-385 was originally established on December 15, 1947. See Maxim Tarasenko, "Evolution of the Soviet Space Industry," presented at the 46th Congress of the International Astronautical Federation, IAA-95-IAA.2.1.01, Oslo, Norway, October 2–6, 1995; Ye. Tkachenko, "The KB Named After Academician Makeyev—50 Years" (English translation), *Novosti kosmonavtiki* 26 (December 15–31, 1997): 75.

149. Golovanov, *Korolev*, p. 441; A. P. Romanov and V. S. Gubarev, *Konstruktory* (Moscow: Politicheskoy literatury, 1989), p. 65.

150. Keldysh, ed., *Tvorcheskoye naslediye akademika Sergeya Pavlovicha Koroleva*, p. 344; Chertok, *Rakety i lyudi*, p. 391.

the two designers yielded. As members of the Department of Technical Sciences in the Academy, Korolev and Glushko not only gained widespread recognition for the first time, but also were privy to a few but important financial perks given to all Corresponding and Full Members of that organization.

For Korolev, as the years passed, the workload also increased, and he found less and less time for pleasure. Most of his personal time was spent with his second wife Nina P. Koroleva, whom he had married in May 1947 soon after she found work at NII-88. While he frequently traveled to and from Kapustin Yar and Kaliningrad, Korolev and his wife and daughter were not allowed to leave the country for any reason. Although he continued to harbor ill feelings toward many of the leaders of the Soviet government, it would be erroneous to suggest that he suppressed "anti-Soviet" feelings in the hopes of seeing his dreams of space travel emerge in reality. In fact, by all accounts, Korolev clearly had a strong and profound love for his country, and his interest in creating such deadly weapons as ICBMs was more than just a byproduct of his love for space exploration. He did often, however, see the absurdity of being involved in such sensitive technology programs.

Chief Designer Sergey Korolev stands at the Kapustin Yar firing range in 1953, the same year that he finally joined the Communist Party and was elected a Corresponding Member of the USSR Academy of Sciences. (files of Asif Siddiqi)

In January 1953, during a sudden warm period in the weather, an area in the central USSR was flooded by melting ice. A missile depot in that region, storing tens of R-1 missiles for battle, was luckily saved from the flood because of the careful construction of storage buildings. Unfortunately, the water entered thousands of subterranean mice burrows, and finding no other place to take shelter, the mice flocked to the missile depot by the thousands. As it happened, the mice found the insulation wiring of the numerous missiles to be quite edible. When news of the incident found its way to the higher leadership, the artillery command was furious and sent Maj. General Lev M. Gaydukov to the depot, where he relieved the local commander, a General Volkodav, on the spot for "criminal negligence."[151] Soon, hundreds of cats and repairmen were rushed to the depot to take care of the problem. When Korolev heard about the entire episode, he reportedly laughed himself to tears, much to the alarm of General Volkodav, who accused Korolev of building a missile with edible insulation.

Famous physicist Academician Andrey D. Sakharov, who was one of the leading individuals in advanced nuclear weapons research in the Soviet Union, has provided some revealing insights to Korolev's character. Sakharov, along with the nuclear physicist Igor V. Kurchatov, met Korolev at the end of 1953 during a break from their work at the famous KB-11, the primary nuclear weapons design bureau in the USSR. According to Sakharov:

151. Golovanov, "Portrait Gallery: Underwater Thunder."

Korolev was a brilliant engineer and organizer and a colorful personality who shared many of Kurchatov's qualities. . . . Korolev dreamed of the cosmos, and he clung to that dream throughout his youth and his stint with the famous Jet Propulsion Research Group [GIRD]. He never believed, as so many did, that the rocket pioneer Konstantin Tsiolkovsky was simply an impractical dreamer. Korolev also shared Kurchatov's rather crude sense of humor. Both took good care of their subordinates and colleagues and had a sure grasp of the practical, but Korolev was possibly a bit more cunning, ruthless, and cynical than Kurchatov.[152]

About the general work of NII-88, Sakharov added:

We had always thought our own work was conducted on a grand scale, but this was something of a different order. I was struck by the level of technical culture; hundreds of highly skilled professionals coordinated their work on fantastic objects they were producing, all in a quite matter-of-fact, efficient manner.[153]

Korolev's relationship with the post-Stalin leadership stabilized over time. Of the four major players, he had had cursory relationships with Beriya, Bulganin, and Malenkov. The latter two had headed the important Special Committee No. 2, but they had evidently remained outside the *de facto* loop of command over the missile program. Thus, with Beriya gone, the new leadership was in the curious position of inheriting a massive and complex program of research that had been completely concealed from them. The fourth major power player, Khrushchev, had met the Korolev a few times during the Stalin regime, but they had never developed a personal relationship at the time. Khrushchev's description of Korolev's first meeting with the new Party leadership is revealing:

Not too long after Stalin's death, Korolyov came to the Politbureau [sic] meeting to report on his work. I don't want to exaggerate, but I'd say we gawked at what he showed us as if we were a bunch of sheep seeing a new gate for the first time. When he showed us one of his rockets, we thought it looked like nothing but a huge cigar-shaped tube, and we didn't believe it could fly. Korolyov took us on a tour of the launching pad and tried to explain to us how the rocket worked. We were like peasants in a marketplace. We walked around and around the rocket, touching it, tapping it to see if it was sturdy enough—we did everything but lick it to see how it tasted.[154]

Speaking of the new ICBM proposal, Khrushchev had unending praise for Korolev:

We had absolute confidence in Comrade Korolyov [sic]. We believed him when he told us that his rocket would not fly, but that it would travel 7,000 kilometers. When he expounded or defended ideas, you could see passion burning in his eyes, and his reports were always models of clarity. He had unlimited energy and determination, and he was a brilliant organizer.[155]

152. Sakharov, *Memoirs*, p. 177.
153. *Ibid.*
154. Khrushchev, *Khrushchev Remembers*, pp. 45–46.
155. *Ibid.*

Firsthand descriptions of his character describe someone who was capable of both outright belligerence and unexpected generosity—a man single-mindedly driven by the dream of space travel. Transcending any possible cliché of the devoted scientist, Korolev was more than the sum of his attributes, a surprisingly humane and emotionally explosive person with both strengths and failings, but ultimately possessed of invaluable genius for managing his engineers. One military associate from the 1950s recalled that:

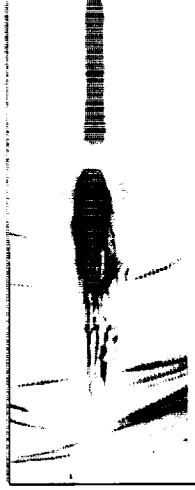
> *Korolev was not only a scientist and designer, but also a great organizer. He never hesitated to take risks, but his risk-taking was always calculated. Sometimes he would take a decision which he intuitively knew to be wrong, but he still wanted to test it and try it out as if he needed to convince himself that it was truly wrong. He would steamroll anything and anybody that tried to prevent him from making a decision which he deemed necessary and proper. Indeed, his main character trait was his iron will. He was very self-disciplined, resolute, certain about what he wanted, and intent on achieving his goals at any cost.*[156]

Despite increased socialization with the upper leadership of the Kremlin, the cultured Korolev never overcame the deleterious effects of his time in prison. Anatoliy P. Abramov, an engineer at the design bureau, recalled many years later that Korolev:

> *used to take his meals with his deputies and assistants, all sitting around in a big table in the canteen. . . . Korolev had a good sense of humor, and his presence never intimidated the others sitting around the table. . . . He ate very quickly, paying more attention to answering questions than to the meal. After finishing the food on his plate, he would wipe it clean with a piece of bread which he subsequently put in his mouth. He even scooped up crumbs and ate them. The people around him looked on with amazement until someone volunteered that this was a habit he had developed during his years in prison and in labor camps.*[157]

The successes of the early Soviet ballistic missile program did not, obviously, belong only to Korolev. Other engineers, artillery officers, and defense industry bureaucrats were instrumental in the creation of the vast infrastructure that supported the development of the R-1, R-2, R-5, and R-11 missiles. But Korolev was the heart of that effort, the one who synthesized the abilities and talents of thousands. By 1953, he was poised to begin the most important phase of his life. A man profoundly affected by the history of the Soviet Union, he began to harness his own energies to affect the history of the world.

156. Mozzhorin, *et al.*, eds., *Dorogi v kosmos: I*, pp. 112–13.
157. Mozzhorin, *et al.*, eds., *Nachalo kosmicheskoy ery*, p. 44.



Chapter Four
Sputnik

Stalin's death in 1953 signaled the beginning of a new era in the history of the Soviet state. As with every other arena of Soviet life, the effects on the rocketry sector were not clear immediately. Given that Stalin himself had an unusually important role in approving or canceling weapons development projects, the new members of the Politburo were less than prepared to handle the institutional and operational challenges of the emerging long-range ballistic missile program. While Beriya, Bulganin, Khrushchev, and Malenkov had found themselves as the major power brokers in the post-Stalin leadership, one by one, three of them were eliminated from the picture in the ensuing years. Nikita Sergeyevich Khrushchev emerged as the most powerful and influential Communist Party leader in the country. Of the four individuals, Khrushchev was, however, the one person least familiar with the workings of the defense industry. His inexperience with the sector, combined with the necessity of revamping an institutional structure set up in the Stalin days, seems to have set the stage for a great degree of flux and ambiguity in the chain of command in the missile programs during the four-year period from 1953 to the first Sputnik launch in 1957. This amorphousness engendered a climate for facilitating the decision to develop and launch the first artificial satellite.

Operation *Baykal*

Through the end of 1953 and the beginning of 1954, specific requirements for the first Soviet ICBM were established at NII-88 during a series of important meetings, which finally brought together nuclear weapons and rockets to create a potent combination. The first step prior to using nuclear explosives on the ICBM was deployment of more modest rockets, such as the short-range R-11 and the medium-range R-5. It was during this period that Korolev's enterprise and the rest of the rocketeers for the first time came into contact with bureaucrats in the Ministry of Medium Machine Building, the individuals responsible for administrating the top-secret nuclear weapons program. Following the end of the Stalin and Beriya era, Minister Malyshev and his deputies from the Ministry of Medium Machine Building almost by default inherited jurisdiction over the missile effort—an unusual state of affairs prompted in part by the ignorance of many high Communist Party leaders on the nature of important military programs.

The collaboration with the nuclear scientists began with an exploratory visit to NII-88 on October 19, 1953, by representatives of the Ministry of Medium Machine Building, who met NII-88 Chief Engineer Yangel to inquire about the basic parameters of the R-5 missile. Korolev was at the time in Kapustin Yar inaugurating the second series of R-5 testing, and upon hearing of the visit, he quickly flew back to Moscow in time for a formal visit by Malyshev to discuss the details of the operation.[1] What emerged from the meeting was an order to modify the two existing missiles into their nuclear weapons variants, the R-11M and the R-5M. The modifications were to rely entirely around issues of reliability, stemming from the understandable concern about putting atomic bombs on inefficient missiles. Given the generally poor performance of newly designed rockets, the pressure was on Korolev to satisfy requirements that were far beyond anything needed before. Close cooperation was called for with the scientists from the Arzamas-16, who, by some accounts, often acted condescendingly to the engineers at OKB-1. Having been the most coveted defense scientists in the Soviet Union, for the first time, the nuclear scientists were forced to submit to design requests from the rocketry industry. One OKB-1 engineer recalled later:

> *At the start of this work Sergey Pavlovich [Korolev] gathered the project leaders to make a speech concerning the program. This was a meeting before the start of work with the [Ministry of Medium Machine Building]. The first thing he said was that we ought to be very careful in our activities, because they had been spoilt . . . due to publicity . . . and considered themselves superior to everybody else . . . after developing the atom bomb . . . S. P. Korolev said that at least in the beginning we should pander to them, but pander very carefully such that in the end we would prove to them that we were in the driver's seat and they were merely passengers.*[2]

Symptomatic of many other rivalries between organizations within the defense industry, the friction between the nuclear and rocket scientists eventually came to a stalemate, but it was a conflict that served as a vehicle to dramatically increase the prominence and clout of the missile engineers.

The Soviets conducted a third series of R-5 testing at Kapustin Yar between August 12, 1954, and February 7, 1955, which verified initial concepts for modernizing the base vehicle. These tests essentially cleared the way for the "nuclear" variant, which had a slated range of 1,200 kilometers and a launch mass of just over twenty-eight and a half tons, slightly less than its predecessor.[3] Korolev himself inaugurated the grueling test series for the new R-5M on January 20, 1955. Coordinating the work with the nuclear weapons engineers and scientists, OKB-1 engineers slowly eliminated a variety of major technical problems during as many as seventeen launches from site 4N at Kapustin Yar, which lasted up to July 1955. Of the launches, only two deviated from their assigned trajectories; their flight was terminated using a special system that switched off the engines in flight. Engineers also studied the impact of dummy steel warheads, which provided information on detonation devices.[4] Korolev was acutely aware of the importance of the work on the new missile, not only because it represented a new step for national defense as a whole, but precisely because of its relevance in consolidating the influence and respect for the work at his organization. In many ways, it was the first crucial step that would make or break the latent aspirations of a future space program under his direction.

1. Yaroslav Golovanov, *Korolev: Fakty i mify* (Moscow: Nauka, 1994), pp. 456–57. Also present were Ministry of Medium Machine Building Directorate Chief G. N. Pashkov, Ministry of Defense Industries Deputy K. N. Rudnev, and a host of senior engineers from NII-88. The meeting is said to have occurred in November 1953. See Boris Nikolayevich Kantemirov, "The History of the Selection of the Design Principles for the First ICBM, the R-7," presented at the 10th International Symposium on the History of Astronautics and Aeronautics, Moscow State University, Moscow, Russia, June 20–27, 1995.

2. Yu. A. Mozzhorin, *et al.*, eds., *Nachalo kosmicheskoy ery: vospominaniya veteranov raketno-kosmicheskoy tekhniki i kosmonavtiki: vypusk vtoroy* (Moscow: RNITsKD, 1994), p. 69.

3. Yu. V. Biryukov, "Materials from the Biographical Chronicles of Sergey Pavlovich Korolev" (English title), in B. V. Raushenbakh, ed., *Iz istorii sovetskoy kosmonavtiki* (Moscow: Nauka, 1983), p. 234; B. Ye. Chertok, *Rakety i lyudi* (Moscow: Mashinostroyeniye, 1994), p. 302.

4. Golovanov, *Korolev*, p. 460; Chertok, *Rakety i lyudi*, p. 389; Steven J. Zaloga, *Target America: The Soviet Union and the Strategic Arms Race, 1945–1964* (Novato, CA: Presidio, 1993), p. 138.

After four final certification launches in January 1956, the Soviet government established a special State Commission for testing the live nuclear-tipped missile; this organization was chaired by Pavel M. Zernov, under whose leadership the KB-11 firm had developed the first Soviet nuclear bomb.[5] The exercise was code-named Operation *Baykal*. The fateful day of the launch, February 2, 1956, Korolev, Voskresenskiy, Pilyugin, and nuclear weapons engineer Aleksandr P. Pavlov gathered at the command point about six kilometers from site 4N to watch the launch. Tension was high at the launch site because, for the first time during the Soviet rocketry program, a live atomic bomb was sitting on top of a rocket. Engineers undertook special measures in case the rocket deviated from its path. One of these included the establishment of the Missile Accident Command Post—that is, a group of engineers who would use their mathematical acumen in real time to distinguish a nominal trajectory from an unacceptable deviation.[6] The launch went off without a problem, and the observers at the impact site were able to observe the effects of the spectacular nuclear explosion, telephoning back to Kapustin Yar: "We observed *Baykal*."[7]

For Korolev and his engineers at NII-88, this was a watershed moment. The years of uncertainty and suspicion from military leaders evaporated in a flush of euphoria. Especially happy with the test and NII-88's performance was Marshal Nedelin, at the time the Deputy Minister of Defense responsible for the procurement of all armaments. Within days, NII-88 was graced by a visit by the top Soviet leadership, including Presidium members such as Nikita S. Khrushchev, Nikolay A. Bulganin, Vyecheslav M. Molotov, Lazar M. Kaganovich, and Nikolay K. Kirichenko.[8] It was an unprecedented honor, heretofore reserved only for the nuclear weapons scientists, which contrasted sharply with the treatment the institute had received in its first ten years of existence. As a mark of recognition of the rocketeers' remarkable work, a decree on April 20, 1956, awarded the highest civilian honor possible for a Soviet citizen, the Hero of Socialist Labor, to the entire Council of Chief Designers (Korolev, Glushko, Pilyugin, Ryazanskiy, Barmin, and Kuznetsov) and two other missile experts (Isayev and Korolev's First Deputy, Mishin).[9] Korolev's other employees—twenty of them, including Bushuyev, Chertok, Okhapkin, Voskresenskiy, Kryukov, and Makeyev—were awarded the less prestigious Order of Lenin. The R-5M missile itself was formally adopted as armament of the Soviet armed forces by an order dated June 21, 1956, serving as the first operational nuclear-tipped missile in the Soviet inventory.[10] The improvement in the fortunes of NII-88 and OKB-1 was particularly significant for Korolev's future space plans; for the first time since his appointment as chief designer in 1946, he had direct access to the top individuals in the Soviet leadership, facilitating quicker

5. Christian Lardier, *L'Astronautique Soviétique* (Paris: Armand Colin, 1992), p. 84. Other members of this state commission were: nuclear weapons experts Ye. A. Negin and N. A. Petrov; military officers M. I. Nedelin (a Deputy Minister of Defense), N. D. Yakovlev (Commander of Air Defense Troops), A. G. Mrykin (the chief representative from the Chief Artillery Directorate for missile affairs), V. I. Voznyuk (Commander of Kapustin Yar), and P. A. Degtyarev (from the Chief Artillery Directorate); bureaucrats D. F. Ustinov (Minister of Defense Industries) and S. I. Vetoshkin (Ustinov's First Deputy), and engineers S. P. Korolev, V. P. Glushko, N. A. Pilyugin, M. S. Ryazanskiy, V. P. Barmin, and V. I. Kuznetsov.

6. Yuriy A. Mozzhorin, *et al.*, eds., *Dorogi v kosmos: I* (Moscow: MAI, 1992), p. 29. The system installed on the missile was designated the Automatic Rocket Disablement (APR) system, which switched off the main engines on a wayward missile. See Chertok, *Rakety i lyudi*, p. 388.

7. Zaloga, *Target America*, p. 139.

8. Golovanov, *Korolev*, p. 464.

9. V. Pappo-Korystin, V. Platonov, and V. Pashchenko, *Dnepropetrovskiy raketno-kosmicheskiy tsentr: kratkiy ocherk stanovleniya i razvitiya* (Dnepropetrovsk: PO YuMZ/KBYu, 1994), pp. 58–59. Note that Mishin was the only non-chief designer to be awarded. Note also that Isayev was given his Hero of Socialist Labor for the development of the S-25 Berkut surface-to-air missile system and not the R-5M.

10. I. D. Sergeyev, ed., *Khronika osnovnykh sobytiy istorii raketnykh voyska strategicheskogo naznacheniya* (Moscow: TsIPK, 1994), p. 35.

and often effective decision-making for projects that had elicited little or no interest from both Communist Party and government leaders during the preceding years.

There was a clear level of flux in the policy and management of the Soviet missile programs in the years following 1953 and leading up to 1957, when Khrushchev conclusively consolidated his power. The Special Committee No. 2, which in its various incarnations had supervised all policy decision-making since its inception in 1946, had ceased to exist as an independent entity in 1949. Later, the nuclear, missile, and air defense programs were all consolidated under Vyecheslav A. Malyshev within the Ministry of Medium Machine Building in 1953. This managerial setup lasted only two years before the Soviet leadership—that is, Malenkov and Khrushchev—decided to concentrate all missile industry supervision under one governmental entity that superseded ministerial jurisdiction. On April 14, 1955, the government created the "Special Committee for Armaments for the Army and Navy of the USSR Council of Ministers" by uniting several former departments from the Ministry of Medium Machine Building and subordinating it directly to the USSR Council of Ministers. By December 1957, this same committee would be renamed the Military-Industrial Commission (VPK), the infamous institution that managed the Soviet military-industrial complex through the entire Cold War.[11] Officially, the role of VPK was "to transform the Party's weapons policy decisions into coordinated plans and assignments, and to ensure that those tasks were accomplished as directed."[12] As Khrushchev himself became the sole arbitrator of Party weapons policy by the late 1950s, VPK served as an implementation mechanism for his pet defense projects. Eventually, there would not be a single program in the entire defense sector, including the future space program, which would get off the ground without the signature of the chairman of VPK.

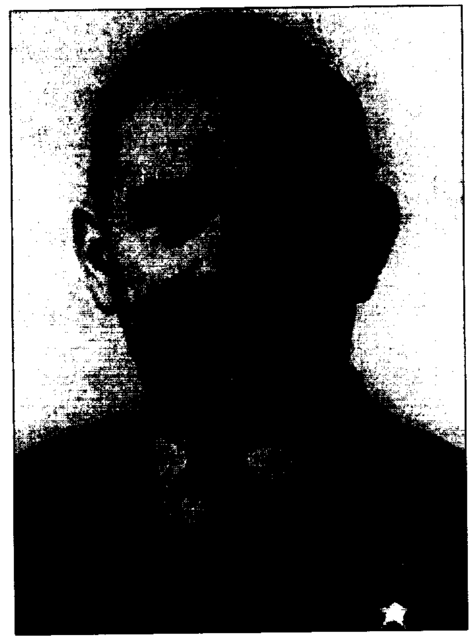
Malyshev, having done much for the growth of the ballistic missile program, was not to be witness to the Soviet space program. When his "sponsor," Presidium member and chairman of the Council of Ministers Georgiy M. Malenkov, was demoted in February 1955, Malyshev's fortunes took a dive. Within months, he lost his grip on power and was demoted to a relatively innocuous position. An ambitious and intelligent man, he was devastated by the course of events. He died within a year of acute leukemia.[13] For Korolev, Malyshev's removal had positive implications. Never close to the chief designer, Malyshev had consistently opposed Korolev's grander plans for space exploration, perhaps suspecting in Korolev a penchant for idle dreaming, which had no relevance to consolidating the defensive might of the Soviet Union.

11. The new Special Committee traced its ancestry back to the Third Chief Directorate of the USSR Council of Ministers, established on February 3, 1951, to oversee the development of all Soviet short- and long-range missiles. On July 1, 1953, the Third Chief Directorate was subordinated to the new Ministry of Medium Machine Building and renamed GlavSpetsMash (Chief Directorate of Special Machine Building). GlavSpetsMash evidently supervised Soviet missile development from 1953 to 1955. The role of the Ministry of Defense Industries under D. F. Ustinov, which had traditionally overseen industrial development of missiles in the 1940s and 1950s, is unclear during this period. On April 14, 1955, several subordinate departments of the Ministry of Medium Machine Building, including GlavSpetsMash, GlavSpetsMontazh (Chief Directorate of Special Assembly), and GlavTransMash (Chief Directorate of Transport Machine Building), were separated from the ministry, henceforth releasing the ministry from any oversight over missile programs. Some of the newly independent departments, including design bureaus such as KB-1 and OKB-2, were transferred to the Ministry of Defense Industries under Ustinov. The remainder, including a large portion of the old GlavSpetsMash, was consolidated into a single entity and subordinated directly to the USSR Council of Ministers, serving as the backbone of the new "Special Committee for Armaments of the Army and Navy." The chairman of the committee was V. M. Ryabikov. The first deputy chairman was G. A. Titov. The two deputy chairmen were A. K. Repin and A. N. Shchukin. The four remaining members were G. N. Pashkov, V. V. Illyuvnev, P. I. Kalinushkin, and B. A. Kyasov. See Grigoriy Kisunko, *Sekretnaya zona* (Moscow: Sovremennik, 1996), pp. 305, 367; Arkadiy Kruglov, *Shtab atomproma* (Moscow: TsNIIatominform, 1998), pp. 107, 117.

12. William P. Barry, "The Missile Design Bureaux and Soviet Piloted Space Policy, 1953–1970," Ph.D. thesis in Politics, Faculty of Social Studies, University of Oxford, 1996.

13. Andrey Sakharov, *Memoirs* (New York: Alfred A. Knopf, 1990), p. 184.

Malyshev's replacement as missile project coordinator was an unusual choice, but one who was evidently more sympathetic to Korolev: Vasiliy M. Ryabikov. The latter had by far one of the most unusual careers in the defense industry—and one whose full facet is still unexplained by declassified information. Ryabikov had served as Ustinov's First Deputy at the Ministry of Armaments until 1951, overseeing the work at NII-88. In February 1951, he was appointed to lead the Third Chief Directorate of the USSR Council of Ministers, a top-secret body established among other things to develop the first Moscow air defense system.[14] His sudden rise to a position of such great importance after a stint as a deputy minister is inexplicably hidden among the minutes of Politburo meetings. From 1953 Ryabikov served briefly under Malyshev, overseeing Soviet missile programs before being tapped to be chairman of the new Special Committee in April 1955. It was a curious position for him because he now served as Ustinov's boss, whereas only a few years before, their roles were reversed.[15] One persuasive Western analysis of Ryabikov's precipitous rise suggests that Ryabikov was an important element in Beriya's control of top-secret programs, and after the latter's fall, Malyshev and Ryabikov were among many who remained behind from the "Beriya group" to serve as a foil against Khrushchev's own overtures for a complete monopoly of power.[16]



Vasiliy Ryabikov, shown here in an official government portrait, headed the so-called "Special Committee of the Council of Ministers" from 1955 to 1957. As manager of the Soviet defense industry during that period, Ryabikov was the most important government official responsible for the genesis of the Sputnik satellite program. (files of Peter Gorin)

Little is known about Ryabikov's personality or allegiances, although it has been suggested that he was not a strong supporter of Korolev's plans.[17] While he may not have been as supportive as Ustinov, Ryabikov was clearly an improvement over the much more traditional Malyshev, with whom Korolev had many a spat. Ryabikov's supervision over the implementation of the missile program was facilitated by a number of deputies, including Georgiy N. Pashkov, a strict Party-line man, who, like Ryabikov, had a long history of involvement in the rocketry industry, both as a member of the Special Committee No. 2 and also in Gosplan, the

14. Col. Gen. (Ret.) Yu. V. Votintsev, "Unknown Troops of the Vanished Superpower" (English title), *Voyenno-istoricheskiy zhurnal* no. 8 (August 1993): 54–61.

15. For reasons that are still unclear, Ryabikov's role as chairman of the new Special Committee has gone almost entirely unmentioned in Soviet or Russian sources. Rare references can be found in Mozzhorin, *et al.*, eds., *Nachalo kosmicheskoy ery*, p. 164; Yu. P. Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya "Energiya" imeni S. P. Koroleva* (Korolev: RKK Energiya, 1996), pp. 79, 87. His standard biography usually refers to his role as a "committee chairman in the USSR Council of Ministers" from 1955 to 1957. See John McDonnell, "The Soviet Defense Industry as a Pressure Group," in Michael McGwire, Ken Booth, and John McDonnell, eds., *Soviet Naval Policy: Objectives and Constraints* (Halifax, NS: Centre for Foreign Policy Studies, 1975), p. 119. From 1953 to 1955, Ryabikov had successively served as the chief of GlavSpetsMash and GlavSpetsMontazh within the Ministry of Medium Machine Building, titles equivalent to a deputy minister in the ministry. See Kisunko, *Sekretnaya zona*, p. 276.

16. Barry, "The Missile Design Bureaux."

17. *Ibid.*

state economic planning organ. Ustinov, still the Minister of Defense Industries, which oversaw NII-88 during this period, continued to maintain very close relationships with Korolev and other chief designers. There is no evidence to suggest that there was any friction between Ustinov and Ryabikov once their positions were reversed. An extremely valuable ally for Korolev, Ustinov was crucial in shielding and protecting NII-88 from undesirable orders.

During the mid-1950s, Korolev also benefited from changes in the military—in particular, the transfer of the important NII-4 organization from the Academy of Artillery Sciences to the Fourth Directorate of the Chief Artillery Directorate, the latter being his primary client for missiles. Many military leaders saw this academy as a hostile environment, nurturing scientific dreamers such as Tikhonravov, but ironically it had become too ineffectual for Korolev's liking. After a tumultuous lifetime, the academy was eventually dissolved on April 23, 1953, and its subordinate NII-4, which included Tikhonravov's group, was transferred directly to the command of the Fourth Directorate, renamed the Directorate of the Deputy Commander of Artillery.[18] With direct access to a sympathetic directorate commander, Maj. General Andrey I. Sokolov, Tikhonravov was in a better position to reinforce the important work on artificial satellites carried out at NII-4. There was a minor reshuffle during 1954–55, when Sokolov was fired from his post because of a Party "witch-hunt," but the resourceful artillery general struggled his way back and was appointed to personally head NII-4 in late 1955.[19] An employee of NII-4 noted later that "in connection with Sokolov's [appointment] there was a sharp reinforcement of work on space themes" at the institute, adding that the relationship with NII-88 showed a significant improvement.[20] Furthermore, the number of people in Tikhonravov's satellite and launch vehicle group increased dramatically following the change in NII-4 leadership. Another change in favor of Korolev and Tikhonravov was the appointment of Marshal Nedelin in March 1955 to the new post of Deputy Minister of Defense for Special Armaments and Reactive Technology.[21] With a far more favorable attitude toward Korolev after the success of the R-5M, Nedelin was a key factor in Korolev's rise, given that the former had direct access to Khrushchev and the rest of the Presidium. Nedelin's new role was to direct the acquisition and integration of new armaments, including ballistic missiles, into the Soviet armed forces. If a satellite were to lift off from Soviet soil, it would be Nedelin who would allow the use of a missile for such a project.

All these changes, seemingly unrelated, each served to reinforce Korolev's standing in key areas. Without the support of these individuals, the first Soviet satellite would not have lifted off when it did. The dismissal of Malyshev, the new appointments of Ryabikov, Sokolov, and Nedelin, the transfer of NII-4, and most of all the success of the R-5M were pivotal events, which came at a very opportune moment in the history of the Soviet ballistic missile program. While a decision on a space satellite was still months away, the pieces in the puzzle were finally beginning to fall into place, as the fortunes of Korolev's group of engineers began to take a historic turn. The last and perhaps most important element of the picture, the ICBM, was already in design. The doors were beginning to open up.

18. Yu. A. Mozzhorin, *et al.*, eds., *Dorogi v kosmos: II* (Moscow: MAI, 1992), pp. 94–95. Note that Sergeyev, ed., *Khronika osnovnykh sobytiy istorii*, p. 6, states that the Directorate of the Deputy Commander of Artillery (UZKA) was formed on April 18, 1953.

19. *Ibid.*, pp. 97–98. UZKA was itself renamed the Directorate of the Chief of Reactive Armaments (UNRV) in March 1955 and was headed at the time by Maj. General A. I. Semenov, a veteran of the A-4 recovery effort in Germany after World War II.

20. *Ibid.*, pp. 95, 97–98.

21. Sergeyev, ed., *Khronika osnovnykh sobytiy istorii*, pp. 6–7.

Alternatives

The T1 and T2 directives from February 1953 sanctioned design work to create intercontinental ballistic and cruise missiles, both to be created at NII-88's OKB-1. Increasingly by late 1953, work on the T2 theme had begun to conflict with the heavy workload on ICBM development—that is, the T1 theme. Cruise missile development was effectively limited to the creation of the short-range experimental EKR vehicle, although it was understood that the EKR would lead directly to a full-scale intercontinental project. By the end of 1953, NII-88 had begun manufacturing various components of the EKR, while ground tests of OKB-670's ramjet engine were producing good results. A special commission formed to monitor the EKR program's progress, which included Academicians Keldysh and Khristianovich, recommended at the time that the research results from the EKR had been so positive that they should move directly to an intercontinental missile instead of building the interim missile.[22] Similar to the abandonment of the R-3 and the jump to an ICBM, it was the second time that Soviet engineers and scientists decided to forego an interim vehicle in favor of a direct leap to an intercontinental missile. Both Korolev and Keldysh were acutely aware that OKB-1 alone would not be able to handle both tasks, and after some "anguished discussions," Korolev decided to let go of the cruise missile option and have it transferred to other design bureaus, specifically ones in the aviation industry whose extensive experience in developing long-range bombers would come in handy.[23] For Korolev, this was in many ways the most visible manifestation that his thinking had irrevocably moved from winged missiles, his dream in the 1930s, to ballistic missiles as a means to explore the upper atmosphere and outer space.

Keldysh's NII-1 had retained overall scientific supervision over the intercontinental cruise missile program, but the actual engineering tasks were distributed to two aviation design bureaus, both of which would eventually become two of the most important organizations in the Soviet space program. Each would design and build its own intercontinental cruise missile, in effect competing against each other to deliver a working model to the Soviet armed forces. In a uniquely Soviet version of "competitive markets," it was not odd for two design bureaus to be assigned projects simultaneously—programs that were geared toward roughly the same requirements. Both proposals would often reach the point of flight testing under supervision of the primary client, the Ministry of Armed Forces (later the Ministry of Defense). Based on the results, the ministry would choose one for full-scale production and integration into the armed forces. The decision to adopt not only was, of course, based on the performance of the given systems in their testing regime, but also was often a function of the level of cordiality between the given chief designers and the Soviet leadership. Because failure for a design bureau could quite often mean the termination of its existence, engineers considered the development of high-stakes weapons such as cruise missiles very seriously.

The organization picked to produce the first cruise missile was the Experimental Design Bureau No. 301 (OKB-301), located at Khimki and headed by fifty-three-year-old Chief Designer Semyon A. Lavochkin, one of the most famous airplane designers in the Soviet Union. Established in July 1937, this design bureau had produced a number of fighter aircraft, such as the LaGG-3, La-5, La-5F, La-5FN, and La-7, which were used extensively during World War II. Later, Lavochkin led the development of several experimental jet aircraft, such as the La-160, the first Soviet aircraft with swept-back wings, and the La-176, the first Soviet aircraft to break the speed of sound. By the early 1950s, OKB-301 had branched out into missiles; its first

22. I. Afanasyev, "Without the Secret Stamp: Halt the Work, Destroy the Materials" (English title), *Aviatsiya i kosmonavtika* no. 6 (June 1993): 42–44.

23. Chertok, *Rakety i lyudi*, p. 290.

forays into the field included the V-300 missile for the Moscow air defense network, code-named Berkut, and the "201" ramjet-powered air-launched drone.[24]

The second aviation organization tapped was the Experimental Design Bureau No. 23 (OKB-23), a relatively new firm that had no prior experience in designing missiles. Instead, it was undertaking important work on long-range bomber design. In the spring of 1951, Stalin had called in Andrey A. Tupolev, the famous aviation patriarch and chief designer of the Moscow-based OKB-156, to discuss the future of strategic intercontinental bombers. When asked to start work on a long-range jet-powered bomber, the old airplane designer firmly refused, arguing that Soviet technology was insufficiently advanced to handle such a task. The furious Stalin took the matter elsewhere and assigned the job to Vladimir M. Myasishchev, a forty-eight-year-old aeronautical engineer who happened to be Tupolev's son-in-law. Myasishchev's achievements up to 1951 had been nothing to boast about. He had worked on various airplanes through World War II as a prisoner, first under Tupolev and later at the independent OKB-482, but none of them had been adopted for serial production. Perhaps seeing a chance to bring some "new blood" into strategic weapons development, Stalin signed an order on March 24, 1951, that gave Myasishchev a new organization, OKB-23, located at the legendary State Aviation Plant No. 23 in Fili. For his new team, the new chief designer gathered up more than 1,500 of the best Soviet aeronautical engineers from the Moscow Aviation Institute (TsAGI) and from his old prison days, transferring all of them to the Fili plant. Established on April 30, 1916, in the center of Moscow, this plant had originally produced automobiles but was restructured for aircraft production as early as 1927. The same plant is today known as the M. V. Khrunichev State Space Scientific-Production Center and is one of the primary participants in the creation of the International Space Station.[25]

Both the Lavochkin and Myasishchev intercontinental cruise missiles shared common features with Korolev's never-built EKR. Both vehicles were two-stage missiles. The first stages were powered by liquid propellant rocket engines, while the second stages were equipped with supersonic ramjets. The Lavochkin design, called the La-350 (or V-350), but better known by its nickname "Burya" (meaning "storm"), used a cluster of two long rocket boosters, which served as the first stage. One four-chamber S2.1100 engine (later replaced by the lighter S2.1150) was installed on each of these boosters, generating a total thrust of 137.22 tons at launch. This engine from the Isayev design bureau was almost identical to the engine used on the R-11 short-range tactical missile. The second cruise stage resembled a large aircraft with stubby swept wings at a 70-degree angle and conventional tail surfaces. The main ramjet was the RD-012U from the Bondaryuk design bureau. This engine had an average thrust of 7.65 to 7.75 tons. The missile was a little less than twenty meters long and had an overall mass of

24. For Lavochkin's early work, see A. N. Ponomarev, *Sovetskiye aviatsionnyye kosntruktory* (Moscow: Voyennoye izdatelstvo, 1990), pp. 183–91; G. P. Svishchev, ed., *Aviatsiya entsiklopediya* (Moscow: Bolshaya Rossiyskaya entsiklopediya, 1994), pp. 304–05. For the Berkut, see Anatoliy Pokrovskiy, "Three Episodes From the Life of Our ABM Defense: There Is No More 'Berkut': What Kind of Geese Will Save Moscow Now?" (English title), *Pravda*, February 3, 1993, p. 4; Votintsev, "Unknown Troops of a Vanished Superpower," pp. 54–61; S. M. Ganin, "The First National Anti-Aircraft System of the Moscow PVO—The S-25 'Berkut'" (English title), *Nevskiy bastion* no. 2 (February 1997): 25–32; Steven J. Zaloga, "Defending the Capitals: The First Generation of Soviet Strategic Air Defense Systems 1950–1960," *The Journal of Slavic Military Studies* 10 (December 1997): 30–43.

25. V. A. Fedotov, "The Scientific-Design Activities of V. M. Myasishchev" (English title), *Iz istorii aviatsii i kosmonavtiki* 50 (1984): 3–13; Ponomarev, *Sovetskiye aviatsionnyye kosntruktory*, p. 233; Zaloga, *Target America*, pp. 81–82; O. Shinkovich, "The Khrunichev Center—80 Years" (English title), *Novosti kosmonavtiki* no. 9 (April 22–May 5, 1996): 75–77; S. A. Zhiltsov, ed., *Gosudarstvennyy kosmicheskiy nauchno-proizvodstvennyy tsentr imeni M. V. Khrunicheva* (Moscow: RUSSLIT, 1997), pp. 12, 20. D. N. Osipov was director of the plant from 1952 to 1961. The Ministry of Aviation Industry order for the establishment of OKB-23 was dated May 26, 1951.

ninety-six tons. The La-350 would be capable of delivering a conventional atomic warhead with a mass of 2.19 tons over a maximum distance of 8,500 kilometers.[26]

The Myasishchev design, designated the M-40 or *Buran* (meaning "blizzard"), had a similar conceptual configuration as its competitor, with the second stage mounted above the first stage like a cluster. The M-40, however, had a different mission than the La-350; it would carry a *thermonuclear* warhead with a mass of three and a half tons (that is, it had a capacity about one and a half times greater than the Lavochkin design). The first stage of the M-40 consisted of a cluster of four booster rockets, each with a single nitric acid-kerosene engine from the Glushko design bureau. Glushko's concurrent work on the RD-211 engine using these same propellants for Yangel's R-12 intermediate range ballistic missile came in handy for work on the M-40. In 1953, Glushko began work on the RD-212, a modified variant of the RD-211, specifically for Myasishchev's new cruise missile. Testing of the original RD-211 in 1953, however, proved to be fraught with many setbacks. Ground testing of the RD-212 for the Buran was eventually never finished because of changes in the requirements for the cruise missile. In August 1956, Myasishchev's engineers recalculated the requirements for the first stage engine, calling for a 22-percent increase in thrust from their original specifications. Thus, Glushko began developing a third engine, the RD-213, to fulfill this requirement for the Buran. Using these engines, the first stage of the M-40 had a total thrust of 220 tons at liftoff. The second stage used a single Bondaryuk RD-018A ramjet with thrust of about ten and a half tons. One of Myasishchev's more original ideas was to use the M-40 as the basis for a rocket-plane—that is, one with a specially designed cockpit for a single pilot. The pilot would eject out of the vehicle prior to impact. The length of the overall vehicle was twenty-four meters, and the mass was 125 tons.[27]

The work on the cruise missiles was backed up by an immense investment in basic aeronautical research focused primarily at Keldysh's NII-1—remnants of the considerable efforts expended on the Sänger-Bredt bomber. Each missile had two-part guidance systems, one based on inertial guidance using gyroscopic platforms and double integrating accelerometers for the early stage of flight and the second based on a celestial navigation system that introduced constant corrections to the trajectory during the cruise phase. Scientists at NII-1 designed both systems. The latter was based on years of research at NII-88 under Izrael M. Lisovich, who perfected an operating system for use by both the Burya and Buran by 1953. The All-Union Institute for Aviation Materials (VIAM) and the N. E. Bauman Moscow Higher Technical School (MVTU) were tasked with the development of heat-resistant structural materials, such as titanium and high-strength stainless steel, which were indispensable for cruise missile operation, as well as the technology to weld them. The venerable TsAGI was responsible for setting the aerodynamic parameters for both missiles, in particular the delta wings and the vehicles' thin supersonic profiles. Although most Western accounts imply that Lavochkin and Myasishchev headed the programs, in truth Academician Keldysh served as the overall coordinator and manager for both of these important projects.[28]

26. V. Aslanov, "'Soviet Shuttle' of the 50s" (English title), *Apogey* 5 (June 1993): 1; Yakov M. Natenzon, "The First Cruise Missile 'Burya,'" *Space Bulletin* 1 (1993): 26–27; Boris V. Rauschenbach, "The 'Burya' Intercontinental Cruise Missile," presented at the 43rd Congress of the International Astronautical Federation, IAA-92-0187, Washington, DC, August 28–September 5, 1992; Afanasyev, "Without the Secret Stamp"; Christian Lardier, "70 Years of Soviet Ramjets," presented at the 48th Congress of the International Astronautical Federation, IAA-97-IAA.2.3.03, Turin, Italy, October 6–10, 1997; Yevgeniy Yerokhin, "The Missiles of Bondaryuk" (English title), *Krylia rodiny* no. 11 (November 1993): 33-37.

27. V. Petrakov and M. Chernyshov, "Without the Stamp 'Secret': The Unknown Buran" (English title), *Sovetskaya rossiya*, April 10, 1991, p. 4; Afanasyev, "Without the Secret Stamp"; Igor Afanasyev, *R-12: Sandalovoye derevo* (Moscow: EksPrint NV, 1997), p. 8; Lardier, "70 Years of Soviet Ramjets"; Yerokhin, "The Missiles of Bondaryuk."

28. Afanasyev, "Without the Secret Stamp"; Rauschenbach, "The 'Burya' Intercontinental Cruise Missile."

The cruise missile and ICBM options were two of three possible strategies for the Soviet search for an intercontinental nuclear delivery system. Given the existing technologies of the 1940s and 1950s, it would have been surprising if the Soviet government had not also been exploring the possibility of using long-range strategic bombers for reaching the contiguous United States. The first jet-engine bomber project for such a mission was Project 25, or "M," at Myasishchev's OKB-23. The aircraft flew its first mission as early as January 1953, less than two years after the program's initiation, and eventually emerged into the modified M-4 Molot bomber, better known by its NATO code-name "Bison-A." Although the bomber entered limited production by late 1955, its operational characteristics (primarily range) fell far short of air force requirements and, in fact, engendered widespread disenchantment among the military. A backup option was "Type 95," developed by Tupolev at OKB-156, which used turboprop instead of jet engines. The project was approved at the same time as Myasishchev's Project 25. When the airplane was accepted for service in August 1957 as the Tu-95, it was full of problems. It would not be until the late 1950s when the modified Tu-95M fulfilled its original long-range requirements, by which time the slow-moving aircraft was already vulnerable to a host of American air defense weaponry.[29] By the mid-1950s, the bomber option began to face serious competition as an effective intercontinental weapons delivery system. The overwhelming advantages of missiles and the unprecedented breakthroughs in rocket propulsion technology in the early 1950s threatened to make bombers a memory of a bygone era. There was no more apt a symbol of this change in generations than the world's first ICBM, Korolev's R-7.

The R-7 ICBM

Original conceptions of the first Soviet ICBM as part of the T1 theme described a missile with a launch mass of approximately 170 to 200 tons that was capable of delivering a nuclear explosive weighing three tons over a distance of 8,500 kilometers.[30] This was compared to the warhead used on the R-5M that was just over one ton. These specifications dramatically changed as a result of developments in the nuclear weapons sector. On August 12, 1953, the Soviet Union exploded its first thermonuclear device at Semipalatinsk, with a power twenty times more than its first atomic bomb.[31] The original ICBM specifications had been set based on earlier atomic bombs, but later, the Soviet leadership was eager to use a thermonuclear device on the missile. As early as May 1953, there had been preliminary discussions on using the hydrogen bomb (H-bomb) on the ICBM, but a cementing of this position did not occur until later in the year. Andrey D. Sakharov, the brilliant physicist at KB-11, played an unusual and critical role in the requirements for the ICBM. In late 1953, Minister of Medium Machine Building Malyshev had asked Sakharov to write a brief report on the "conception of a second generation [thermonuclear] device."[32] Under pressure and in a hurry, Sakharov was in a difficult position. He later recalled:

29. Bill Gunston, *The Osprey Encyclopedia of Russian Aircraft: 1875–1995* (London: Osprey Aerospace, 1996), pp. 257–58, 424–25; Zaloga, *Target America*, pp. 81–88.

30. Kantemirov, "The History of the Selection of the Design"; Timothy Varfolomeyev, "Soviet Rocketry that Conquered Space: Part 1: From First ICBM to Sputnik Launcher," *Spaceflight* 37 (August 1995): 260–63.

31. David Holloway, *Stalin and the Bomb* (New Haven, CT: Yale University Press, 1994), pp. 306–07. There has been some disagreement on whether this particular test was a true hydrogen bomb or merely a "boosted fission" weapon, but the Soviets themselves clearly viewed the test as a hydrogen bomb. As Holloway states, "It is, to some degree, a matter of taste whether one calls it a thermonuclear weapon or a boosted weapon."

32. Sakharov, *Memoirs*, p. 180; Lardier, *L'Astronautique Soviétique*, p. 90.

I should have refused, pointing out that such things could not be decided in haste by a single scientist: they require more serious deliberation. But I had an idea which at the moment seemed promising (it later turned out to be neither very original nor successful). I had no one with whom to consult. I nevertheless wrote a report on the spot and gave it to Malyshev.[33]

Based on Sakharov's report, Malyshev had the basic parameters for the mass and volume constraints for a next-generation thermonuclear payload. Armed with this information, he soon arranged a meeting at NII-88's OKB-1 in October 1953 to discuss "future work," arriving alone without any assistants. Malyshev was unusually cheerful and animated during the meeting, which was attended by Korolev's inner circle, including his First Deputy Mishin. The engineers were quick to suspect that everything was not well. Malyshev casually inquired about the lifting capability of the ICBM, to which Sergey S. Kryukov, one of its designers, announced "about 3 tons." Malyshev firmly replied that the rocket must be able to lift six tons, at the very least five.[34] There was a brief moment of resistance from Korolev, but Malyshev would hear none of it. Later, Kryukov firmly told Korolev that this would simply not be possible given the current design of the missile. In the end, of course, the rocketry engineers capitulated, and they began a total overhaul of the design.

The new chairman of the Council of Ministers, Malenkov, sealed the decision to increase the payload at two meetings of the Presidium in late November 1953. The first one was attended not only by all the members of the Presidium, but also the key nuclear weapons scientists, including Sakharov. At this meeting, the attendees adopted an official Central Committee resolution to develop and explode Sakharov's new device by 1955. The second meeting was attended by missile administrators (most likely Ustinov, Ryabikov, and Pashkov) and set the specifications for the new ICBM so that it could carry Sakharov's thermonuclear device. Based on Malyshev's advice, Malenkov set the payload mass capability of the new vehicle between just over five and a half and six tons. In an ironic epilogue to the redesign, the new Sakharov bomb was never built and was replaced by a concept that was completely different.[35] However, Sakharov's quick and hasty report significantly influenced the design of the world's first ICBM—a rocket that in its modern variants continued to loft Russian cosmonauts to the *Mir* space station into the late 1990s.

Work on the revised draft plan for the ICBM, by then named the R-7, or "product 8K71," began in the fall of 1953, culminating in a major meeting in January 1954 attended by all the major chief and deputy chief designers to discuss the changes in the missile.[36] The biggest challenge for Korolev's engineers was how to improve the lifting characteristics of the missile without any major changes in layout, which might delay the program even further. The most important factor was clearly propulsion. Preliminary calculations showed that Glushko's single-chamber LOX-kerosene RD-105 and RD-106 engines with thrust ranges of fifty to sixty tons would prove inadequate for the task of lifting a five-and-a-half-ton payload. The engines themselves were performing poorly during ground tests at OKB-456 because of burning instabilities

33. Sakharov, *Memoirs*, p. 180.

34. Golovanov, *Korolev*, pp. 473–74.

35. Sakharov, *Memoirs*, pp. 180–81; Lardier, *L'Astronautique Soviétique*, p. 90; Kantemirov, "The History of the Selection of the Design."

36. Mozzhorin, *et al.*, eds., *Nachalo kosmicheskoy ery*, p. 71. The chief designers included S. P. Korolev (NII-88 OKB-1), V. P. Barmin (GSKB SpetsMash), V. P. Glushko (OKB-456), B. M. Konoplev (NII-885), V. I. Kuznetsov (NII-10), and N. A. Pilyugin (NII-885). The deputy chief designers included M. I. Borisenko (NII-885), K. D. Bushuyev (NII-88 OKB-1), S. S. Kryukov (NII-88 OKB-1), and V. P. Mishin (NII-88 OKB-1). See Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p. 73.

in the combustion chambers, which led to high-frequency vibrations. Glushko's introduction of ribbed combustion chamber walls for cooling helped alleviate heating problems, but the engines had reached the physical upper limits of thrust. A way out of this quandary was offered by yet another idea tested by Chief Designer Isayev at NII-88. Using a single-chamber forty-ton-thrust engine, he had recently built and tested a multichamber engine that provided a cumulative thrust much higher than its single component. With Isayev's results in hand, Glushko could combine four combustion chambers together, all fed by the same turbopump. Although the unstable burning problem remained, its effects were drastically reduced because of the low thrust of each chamber. The advantages were numerous. Not only were performance values improved, but there also were considerable savings in engine mass compared to the thrust levels achieved. Furthermore, given that the chambers were identical, research and development, construction, and testing were simplified to a great extent. The engines that emerged from this redesign were the RD-107 and RD-108. One of each of the former, with a sea-level thrust of eighty-three tons, would be installed on the four lateral strap-ons. A single RD-108 with a sea-level thrust of seventy-five tons was earmarked for the central core. In March 1954, Glushko named Yuriy D. Solovyev, an engineer at his design bureau, to lead the design and construction of these engines.[37]

A second redesign was related to the problem of steering during flight after the strap-ons had been discarded. The engineers had originally settled on using graphite steering rudders, such as those used on early missiles (for example, the German A-4), but further research proved that not only would they not tolerate high velocities and temperatures for long periods of time, they would deleteriously affect the configuration at the base of the missile. Korolev's First Deputy Mishin suggested the use of small steering engines firing off their own combustion chambers, which would be integrated into the main engines and use propellants diverted from the main turbopumps. Korolev had invited Glushko to develop these engines, but he refused outright, not only fearful of being diverted from his primary work on the main engines, but also because he believed that "it would be impossible to control a rocket by such thrusters."[38] Mishin instead facilitated the transfer of a group of young engineers led by Mikhail V. Melnikov from Keldysh's NII-1 to OKB-1 for this project. Mishin's enthusiasm for the idea eventually resulted in the use of steering thrusters on not only the central block, but the four lateral blocks as well. Each lateral block had two verniers, while the central block had four, each with a thrust of two and a half tons, bringing the total number of combustion chambers firing at liftoff to thirty-two. In later years, when these vernier thrusters performed flawlessly, Glushko apparently asked Korolev if he could take over production of the motors. Not only did Korolev allow this, but he did not mind when Glushko changed his thinking and began building the verniers himself, taking full credit for their early development.[39] These vernier engines had a remarkable history. They were used as the basis for upper stage engines for the Vostok, Soyuz, Molniya, N1, and Proton launch vehicles.

The development of an effective guidance system for the R-7 was a major problem for engineers. Because the missile would fly over a larger distance than any previous vehicle, an iner-

37. Peter Stache, *Soviet Rockets*, Foreign Technology Division Translation, FTD-ID(RS)T-0619-88 (from unnamed source), Wright-Patterson Air Force Base, Ohio, November 29, 1988, pp. 299–302. This is a translation of Peter Stache, *Sowjetischer Raketen* (Berlin: Militarverlad der DDR, 1987). Also see Varfolomeyev, "Soviet Rocketry that Conquered Space: Part 1"; A. Yu. Ishlinskiy, ed., *Akademik S. P. Korolev: uchenyy, inzhener, chelovek* (Moscow: Nauka, 1986), p. 270; V. P. Mishin, "Problems of the First Flight of a Man into Space" (English title), in *Gagarinskiye nauchnyye chteniya po kosmonavtike i aviatsii* (Moscow: Nauka, 1991), p. 21.

38. Vasiliy P. Mishin, ". . . He Said, 'Here We Go!'" (English title), *Aviatsiya i kosmonavtika* no. 4 (April 1991): 13–14; Chertok, *Rakety i lyudi*, pp. 394–95; Ishlinskiy, ed., *Akademik S. P. Korolev*, pp. 208–09.

39. Mozzhorin, *et al.*, eds., *Nachalo kosmicheskoy ery*, p. 79. Korolev drew up the production instructions for the vernier thrusters on August 7, 1954. See Biryukov, "Materials from the Biographical Chronicles," p. 233.

tial guidance system such as that installed on the German A-4 would be woefully inadequate because of gross inaccuracies symptomatic of the technology of the time. Korolev proposed the development of both radio and autonomous guidance systems for the first ICBM.[40] Eventually, the system chosen was a combination of both. After liftoff, a complex set of inertial guidance systems would maintain angular stability, apparent velocity, and synchronization of propellant consumption at nominal levels. At about twenty to thirty seconds prior to core engine cutoff, the four small verniers on the central block would be fired into operation, after which the radio control system would be switched on to manually control deviations from the desired trajectory.[41] Both guidance systems were developed by NII-885—the radio-controlled portions led by Chief Designer Ryazanskiy and the inertial part led by Chief Designer Pilyugin. The development of precisely calibrated gyroscopes for the instrumentation was the responsibility of Chief Designer Kuznetsov of NII-10. All three were original members of the Council of Chief Designers.

The missile itself looked unlike anything created before. At launch, the four conical strap-ons (Bloks B, V, G and D), each just over nineteen meters in length, surrounded the center hammerhead-shaped core (Blok A), itself 26 meters long. The lateral boosters, each containing about forty tons of propellant, tapered up to a point at the top and were connected by ball-and-socket joints to the core at the apex and secured by tension bands at the bottom. With the four strap-ons, the total base diameter was more than ten meters, and the total length of the missile was thirty-three meters. The launch mass was 270 tons, of which about 247 tons was propellant. At liftoff, the total thrust was 398 tons. After launch, at an altitude of fifty kilometers and about 100 kilometers from the launch site, shortly prior to propellant cutoff, pyrotechnical devices would loosen the tension bands at the base of the vehicle, which connected the four exterior blocks to the core. With the four strap-ons still firing, albeit at much lower thrust by then, the lateral blocks would by their natural force move away from the central block, rotating upwards and away from the base. At a certain angle, the mountings at the apex of the four blocks would automatically release. Oxygen valves would also automatically open to exert gentle pressure on the strap-ons to move them independently away from the core. The core stage (called the second stage by the Soviets) would continue to operate until reaching an altitude of 170 kilometers and a range of 700 kilometers, at which point engine cutoff would occur. For the remaining portion of the flight, the payload would coast on a ballistic trajectory until reentry.[42]

One of the most expensive and time-consuming aspects in the development of the R-7 was the design of a launch structure to accommodate the unwieldy looking missile. Originally, the plan was to assemble the missile at the launch pad in a vertical position. At least three preliminary designs for the launch pad, based on this option, were prepared between September and December 1954.[43] All three plans used a single load-carrying platform with four circumferential and central supports for the five boosters on the missile, restrained by a variety of weights, levers, and spring mechanisms. All the plans, however, proved unwieldy because of concerns about damaging the missile itself at takeoff. It was at this point that Mishin emerged with an original idea for a launch pad. The conception involved assembling the booster horizontally in a hangar and then transporting the rocket to the launch pad, where it would be raised into a vertical position. At the pad, the R-7 would be suspended at "the waist" above its center of

40. Mozzhorin, *et al.*, eds., *Nachalo kosmicheskoy ery*, p. 282.

41. Varfolomeyev, "Soviet Rocketry that Conquered Space: Part 1"; Zaloga, *Target America*, p. 141; B. Pokrovskiy, "Chief Designer of Radio Control Systems" (English title), *Krylia rodiny* no. 4 (April 1989): 44–45.

42. Stache, *Soviet Rockets*, pp. 296–98, 307; Mozzhorin, *et al.*, eds., *Nachalo kosmicheskoy ery*, p. 74; G. A. Kustova, ed., *Ot pervogo Sputnika do "Energii"-"Burana" i "Mira"* (Kaliningrad: RKK Energiya, 1994), p. 35. OKB-1 engineer S. P. Parmuzin invented the ingenious separation mechanism for the exterior blocks of the R-7.

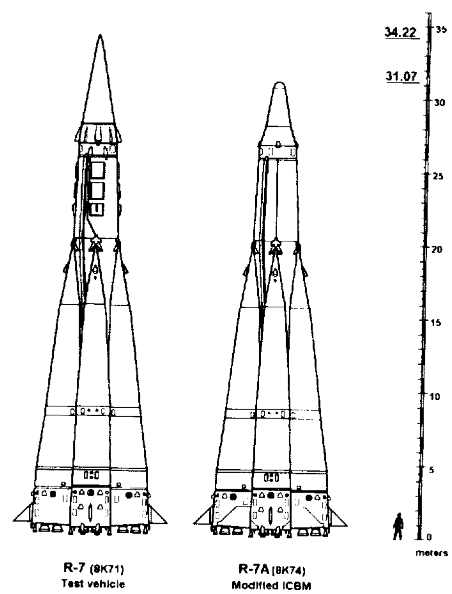
43. Mozzhorin, *et al.*, eds., *Nachalo kosmicheskoy ery*, pp. 116–17.

gravity, about twenty meters from the base, by four identical and huge "petals." Chief Designer Barmin, who was responsible for the design of launch complexes, later recalled:

> *The heavy rocket "hangs" on them [the "petals"] until its engines go into primary thrust mode. And then they pull away to the side simultaneously, and the gas blasts from all the operating engines exit in one large opening and escape the steppe through a special concrete conduit.*[44]

The petals would swing into motion not by any external hydraulic power, but by an ingenious system of counterbalanced weights that worked because of gravity. The engineers nicknamed the system *Tyulpan* ("tulip") because of the peeling nature of the petals at launch time. Each of the petals would contain work gantries and other systems required to fuel and test the rocket prior to launch. In late 1955, a commission headed by Academician Blagonravov, a mechanical engineer himself, reviewed this revolutionary idea. While generally supportive of the idea, the commission recommended that the system could be improved by making the petaled swing gantries work on hydraulics rather than by gravity. Korolev also weighed in with the nongravitational option. Barmin did not budge from his position, arguing that there was no redundancy required for "God's powers." Korolev eventually gave in, but he added that "should anything go wrong, you will be liable with your life."[45] On September 22, 1955, the commission approved the launch pad complex for full-scale construction led by Barmin's GSKB SpetsMash organization.[46] Korolev did not need to have had any doubts. For more than forty years, Mishin's original conception has serviced the space program; it was from the same type of launch pad that cosmonauts flew to the *Mir* space station from 1986 to 1999.

In February 1954, the primary participants of the work on the R-7 finally agreed to the revised conception of the ICBM, clearing the way for governmental intervention. On May 20, 1954, the USSR Council of Ministers issued an official decree calling for the development of the two-stage 8K71 R-7 ICBM. A second decree a month later on June 28 added clarifications to the schedule for the development of the rocket. Finally, by order of Minister of Defense Industries Ustinov on July 6, the Soviet government elevated the development of the ICBM to a level of "state importance."[47] The same



The Soviet R-7 ICBM. The left diagram is the original variant of the missile, the 8K71, as it was flown in 1957. The later operational version, the R-7A or 8K74, is shown on the right. (copyright Peter Gorin)

44. B. Konovalov, "Lessons of the First Satellite" (English title), *Izvestiya*, September 29, 1987, p. 3

45. Boris Khlebnikov, "Vladimir Barmin: One of the Top Six Designers," *Aerospace Journal* no. 2 (March–April 1997): 81–83; Mozzhorin, *et al.*, eds., *Nachalo kosmicheskoy ery*, p. 117.

46. Mozzhorin, *et al.*, eds., *Nachalo kosmicheskoy ery*, p. 117.

47. Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p. 74; Sergeyev, ed., *Khronika osnovnykh sobytiy istorii*, p. 35; Golovanov, *Korolev*, p. 475; "TsNIIMash—One of the Leading Space Branches" (English title), *Novosti kosmonavtiki* no. 6 (March 15–28, 1993): 26–28. Note that in the last source, the missile is referred to as the R-6 and not the R-7.

month, on July 24, NII-88's OKB-1 completed the draft plan for the rocket, which spanned a total of fifteen volumes of technical documentation. Unwilling to commit to something that might prove to be a colossal waste of money, the Soviet government established an "Expert Commission" of independent scientists and engineers to study the draft plan and recommend a course of action. Headed by Academician Keldysh, this commission consisted of aeronautical engineers, mathematicians, gas dynamics specialists, propulsion experts, and military officers. Their evaluations were overwhelmingly positive, clearing the way for full-scale industrial work on the ICBM. On November 20, 1954, in an unusual move, the USSR Council of Ministers officially approved the draft plan for the R-7 missile—a decision that normally would have been left in the hands of engineers or scientists.[48]

The individuals who worked on the R-7 began to affectionately call the missile *semerka*, the Russian expression roughly equivalent to "old number seven," and it was a nickname that has remained with the vehicle for more than forty years. Although all of the leading engineers at NII-88's OKB-1, such as Bushuyev, Voskresenskiy, Okhapkin, Chertok, and Kryukov, were involved in its design, it was perhaps Mishin more than any other individual who shaped its look. Many years later, when a noted Soviet journalist asked numerous veterans of the organization who besides Korolev contributed more to the emergence of the R-7, most replied, "This was, of course, Mishin's rocket."[49] Once the documentation and design had been completed, Korolev assigned one of his middle-level engineers, thirty-five-year-old Dmitriy I. Kozlov, the man who had encouraged Korolev to join the Communist Party a few years earlier, to oversee its creation as the "lead designer" of the missile.[50] Kozlov had already served in the same capacity for the R-5 missile. A total of 200 institutes and design bureaus within twenty-five ministries were engaged in the project, which, save for the development of nuclear weapons, was perhaps the largest military project undertaken in the Soviet Union up to that point.

The May 1954 decree also specified at least two other items. The first was the official assignment to develop intercontinental winged cruise missiles to design bureaus within the Ministry of Aviation Industry. Lavochkin's OKB-301 would design and develop the La-350 Burya, while Myasishchev's OKB-23 would do the same for the M-40 Buran. Finally, the decree called for the selection of a new firing range for the R-7 ICBM.[51]

At the outset, the planners realized that the location and facilities at the State Central Range No. 4 at Kapustin Yar would be inadequate for the mammoth requirements of the new rocket. A major concern was the proximity of the Kapustin Yar site to radar stations operated by U.S. intelligence services in Turkey. In late 1953, Ustinov, Nedelin, Korolev, and other leaders of the rocketry industry had authored a letter to the USSR Council of Ministers containing the requirements for such a site. The following year, Nedelin appointed Maj. General Vasiliy I. Voznyuk, the commander of Kapustin Yar, to head a special commission to select an

48. M. V. Keldysh, ed., *Tvorcheskoye naslediye Akademika Sergeya Pavlovicha Koroleva: izbrannyye trudy i dokumenty* (Moscow: Nauka, 1980), p. 398; Golovanov, *Korolev*, p. 475; Biryukov, "Materials from the Biographical Chronicles," p. 233; Yu. V. Biryukov and A. A. Yeremenko, "50 Years for the Native Rocket-Space Industry. The Early Period of Development" (English title), *Novosti kosmonavtiki* no. 10 (May 6–19, 1996): 54–64; Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p. 75. The individuals on the R-7 "Expert Commission" included M. V. Keldysh (NII-1), A. A. Dorodnitsyn (TsAGI), S. A. Lavochkin (OKB-301), A. M. Lyulka (OKB-165), A. I. Makarevskiy (TsAGI), A. G. Mrykin (UZKA), B. N. Petrov (Institute of Control Problems AN SSSR), Kh. A. Rakhmatulin (MVTU), N. N. Smirnitskiy (GURVO), B. S. Stechkin (OKB-300), G. A. Tyulin (NII-4), and A. P. Vanichev.

49. Golovanov, *Korolev*, p. 502.

50. Aleksandr Romanov, *Korolev* (Moscow: Molodaya gvardiya, 1996), pp. 257–58, 272; V. Drebkova, "General Designer D. I. Kozlov—75 Years" (English title), *Novosti kosmonavtiki* no. 20 (September 24–October 7, 1994): 56.

51. Afanasyev, "Without the Secret Stamp"; Jacques Villain, ed., *Baïkonour: la porte des étoiles* (Paris: Armand Colin, 1994), p. 47.

alternative launch site. Perhaps to draw out an impartial verdict, Nedelin told Voznyuk that "you'll be the chief of the new test range, so make the selection to suit yourself."[52] Chief Designers Korolev, Barmin, and Ryazanskiy were the leading engineering representatives on the commission. Barmin was to advise on launch complex requirements, and Ryazanskiy was on hand to make recommendations on the placement of radio stations to control the R-7. Tikhonravov's team at NII-4 also provided supplementary data for the selection. At the end of the year, the Voznyuk commission emerged with three competitive sites:

- A location in the Yochkar-Orla region in Mordoviya (in the Mari region), where there were large clear spaces and room for more because of a vigorous lumber industry
- A location near Makhachkala (in Dagestan) on the shores of the Caspian Sea so discarded lower stages could fall into the sea
- The semi-arid Kzyl-Orda region (in the Kazakhstan Soviet Socialist Republic) near the Syr Darya River[53]

One of the major requirements for the new site was that radio tracking stations be located on either side of the ICBM's trajectory, and this specification eventually eliminated the first two choices, leaving the Kazakhstan site, which was formally selected by USSR Minister of Defense Georgiy K. Zhukov. Ironically, by the time that the Voznyuk commission finally decided on the site, the criterion for radio station placement, which had supported the Kazakhstan choice, was invalidated by some ground-breaking work by Chief Designers Ryazanskiy and Konoplev. The members of the commission were apparently too afraid of Zhukov to inform him that the reason for selecting Kazakhstan had been neutralized.[54] In the end, the commission touted six major advantages of the new site:

- It was far enough from Soviet borders to conduct work in secret.
- The weather was acceptable for launches during at least 300 days of the year.
- The presence of vast areas of desert nearby was useful for dropping stages.
- Radio guidance for the R-7 could be conducted by two stations, which could be constructed 500 kilometers from the launch pad.
- The site was on the railway line between Moscow and Tashkent on the Syr-Darya River for bringing materials to the range.
- The site had the advantage of being located close to the equator, thus imparting the highest possible velocity to airborne payloads.[55]

Marshal Nedelin assigned the mammoth task of directing the design, layout, and construction of the new launch range to the Chief Directorate of Special Construction of the USSR

52. Mozzhorin, *et al.*, eds., *Nachalo kosmicheskoy ery*, p. 129; Romanov, *Korolev*, p. 248. The actual Council of Ministers decree for the selection of a launch range was issued on March 17, 1954. The selection commission was obliged to report on its decision by January 1, 1955. See K. V. Gerchik, ed., *Nezabyvayemyy Baykonur* (Moscow: Interregional Council of Veterans of the Baykonur Cosmodrome, 1998), pp. 21–22.

53. Konovalov, "Lessons of the First Satellite"; Golovanov, *Korolev*, pp. 481–82; Mozzhorin, *et al.*, eds., *Dorogi v kosmos: I*, 175–76; Mozzhorin, *et al.*, eds., *Nachalo kosmicheskoy ery*, pp. 56–57. There may also have been a fourth final choice, the village of Kharabol in the Astrakhan region. See Chertok, *Rakety i lyudi*, p. 407. For a mention of Tikhonravov's contribution to the selection of the launch range, see I. K. Bazhinov, "The Activities of M. K. Tikhonravov in 1950–1956 in the Sphere of Researching the Basic Problems of the Creation of ISZs" (English title), *Iz istorii aviatsii i kosmonavtiki* 42 (1980): 39–45.

54. Mozzhorin, *et al.*, eds., *Nachalo kosmicheskoy ery*, p. 76.

55. Jacques Villain, "A Brief History of Baikonur," presented at the 45th Congress of the International Astronautical Federation, IAA-94-IAA.2.1.614, Jerusalem, Israel, October 9–14, 1994; Villain, ed., *Baïkonour*, p. 46.

Ministry of Defense. The primary task of coordinating the entire effort fell on the shoulders of a fifty-one-year-old colonel named Georgiy M. Shubnikov. For architectural and structural expertise, the Central Planning Institute No. 31 of the Ministry of Defense established a group under the tutelage of army Lt. Colonel Aleksey A. Nitochkin, who, like Shubnikov, was a veteran of World War II when he had helped build military fortifications.[56] It was these two individuals who perhaps contributed more than anyone else in bringing the project to fruition during the ensuing two years.

The USSR Council of Ministers signed a decree (no. 292-181), dated February 12, 1955, that officially sanctioned the creation of a new launch range for the R-7 ICBM and subsequent generations of new missiles in Kazakhstan. The decree authorized 586 soldiers and 325 blue- and white-collar employees to be initially assigned to the test area, officially designated the Scientific-Research and Testing Range No. 5 (NIIP-5). The first group of thirty blue-collar workers, led by a twenty-three-year-old lieutenant in the Soviet army, Igor I. Denezhkin, had already arrived at the projected site exactly a month earlier, on January 12, to prepare for actual construction workers.[57] Marshal Nedelin had an unusual choice for the commander of NIIP-5. He was a man who had crossed Korolev's path in the early 1950s by authoring a letter critical of the early ballistic missile effort to Beriya himself. Maj. General Aleksey I. Nesterenko, at the time forty-eight years old, had been fired as director of NII-4 in 1950 and spent the next four years as a head of the "rocketry faculty" at the F. E. Dzherzhinskiy Military Academy in Moscow. Perhaps his appointment was a not so subtle move to have a range commander who would not capitulate in the face of Korolev's juggernaut personality.

Nesterenko arrived at NIIP-5 three months after his formal appointment on March 19, 1955, in the company of Nedelin himself. His first impressions of the place were not encouraging:

> *We flew into Dzhusaly, disembarked from the aircraft, and were instantly buffeted by a hot wind, and with the temperature above 45 degrees [Centigrade] it was like walking into a blazing furnace. When we arrived at the construction site, our hearts sank: there was nothing but naked steppe, not a tree in sight, with only piles of sand and an assortment of animals scattered across the countryside.*[58]

As inhospitable as Kapustin Yar was, those who transferred to NIIP-5 from the former test range must have wondered whether they were not leaving one part of hell for another. The closest town to the site was named Tyura-Tam, a small settlement of local Kazakhs, which prior to 1955 was "a couple of two-story houses for the railwaymen, a couple of dozen small mud-plastered houses, and the tents of geologists prospecting for oil."[59] Tyura-Tam itself was an isolated railway stop on the important Moscow-Tashkent line; earlier in the century, a British mining company had apparently ran a station not far northeast of the town. The tsars had also used the location as a place of exile for undesirable citizens. In the late nineteenth century, Nikifor Nikitin was banished here for "his seditious plans for a flight to the Moon." The judge

56. Mozzhorin, *et al.*, eds., *Nachalo kosmicheskoy ery*, pp. 177–79; Golovanov, *Korolev*, pp. 482–85. The directorate's chief engineer at the time was Lt. General M. G. Grigorenko.

57. M. Rebrov, "Chief of the Cosmodrome: The Time Has Come to Tell" (English title), *Krasnaya zvezda*, September 18, 1990, p. 2; Yu. P. Maksimov, ed., *Raketnyye voyska strategicheskogo naznacheniya: voyenno-istoricheskiy trud* (Moscow: RVSN, 1992), p. 42; Ivan Borisenko and Alexander Romanov, *Where All Roads into Space Begin* (Moscow: Progress Publishers, 1982), p. 14; Council of Veterans of the Baykonur Cosmodrome, *Proryv v kosmos: ocherki ob ispitatelyakh spetsialistakh i stroitelyakh kosmodroma Baykonur* (Moscow: TOO Veles, 1994), p. 5; Villain, ed., *Baïkonour*, p. 48.

58. Mozzhorin, *et al.*, eds., *Nachalo kosmicheskoy ery*, p. 146.

59. Borisenko and Romanov, *Where All Roads into Space Begin*, p. 33.

apparently believed that work in the local copper mines would knock some sense into the hapless individual.[60]

Shubnikov, the chief engineer for the construction project, arrived at Tyura-Tam on March 5 with a host of important individuals, including a "political commissar." The first cubic meter of concrete was poured in April in support of building a highway from the initial troop settlement to the location of the actual launch pad. Finally, on May 5, 1955, the foundation stone was set at the living settlement at site 10, henceforth called Zarya, following which Shubnikov gave a short inspirational speech to the attendant workers and soldiers on the hard work still to be done within the following two years. A General Staff directive dated June 2 from the Ministry of Defense called for the formation of a complex organizational structure at NIIP-5, and it is this date that was henceforth commemorated as the birthday of the launch site.[61]

Under the coordination of Shubnikov, Nitochkin, Nesterenko, and Chief Designer Barmin, construction at NIIP-5 was facilitated at an unusually accelerated pace. The first concrete houses at Zarya were finished by September 1955. At the time, a twenty-kilometer-long road due north from Zarya was marked out, which led to the actual location of the projected launch pad of the R-7 ICBM. The area was named site 1, a designation that it still holds to this day. The actual location of the launch pad was determined by Nedelin's requirement that the facility be located within thirty kilometers of the residential area, but out of visual range of any passing trains.[62] A network of railway lines, which connected the major areas of the range, primarily to transport supplies and the rocket itself, was completed by early November. This work was by no means easy. As one veteran recalled many years later:

> *All the desert offered was a thin layer of clay which disintegrated into dust after a lorry had passed over it a couple of times. Deep dust-filled ruts were formed. The lorries would grind to a halt in them, often scratching their chassis. A thick cloud of dust hung all over the area, filling nose, eyes and ears. Cars crawled at a snail's pace. The dust permeated food, bread and petrol and . . . a cloud could be seen from a distance of 20 to 30 kilometers.*[63]

As at Kapustin Yar, the workers once again had to face a wide range of unpleasant temperatures. Although construction was started in mid-1955 to take advantage of the long summers, by the end of the year, the workers were treated to the reality of minus forty-two degrees Centigrade temperatures with winds of cyclone forces. Work in fact had to be abandoned on December 26 on a particularly harsh night, significantly delaying construction efforts. When the work resumed, it was primarily on a system of water pipes in preparation for building the actual launch pad in 1956.

Although workers began initial construction of the foundation of the launch complex in August 1955, the pad was not the primary focus of the work at NIIP-5 until early 1956. Between January and March of that year, about 15,000 cubic meters of earth were displaced per day at site 1. This was in preparation for pouring concrete for the giant launch pad structure, which began on April 19 an hour before midnight in front of about 300 people who were present to witness the event.[64] The 250-by-100-by-forty-five-meter launch platform took almost five

60. *Ibid.*, p. 32. The account of Nikitin's sentence was printed in an issue of *Moskovskiye gubernskiye novosti* (*Moscow Provincial News*) in 1878.

61. Villain, ed., *Baïkonour*, pp. 48–49; Borisenko and Romanov, *Where All Roads into Space Begin*, pp. 14–17; Stache, *Soviet Rockets*, pp. 310–11; Council of Veterans of the Baykonur Cosmodrome, *Proryv v kosmos*, p. 89. In official documentation, Zarya was named Tashkent-50, no doubt to disguise its real location.

62. Lardier, *L'Astronautique Soviétique*, p. 91; Mozzhorin, *et al.*, eds., *Nachalo kosmicheskoy ery*, p. 132.

63. Borisenko and Romanov, *Where All Roads into Space Begin*, p. 33.

64. *Ibid.*, p. 58; Villain, ed., *Baïkonour*, pp. 53–54; Lardier, *L'Astronautique Soviétique*, p. 91.

months to complete and used 30,000 cubic meters of concrete. Finally, on October 5, the workers completed the road and railway system from Zarya to site 1.

The engineers responsible for the design and construction of the launch pad were remarkably cautious in their efforts, and prior to work at Tyura-Tam, they had expended a huge amount of effort to duplicate the entire structure at a plant in Leningrad to eliminate any potential defects. Every single element of the launch pad was constructed and assembled over a nineteen-meter-diameter pit in a special building at the Leningrad Metallurgical Plant, and a full-scale test version of the R-7 was installed in the facility and loaded with water instead of propellant to simulate the expected loads.[65] Not only was the missile tested for potential wind effects, but a special lifting beam was used to raise the 100-ton rocket off the "launch pad" at the plant to simulate a liftoff and observe the dynamics of the launch. Yevgeniy V. Shabarov and Anatoliy P. Abramov, two engineers from OKB-1 in their mid-thirties, were tasked by Korolev to head the work at the plant, although, as was usual for Korolev, he kept close tabs on the work with daily reports. Notorious for exploding into rages of censure, Korolev did not spare any effort to make sure that the work remained on schedule. As Abramov wrote years later:

> *Once we reported that a mistake had been committed on the job . . . he [Korolev] reacted furiously, verbally ground us into dust, called us imbeciles, and promised to have us dismissed. At first we were upset, but then we began to laugh hysterically to release our pent-up stress. It was not the first time that this had happened. Korolev's diatribes were the stuff of legend, and he was a master at it; his eyes would flash, his words would destroy yours, he would threaten to send you home walking between the railway tracks, tell you to go work at the boiler shop or at the "wood-mill." But we all knew that these were just words. Nobody was dismissed, and no one took offense. And although people admitted to being afraid of him, they respected him just the same.*[66]

For this and other work, both Abramov and Shabarov were rewarded well, and both in fact later went on to become key deputy chief designers at OKB-1.

The tests at the Leningrad plant were conducted between May and August 1956, and much to the relief of the engineers, both from OKB-1 and GSKB SpetsMash, they were all uniformly successful. The structure was then disassembled and shipped in October to Tyura-Tam for assembly at site 1. Not far from this site, at site 2, a gigantic building designated the Assembly-Testing Building was constructed for assembly of the R-7. With dimensions of 100 by fifty by twenty meters, it was one of the largest buildings in the world at the time, and it continues to serve as the primary assembly point for many R-7–derived launchers to this day. Preparations for the first launches were not limited to the Leningrad plant. The extensive testing stands at NII-88's Branch No. 2 at Zagorsk served as the site of a number of important tests in support of the R-7. These included tests of propellant loading, booster separation systems, and engine firings. Engineers built three static test stands for the core block, three for the strap-ons, and two for the complete R-7 at Zagorsk. The initial ground tests of the engines had begun as early as mid-1955 in the form of experimental single-chamber versions of the main engines. A step-by-step process led to the use of two combined chambers and eventually full-scale four-chamber versions in January 1956. Within seven months, engineers were able to test-fire the full core block with the RD-108 engine for periods of twenty seconds. This led up to firings simulating a full cycle of flight. A major accident occurred at Zagorsk during a refueling exercise

65. Mozzhorin, *et al.*, eds., *Dorogi v kosmos: I*, p. 175. On page 52 of this source, it is stated that Chief Designer Barmin recalls that potassium bichromate was used instead of water.

66. Mozzhorin *et al.*, eds., *Nachalo kosmicheskoy ery*, p. 14.

when a feeding pipe supplying liquid oxygen to the central block broke because of "hydroshock." An extensive series of repairs and a major redesign effort ensued to preclude such a dangerous incident.[67]

OKB-1 engineers also launched a number of experimental missiles from Kapustin Yar during 1955–56 to test a variety of systems crucial to the operation of the R-7 missile. Original concepts of a radio control system for the ICBM were used on the R-2R missile during launches in January 1955.[68] Later tests used modifications of the original R-5M missile by replacing the nuclear warhead with large instrumentation containers. Between May 15 and June 15, 1956, three of the R-5R missiles were launched, the very first Soviet ballistic missiles using radio guidance. The flights utilized a series of ground stations, which served as prototypes for stations being constructed at NIIP-5 in support of R-7 operations. The experiments also studied the effects of jet plumes on radio wave propagation. All the launches were successful.[69]

A second experimental missile, the M-5RD, also a modification of the R-5M, was launched in two separate series of five launches each between February and August 1956.[70] These launches focused on perfecting three major systems in the R-7: a guidance system for the Adjustment of Apparent Velocity (RKS), a control system for Normal and Lateral Stabilization (NS and BS), and an electro-mechanical system for the Simultaneous Emptying of Tanks (SOBIS), the last being a test for propellant feeding from the lateral blocks on the ICBM.[71] Once again, all the launches were successful, and laying to rest a number of concerns that had troubled the R-7 designers.

As is true of any large-scale missile program, the work expended on supporting infrastructure and supplementary systems far outweighed the actual amount of effort on the missile itself. Apart from the construction of the launch site at Tyura-Tam, the launches of experimental missiles from Kapustin Yar, the testing of engines at Zagorsk, and the creation of a simulated launch structure at Leningrad, there were numerous other elements that contributed significantly to the success of the program. These included the development of a nationwide ground telemetry system—a tracking and command network that was directed by the military NII-4 entity under the management of institute Deputy Director Yuriy A. Mozzhorin. This thirty-five-year-old artillery forces colonel, as a result of his remarkable success in this particular job, earned himself a bright and powerful role in the future Soviet space program.[72] From designers to military officers to industrial administrators, the individuals who made noteworthy contributions to the creation and development of the R-7 would emerge quickly in important positions during the space era. There was, of course, no hint of a space program in 1954 when work on the R-7 began, but within two years, the state of affairs took a dramatic turn—one that for the first time in history shifted the focus of much of the work of hundreds of organizations from building rockets to launching satellites into space.

67. *Ibid.*, p. 54; Varfolomeyev, "Soviet Rocketry that Conquered Space: Part 1."

68. Biryukov, "Materials from the Biographical Chronicles," p. 234; Mozzhorin, *et al.*, eds., *Nachalo kosmicheskoy ery*, pp. 280–81. Details on the R-2R are still lacking, although it is known that the radio control system was designed by Chief Designer B. M. Konoplev, who was at NII-20 until 1955, when he was transferred to NII-885.

69. Mozzhorin, *et al.*, eds., *Nachalo kosmicheskoy ery*, pp. 53, 282; Chertok, *Rakety i lyudi*, p. 404. The first launch date may have been May 31.

70. Mozzhorin, *et al.*, eds., *Nachalo kosmicheskoy ery*, p. 53. The first series was conducted between February 16 and March 23, 1956, while the second series was carried out between July 20 and August 18, 1956.

71. *Ibid.*, pp. 76, 169; Chertok, *Rakety i lyudi*, p. 406.

72. A. A. Maksimov, "People of Science: A Veteran of the Space Program" (English title), *Zemlya i uselennaya* no. 6 (November–December, 1990): 30–31; Mozzhorin, *et al.*, eds., *Dorogi u kosmos: I*, p. 158.

A Report on an Artificial Satellite of Earth

Mikhail K. Tikhonravov's team at NII-4 laid the conceptual foundation for concrete work on the first Soviet ICBM. At the same time, he had quietly begun research work on many of the scientific and technical questions associated with the development of artificial Earth satellites. By the time that work on the ICBM moved into high gear at NII-88 in 1953, Tikhonravov's team members had already abandoned work on multistage rockets, instead shifting their thematic focus exclusively to research on satellites. One of the earliest was started in 1952, when the group studied methods of dissipating heat and cooling an object reentering Earth's atmosphere from orbit. Later, the NII-4 group had continued to conduct "unofficial" research into satellites in general, and it produced three important memoranda in 1952–53 and early 1954, which answered a number of important questions required for the creation of a satellite:

- What kind of satellites could be launched by the early version of Korolev's R-7?
- What kind of equipment could be placed in them?
- How were they to be controlled with special orientation systems?
- What problems could they solve, no doubt including both scientific and military goals?[73]

At Korolev's prompting, Tikhonravov himself played an important role in moving his work to "official" status. Armed with two large sketchbooks, he made an appointment to meet Georgiy N. Pashkov, the missile department chief at the Ministry of Medium Machine Building. One of the books contained a huge number of clippings from the Western press with descriptions of American "plans" for artificial satellites. The other sketchbook contained detailed drawings and calculations proving that not only was such a launch within the grasp of Soviet technology, but that if given approval, any Soviet satellite would be ten times more heavy than an American one.[74] Pashkov was sufficiently impressed by Tikhonravov's presentation to telephone Marshal Aleksandr M. Vasiliyevskiy, the former Minister of Defense who was at the time a deputy in the ministry, to permit some modest but official support for Tikhonravov's work. Subsequently, a two-year dedicated scientific research program on the creation of an artificial satellite was approved on September 16, 1953, the first official effort in the Soviet Union on such a topic.[75]

Tikhonravov's group, composed mostly of the same individuals who had participated in his earlier ICBM studies, such as Bazhinov, Maksimov, Soldatova, and Yatsunskiy, coordinated the satellite work closely with Korolev, although the two did not have any formal institutional connections. Korolev also consulted with Academician Keldysh to undertake parallel studies at his Department of Applied Mathematics of the V. A. Steklov Mathematics Institute. The same young scientists at the department who had provided much of the brain power for the design of the ICBM thus began a new effort to solve the problems involved in the "ballistic return of a space apparatus from Earth orbit and to show the possibility of using this method of

73. I. M. Yatsunskiy, "On The Activities of M. K. Tikhonravov in the Period From 1947 to 1953 on Substantiating the Possibility of Creation of Composite Missiles" (English title), *Iz istorii aviatsii i kosmonavtiki* 42 (1980): 31–38. An English translation of this can be found as I. M. Yatsunsky, "The Role of Mikhail Klavdiyevich Tikhonravov in Creating Stage Rockets, 1947–1953," in John Becklake, ed., *History of Rocketry and Astronautics, Vol. 17* (San Diego: American Astronautical Association Publications, 1995), pp. 451–56. See also Bazhinov, "The Activities of M. K. Tikhonravov in 1950–1956."

74. Nikolay Dombkovskiy, "October – April – Universe" (English title), *Sovetskaya rossiya*, April 12, 1989, p. 3. Pashkov recalls that the visit occurred in 1954, but it seems more likely that the meeting took place in late 1953.

75. Valeriy Baberdin, "The Once Secret Space NII Will Now Bear the Name of Tikhonravov" (English title), *Krasnaya zvezda*, January 18 1996, p. 6; Yatsunskiy, "On the Activities of M. K. Tikhonravov"; Ishlinskiy, ed., *Akademik S. P. Korolev*, p. 445.

Mikhail Tikhonravov's famous "satellite team" shown here in a photo from 1970. It was during 1950–54 that these young men and women developed the first engineering conceptions of a Soviet Earth satellite. Based on this important research, Tikhonravov authored a landmark report on artificial satellites in 1954 that laid the groundwork for the early Soviet space program. Sitting from left are: Vladimir Galkovskiy, Gleb Maksimov, Lidiya Soldatova, Tikhonravov, and Igor Yatsunskiy. Standing from left to right are: Grigoriy Moskalenko, Oleg Gurko, and Igor Bazhinov. (files of Asif Siddiqi)

returning on piloted flights."[76] Although these studies were not intended to support actual launches, they were giant steps forward for Korolev and Tikhonravov, for they underscored that the climate for space research was becoming more favorable. Tikhonravov's two-year research project consisted of a ten-point program to study the feasibility of launching artificial satellites. The ten topics studied were:

- Development of practical methods for computing optimal trajectories for inserting satellites into orbit
- Effects of external factors on lowering orbits of satellites
- Effects of incorrect orbital insertion on the operation of satellites
- Analysis of using solar energy on satellites
- Analysis of orienting satellites in orbit
- Preliminary conceptions of unoriented and oriented satellites
- Research on observing the motion of launch vehicles and satellites during orbital insertion and later
- Analysis of regulating heat within satellites
- Analysis of the dangers of meteorite impact on satellites in Earth orbit
- Analysis on the possibility of returning both automated and piloted capsules from Earth orbit, which included studies of trajectories, thermal protection, and so on[77]

76. V. S. Avduyevskiy and T. M. Eneyev, eds., *M. V. Keldysh: izbrannyye trudy: raketnaya tekhnika i kosmonavtika* (Moscow: Nauka, 1988), p. 9; Ishlinskiy, ed., *Akademik S. P. Korolev*, p. 445.

77. Bazhinov, "The Activities of M. K. Tikhonravov in 1950–1956."

In late 1953, Korolev began to consolidate all the current work on space issues. While in earlier years he may have been reluctant to formally request the Soviet government to sanction some kind of space project, three factors played into his hands by the end of the year. First, the removal of Stalin and Beriya from the political milieu earlier in 1953 allowed him to think of proposing such ideas to the higher leadership without fear of reprisals. Second, his ICBM was finally beginning to take shape, and it was all but given that the Soviet government would enthusiastically approve that program. Without an ICBM, he would not be able to launch any satellite. Finally, the major expansion of work on satellites under Tikhonravov would support his cause with solid scientific research. In December 1953, when he was preparing the decree on approving work on the R-7, Korolev inserted the following lines into the text:

> *We should organize at NII-88 a scientific-research department with the goal of working on problems [together with the Academy of Sciences] of flights to altitudes of 500 or more km, and also work on questions associated with the creation of an artificial satellite of the Earth and the study of interplanetary space with the aid of the [R-7].*[78]

In the seven years he had been a chief designer, it was Korolev's very first formal request to the government on a matter related to spaceflight. Clearly, he still had some doubts. As one Russian historian recalled, while the draft of the decree "was making its way to the top," mention of the satellite was crossed out.[79]

Knowing that he could not go alone on this matter, in the following months, Korolev marshaled a vast amount of support for his satellite proposal, most significantly from the USSR Academy of Sciences. Korolev spoke with Academician Keldysh on January 23, 1954, to schedule a meeting between the scientists at NII-4 and the Department of Applied Mathematics, to coordinate the entire effort. Approximately two weeks later, on February 7, Korolev spoke for the first time to Minister of Defense Industries Ustinov on the satellite issue, "sounding his boss out" on a formal proposal. Ustinov was restrained but promised that he would review any document when it was on his desk. Korolev immediately telephoned Tikhonravov and asked him to prepare a formal proposal to launch a Soviet satellite. The document would be based on his team's extensive research work in 1953–54. With the "ball rolling," Tikhonravov and two of his principal aides, Yatsunskiy and Maksimov, prepared a rough draft, which was then passed on to Korolev, who consulted *his* principal deputies, Mishin and Bushuyev, to make amendments. Chief Designer Glushko, the only other "space fanatic" on the Council of Chief Designers, also offered comments.

The activity led to a major meeting on March 16 at the offices of Academician Keldysh at the Academy of Sciences. In attendance were scientists from the Department of Applied Mathematics and NII-4, as well as renowned Soviet scientists, including Academician Petr L. Kapitsa, the nuclear physicist.[80] A draft version of the report was then typed up at the end of March, before Keldysh took the matter to Academy of Sciences President Aleksandr N. Nesmeyanov on April 24. Nesmeyanov promised full academy support for the proposal, significantly bolstering Korolev's case. Final revisions of the typed document were carried out on

78. Georgiy Stepanovich Vetrov, "The First Satellite: Historical Limits" (English title), *Novosti kosmonavtiki* 16 (July 28–August 10, 1997): 2–9; G. S. Vetrov, "The World's First Artificial Earth Satellite Was Launched Forty Years Ago" (English title), *Nauka i zhizn* no. 10 (October 1997): 2–5.

79. James Harford, *Korolev: How One Man Masterminded the Soviet Drive to Beat America to the Moon* (New York: John Wiley & Sons, 1997), p. 123.

80. B. V. Raushenbakh, ed., *Materialy po istorii kosmicheskogo korabl "vostok"* (Moscow: Nauka, 1991), p. 209; Golovanov, *Korolev*, p. 519. Also present were S. E. Khaykin, I. A. Kibel, astronomer B. V. Kukarin, and physicist S. N. Vernov. Vernov was closely involved in scientific suborbital launches in the 1940s and 1950s.

May 13 during a meeting with Korolev, Tikhonravov, and two of "Keldysh's boys," Timur M. Eneyev and Vsevolod A. Yegorov. Having a final draft in their hands, Korolev and Tikhonravov then attended a formal ceremony of the Presidium of the Academy of Sciences on May 25, hosted by President Nesmeyanov to draw official support from the academy. The three-hour meeting ended with a fully approved plan. As Tikhonravov wrote later in his personal journal: "All has been signed . . . one may say that the first stage is finished."[81]

Concurrently with this activity at the academy, both Korolev and Tikhonravov had been busy convincing key officials in the military of the satellite idea. After all, there would be no satellite unless the military agreed to relinquish an ICBM for the job. Korolev had first approached NII-4 Deputy Director Maj. General Georgiy A. Tyulin, his old friend from the Germany days. The latter was not, however, particularly enthusiastic, and Korolev only agitated Tyulin more when he began to overtly pressure him to give his consent. Tikhonravov had more success; he successfully secured the support of Marshal Vasiliyevskiy, who, having read the report, wrote back with gusto: "Comrade Tikhonravov: If you have any problems, call me at any moment. . . ."[82] Despite the rebuke from Tyulin, Korolev prepared three copies of Tikhonravov's report, each attached with a cover letter authored by himself and a set of translations of articles on satellites published in the West. He sent a set of each, two days after the academy meeting on May 27, 1954, to Ryabikov (a Deputy Minister of Medium Machine Building), Ustinov (the Minister of Defense Industries), and Pashkov (Ryabikov's department chief in charge of missiles).[83] Only seven days had passed since the R-7 ICBM project had been formally approved by the government. Clearly, Korolev was not about to waste any time.

Tikhonravov's document, remarkable even in the present day, was a *tour de force* of foresight in the mid-1950s. Classified top secret for thirty-seven years, it was finally published in its original form in 1991, just prior to the dissolution of the Soviet Union.[84] The memorandum, titled "A Report on an Artificial Satellite of the Earth," began:

> *At the present time there are real technological possibilities to achieve sufficient velocity with the use of powerful rockets for the creation of an artificial satellite of the Earth. Most realistic and feasible in the shortest time is the creation of an artificial Earth satellite composed of automatic instruments which will have scientific apparatus on the exterior, carry out radio communications with the Earth, and circle the Earth at a distance on the order of 170–1,110 kilometers from the surface. Such a capsule will be the Simplest Satellite.*[85]

The complete report was divided into two broad thematic sections—one focused on immediate objectives of a space program and one focused on long-term goals. The immediate goals were to:

81. *Ibid.*

82. Golovanov, *Korolev*, p. 519.

83. Raushenbakh, ed., *Materialy po istorii kosmicheskogo*, p. 209; Golovanov, *Korolev*, p. 519; Ishlinskiy, ed., *Akademik S. P. Korolev*, p. 445; Biryukov, "Materials from the Biographical Chronicles," p. 233. Although Ryabikov was officially a Deputy Minister of Special Machine Building, he was simultaneously the chief of GlavSpetsMash ("Chief Directorate of Special Machine Building") within the Ministry of Medium Machine Building, which oversaw missile programs. Pashkov's official position was head of GlavTransMash within the Ministry of Medium Machine Bulding. Note that sources differ on the date the document was sent to Ustinov, with both May 26 and May 27, 1954, quoted widely.

84. The entire document is reproduced as M. K. Tikhonravov, "A Report on an Artificial Satellite of the Earth" (English title), in Raushenbakh, ed., *Materialy po istorii kosmicheskogo*, pp. 5–15.

85. *Ibid.*, p. 5.

- Create and launch the Simplest Satellite into Earth orbit
- Launch a human on a "vertical" trajectory into space
- Recover a portion of the Simplest Satellite from Earth orbit

These three goals were to be carried out in parallel with each other and with the development of the R-7 ICBM, which would facilitate the implementation of the first objective.

Throughout the document, Tikhonravov goes into unusual detail for a report aimed at government bureaucrats, and one wonders, given the times, how much of it Ustinov or the others truly comprehended. The description of the Simplest Satellite included explanations of its launch trajectory, the characteristics of various potential orbits, its albedo in the night sky, three different orientation systems, power sources, and on-board instrumentation. Interestingly, he mentioned that a "special cassette" with scientific data would be recovered; this presumably would be exposed film of Earth's surface. Furthermore, a 300-kilogram television system would be installed on the satellite for transmitting images of Earth. Acknowledging that the creation of an oriented satellite would be a complex task, Tikhonravov wrote that:

> *in the event of the impossibility of a speedy solution [to installing an orientation system], it would be agreeable to have an unoriented [satellite], since aside from its scientific importance, the launch of the first satellite in our country would also have vast political significance.*[86]

The total mass of the vehicle was noted at 3,000 kilograms, composed of orientation systems, power sources, communications systems, a television unit, a recoverable cassette, film, scientific apparatus, and a container for an animal. The animal container would be installed on later Simplest Satellites.

The second section of the report addressed the launch of humans on vertical flights into space. Although particular rockets were not mentioned, it is likely that the reference was not to the R-7, but rather more modest missiles, such as the R-2 and R-5, in their scientific versions. Tikhonravov noted that these vertical launches would progress to true suborbital missions down range. Experience from the aviation industry would be used to design and construct appropriate cockpits for the single passenger.

In the third section, Tikhonravov addressed the methods of returning either the complete satellite or a portion of it to Earth. Both ballistic return and reentry with the aid of wings were detailed. The final section addressed future work:

- Creation of an "experimental satellite with humans"
- Creation of a "satellite-station"
- "[P]roblems of reaching the Moon"[87]

It is clear throughout the entire document that Tikhonravov and Korolev's primary goal was to put one to two humans into Earth orbit aboard a satellite. In fact, at one point, the Simplest Satellite is described as "an apparatus without people." Orbital human spaceflight, according to the writing in the document, would be possible to accomplish in the nearest future based on the results of the three preliminary goals. The so-called "satellite-station" was merely an extension of piloted spaceflight; orbital assembly would be used as a means to create a large space station in Earth orbit crewed by specialists. The final long-term goal was the first-ever

86. *Ibid.*, p. 8.
87. *Ibid.*, pp. 13–14.

official mention in a Soviet document of plans to send spacecraft to the Moon. Although piloted flight was not explicitly mentioned, Tikhonravov described a one-and-a-half-ton spacecraft capable of landing on the Moon and then returning to Earth by means of atmospheric braking. A three-stage "packet"-type rocket with a liftoff mass of 650 tons could be used for this purpose; he acknowledged that engine performance would have to be increased significantly for such a mission. There was even mention of interplanetary flight, which would be possible after accomplishment of the lunar expedition.

In the conclusion, Tikhonravov listed a number of goals of the complete program, focusing mostly on the scientific aspects, but noted that the creation of an artificial satellite would be of great importance to "defense." Korolev's attached letter was short and to the point:

> *At your request, I am enclosing the memorandum of Comrade M. K. Tikhonravov, "A Report on an Artificial Satellite of the Earth," and also forwarded materials from the U.S.A. on work being carried out in this field. The current development of [the R-7] makes it possible for us to speak of the possibility of developing in the near future an artificial satellite. By reducing the mass of the payload somewhat, we will be able to achieve the final velocity of 8,000 m/s necessary for a satellite. The product—the satellite—may be developed on the basis of the new [R-7] being developed now, referred to above, but with major modifications to the latter. It seems to me that in the present time there is the opportunity and expediency of organizing a scientific-research department [at NII-88] for carrying out the initial exploratory work on a satellite and more detailed work on complex problems involved with this goal. I await your decision.*[88]

These two documents were the blueprints for the early days of the Soviet space program and stand testament to the vision of both Korolev and Tikhonravov. Most of the goals were eventually accomplished, although in 1954 none of the involved participants could foresee the eventual impact of the report.

If Korolev's goal was to elicit a formal decree for his proposal, his appeal was not very successful. However, his request seems to have been passed on through various levels of the government and reached the office of defense industry chief Malyshev, officially the Minister of Medium Machine Building. Prompted by Korolev's persuasive arguments, Malyshev, along with three other top defense industry officials, submitted a proposal to Soviet leader Malenkov asking permission to carry out "work on the scientific-theoretical questions associated with space flight."[89] No doubt interested in the military applications of Tikhonravov's satellite, Malenkov approved the suggestion. Armed with a modicum of support, Korolev commenced a modest research project at his design bureau, coordinated with Tikhonravov's own work at NII-4. Incredibly, as this research was taking place, the satellite issue remained divorced from further governmental involvement as Korolev was diverted to more important matters relating to the operation of the nuclear-tipped R-5M missile and, of course, the work on the R-7 ICBM. It was, however, the very first intervention by the Soviet government on an issue related to space exploration.

88. The text of this letter in a censored version has been published as S. P. Korolev, "On the Possibility of Work on an Artificial Satellite of the Earth" (English title), in Keldysh, ed., *Tvorcheskoye naslediye Akademika Sergeya Pavlovicha Koroleva*, p. 343. See also Raushenbakh, ed., *Materialy po istorii kosmicheskogo*, p. 209; Yaroslav Golovanov, "The Beginning of the Space Era" (English title), *Pravda*, October 4, 1987, p. 3; A. P. Romanov and V. S. Gubarev, *Konstruktory* (Moscow: Politicheskoy literatury, 1989), p. 75.

89. Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p. 86. The co-authors of the proposal were B. L. Vannikov (First Deputy Minister of Medium Machine Building), M. V. Khrunichev (First Deputy Minister of Medium Machine Building), and K. N. Rudnev (Deputy Minister of Defense Industries).

The International Geophysical Year and the Soviet Satellite

Korolev's satellite work may have continued at a leisurely pace through the mid-1950s with lukewarm governmental support were it not for some surprising and well-publicized events outside the Soviet Union. In the spring of 1950, a group of American scientists led by James A. Van Allen met in Silver Spring, Maryland, to discuss the possibility of an international scientific program to study the upper atmosphere and outer space via sounding rockets, balloons, and ground observations. Strong support from Western European scientists allowed the idea to expand into a worldwide program timed to coincide with a period of intense solar activity from July 1, 1957, to December 31, 1957. The participants named this period the International Geophysical Year (IGY) and created the *Comité speciale de l'année géophysique internationale* (the "Special Committee for the International Geophysical Year," or "CSAGI") to establish an agenda for the program. Soviet representatives, including Academy of Sciences Vice-President Academician Ivan P. Bardin, served on CSAGI, but it does not seem that they had any significant contribution to its proceedings. In fact, the May 1954 deadline for submissions for participating in the IGY passed without any word from Soviet authorities. At a subsequent meeting in Rome on October 4, 1954, Soviet scientists silently witnessed the approval of a historic U.S.-sponsored plan to orbit artificial satellites during the IGY.[90] The satellite proposal clearly surprised the Soviet delegation, and perhaps it had repercussions within the USSR Academy of Sciences. In the fall of 1954, the academy established the Interdepartmental Commission for the Coordination and Control of Work in the Field of Organization and Accomplishment of Interplanetary Communications, a typically long-winded title that obscured its primary role—a forum for Soviet scientists to discuss space exploration in abstract terms, both in secret and in public.[91]

The existence of the commission was announced on April 16, 1955, in an article in a Moscow evening newspaper. Academician Leonid I. Sedov, a relatively well-known gas dynamics expert, was listed as the chairman of the commission.[92] Unlike the title of the body, the primary duty of the commission was stated with unusual explicitness: "One of the immediate tasks of the Commission is to organize work concerning building an automatic laboratory for scientific research in space."[93] In hindsight, it is clear that the commission, a part of the Astronomy Council in the USSR Academy of Sciences, had very little input or influence over *de facto* decision-making in the Soviet space program. Although one of its functions was to collect proposals from various scientists on possible scientific experiments that could be mounted on future satellites, its more important role was to allow Soviet scientists, *but not designers*, to discuss general space issues in a public forum. Sedov played a major role in this respect by appearing at numerous international conferences talking in very general terms on the future of space exploration. None of the commission's members had any direct connection or contact

90. Edward Clinton Ezell and Linda Neuman Ezell, *The Partnership: A History of the Apollo-Soyuz Test Project* (Washington, DC: National Aeronautics and Space Administration (NASA) Special Publication (SP)-4209, 1978), p. 16; Nicholas Daniloff, *The Kremlin and the Cosmos* (New York: Alfred A. Knopf, 1972), p. 54.

91. Ishlinskiy, ed., *Akademik S. P. Korolev*, p. 453; U.S. Central Intelligence Agency (CIA), *National Intelligence Estimate 11-5-58: Soviet Capabilities in Guided Missiles and Space Vehicles* (Washington, DC: CIA, August 19, 1958), as declassified February 15, 1995, by the CIA Historical Review Program, pp. 26–27; Boris Konovalov, "The Genealogy of Sputnik" (English title), in V. Shcherbakov, ed., *Zagadki zvezdnykh ostrovov* (Moscow: Molodaya gvardiya, 1989), p. 115.

92. "Commission on Interplanetary Communications" (English title), *Vechernaya moskva*, April 16, 1955, p. 1. An English translation of the article is included in F. J. Krieger, *Behind the Sputniks: A Survey of Soviet Space Science* (Washington, DC: Public Affairs Press, 1958), pp. 328–30. The names of only four other members were announced at the time: V. A. Ambartsumyan, P. L. Kapitsa, B. V. Kukarin, and P. P. Parenago. A larger twenty-seven-member list was submitted to the International Astronautical Federation in October 1957.

93. *Ibid.*

with the missile and space program, although they were clearly aware of the broad nature of Korolev's work. It seems that the latter had little to do with the formation or work of the commission. He evidently attended one meeting in 1954 to inquire about the group's work.[94]

While this Commission had little real authority, Chairman Sedov may have played a crucial role in connecting Korolev's satellite efforts with the IGY. The chain of events was set off on July 29, 1955, by U.S. President Dwight D. Eisenhower's Press Secretary James C. Hagerty, who announced at the White House that the United States would launch "small Earth-circling satellites" as part of its participation in the IGY.[95] It was at this same time that the International Astronautical Federation was holding its Sixth International Astronautical Congress in Copenhagen, Denmark. Heading the Soviet delegation were Sedov and Kirill F. Ogorodnikov, the editor of a respected astronomy journal in the USSR. The two were called into action by an announcement on August 2 by Fred C. Durant III, the president of this congress, who reported the Eisenhower administration's intentions of launching a satellite during the IGY. Not to be outdone, Sedov convened a press conference the same day at the Soviet Embassy in Copenhagen for about fifty journalists during, at which he announced, "In my opinion, it will be possible to launch an artificial Earth satellite within the next two years." He added, "The realization of the Soviet project can be expected in the near future."[96]

It is quite unlikely that Sedov was speaking on his own authority, and he possibly had taken cues from highly placed Communist Party officials who were aware of the government's approval in August 1954 of exploratory research on space issues. Perhaps a Party or Academy of Sciences official back in Moscow had decreed that Durant's statement warranted a response from Sedov. Certainly, there had been much discussion on the possibility of Soviet satellites by that time, although no single project had received approval. What is known is that the two pronouncements, the one by the Eisenhower administration and the one by Sedov, were the subject of relatively intense scrutiny by the press all over the world. This response seems to have been critical for Korolev.

The May 1954 satellite proposal from Korolev and Tikhonravov had not elicited the kind of response its authors had wanted. Despite the lukewarm reaction, both continued to appeal to various senior governmental officials. On January 18, 1955, Tikhonravov, with Korolev's agreement, sent a letter to Pashkov once again describing the possible uses of artificial satellites. By May, Tikhonravov, also with Korolev's supervision, prepared a series of documents on satellites, including a rough draft of a governmental decree, and he sent them to Pashkov, now a member of the new Special Committee, and Ustinov's Deputy Rudnev.[97] There were also changes made to the original satellite document from 1954. On June 16, 1955, Tikhonravov and OKB-1 engineer Ilya V. Lavrov finished their latest study on artificial satellites. Based on Tikhonravov's earlier work, the two suggested a reduced mass of 1,000 to 1,400 kilograms for

94. Of the twenty-seven commission members listed in 1957, only two individuals, A. A. Blagonravov and D. Ye. Okhotsimskiy, were directly involved in the ballistic missile and space programs. The former headed the Commission for Upper Atmosphere Research of the Academy of Sciences, which oversaw all scientific vertical launches. The latter was one of the leading mathematicians at the Department of Applied Mathematics of the V. A. Steklov Mathematics Institute of the Academy of Sciences, who was involved in the early design of the R-7 ICBM. See Ishlinskiy, ed., *Akademik S. P. Korolev*, p. 453.

95. "Statement by James C. Hagerty, The White House, July 29, 1955," reproduced as Document I-17 in John M. Logsdon, gen. ed., with Linda J. Lear, Jannelle Warren-Findley, Ray A. Williamson, and Dwayne A. Day, *Exploring the Unknown: Selected Documents in the History of the U.S. Civil Space Program: Volume I: Organizing for Exploration* (Washington, DC: NASA SP-4218), pp. 200–01; Ezell and Ezell, *The Partnership*, p. 18.

96. Robert W. Buchheim and the Staff of the Rand Corporation, *Space Handbook: Astronautics and its Applications* (New York: Random House, 1959), p. 277; "We'll Launch 1st Moon, and Bigger, Says Russ," *Los Angeles Examiner*, August 3, 1955; John Hillary, "Soviets Planning Early Satellite," *New York Times*, August 3, 1955.

97. Vetrov, "The First Satellite."

the automated satellite. They also proposed the formation of a group of seventy to eighty people to carry out the task of designing and building the satellite and work on future piloted spacecraft (Korolev wrote in the margins: "Too many, 30–35 people."). Korolev, more attuned to the political reality of such a project, also added that "the creation of [a satellite] will have enormous political significance as evidence of the high development level of our country's technology."[98]

The process seems to have gained extra urgency with the Eisenhower administration' announcement in late July. On August 8, Tikhonravov sent both Pashkov and Korolev a report titled "Basic Information on the Scientific Significance of the Simplest Satellite and Proposed Costs." Finally, on August 27, Tikhonravov sent another report to Pashkov, Chief Designer Glushko, and Chief Designer Ryazanskiy on the technical details of the satellite.[99] All this seemed to have had an effect. Pashkov asked his boss Ryabikov to hold a meeting of the powerful Special Committee to discuss the issue. Perhaps encouraged by the government's interest, Korolev decided to aim much higher than just a simple satellite. In a move that underscores Korolev's push for a space program, he had one of his sector chiefs at OKB-1, Yevgeniy F. Ryazanov, quickly prepare a technical report on the possibility of sending a probe to the Moon using modified versions of the R-7 ICBM. Ryazanov emerged with two different three-stage variants of the missile, one using the traditional liquid oxygen-kerosene combination and the other using fluorine monoxide and ethyl amine propellant. The former would launch a probe weighing 400 kilograms, and the latter would have a probe of 800 to 1,000 kilograms.

The meeting at the offices of the Special Committee was held on August 30, 1955. In attendance, besides Committee Chairman Ryabikov, Korolev, and Keldysh, was an engineer named Colonel Aleksandr G. Mrykin, Marshal Nedelin's chief means of contact with the missile design bureaus.[100] At the meeting, Korolev spoke of both his satellites and lunar probes but ran into resistance from Mrykin. Notorious for his legendary short temper and larger-than-life personality, Mrykin was not receptive to Korolev's old arguments of the possibly great political importance of a Soviet satellite. The artillery officer told Korolev that only when the R-7 had completed its flight testing would they consider a satellite. Fortunately for Korolev, he had Keldysh's support, and that may have tipped the scales. While details of the deliberations remain extremely sketchy, it seems that Ryabikov approved the use of an R-7 ICBM for a modest satellite program. Lunar probes were considered too outlandish. There were probably two factors working in Korolev's favor: the possible use of a satellite for military purposes and the Eisenhower administration's announcement of an IGY satellite program.

Armed with Ryabikov's approval, Korolev attended a second meeting the same day at the offices of the "chief scholarly secretary" of the Academy of Sciences, Gennadiy V. Topchiyev. Many other scientists and designers, including Keldysh, Tikhonravov, and Glushko, were present. Korolev reported to the distinguished assemblage that the Council of Chief Designers at a recent meeting had conducted a detailed examination of modifying the original R-7 into a vehicle capable of launching a satellite into orbit. No doubt, he also spoke of the government's interest on the matter. At the end of his speech, he made a formal call to build and launch a

98. *Ibid.*; Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, pp. 86–87; Golovanov, "The Beginning of the Space Era." There is some confusion as to who authored this report and when it was issued. The above sources suggest that it was Lavrov alone who authored the report and that it was dated June 16, 1955. On the other hand, in his own memoirs, Tikhonravov writes that the memorandum was co-authored by both and that it was dated July 16, 1955. See Ishlinskiy, ed., *Akademik S. P. Korolev*, p. 445.

99. Vetrov, "The First Satellite."

100. Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p. 87. Mrykin's official post was First Deputy Commander of the Directorate of the Chief of Reactive Armaments (UNRV). UNRV was part of the Chief Artillery Directorate (GAU) of the Ministry of Defense.

series of satellites, including one with animals, into space, and he asked that the Academy of Sciences establish a formal commission to carry out this goal. Korolev had a specific timetable in mind. He told his assemblage, "As for the booster rocket, we hope to begin the first launches in April–July 1957 . . . before the start of the International Geophysical Year."[101] If Korolev's earlier Simplest Satellite plans had been timed for the indefinite future, the Eisenhower administration's announcement in July 1955 completely changed the direction of Korolev's attack. Not only did it imbue Korolev's satellite proposal with a new sense of urgency, but it also gave him a specific timetable for which to aim. If the United States was planning to launch during the IGY, then the Soviets would launch one a few months *before* the beginning of the IGY. The attending scientists at the meeting accepted the new satellite proposal. At Korolev's recommendation, Keldysh was designated the chairman of the commission; Korolev and Tikhonravov were to serve as his deputies.

The following day, on August 31, a smaller group, including Korolev, Tikhonravov, and Keldysh, met to discuss some of the proposals for satellite instruments that many scientists had submitted to Sedov's commission during the past year. A few days later, Tikhonravov and Keldysh convened with some prominent Soviet scientific scholars to explain details of the satellite design and how their instruments were being considered. Korolev himself approved a preliminary scientific program in September 1955, which included the study of the ionosphere, cosmic rays, Earth's magnetic fields, luminescence in the upper atmosphere, the Sun and its influence on Earth, and other natural phenomena. The detailed development of a scientific program was left in the hands of the two existing commissions of the Academy of Sciences headed by Blagonravov and Sedov.[102]

The approval by the Academy of Sciences to conduct a purely scientific research program accelerated matters considerably. In the ensuing months, several important meetings were held, both by Keldysh's commission and by the Council of Chief Designers, which elaborated on the details of the project. Between December 1955 and March 1956, Keldysh consulted a huge number of distinguished scholars to refine the scientific experiments package. They included numerous famous Soviet scientists, many of whose names were public knowledge, unlike those who were actually developing the spacecraft.[103] It was a large-scale operation with a single coordinating mechanism, which, because of its "civilian" nature, had no precedent. Korolev himself was very conscious of the fact that official governmental approval had yet to be granted, which meant that a rocket for the project was still not available, but the magnitude of the immediate tasks obscured that important issue for the time being. There were continuous problems with the program because many of those who were cooperating did not share Korolev's enthusiasm for the project. For a purely civilian endeavor, the wealth of institutes and design bureaus with which he had to deal was also unprecedented.

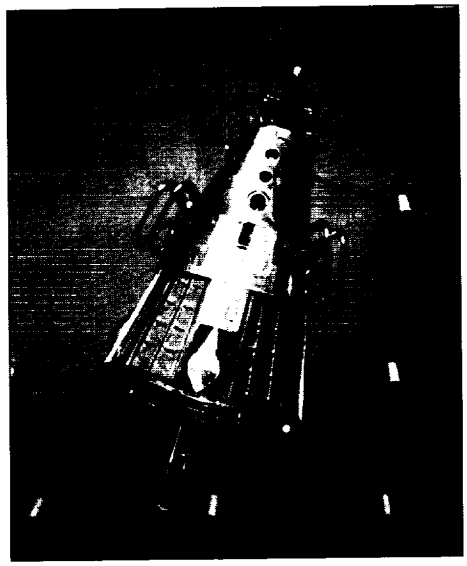
It took about four months for Ryabikov's spoken approval in August 1955 to translate into a formal decree of the Soviet government. As a purely scientific project managed by the

101. Ishlinskiy, ed., *Akademik S. P. Korolev*, p. 455; Golovanov, *Korolev*, pp. 523–24; Golovanov, "The Beginning of the Space Era." Others present at this meeting were M. A. Lavrentiyev and G. A. Skuridin.

102. Ishlinskiy, ed., *Akademik S. P. Korolev*, pp. 455–56; Lardier, *L'Astronautique Soviétique*, p. 107; Golovanov, "The Beginning of the Space Era." Blagonravov's commission was at the time directing the scientific investigations aboard suborbital rockets, while Sedov's commission had recently been established as a public forum for Soviet scientists to discuss space exploration.

103. These included: atmospheric specialists V. I. Krasovskiy, L. V. Kurnosovaya, and S. N. Vernov; the young mathematicians from the Department of Applied Mathematics, T. M. Eneyev, M. L. Lidov, D. Ye. Okhotsimskiy, and V. A. Yegorov; solar battery expert N. S. Lidorenko; and the more famous Academicians L. A. Artsimovich, V. L. Ginsburg, A. F. Ioffe, P. L. Kapitsa, B. P. Konstantinov, and V. A. Kotelnikov. See Ishlinskiy, ed., *Akademik S. P. Korolev*, pp. 446, 456; Golovanov, "The Beginning of the Space Era."

Academy of Sciences, it was not considered a top priority. In fact, Soviet government officials probably viewed the satellite project in much the same manner as they viewed the continuing series of scientific rocket flights into the upper atmosphere—an effort that also used military missiles for civilian purposes. Such flights were relatively inexpensive, unobtrusive, and ignored by the political leadership. Consequently, the USSR Council of Ministers issued a decree (no. 149-88ss) on January 30, 1956, calling for the creation of an unoriented artificial satellite. The document approved the launch of a satellite, designated "Object D," in 1957 in time for the IGY. As per Tikhonravov's previous computations, the mass of the satellite was limited to 1,000 to 1,400 kilograms, of which 200 to 300 kilograms would be scientific instruments. Apart from the Academy of Sciences, five industrial ministries would be involved in the project. The responsibility for preparing a draft plan for Object D fell on the shoulders of Sergey S. Kryukov, at the time a department chief at OKB-1. Tikhonravov served as the "chief scientific consultant."[104] At least two main points of the original report from 1954 were ignored: the Party squelched any hope that the satellite would have an orientation system or that it would carry a human. Although the text of the decree remains classified, other evidence hints that one of the stipulations of the document was to approve exploratory work on a military photo-reconnaissance satellite at NII-4 based on the design of Object D.[105]



A model of the Object D satellite shown suspended in a museum. The 1.3-ton observatory carried instruments for the study of Earth's ionosphere, magnetic fields, radiation belts, cosmic rays, meteoroids, and so forth. (copyright Quest*)*

At the time that the resolution was adopted, Korolev was at Kapustin Yar in preparation for the nuclear R-5M test, an experiment that was certainly far more important to the fortunes of OKB-1 than the satellite project. It is apparent, however, that Korolev did not want to consign his dreams of space exploration to a single decree, one among as many as 250 discussed per month by the Presidium (later the Politburo). He wanted a direct verbal promise from the Soviet leadership on the satellite project, in particular from Khrushchev himself. His chance came in February 1956 during a high-level state visit to OKB-1. Khrushchev, escorted by the top Presidium members Bulganin, Molotov, and Pervukhin, as well as Minister Ustinov, were on hand to congratulate OKB-1 on its recent success with the R-5M and also to review the progress on the R-7 ICBM project.[106]

104. Keldysh, ed., *Tvorcheskoye naslediye Akademika Sergeya Pavlovicha Koroleva*, p. 362; Ishlinskiy, ed., *Akademik S. P. Korolev*, p. 445; Konovalov, "The Genealogy of Sputnik," pp. 116–17; Golovanov, *Korolev*, p. 529; Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p. 87; B. Konovalov, "Dash to the Stars" (English title), *Izvestiya*, October 1, 1987, p. 3. The five industrial ministries were the Ministry of Defense Industries, the Ministry of Radiotechnical Industry, the Ministry of Ship Building Industry, the Ministry of Machine Building, and the Ministry of Defense.

105. See, for example, Valery Menshikov, "Theory and Practice Go Together," *Aerospace Journal* no. 2 (March–April 1997): 28–29. Referring specifically to the January 1956 decree, the author states, "The task of researching possible applications of defense satellites . . . was entrusted to the country's Defense Ministry."

106. Sergey Khrushchev, *Nikita Khrushchev: krizisy i rakety: uzglyad iznutri: tom 1* (Moscow: Novosti, 1994), p. 97.

The visit, on the morning of February 27, was important for Khrushchev because it was his first direct exposure to the top-secret ballistic missile program—an effort that had essentially been run by a number of industrial bureaucrats since Stalin's death, out of view from Party leaders such as Khrushchev.[107] During the visit, the delegation was escorted by Korolev and NII-88 Director Aleksey S. Spiridinov on a tour that culminated with a presentation of a full-scale model of the R-7 ICBM. The guests were apparently stunned into silence by the size of the vehicle. Like a good performer, Korolev waited a few seconds for the sight to sink in before giving a brief presentation on the vehicle. Khrushchev simply beamed after the report, visibly impressed with the capabilities of the missile.

Glushko then began an elaborate presentation, much different from Korolev's, filled with extraneous technical details "like he was talking to first course students at the neighboring forestry institute . . . rather than the higher leadership."[108] Recognizing the pointlessness of a technical treatise, Korolev cut Glushko short, before summarizing with a succinct conclusion. After a short discussion on the R-7's capabilities, Korolev innocuously added, "Nikita Sergeyevich [Khrushchev], we want to introduce you to an application of our rockets for research into the upper layers of the atmosphere, and for experiments outside the atmosphere."[109] The Soviet leader expressed polite interest, although it was clear by this time that most of the guests were becoming tired and bored with the proceedings. Undeterred, Korolev first showed them huge photographs of suborbital missiles that were used for biological and geophysical investigations. Detecting that his guests were in a hurry to leave, he quickly moved ahead and pointed everyone's attention to a display in a corner of the room of a model of an artificial satellite that had been created as part of the satellite program of the Academy of Sciences. Invoking the name of a legendary Soviet scientist, Korolev hurriedly explained that it was possible to realize the dreams of Tsiolkovskiy with the use of the R-7 missile. Korolev pointed out that the United States had stepped up its satellite program, but that compared to the "skinny" U.S. launch vehicle, the Soviet R-7 could significantly outdo that project in terms of the mass of the satellite. In closing, he added that the costs for such a project would be meager, because the basic expense for the launcher was already allocated in the R-7 booster.

Khrushchev began to exhibit some interest, and he asked Korolev if such a plan might not harm the R-7 weapons research program, given that was the primary focus of work at Korolev's design bureau. Clearly oversimplifying the difficulties involved, Korolev shot back that unlike the United States, which was spending millions of dollars to develop a special rocket to launch a satellite, all the Soviets would have to do was replace the warhead with a satellite on the R-7. Khrushchev hesitated for a second, perhaps suspicious of Korolev's intentions, but answered back, "If the main task doesn't suffer, do it."[110]

After more than two years of explicit lobbying, the artificial satellite project was a reality. And it owed its approval to Korolev more than anyone. Tikhonravov had provided the technical expertise, and Keldysh had helped with his political clout, but it was finally Korolev's repeated requests, letters, meetings, reports, and entreaties that finally forced the decision. Korolev also had a climate conducive to his needs. His standing among the military and industrial community had evolved over the years from maverick engineer to genius manager. His successes with the series of ballistic missiles pleased both the military and industry. Also, it did not hurt that both of these sectors, by 1956, were populated by individuals who were sympathetic to the Korolev's unquenchable thirst for space exploration. Clearly, Korolev alone could not have

107. Barry, "The Missile Design Bureaux."

108. Khrushchev, *Nikita Khrushchev: tom 1*, p. 106.

109. *Ibid.*, p. 109.

110. *Ibid.*, pp. 110–11. For other brief descriptions of the February 1956 visit, see Ishlinskiy, ed., *Akademik S. P. Korolev*, pp. 319–20, 337–38.

done it. Events outside his control—such as the Eisenhower administration's announcement, Sedov's press conference, the fall of the Beriya group in the nuclear weapons industry, and Khrushchev's rise to power—were pivotal events on the road to approval. But hindsight suggests that the Soviet space program was born on January 30, 1956, and without Korolev, it would have never been conceived.

From Object D to the Simple Satellite

Object D (or D-1) was so named because it would be the fifth type of payload to be carried on an R-7. Objects A, B, V, and G were designations for different nuclear warhead containers.[111] The satellite was a complex scientific laboratory, far more sophisticated than anything planned for launch in the world in 1956. While Kryukov's engineers depended greatly on Tikhonravov's early work on satellites, much of the actual design was a journey into uncharted territory for OKB-1. There was little precedent for creating pressurized containers and instrumentation for work in Earth orbit, while long-range communications systems had to be designed without the benefit of prior experience. The engineers were aware of the trajectory tracking and support capabilities for the R-7 missile, and this provided a context for determining the levels of contact with the vehicle. The fact that the object would be out of contact with the ground for long periods of time (unlike sounding rockets) meant that new self-switching automated systems would have to be used. The selection of metals to construct the satellite also presented problems to the engineers because the effects of continuous exposure to the space environment were still in the realm of conjecture. The experiments and experience from sounding rocket tests provided a database for the final selection.

On February 25, 1956, the Keldysh commission issued the technical requirements for building the satellite; detailed design work began on March 5. Tikhonravov's group at NII-4 and Korolev's OKB-1 at NII-88 were the two most active participants in this process, but numerous other organizations contributed to various elements of the complete satellite. By June 14, Korolev had finalized the necessary changes to the basic 8K71 version of the R-7 ICBM to use it for a satellite launch. The new booster, designated "product 8A92," would incorporate a number of major changes, including the use of uprated main engines, the deletion of the central radio package on the booster, and a new payload fairing replacing the one used for a nuclear warhead. A month later, at a meeting of chief designers on July 24, 1956, Korolev formally signed the initial draft plan for Object D. The document was co-signed by his senior associates Tikhonravov, Bushuyev, Okhapkin, and Voskresenskiy.[112]

The intensive work on Object D was obviously not only project at OKB-1. In fact, officially at least, it was an effort with very low priority, far behind the plethora of military work that Korolev oversaw during this period. These included the dozens of test launches of the strategic R-5M, the experimental M-5RD and R-5R missiles, and the world's first submarine-launched ballistic missile, the R-11FM. He also directed draft plan work on an improved version of the nuclear R-5M, the experimental R-5R, the basic R-11FM, and an underwater version of the same missile. He was the scientific leader for the enormous R-7 ICBM effort and the work on the short-range R-11M, both yet to fly. This was in addition to work on scientific missiles such as the R-1Ye, the R-5A, and of course Object D. There were also various conferences, meetings, and functions to attend. Given the magnitude of work at OKB-1, it was becoming cumbersome

111. Raushenbakh, ed., *Materialy po istorii kosmicheskogo*, p. 209. A, B, V, G, and D are the first five letters of the Russian cyrillic alphabet.

112. Golovanov, *Korolev*, p. 530; Ishlinskiy, ed., *Akademik S. P. Korolev*, p. 446; Varfolomeyev, "Soviet Rocketry that Conquered Space: Part 1." Tikhonravov was officially an employee of NII-4, but he was temporarily working as the chief consultant to NII-88's OKB-1.

to deal with OKB-1 as a functional unit of NII-88. Thus, by an order (no. 310) of the Ministry of Defense Industries, dated August 14, 1956, OKB-1 became a separate and independent organization within the ministry, with its own production plant and scientific research departments.[113] It took ten years for Korolev's small department at a research institute to evolve into an independent organization with thousands of employees—one that was the leading developer of long-range ballistic missiles in the Soviet Union, and the only one working on a space program.

It was at the same time that four of Korolev's deputies were officially named deputy chief designers of the independent entity: Vasiliy P. Mishin (first deputy for planning-design work), Konstantin D. Bushuyev (deputy for planning), Sergey O. Okhapkin (deputy for design and documentation), and Leonid A. Voskresenskiy (deputy for ground and flight-testing).[114] With the exception of Korolev and Mishin, Bushuyev was the most powerful person at OKB-1. An exceptionally intelligent and learned individual, he had played a leading role in the development of every single ballistic missile at NII-88, beginning with the R-2 rocket in the late 1950s. The forty-two-year-old engineer was OKB-1's expert in the areas of project planning, project parameter selection, and computation and research work on aerodynamics, ballistics, stability, surface tension, and missile mass balance. Upon Bushuyev's new appointment as deputy at OKB-1, he inherited all the work on space themes at the design bureau. By 1961, his sole responsibility was all of the space vehicle development, thus overseeing every single piloted space project through the 1960s and 1970s.[115] Bushuyev's new appointment had a second dimension. For almost two years, Korolev had been lobbying for a transfer of Tikhonravov's productive group at NII-4 to OKB-1. With the acceleration of work on Object D, the government finally agreed to the request, and on November 1, 1956, Tikhonravov and most of his group of assistants were institutionally transferred to OKB-1, under Bushuyev's command, to comprise the new Department No. 9 dedicated to space themes.[116] Yevgeniy F. Ryazanov was named Tikhonravov's deputy, while another assistant, Ilya V. Lavrov, was appointed to oversee the technical aspects of the Object D effort.

By mid-1956, the Object D project was beginning to fall significantly behind schedule. Some subcontractors were particularly lackadaisical in their assignments, and parts were often delivered that did not fit the original specifications. On September 14, Keldysh made a personal plea at a meeting of the Academy of Sciences Presidium for speeding up work, invoking a threat all would understand: "we all want our satellite to fly earlier than the Americans."[117] To com-

113. Chertok, *Rakety i lyudi*, p. 356; Golovanov, *Korolev*, p. 464; "TsNIIMash—One of the Leading Space Branches"; Ishlinskiy, ed., *Akademik S. P. Korolev*, p. 446. Although the order was signed in August 1956, it seems that the separation was not enacted until September–October 1956. See Yu. A. Mozzhorin, "The Central Scientific-Research Institute of Machine Building—The Chief Center in the Soviet Rocket-Space Industry" (English title), *Iz istorii aviatsii i kosmonavtiki* 60 (1990): 20–40.

114. Chertok, *Rakety i lyudi*, p. 356. All had already been officially appointed deputy chief designers, but they had been serving in that capacity in NII-88's OKB-1, not the independent OKB-1. Mishin had been appointed in April 1950, Okhapkin in December 1952, Voskresenskiy in October 1953, and Bushuyev in 1954. Chertok also suggests that A. P. Abramov was one of those appointed as chief designers in August 1956, but by Abramov's own account, he was not promoted to such a post until 1966. By 1961, at least nine other engineers had been appointed deputy chief designers: B. Ye. Chertok, D. I. Kozlov, S. S. Kryukov, P. I. Meleshin, M. V. Melnikov, M. F. Reshetnev, Ye. V. Shabarov, M. K. Tikhonravov, and P. V. Tsybin.

115. S. S. Kryukov, "K. D. Bushuyev—Scholar, Planner, Technical Director of the 'Soyuz-Apollo' Program" (English title), in B. V. Raushenbakh, ed., *Issledovaniye tvorchestva osnovopolozhnikov kosmonavtiki i ee sovromennyye problemy* (Moscow: Nauka, 1989), p. 41; M. V. Keldysh, A. A. Dorodnitsyn, and S. P. Korolev, "On the Scientific Activities of K. D. Bushuyev" (English title), in Avduyevskiy and Eneyev, eds., *M. V. Keldysh*, pp. 197–98.

116. Ishlinskiy, ed., *Akademik S. P. Korolev*, p. 447. Korolev's first request for transferring Tikhonravov's department was during a meeting with Ustinov on December 22, 1954. He repeated the request to Nedelin on December 27, 1955.

117. An edited version of Keldysh's speech has been published as M. V. Keldysh, "On Artificial Satellites of the Earth" (English title), in Avduyevskiy and Eneyev, eds., *M. V. Keldysh*, pp. 235–40. See also Golovanov, *Korolev*, p. 530.

pensate for the volume of work. Korolev finalized a plan ten days later to divide the work into three variants of the basic Object D, each distinguished by the nature of its scientific apparatus. He then signed an amended draft plan for the satellite on September 25. Its eight scientific goals were listed as:

- Measurement of atmospheric density, pressure, and ion composition at altitudes between 200 and 500 kilometers
- Research into solar corpuscular radiation
- Measurement of ion concentrations in the chosen orbit
- Measurement of inherent electrical charges
- Measurement of Earth's magnetic fields at altitudes of 200 to 500 kilometers
- Studies of cosmic rays
- Research into ultraviolet and x-ray portions of the solar spectrum
- Research into the possibility of ensuring the survival of an animal in orbit[118]

Although many of the specifics had changed, much of the basis for Object D was taken from the historic proposal for the Simplest Satellite, which was submitted to the government in 1954. At a special meeting on September 28, 1956, the Keldysh commission fully approved the draft plan, thus freezing the final design of the spacecraft.[119]

Tikhonravov's department had by this time emerged with three airtight designs of Object D, each with a roughly conical shape and a mass between 1,000 and 1,400 kilograms. The most favored version included a power supply system with solar and chemical batteries and used a special system of louvers on the exterior and fans on the interior for thermal regulation. There were also radio communications devices with multichannel capability for transmitting telemetric data and receiving ground commands. Three quarters of the mass of the object consisted of scientific instruments. In one of the three versions of Object D, engineers ensured the possibility of installing a small cockpit to carry a dog into orbit.[120] This cabin was a direct modification of capsules launched aboard the upper atmosphere sounding rockets throughout the 1950s. Few details have been released on the biological version of Object D, although presumably the animal capsule inside the conical spacecraft was not recoverable, as specified in the original 1954 document.

Events in the satellite program took an abrupt turn in the waning months of 1956. Actual test models of Object D, expected to be ready by October, remained unfinished. By early November, Korolev was suffering from great anxiety, no doubt compounded by his extraordinarily busy plans, as he traveled from Kaliningrad to Kapustin Yar to Tyura-Tam to Molotovsk and back several times to oversee various projects.[121] Part of this anxiety was from serious concerns that his project would be suddenly preempted with a satellite launch from the United States. In September 1956, the U.S. Army had launched a Jupiter C missile from Patrick Air Force Base at Cape Canaveral, Florida, that could have launched a satellite into orbit if it had included a live third stage. Korolev mistakenly believed that it had been a secret attempt to launch a

118. The complete text of the draft plan has been published as S. P. Korolev, *et al.*, "Thesis Report on the Development of a Draft Plan for an Artificial Satellite of the Earth" (English title), in Keldysh, ed., *Tvorcheskoye naslediye Akademika Sergeya Pavlovicha Koroleva*, pp. 362–68.

119. Ishlinskiy, ed., *Akademik S. P. Korolev*, p. 447. The draft plan was approved by the Special Committee on September 30, 1956.

120. Yu. Biryukov, "From the History of Space Science: The Price of Decision—First Place (The First Satellites)" (English title), *Aviatsiya i kosmonavtika* no. 10 (October 1991): 37–39.

121. Kaliningrad was the location of OKB-1, while sea trials of the R-11FM were carried out near Molotovsk.

satellite.[122] A second concern were the results of static testing of the R-7 engines on the ground. Instead of the projected specific impulse of 309 to 310 seconds, the R-7 engines could not produce more than 304 seconds—too low for the heavy Object D satellite. He realized that perhaps he was making this effort too complicated. Why not attempt to launch something simpler on the first orbital attempt instead of a sophisticated one-and-a-half-ton scientific observatory?

At the end of November, Tikhonravov was perceptive enough to detect Korolev's anxiety and verbalized it: "What if we make the satellite a little lighter? Thirty kilograms or so, or even lighter?"[123] Not one to sit still, Korolev immediately took action on the matter. On November 25, he ordered a young engineer at OKB-1, Nikolay A. Kutyrkin, to begin designing this new smaller satellite. Another young man, Georgiy M. Grechko, set about calculating preliminary ballistics on the launch. Politically, it was not all that easy. Keldysh was dead set against the idea, which was not surprising because he had invested so much time and energy into Object D. There were other engineers within OKB-1 who were also not too enthused by the new plan. All eventually ceded to the strong-willed Korolev. As insurance, Korolev decided not to depend on dozens of other subcontractors. He made sure that the satellite would be designed and manufactured completely within his own design bureau with the help of only two outside organizations: the Scientific-Research Institute of Current Sources under Nikolay S. Lidorenko for the design of the on-board batteries and NII-885 under Chief Designer Ryazanskiy for the radio transmitters.

On January 5, 1957, Korolev sent a letter describing his revised plan to the Special Committee. He asked for permission to launch two small satellites, each with a mass of forty to fifty kilograms, during the period of April–June 1957 immediately *prior to* the beginning of the IGY. Once again, his thinking was simple: because the United States had plans for launching satellites during the IGY, he could ensure Soviet preeminence by launching one before the start of the IGY. This plan would be contingent on the timetable for the R-7 program, which Korolev admitted was behind schedule; the first launch of the missile was set for March 1957, at the earliest. Each satellite would orbit Earth at altitudes of 225 to 500 kilometers and contain a simple shortwave transmitter with a power source sufficient for ten days' operation. Korolev did not obscure the reasons for the abrupt change in plans:

> *. . . the United States is conducting very intensive plans for launching an artificial Earth satellite. The most well-known project under the name "Vanguard" uses a three-stage missile . . . the satellite proposed is a spherical container of 50 centimeters diameter and a mass of approximately 10 kilograms. In September 1956, the U.S.A. attempted to launch a three-stage missile with a satellite from Patrick Base in the state of Florida which was kept secret. The Americans failed to launch the satellite . . . and the payload flew about 3,000 miles or approximately 4,800 kilometers. This flight was then publicized in the press as a national record. They emphasized that U.S. rockets can fly higher and farther than all the rockets in the world, including Soviet rockets. From separate printed reports, it is known that the U.S.A. is preparing in the nearest months a new attempt to launch an artificial Earth satellite and is willing to pay any price to achieve this priority.*[124]

122. The launch about which Korolev was informed was a Jupiter C missile (no. RTV-1), which flew a distance of 5,300 kilometers on September 20, 1956, during a reentry test. A live third stage could have put a small payload into orbit.

123. Golovanov, "The Beginning of the Space Era"; Golovanov, *Korolev*, p. 532.

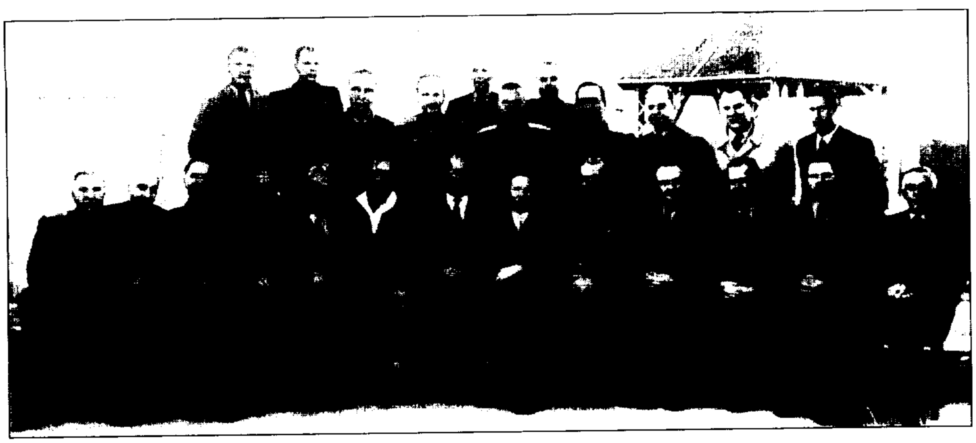
124. The complete text of Korolev's letter is reproduced as S. P. Korolev, "Proposal on the First Launch of an Artificial Satellite of the Earth Before the Start of the International Geophysical Year" (English title), in Keldysh, ed., *Tvorcheskoye naslediye Akademika Sergeya Pavlovicha Koroleva*, pp. 369–70.

While Korolev's information on U.S. plans may have been in error, his instincts were not that far off. The United States could have launched a satellite by early 1957, but various institutional and political obstacles precluded such an attempt.

By January 25, 1957, Korolev had approved the initial design details of the satellite officially designated the Simple Satellite No. 1 (PS-1). It seems that his letter had adequately invoked the specter of U.S. eminence in the field of military technology; Special Committee Chairman Ryabikov was evidently strongly in favor of the new plan. His support proved to be crucial. On February 15, the USSR Council of Ministers formally signed a decree (no. 171-83ss) titled "On Measures to Carry out in the International Geophysical Year," agreeing to the new proposal.[125] The two new satellites, PS-1 and PS-2, would weigh approximately 100 kilograms and be launched in April–May 1957, after one or two fully successful R-7 ICBM launches. Meanwhile, the Object D launch was pushed back to April 1958. Focused on a more modest objective, Korolev wasted little time. He quickly sent out technical specifications for the initial satellite PS-1 to the two subcontractors. In addition, the Experimental Design Bureau of the Moscow Power Institute under Chief Designer Aleksey F. Bogomolov modified its Tral telemetry system on the R-7 for use on the satellite launch.[126] By this time, there was an impressive sight at the Tyura-Tam launch base: the first flight article of the magnificent R-7 was on the launch pad.

The R-7 in Flight

The R-7 launch program, as with any other important weapons project, was overseen through its test program under the guidance of a special State Commission, a temporary ad hoc body comprised of various representatives of the military, industry, and the design bureaus.



The State Commission for the Sputnik satellite shown in 1957. Seated left to right are: Ivan Bulychev, Grigoriy Udarov, Aleksandr Mrykin, Nikolay Pilyugin, Mstislav Keldysh, Vasiliy Mishin, Leonid Voskresenskiy, Vasiliy Ryabikov, Mitrofan Nedelin, Sergey Korolev, Konstantin Rudnev, Valentin Glushko, and Vladimir Barmin. Standing left to right are: Aleksey Bogomolov, Pavel Trubachev, Viktor Kuznetsov, Anatoliy Vasilyev, Konstantin Bushuyev, Aleksandr Nosov, Ivan Borisenko, Aleksey Nesterenko, Georgiy Pashkov, Mikhail Ryazanskiy, and Viktor Kurbatov. (files of Asif Siddiqi)

125. Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, pp. 88, 632; Ishlinskiy, ed., *Akademik S. P. Korolev*, p. 447. Other sources say that the decree was issued on February 7, 1957. See Vetrov, "The First Satellite."

126. Lardier, *L'Astronautique Soviétique*, p. 108; Ishlinskiy, ed., *Akademik S. P. Korolev*, p. 447. Actual tests of the instrument were conducted beginning May 5, 1957, in which a helicopter was used to track the satellite using a 200-meter cable. The technical specifications for the PS-1's radio transmitter were approved on February 15, 1957, the same day that the project was approved by the Soviet government.

Unlike formal and permanent institutions such as the Special Committee or the Military-Industrial Commission, the State Commission would remain in existence only during the testing phase, and it would serve as the primary conduit for communication with Party leaders, such as Khrushchev, on the state of the program. The USSR Council of Ministers—that is, Khrushchev and Bulganin—established a fourteen-member State Commission for the R-7 test series on August 31, 1956. Vasiliy M. Ryabikov, the powerful industrial bureaucrat who oversaw the entire missile industry as chairman of the Special Committee for Armaments of the Army and Navy, was appointed to lead the body. Korolev was a deputy chairman and "technical leader." The remainder consisted of three military representatives (Mrykin, Nedelin, and Nesterenko), five chief designers (Barmin, Glushko, Kuznetsov, Pilyugin, and Ryazanskiy), and four men from the defense industry (Pashkov, Peresypkin, Udarov, and Vladimirskiy). Although they were not official members of the commission, two scientists, Mstislav V. Keldysh and Aleksandr Yu. Ishlinskiy, participated in its proceedings.[127]

The R-7 had run into some major delays in late 1956, primarily related to the work on the main engines. Although the first launch was originally planned for early 1957, it had been progressively shifted to March of that year. Typical of large-scale endeavors, there were numerous subcontractor and management problems, all of which were addressed by the State Commission in late 1956. As Korolev reported in a letter to the government, "The preparatory operations for the first launch of the rocket are proceeding with significant difficulties and behind schedule. . . ."[128] The static tests of complete first and second stages at Zagorsk finally cleared the way for launch planning, and the first experimental model of the R-7, the 8K71SN, was transported from Leningrad and assembled at Tyura-Tam in December 1956 for placement on the launch pad and subsequent captive tests. The operation of the ground segment of the telemetry network was also given a thorough checkout at the time, with the first telemetric contact between Tyura-Tam and Moscow established on December 27. The tracking, telemetry, and command network, officially called the Range Measurement Complex, comprised nine Tayga stations located at various points between one and a half and 800 kilometers from the launch pad at site 1, as well as six Kama stations placed between thirty-two and 120 kilometers from

127. Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p. 79. The official positions of the members of the state commission for the R-7 were: V. M. Ryabikov (Chairman of the Special Committee), S. P. Korolev (Chief Designer of OKB-1), A. G. Mrykin (First Deputy Chief of the Directorate of the Chief of Reactive Armaments), M. I. Nedelin (Deputy Minister of Defense for Reactive Armaments), A. I. Nesterenko (Commander of NIIP-5), V. P. Barmin (Chief Designer of GKSB SpetsMash), V. P. Glushko (Chief Designer of OKB-456), V. I. Kuznetsov (Chief Designer of NII-10), N. A. Pilyugin (Chief Designer of NII-885), M. S. Ryazanskiy (Chief Designer and Director of NII-885), G. N. Pashkov (Deputy Chairman of the Special Committee), I. T. Peresypkin (Minister of Communications), G. R. Udarov (Deputy Minister of Machine Building), and S. M. Vladimirskiy (Deputy Minister of Radio-Technical Industry). M. V. Keldysh was the Chief of the Department of Applied Mathematics of the V. A. Steklov Mathematics Institute of the Academy of Sciences and Director of NII-1, while A. Yu. Ishlinskiy was the Director of the Moscow Institute for Problems of Mechanics and "Scientific Consultant" to NII-10. By the time that launches of the R-7 began in May 1957, several other men were involved with the work of the State Commission, including I. T. Bulychev (Chief of the Communications Directorate of the Ministry of Defense), I. S. Konev (First Deputy Minister of Defense), A. A. Maksimov (from the Directorate of the Chief of Reactive Armaments), N. D. Psurtsev (Minister of Communications), K. N. Rudnev (Deputy Minister of Defense Industries), and S. P. Shishkin (Chief Designer of KB-11). See Council of Veterans of the Baykonur Cosmodrome, *Proryv v kosmos*, pp. 10–11; A. A. Maksimov, "Heat, Water, and Red Buttons, or Rehearsal of the Historic Launch" (English title), *Zemlya i vselennaya* no. 5 (September–October 1990): 60–65; A. A. Maksimov, "The First Launch From Baykonur" (English title), *Zemlya i vselennaya* no. 1 (January–February 1991): 89–93.

128. Golovanov, "The Beginning of the Space Era."

the target area in the Kamchatka peninsula in the eastern Soviet Union, about 6,500 kilometers from Tyura-Tam.[129]

On March 4, 1957, Korolev signed the Technical Assignment No. 1 document, formally approving preparations for the launch. Through the remaining days of March and April, various members of the State Commission flew into Tyura-Tam. Korolev, in the company of Chief Designer Pilyugin, arrived on April 10, followed by Chairman Ryabikov six days later. On the way to the launch range, Korolev had told Pilyugin that he would not return until the missile had flown. The presence of high-ranking military officers Nedelin and Mrykin markedly increased the tension at the launch site, partly because of Mrykin's reputation for terrifying reprimands for those that were not doing their job well. Others remember the atmosphere as being festive as a result of local troops being relocated to new barracks from their previous homes in railway cars. On Korolev's suggestion, officials carried out a complete dress rehearsal of the transportation from the Assembly-Testing Building at site 2 to the launch pad at site 1 on May 4.[130] At the pad itself, the missile was uprighted over the launch structure and held down by the pad's four "petals." After installation, engineers established electrical and pneumatic connections with ground equipment. The entire rehearsal was uneventful, save for a humorous incident involving Marshal Nedelin, who had decided to check whether the emergency alarm system for the launch site was in working order. When the appropriate alarm button was pressed, nothing happened. Fuming at the failure, Nedelin vented with full force at engineer Lt. Colonel Aleksandr I. Nosov, the Deputy Commander of NIIP-5 for Experimental-Test Work. Several members of the State Commission entered the command bunker, where they discovered that a young army sergeant on a cigarette break had left a particularly important switch in the wrong position. Suddenly, the emergency alarm went off, and the fire squadron rushed to the site as part of the rehearsal and completely doused the bunker with an extinguisher. Needless to say, all the commission members, fully soaked by accident, were not too happy.[131]

On the afternoon of May 6, the R-7 (product 8K71 number M1-5) was moved once again to the pad, this time escorted on foot by Ryabikov, Korolev, Nedelin, and others in a ceremonial and solemn act that would become common for future launches.[132] Two days later, the State Commission formally met to set the first launch window between the 13th and 18th of the month. The only major problems were some communications difficulties with the center at the target site near the Klyuchevskhaya-Sopka volcano in Kamchatka. Controllers faced other major problems in the following days: there was a guidance system problem as a result of a loose screw on the 11th and a more serious electrical supply malfunction the following day during a rehearsal launch.[133] Having rectified these problems, the State Commission met on the night of the 14th to approve the first launch between 1400 and 1700 hours, Moscow Time, the following day.[134] There were several reasons for the time slot selection. The launch time had to be during daylight hours for local optical tracking. The reentry over Kamchatka peninsula of the

129. Council of Veterans of the Baykonur Cosmodrome, *Proryv v kosmos*, p. 90; Villain, ed., *Baïkonour*, p. 55; Varfolomeyev, "Soviet Rocketry that Conquered Space: Part 1"; Mozzhorin, *et al.*, eds., *Nachalo kosmicheskoy ery*, p. 57. Each station consisted of a set of buildings for equipment and staff accommodations. The equipment was composed of telemetry, tracking, and time code receivers, which were powered by an independent power generator. In the total Range Measurement Complex in early 1957, there were twelve Binokl tracking devices, eight Irtysh interferometers, ten KT-50 cinetelescopes, two KST-80 movie telescopes, three cinetheodolites, and various other smaller instruments.

130. Villain, ed., *Baïkonour*, p. 27; Maksimov, "Heat, Water, and Red Buttons"; Romanov, *Korolev*, pp. 268–69; Lardier, *L'Astronautique Soviétique*, p. 92.

131. Mozzhorin, *et al.*, eds., *Nachalo kosmicheskoy ery*, pp. 134–35.

132. Golovanov, *Korolev*, p. 503. Articles M1-1 to M1-4 were ground-test versions.

133. Villain, ed., *Baïkonour*, p. 27; Maksimov, "The First Launch From Baykonur."

134. Local time was three hours ahead of Moscow Time.

dummy warhead had to be observed in the night sky. Finally, the launch had to occur as close to nighttime as possible so as to prevent observation by U.S. optical tracking stations.

Fueling began on the R-7 at 0400 hours Moscow Time, on May 15, under the direction of Georgiy M. Grechko, a twenty-six-year-old engineer from OKB-1 who would fly into space from the same site eighteen years later. The process was quite a grueling ordeal and something to which neither the artillery men nor the engineers particularly looked forward. The hardest part was handling liquid oxygen (LOX), which was maintained at a temperature of minus 190 degrees Centigrade. The oxidizer could not be pumped all at once into the missile because the sudden change in temperature would have caused undesirable structural changes in the missile. Thus, a little amount was transferred to wash and chill the tanks of the five boosters. Only after this could pad workers fill the missile with the bulk of the LOX. Even after complete fueling, the LOX hoses were kept attached to the rocket to continually compensate for the change to gaseous state of the LOX in the hot temperatures in Kazakhstan. The entire process of fueling for the initial variant took close to five hours.[135]

Tensions were high during launch day, and there was a major altercation between Colonel Aleksandr A. Maksimov, the secretary of the State Commission, and Korolev, when the former detected a large oxygen leak at the base of the rocket. As more and more individuals began to congregate at the pad, Korolev lost his temper and began to demand to Chairman Ryabikov that Maksimov be immediately taken off the pad area for insubordination. The matter was eventually resolved when Korolev admitted that there was in fact a leak; he apologized in front of the entire commission to Maksimov. The leak was repaired quickly, and launch preparations continued.[136]

The launch took place at 1901 hours Moscow Time on May 15, 1957. Deputy Chief Designer Voskresenskiy and Lt. Colonel Nosov supervised the launch sequence from a bunker 300 meters from the pad.[137] The launch pad's "petal" structure performed flawlessly, and the rocket lifted gracefully into the sky. The expectations of the State Commission turned sour when incoming telemetry indicated that the engine in one of the strap-ons (Blok D) had cut off at T+98 seconds. Engineers later discovered that the entire strap-on had broken away from the central core, following which the missile disintegrated, with various parts landing as far away as 400 kilometers from the launch site. Chief Designer Bogomolov, responsible for the Tral telemetry system for the booster, had continued to shout until almost 300 seconds that all was well because signals were still coming in, but Korolev intuitively knew that the rocket was going nowhere. "We wanted to surprise

The first R-7 ICBM shown on the single launch pad at site 1 at Tyura-Tam in early 1957. Note the "tulip" launch structure around the base of the rocket. Later operational models of the rocket had a different payload fairing. (copyright Steven Zaloga)

135. Zaloga, *Target America*, p. 144.

136. Mozzhorin, *et al.*, eds., *Dorogi v kosmos: I*, p. 114; Villain, ed., *Baïkonour*, pp. 29–30.

137. The launch button for this first launch from Tyura-Tam was pressed by thirty-three-year-old Lt. Colonel Ye. I. Ostashev, the chief of the First Testing Directorate of NIIP-5. One source states that the launch was at 1905 hours Moscow Time. See Maksimov, "The First Launch From Baykonur."

the world, but the rocket is lying on the ground 300 kilometers from here," he was quoted as saying.[138] An extensive investigation later revealed that a fuel leak in the Blok D engine's pump outlet, combined with the heat from the neighboring engines, had led to a fire that had literally engulfed the booster almost from launch.[139]

Khrushchev was evidently disappointed by the result. Although he was keenly interested in the proceedings at Tyura-Tam, he was careful enough to let Ryabikov, Korolev, and Nedelin do their jobs without interference from the higher-ups. He only spoke to Korolev once prior to the launch. He told his son: "If there is any need, Korolev will call me, that's how we arranged it."[140] On the evening of May 15, when the bad news was relayed to him, Khrushchev was silent and pensive, recognizing that accidents were inevitable in such complex projects. The failure took a more serious toll with the engineers back in Kazakhstan. Korolev's deputy Voskresenskiy was severely ill immediately following the failure, and Korolev sent him back to Moscow along with Chief Designers Barmin and Pilyugin. Most members of the State Commission also returned to their duties in Moscow until preparations could be made for a second attempt, leaving Korolev to direct the accident investigation and preparations for a second launch. The fifty-year-old Korolev was not in good health; he had a bad sore throat and had to take penicillin shots several times. His letters to his wife at the time were punctuated with musings full of doubt and frustration:

> *When things are going badly, I have fewer "friends." . . . My frame of mind is bad. I will not hide it, it is very difficult to get through our failures. . . . There is a state of alarm and worry. . . . It is a hot 55 degrees here.*[141]

The second R-7 vehicle, 8K71 number M1-6, arrived at the pad in early June after new heat-deflecting shields had been installed in the tail section of the missile. During a launch attempt on June 9, there was a sudden abort after the launch command—a problem traced to a nitrogen valve that had remained in the closed position instead of open. The exact same thing occurred on another attempt the following day. A final attempt at launch on June 11 also ended in a launch abort. Just after the abort, the entire area was drenched in a tropical rainstorm, which flooded the basement of several buildings, including the Assembly-Testing Building at site 2. Luckily, military personnel were able to save almost all of the valuable equipment, some simply by drying out in the Sun.[142]

As the engineers pored over telemetry, they determined one of the causes for the abort relatively quickly: yet another valve was left in a wrong position. It was clear that OKB-1 was to blame for the incorrect assembly, but Korolev tried every trick he could think of to obscure the fact that it was one of his employees who had made the egregious error. Although Korolev was magnanimous and fair in his technical evaluations, he was not, by any means, willing to take the blame when it was a case of his design bureau over another. His usual strategy in such situations would be to either cloud the problem with double-talk or force Glushko or Pilyugin to admit to errors. If an accident commission had to be established to address the issue, he always sent either Mishin or Voskresenskiy to defend OKB-1, preferring to remain "above the

138. Mozzhorin, *et al.*, eds., *Nachalo kosmicheskoy ery*, pp. 20, 58, 77; Council of Veterans of the Baykonur Cosmodrome, *Proryv v kosmos*, p. 173.

139. Mozzhorin, *et al.*, eds., *Nachalo kosmicheskoy ery*, p. 77. Some sources suggest that the failure was caused by a rupture in a nitrogen pipe at T+103.6 seconds. See A. A. Maksimov, "The Results of the First Launch From Baykonur" (English title), *Zemlya i vselennaya* no. 2 (March–April 1991): 63–67.

140. Khrushchev, *Nikita Khrushchev: tom 1*, p. 287.

141. Golovanov, "The Beginning of the Space Era."

142. Council of Veterans of the Baykonur Cosmodrome, *Proryv v kosmos*, pp. 21, 173.

battle." This time, none of those tactics worked. Ryabikov was too smart for that, reading through the technical jargon that Korolev had used to obfuscate OKB-1's role in the valve failure. Ryabikov reportedly told Korolev, "What a cunning man you are, Sergey Pavlovich! So much stink about what might have been caused by others, and so much perfume for your own shit. . . ."[143]

After an in-depth investigation, a third rocket, 8K71 number M1-7, was moved to the pad for launch at 1553 hours on July 12. This time, the missile lifted off into the sky to the cheers of observers. The euphoria evaporated when at T+33 seconds, all four strap-ons spuriously separated from the core because of a rapid rotation around the longitudinal axis.[144]

The days following this failure were the lowest point for Korolev and his associates. Suddenly, everything for which they had labored over three years had been put into doubt. There was severe criticism from higher officials and even talk of curtailing the entire program. For Korolev, the headaches were compounded by the cumulative delays of his Simple Satellite project. He had originally planned for an orbital launch before the beginning of the IGY. After a month into the IGY, the R-7 had not flown a successful mission. His dreams, his position, and his status were all in jeopardy, and this began to affect his temperament. In mid-June, he wrote to his wife, "Things are not going very well again," adding with a note of optimism, "Here, right here and now, we must strive for the solution we need!" By July, things began to deteriorate. On the 8th, he wrote, "We are working very hard," but after the second launch failure, he wrote on the 23rd, "Things are very, very bad."[145] One of Korolev's biographers wrote in 1987, "In all the postwar years, no days were more painful, difficult, or tense for Sergey Pavlovich Korolev than those of that hot summer of 1957."[146] At this point, it seems that had abandoned his old ways of pitting design bureau against design bureau and genuinely asked for cooperation. Anatoliy A. Abramov, the senior designer at OKB-1 responsible for launch complexes, later recalled:

> *Now, if ever, was the time to despair, to lose faith in the whole program. However S. P. Korolev's composure and the absence of any attempt to find "scapegoats" made people realize that we had embarked on a new level of scientific-technical complexity where no one had gone before. To have fallen into confusion or become mired in apportioning blame would have destroyed the team, its unity and self-confidence. The weight of responsibility resting on S. P. Korolev's shoulders was enormous, especially when you consider that he had still not been formally rehabilitated [after his imprisonment]. Arrest, prison and exile were still fresh in his mind. There were, moreover, certain people gossiping behind his back about the missile being conceptually flawed on the premise that the 32 parallel combustion chambers could never be made to operate simultaneously and reliably.*[147]

Another R-7, 8K71 number M1-8, was brought to the pad, this one lovingly prepared with the utmost care. The rocket successfully lifted off the pad at site 1 at 1515 hours Moscow Time on August 21, 1957. To the delight of the controllers, all the main engines, all the combustion chambers, the four strap-ons, the launch complex, and the hybrid guidance system—all of it—worked with clockwork precision. The missile and its payload flew 6,500 kilometers, and the warhead entered the atmosphere over the target point at Kamchatka. The only damper on the mission came when the specially constructed heat shield for the dummy warhead disintegrat-

143. Golovanov, *Korolev*, pp. 504–06.
144. Mozzhorin, *et al.*, eds., *Nachalo kosmicheskoy ery*, p. 21; Villain, ed., *Baikonour*, p. 31.
145. Golovanov, "The Beginning of the Space Era."
146. *Ibid.*
147. Mozzhorin, *et al.*, eds., *Nachalo kosmicheskoy ery*, p. 21.

ed at an altitude of ten kilometers because of excessive thermodynamic forces. Despite the unfortunate end, the R-7 had finally flown, vindicating the hopes of thousands of engineers who had invested so much in it. Korolev was so subsumed by euphoria that he stayed awake until three in the morning, speaking to his deputies and aides about the great possibilities that had opened up, about the future, and mostly about his artificial satellite.[148] As for the missile, a quickly dispatched search party of approximately 500 men spent almost a whole week gathering the remains of the dummy warhead and its thermal coating.

It was only after the search party returned that the State Commission wrote up an official communiqué on the launch—a statement that was published in the Soviet media. It was extremely unusual for Soviet authorities to publicize successes in any military field, and this particular anomaly can perhaps be explained by the fact that the press release was aimed as much at the United States as it was at Khrushchev's own opponents after the dangerous "Anti-Party Group" had nearly wrested power from him during the summer of 1957. The communiqué included the following:

> *A few days ago a super-long-range, intercontinental multistage ballistic missile was launched. The tests of the missile were successful; they fully confirmed the correctness of the calculations and the selected design. The flight of the missile took place at a very great, hitherto unattained, altitude. Covering an enormous distance in a short time, the missile hit the assigned region. The results obtained show that there is the possibility of launching missiles into any region of the terrestrial globe. The solution of the problem of creating intercontinental ballistic missiles will make it possible to reach remote regions without resorting to strategic aviation, which at the present time is vulnerable to modern means of antiaircraft defense.*[149]

Clearly, it did not have the intended effect on the U.S. public or media, because, for the most part, little attention was given it. Those who did pay attention spoke only to dismiss the claim—a stance justified partly by the black hole of information on Soviet ballistic missiles in the open press. It would take thirty-eight more days before the entire world would take notice that a new age had arrived, heralded by that same ICBM.

Sputnik

Work on the Simple Satellite PS-1 had continued at an uneven pace since the development of the object began in November 1956. Between March and August 1957, engineers carried out computations to select and refine the trajectory of the launch vehicle and the satellite during launch. These enormously complicated computations for the R-7 program were initially done by hand using electrical arithrometers and six-digit trigonometric tables. When more complex calculations were required, the engineers at OKB-1 were offered the use of a "real" computer recently installed at the premises of the Department of Applied Mathematics at Keldysh's request. The gigantic machine filled up a huge room and may have been the fastest computer in the Soviet Union in the late 1950s; it could perform 10,000 operations per second, a remarkable capability for Soviet computing machines of the time.[150]

148. Golovanov, "The Beginning of the Space Era"; Golovanov, *Korolev*, p. 514; Council of Veterans of the Baykonur Cosmodrome, *Proryv v kosmos*, pp. 25, 174; Villain, ed., *Baïkonour*, p. 31.

149. "Report on Intercontinental Ballistic Missile" (English title), *Pravda*, August 27, 1957. A complete English translation of the press release is included in Krieger, *Behind the Sputniks*, pp. 233–34.

150. Ishlinskiy, ed., *Akademik S. P. Korolev*, p. 447; V. Lysenko, ed., *Three Paces Beyond the Horizon* (Moscow: Mir Publishers, 1989), p. 58.

Engineers, scientists, and military officers expended a major effort in creating a ground infrastructure to track and make contact not only with the PS-1, but also with the much more complex Object D, still awaiting launch in 1958. After fierce competition between the Academy of Sciences and NII-4 in the Ministry of Defense for the contract to build the tracking, telemetry, and command network for the satellite, the latter establishment took on the job, in addition to its duties in connection with the R-7 tracking network.[151] This was the beginning of the creation of the so-called Command-Measurement Complex (KIK), which has served every single piloted, interplanetary, scientific, and military space mission from 1957 to the present time. Overseen by NII-4 Deputy Director Mozzhorin, KIK initially comprised seven major stations spread all across the country at Tyura-Tam, Makat, Sary-Shagan, Yeniseysk, Iskhup, Yelizovo, and Klyuchi.[152] All the tracking and telemetry data were relayed to a new Coordination-Computation Center, established at NII-4's headquarters in Moscow in early 1957, under the command of Pavel A. Agadzhanov, who was personally responsible for overseeing the tracking of all satellites in the early space program. This center eventually became part of the larger KIK when the KIK command center was established on July 12, 1957.[153] An analogous group was also stationed at Tyura-Tam to support the launch of satellites. Although Soviet sources suggest that the center and KIK were primarily designed and built to support operations of Object D, it is clear that the primary *raison d'être* was to support future operations of military satellites.

Work on the Simple Satellite seems to have slowed down somewhat during the intense preparations for the R-7 launch in the summer 1957. There were many debates on the shape of the first satellite, with most senior OKB-1 designers preferring a conical form because it fit well with the nose cone of the rocket. At a meeting early in the year, Korolev had a change-of-heart and suggested a metal sphere at least one meter in diameter.[154] There were six major guidelines followed in the construction of the PS-1:

- The satellite would have to be of maximum simplicity and reliability while keeping in mind that methods used for the spacecraft would be used in future projects.
- The body of the satellite would be spherical to determine atmospheric density in its path.
- The satellite would be equipped with radio equipment working on at least two wavelengths of sufficient power to be tracked by amateurs and to obtain data on the propagation of radio waves through the atmosphere.
- The antennas would be designed so as not to affect the intensity of the radio signals because of spinning.
- The power sources would comprise on-board chemical batteries, ensuring work for two to three weeks.
- The attachment of the satellite to the core stage would be designed in such a way as to minimize the possibility of a separation failure.

151. Mozzhorin, *et al.*, eds., *Nachalo kosmicheskoy ery*, p. 266. The Soviet government issued an official decree on September 3, 1956, for the creation of the ground tracking network.

152. Many of the major participants involved in the creation of KIK are named in B. A. Pokrovskiy, *"Zarya"—pozyvnoye zemni* (Moscow: Moskovskiy rabochiy, 1987), pp. 58, 70. They included numerous individuals who went on to powerful positions in the Soviet space program: A. I. Sokolov (NII-4 Director), G. A. Tyulin (NII-4 First Deputy Director), P. A. Agadzhanov, I. A. Artelshchikov, I. K. Bazhinov, A. V. Brykov, Yu. V. Devyatkov, P. E. Eliasberg, V. T. Dolgov, G. I. Levin, M. P. Likhachev, G. S. Narimanov, Ye. V. Yakovlev, and I. M. Yatsunskiy. Bazhinov, Brykov, and Yatsunskiy were members of Tikhonravov's original satellite research group at NII-4, but they were not transferred to OKB-1 in 1956 like most of their associates. The Pokrovskiy text is a detailed exposition on the history of KIK. Some more details were added in Mozzhorin, *et al.*, eds., *Nachalo kosmicheskoy ery*.

153. Pokrovskiy, *"Zarya"—pozyvnoye zemni*, pp. 75–76; Maksimov, ed., *Raketnyye voyska strategicheskogo naznacheniya*, p. 49; Mozzhorin, *et al.*, eds., *Nachalo kosmicheskoy ery*, p. 310. The first commander of the KIK center (TsKIK) was Maj. General A. A. Vitruk.

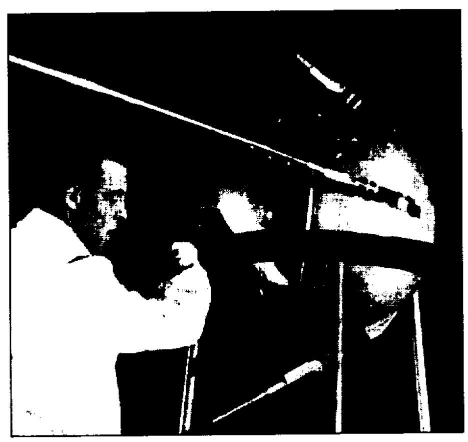
154. I. Minyuk and G. Vetrov, "Fantasy and Reality" (English title), *Aviatsiya i kosmonavtika* no. 9 (September 1987): 46–47.

The five primary scientific objectives of the mission were to:

- Test the method of placing an artificial satellite into Earth orbit
- Provide information on the density of the atmosphere by calculating its lifetime in orbit
- Test radio and optical methods of orbital tracking
- Determine the effects of radio wave propagation through the atmosphere
- Check principles of pressurization used on the satellite[155]

The satellite as it eventually emerged was a pressurized sphere, fifty-eight centimeters in diameter, made of an aluminum alloy. The sphere was constructed by combining two hemispherical casings together. The pressurized internal volume of the sphere was filled with nitrogen at 1.3 atmospheres, which maintained an electro-chemical source of power (three silver-zinc batteries), two D-200 radio transmitters, a DTK-34 thermo-regulation system, a ventilation system, a communications system, temperature and pressure transmitters, and associated wiring. The two radio transmitters operated at frequencies of 20.005 and 40.002 megacycles at wavelengths of one and a half and seven and a half meters, respectively. The signals on both the frequencies were spurts lasting 0.2 to 0.6 seconds, and they carried information on the pressure and temperature inside the satellite. They provided the famous "beep-beep" sound to the transmissions. The antenna system comprised four rods, two with a length of 2.4 meters each and the remaining two with a length of 2.9 meters each, all of which would spring open into their unfurled position once the satellite was in orbit. Engineers had conducted tests of this radio system as early as May 5, 1957, using a helicopter and a ground station. The total mass of the satellite was 83.6 kilograms, of which fifty-one kilograms represented the power source. The "lead designer" for the PS-1 was Mikhail S. Khomyakov; Oleg G. Ivanovskiy served as his deputy.[156]

Korolev, of course, kept close tabs on the development of the PS-1 and continuously made sure that the spherical satellite was kept spotlessly clean and shiny, not only for its reflective qualities, but also for its overall aesthetic beauty. On one occasion, he flew into a rage at a junior assembly shop worker for doing a poor job on the outer surface of a *mock-up* of the satellite. "This ball will be exhibited in museums!," he shouted.[157] Deputy Chief Designer Bushuyev telephoned Korolev at Tyura-Tam on June 24 to inform him that he had just signed the document specifying the final configuration of the satellite. Actual construction took place in August. The launch vehicle earmarked for the satellite was a slightly uprated version of the basic 8K71 ICBM variant, renamed the 8K71PS.



The PS-1 satellite is shown here on a rigging truck in the assembly shop in the fall of 1957 as a technician puts finishing touches on it.

155. M. K. Tikhonravov, "The Creation of the First Artificial Earth Satellite: Some Historical Details," *Journal of the British Interplanetary Society* 47 (May 1994): 191–94.

156. *Ibid.*; Kustova, ed., *Ot pervogo Sputnika*, p. 37; Villain, ed., *Baïkonour*, p. 26; Golovanov, *Korolev*, p. 537; O. G. Ivanovskiy, *Naperekor zemnomy prityazhenyu* (Moscow: Politicheskoy literatury, 1988), pp. 167–69.

157. Mikhail Florianskiy, "October 4—For the First Time in the World," *Moscow News Supplement* 40 (1987).

The modifications included omitting the 300-kilogram radio package from the top of the core booster, changing the burn times of the main engines, removing a vibration measurement system, using a special nozzle system to separate the booster from the satellite installed at the top of the core stage, and installing a completely new payload shroud and container, which replaced the warhead configuration.[158] The length of the booster with the new shroud was 29.167 meters, almost four meters shorter than the ICBM version. Because there was some doubt as to whether ground observers would be able to observe the tiny satellite in orbit, Korolev ensured that the central core of the launch vehicle was sufficiently reflective. Academician Vladimir A. Kotelnikov, the Director of the Institute of Radio-technology and Electronics at the Academy of Sciences, had one of his scientists develop an angular reflector for this purpose, which was installed on the booster core.[159]

Apart from competition from the United States, Korolev had to unexpectedly address a different kind of threat at the time, one from within the Soviet Union in the person of Chief Designer Mikhail K. Yangel of OKB-586. In the first quarter of 1957, Yangel's design bureau at Dnepropetrovsk, on orders from Ustinov, had begun a study to explore the possibility of modifying its R-12 intermediate-range ballistic missile for a satellite launch.[160] The missile itself, fueled by storable hypergolic propellants, unlike the R-7, was the focus of a five-year-long development program, at first under Korolev's tutelage, but later transferred to Dnepropetrovsk. Prodded by the unending delays in the R-7 program, Yangel evaluated "the possibility of the *immediate* launch of a similar satellite [as Korolev's] using the simplest of booster rockets based on the strategic R-12 missile."[161] Although analysis proved that a hastily modified two-stage R-12 could be used for this goal, it did not seem likely that a first launch could be carried out prior to either the R-7 or the Americans. To Korolev's relief, the plan was shelved. The R-12 meanwhile began a successful flight test program on June 22, 1957, from Kapustin Yar, at the very same time that Korolev was watching his R-7s blow up in the air.[162] Ironically, Yangel *did* end up using the R-12 as the basis for a satellite launch vehicle, but that would not be until the early 1960s.

The Council of Ministers had formally approved the Simple Satellite program in February 1957. With one R-7 success under his belt, Korolev needed final permission from the State Commission to proceed with an orbital launch. Despite the official governmental sanction, it seems that this process was fraught with difficulty, suggesting that even at this late stage, there were individuals on the commission who were not interested in the satellite attempt. At a State Commission meeting soon after the August launch, Korolev formally asked for permission to launch a satellite if a second R-7 successfully flew in early September. For many of the members, while they were aware of the Object D project, the existence of the PS-1 effort was a com-

158. Varfolomeyev, "Soviet Rocketry that Conquered Space: Part 1"; Keldysh, ed., *Tvorcheskoye naslediye Akademika Sergeya Pavlovicha Koroleva*, p. 365; Mozzhorin, *et al.*, eds., *Nachalo kosmicheskoy ery*, pp. 60-61.

159. Ishlinskiy, ed., *Akademik S. P. Korolev*, p. 459. The scientist in question was V. M. Vakhnin.

160. Pappo-Korystin, Platonov, and Pashchenko, *Dnepropetrovskiy raketno-kosmicheskiy tsentr*, p. 60; S. N. Konyukhov and V. A. Pashchenko, "History of Space Launch Vehicles Development," presented at the 46th International Astronautical Congress, IAA-95-IAA 2.2.09, Oslo, Norway, October 2–6, 1995. The range of the missile was about 2,000 kilometers.

161. Biryukov, "From the History of Space Science." Author's emphasis. Confusingly, Korolev's own OKB-1 had also examined the possibility of a "light" alternative satellite launch vehicle to the R-7. In late 1957, a department at OKB-1 had begun studying the possibility of a two-stage vehicle, the first using the R-5M and the second using the R-11M, as a launcher. The study, finished on August 9, 1957, proved that this multistage booster would not be able to launch a forty- to fifty-kilogram payload into Earth orbit. OKB-1 also studied a possible satellite launch vehicle using simply the core of the R-7. See Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p. 61; Vetrov, "The First Satellite"; Afanasyev, *R-12: Sandalovoye derevo*, pp. 17–18.

162. Sergeyev, ed., *Khronika osnovnykh sobytiy istorii*, p. 36. The series ended in December 1958, and the missile was declared operational on March 4, 1959. The U.S. Department of Defense designation for the R-12 was the SS-4, while the North Atlantic Treaty Organization (NATO) later named the missile "Sandal."

plete surprise. Convincing the commission proved to be much harder than expected, and the meeting ended in fierce arguments and recriminations. Not easily turned away, Korolev tried again at a second session soon after, this time using a political ploy: "I propose let us put the question of national priority in launching the world's first artificial Earth satellite to the Presidium of the Central Committee of the Communist Party. Let them settle it."[163] It worked. None of the members wanted to take the blame for a potential miscalculation, and Korolev got what he wanted. A final document for launch, "The Program for Carrying out a Test Launch of a Simple Unoriented ISZ (Object PS) Using the Product 8K71PS," was later signed by Ryabikov (Special Committee), Nedelin (Ministry of Defense), Ustinov (Ministry of Defense Industries), Kalmykov (Ministry of Radio-Technical Industry), and Nesmeyanov (Academy of Sciences).[164]

The subsequent launch of the R-7 on September 7 was as successful as the one in August, and the missile, 8K71 number M1-9, flew across the Soviet Union before depositing its dummy warhead in Kamchatka. Like the previous time, the warhead container disintegrated.[165] For the engineers working on the satellite, this was of minor significance, because the flight profile on the orbital mission would be different. In the summer, Korolev, Glushko, and the other chief designers had informally targeted the satellite launch for the 100th anniversary of Tsiolkovskiy's birth on September 17th, but achieving this date proved increasingly unrealistic. Instead of being at Tyura-Tam for a space launch on that day, Korolev and Glushko were both in attendance at the Pillard Hall of the Palace of Unions in Moscow for a special celebration of the great visionary's birthday. In a long speech to the distinguished audience, Korolev, whose real job was not revealed, predicted that "in the nearest future the first test launches of artificial satellites of the Earth with scientific goals will take place in the USSR and the USA."[166] The audience, of course, had little evidence to suspect that Korolev's pronouncement was not simply a vague prediction for an indefinite time.

On September 20, Korolev was in Moscow for a meeting of the State Commission for the PS-1 launch.[167] Chairman Ryabikov, Marshal Nedelin, Korolev, and Keldysh were the principal participants, and they established October 6 as the launch's target date based on the pace of preparations. At the same meeting, they decided to publicly announce the launch of the PS-1 after the completion of the first orbit. Ryabikov wrote up a communiqué to this effect on September 23.[168] The frequencies for tracking by amateurs had already been announced earlier in the year in issues of the journal *Radio*, although details of the program had obviously been omitted. Korolev meanwhile flew into Tyura-Tam on September 29, staying in a small house close to the primary activity area near site 2.

163. Council of Veterans of the Baykonur Cosmodrome, *Proryv v kosmos*, pp. 29–30.

164. Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p. 90. "ISZ" is the Russian acronym for "Artificial Satellite of the Earth."

165. Biryukov, "Materials From the Biographical Chronicles," p. 238; Lardier, *L'Astronautique Soviétique*, p. 93; Golovanov, *Korolev*, p. 517.

166. S. P. Korolev, "On the Practical Significance of K. E. Tsiolkovskiy's Proposals in the Field of Rocket Technology" (English title), in B. V. Raushenbakh, ed., *Issledovaniya po istorii i teorii razvitiya aviatsionnoy i raketno-kosmicheskoy nauki i tekhniki* (Moscow: Nauka, 1981), p. 40. This is a complete version of his speech. An abridged English translation has been reproduced in Institute of the History of Natural Sciences and Technology, *History of the USSR: New Research, 5: Yuri Gagarin: To Mark the 25th Anniversary of the First Manned Space Flight* (Moscow: Social Sciences Today, 1986), pp. 48–63. Note that the latter does not include the above quote.

167. The State Commission for the Launch of the First Satellite may have been slightly expanded from the original R-7 State Commission. See Yu. A. Skopinskiy, "State Acceptance of the Space Program: Thirty Years of Work" (English title), *Zemlya i vselennaya* no. 5 (September–October 1988): 73–79; Lardier, *L'Astronautique Soviétique*, p. 285.

168. Ishlinskiy, ed., *Akademik S. P. Korolev*, p. 447; Lardier, *L'Astronautique Soviétique*, pp. 108–09; Konovalov, "The Genealogy of Sputnik," pp. 122–23.

The preparations for launching were for the most part uneventful, save for the last-minute replacement of one of the batteries on the flight version of the PS-1. Still apprehensive over a last-minute launch from the United States, Korolev abruptly proposed to the State Commission that the launch be brought forward two days. His concerns were apparently prompted by plans for a conference in Washington, D.C., to be held in early October as part of IGY proceedings. According to Korolev's information, American delegates would present a paper titled "Satellite Over the Planet" on the 6th, the day of the PS-1's scheduled launch. He believed that the presentation was timed to coincide with a hitherto unannounced launch attempt of a U.S. satellite.[169] Local KGB representatives assured Korolev that this was not so, but Korolev was convinced that there would be a launch of an Army Jupiter C on that day. The State Commission buckled under Korolev's wishes and moved the PS-1 launch forward by two days to the 4th; Korolev signed the final order for launch at four in the afternoon on the 2nd and sent it to Moscow for approval.[170]

The R-7, 8K71PS number M1-PS, was transported and installed on the launch pad in the early morning of October 3, escorted on foot by Korolev, Ryabikov, and other members of the State Commission. Fueling began the following morning at 0545 hours local time under Grechko's supervision. Korolev, although under pressure, remained cautious throughout the proceedings. He told his engineers, "Nobody will hurry us. If you have even the tiniest doubt, we will stop the testing and make the corrections on the satellite. There is still time. . . ."[171] Most of the engineers, understandably enough, did not have time to ponder over the historical value or importance of the upcoming event. The PS-1's Deputy Designer Ivanovskiy recalled, "Nobody back then was thinking about the magnitude of what was going on: everyone did his own job, living through its disappointments and joys."[172]

On the night of the 4th, huge flood lights illuminated the launch pad as the engineers in their blockhouse checked off the rocket's systems. In the command bunker, accompanying Korolev were some of the senior members of the State Commission: Ryabikov, Keldysh, Glushko, and Pilyugin, as well as Deputy Chief Designer Voskresenskiy and Lt. Colonel Nosov, the two individuals overseeing all launch operations. Both viewed the launch pad through periscopes as they gave the final orders. Boris S. Chekunov, a young lieutenant in charge of pushing the launch button, later recalled the final moments as the clock ticked past midnight local time:

> *When only a few minutes remained until liftoff, Korolev nodded to his deputy Voskresenskiy. The operators froze, awaiting the final order. Aleksandr Nosov, the chief of the launch control team, stood at the periscope. He could see the whole pad. "One minute to go!," he called.*[173]

OKB-1 senior engineer Shabarov, also in the bunker, adds:

> *With the exception of the operators, everybody was standing. Only N. A. Pilyugin and S. P. Korolev were allowed to sit down. The launch director [Nosov] began issuing commands. I kept an eye on S. P. Korolev. He seemed nervous although he tried to conceal it. He was carefully examining the readings of the various instruments without missing any nuance of our body language and tone of voice. If anybody raised their voice or showed signs of nervousness, Korolev was instantly on the alert to see what was going on.*[174]

169. Golovanov, *Korolev*, pp. 537–38.
170. This document was not actually signed until the morning of the launch. See Ishlinskiy, ed., *Akademik S. P. Korolev*, p. 448.
171. Golovanov, "The Beginning of the Space Era"; Mozzhorin, *et al.*, eds., *Nachalo kosmicheskoy ery*, p. 63.
172. Golovanov, "The Beginning of the Space Era."
173. Borisenko and Romanov, *Where All Roads into Space Begin*, p. 66.
174. Mozzhorin, *et al.*, eds., *Nachalo kosmicheskoy ery*, p. 63.

The seconds counted down to zero, and Nosov shouted the command for liftoff. Chekunov immediately pressed the launch button. At exactly 2228 hours, 34 seconds, Moscow Time, the engines ignited, and the 272,830-kilogram booster lifted off the pad in a blaze of light and smoke. The five engines of the R-7 generated about 398 tons of thrust at launch. Although the rocket lifted off gracefully, there were problems. Delays in the firing of several engines could have easily resulted in a launch abort. Second, at T+16 seconds, the Tank Emptying System malfunctioned, resulting in a higher than normal kerosene consumption. A turbine failure because of this resulted in main engine cutoff one second prior to the planned moment.[175] Separation from the core stage, however, occurred successfully at T+324.5 seconds, and the 83.6-kilogram PS-1 successfully fell into a free-fall elliptical trajectory. The first human-made object had entered orbit around Earth. A new era had begun.

With most State Commission members still in the bunker, engineers at Tyura-Tam awaited confirmation of orbit insertion from the PS-1 in a van set up about 800 meters from the launch pad. As a huge crowd waited outside the van, radio operator Vyecheslav I. Lappo, from NII-885, who had personally designed the on-board transmitters, sat expectantly for the first signal. There was cheering once the Kamchatka station picked up signals from the satellite, but Korolev cut everybody off: "Hold off on the celebrations. The station people could be mistaken. Let's judge the signals for ourselves when the satellite comes back after its first orbit around the Earth."[176] Eventually the distinct "beep-beep-beep" of the craft came in clearly over the radio waves, and the crowd began to celebrate. Chief Designer Ryazanskiy, who was at the van, immediately telephoned Korolev in the bunker. The ballistics experts at the Coordination-Computation Center back in Moscow had determined that the satellite was in an orbit with a perigee of 228 kilometers and an apogee of 947 kilometers, the latter about eighty kilometers lower than planned because of the early engine cutoff. The inclination of the orbit to Earth's equator was 65.6 degrees, while the orbital period was 96.17 minutes.[177] Experts at the center had also determined that the satellite was slowly losing altitude, but State Commission Chairman Ryabikov waited until the second orbit was over prior to telephoning the Soviet leader.

According to conventional wisdom, Khrushchev's reaction to the launch was unusually subdued for an event of such magnitude, indicating that he, like many others, did not immediately grasp the true propaganda effect of such a historic moment. He told the press:

> *When the satellite was launched, they phoned me that the rocket had taken the right course and that the satellite was already revolving around the earth. I congratulated the entire group of engineers and technicians on this outstanding achievement and calmly went to bed.*[178]

Khrushchev's son, however, recalls that his father's reaction was a little more enthused. The older Khrushchev at the time was on visit to Kiev to discuss economic issues with the Ukrainian Party leadership. Around 11:00 p.m., these negotiations were interrupted by a telephone call. Khrushchev quietly took the call, then returned back to his discussions without saying anything. Eventually, as his son recalled, the news was too difficult to keep under wraps:

175. Ishlinskiy, ed., *Akademik S. P. Korolev*, pp. 448, 464; B. Ye. Chertok, *Rakety i lyudi: Fili Podlipki Tyuratam* (Moscow: Mashinostroyeniye, 1996), p. 197.

176. Mozzhorin, *et al.*, eds., *Nachalo kosmicheskoy ery*, p. 64.

177. Ishlinskiy, ed., *Akademik S. P. Korolev*, p. 464.

178. Daniloff, *The Kremlin and the Cosmos*, pp. 65–66.

He finally couldn't resist saying [to the Ukrainian officials]: "I can tell you some very pleasant and important news. Korolev just called (at this point he acquired a secretive look). He's one of our missile designers. Remember not to mention his name—it's classified. So, Korolev has just reported that today, a little while ago, an artificial satellite of the Earth was launched."[179]

The Soviet leader was animated the rest of the evening, speaking in glowing terms about the new era of missiles, which could "demonstrate the advantages of socialism in actual practice" to the Americans.

For the engineers and scientists responsible for the achievement, October 5 was a day like no other. Korolev's deputy Shabarov ordered the chief of the dispatch office to hand out one teapot of alcohol to each man at the firing range. During the latter part of the day, there was a celebration in a small movie theater in Tyura-Tam; Ryabikov made a speech congratulating all, followed by Korolev and Keldysh. It was only later, after nightfall, that Korolev and a small group of his co-workers took off in an Il-14 aircraft from Tyura-Tam to head for Moscow. Most were exhausted and slept through the flight, having spent the previous night without any rest. After takeoff, the pilot of the airplane, Tolya Yesenin, came out of the cockpit and bent over Korolev's seat to tell him that "the whole world was abuzz" with the launch. Korolev quickly got up and went into the pilot's cabin. Returning back to the passenger's area, he announced gleefully to everybody, "Well comrades, you can't imagine—the whole world is talking about our satellite," adding with a huge smile, "It seems that we have caused quite a stir. . . ."[180]

On the morning of October 5, the official Soviet news agency TASS released the communiqué Ryabikov had authored. Published in the morning edition of *Pravda*, it was exceptionally low key and was not the headline of the day:

For several years scientific research and experimental design work have been conducted in the Soviet Union on the creation of artificial satellites. As has already been reported in the press, the first launching[s] of the satellites in the USSR were planned for realization in accordance with the scientific research program of the International Geophysical Year. As a result of very intensive work by scientific research institutes and design bureaus the first artificial satellite in the world has been created. On October 4, 1957, this first satellite was successfully launched in the USSR. According to preliminary data, the carrier rocket has imparted to the satellite the required orbital velocity of about 8000 meters per second. At the present time the satellite is describing elliptical trajectories around the earth, and its flight can be observed in the rays of the rising and setting sun with the aid of very simple optical instruments (binoculars, telescopes, etc.).[181]

The Soviet media did not ascribe a specific name for the satellite, generally referring to it as *Sputnik*, the Russian word for "satellite," often also loosely translated as "fellow traveler."

As the media tumult over Sputnik began to mount in the West, the Soviet leadership began to capitalize on the utter pandemonium pervading the discourse on the satellite in the United States. On October 9, *Pravda* published a long report detailing the construction and design of the satellite.[182] The parties responsible for this great deed were, of course, not named. Having

179. Khrushchev, *Nikita Khrushchev: tom 1*, pp. 337–38.

180. Golovanov, *Korolev*, pp. 540–41.

181. "Announcement of the First Satellite" (English title), *Pravda*, October 5, 1957, p. 1. A complete English translation of this announcement is included in Krieger, *Behind the Sputniks*, pp. 311–12.

182. "Report on the First Satellite" (English title), *Pravda*, October 9, 1957, p. 1. A complete English translation of this article in included in Krieger, *Behind the Sputniks*, pp. 313–25. This particular article was authored jointly by A. G. Azizyan (*Pravda*), V. P. Glushko (OKB-456), M. V. Keldysh (OPM MIAN and NII-1), S. P. Korolev (OKB-1), D. Ye. Okhotsimskiy (OPM MIAN), G. A. Skuridin (AN SSSR), and others, although none were named.

been involved in the defense industry, the real job titles of the members of the Council of Chief Designers had always remained secret, although Tikhonravov and others had freely published under their own names through the 1950s on topics of general interest. This suddenly changed as their names disappeared from official histories. Beginning with the launch of Sputnik, of the major contributors to the success of Sputnik, Korolev, Glushko, and Keldysh were referred in the open press as the Chief Designer of Rocket-Space Systems, the Chief Designer of Rocket Engines, and the Chief Theoretician of Cosmonautics, respectively. The fourth, Tikhonravov, did not even have a pseudonym for himself.

The titles not only hid their identities, but also added an element of enigma to the men behind the world's first space program. New editions of histories of Soviet rocketry published prior to 1957 ceased to carry Korolev's name, and Soviet encyclopedias subsequently listed him as heading a laboratory in an unspecified "machine building" institute in the Soviet Union. Glushko, meanwhile, was said to be laboratory chief at the Moscow Institute of Mineral Fuels.[183] Korolev, certainly in recognition of the key role he played, was allowed to write in no less an important newspaper as *Pravda*, but under the pseudonym "Professor K. Sergeyev." His first article, titled "Research into Cosmic Space," was published on December 12, 1957. Khrushchev claimed at the time that as the years went by, "the photographs and names of these illustrious people will be made public," but that for the moment, "in order to ensure the country's security and the lives of these scientists, engineers, technicians, and other specialists, we cannot yet make known their names or publish their photographs."[184]

As time went by, the publicity afforded the Soviet space program by its own media became uniquely perverse. One could read countless books and articles on the effort and not learn anything new about the program. Pages and pages would often be filled with supposedly amusing anecdotes about anonymous people without once mentioning a name, a date, a place, or an institution. Although this state of events marginally improved by the end of the 1960s, there were four main elements of the veil of secrecy: plans for future space missions were never mentioned; failures were omitted from historical discussion; the names of engineers and administrators were not mentioned until they were deceased; and the military was never implicated in the operation of the space program. There were, of course, other corollaries, such as the vagueness of details about spacecraft, missions, launching sites, funding, and administrative structure, but by and large, these four elements dominated the reportage of the Soviet space program from its inception in 1957.

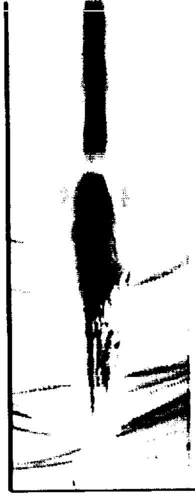
The chief designers toiling in anonymity not only had to have their work go unrecognized, but they were often the subject of ironic twists of fate. For example, Academician Sedov, the erstwhile chairman of the Commission for Interplanetary Communications, was allowed to publicly travel and speak prominently concerning the Soviet space program, presumably because he had no direct responsibility or connection with anything in the program. Korolev's engineers would, in fact, joke about the time Korolev invited Sedov to the launch pad at Tyura-Tam to see an R-7 with a satellite on it. Sedov surprised everyone by asking where exactly the satellite was on the rocket. Some, such as Academicians Blagonravov and Vernov, who had peripheral knowledge about the space program were allowed to talk, but as one Russian journalist later wrote, they "were so ensnared by what they had signed about not disclosing governmental secrets, that they uttered only banalities, and thus differed only slightly from the uninitiated [such as Sedov]."[185]

183. *Soviet Space Programs, 1962–65; Goals and Purposes, Achievements, Plans, and International Implications*, prepared for the Committee on Aeronautical and Space Sciences, U.S. Senate, 89th Cong., 2d sess. (Washington, D.C.: U.S. Government Printing Office, December 1966), pp. 149–50.

184. *Ibid.*, pp. 71–72.

185. Golovanov, *Korolev*, p. 553.

One can imagine how Korolev, Glushko, Pilyugin, Barmin, and Tikhonravov must have felt watching Sedov, Blagonravov, and others traveling across the world, giving speeches to awestruck audiences, who believed they were looking at the founders of the Soviet space program. Eventually, the secrecy was loosened, and the names were released. Of the six original chief designers whose names were classified top secret in 1957, all would eventually live to see their names in the press—except one, the founder and instigator of humankind's first step into the cosmos, Sergey Pavlovich Korolev.



Chapter Five
Designing the First Spaceship

On October 4, 1957, in an imperceptible way, the course of human history changed. In the forty years following that singular event, it is easy to lose sight of the significance of Sputnik. For the first time in history, humans had managed to break free of Earth's atmosphere and loft a modest product of their handiwork into the heavens. There were, of course, more earthly considerations. The Soviet satellite served as a distinct milestone; it moved the Cold War into a new phase—one characterized by the very real possibility of Soviet dominance in the new arena of space, and thus, by extension, on Earth. With only a ball of metal, the Soviets had managed to achieve what they were unable to convey with decades of rhetoric on the virtues of socialism: that the USSR was a power with which to be reckoned. In this climate, the Soviet space program was much more than the sum of its parts. In reality, its parts were very far and few in between. Barring a few isolated proposals, there was, in fact, no Soviet space program in 1957. There were no long-range goals, no governing body for the space program, no financial planning, no agenda, and no direction. This suspension into limbo continued to exist for the next few years, hidden, of course, beneath the pages and pages of Soviet propaganda hailing the glorious benefits of a nationwide effort.

The Immediate Aftermath

The engineers at OKB-1 could be forgiven for hoping for a respite from the relentless months of hard work in support of both the R-7 and the first Sputnik. At the time, Korolev allowed all his key deputies to take a short vacation—the first in many years—to rejuvenate their energies. First Deputy Chief Designer Mishin, Deputy Chief Designer Voskresenskiy, their assistants, and "a group of the main workers" from the Design Bureau were sent off to the seaside resort of Sochi.[1] Korolev, who returned to Moscow on October 5, elected not to take advantage of the break but instead began to play with an ambitious idea to sustain the successes of the new space program. After Korolev's return, Soviet leader Khrushchev immediately called him to find out all the details of the Sputnik launch. During the conversation, Khrushchev asked casually whether Korolev could launch another satellite, possibly in time for the fortieth anniversary of the Great October Socialist Revolution on November 7. Without any hesitation, Korolev suggested that his team could launch a dog. Khrushchev was ecstatic about the idea, stipulating only that the launch had to take place by the holiday. Korolev assured him

1. A. Tarasov, "Missions in Dreams and Reality" (English title), *Pravda*, October 20, 1989, p. 4.

they would do their best to make the deadline.[2] Khrushchev asked his "right-hand man," Frol R. Kozlov, to handle all logistical issues. The next day, the Central Committee held a meeting in Kozlov's presence, during which the six key chief designers agreed that to facilitate the launch in less than a month, the design of the spacecraft would have to be simplified as much as possible. Kozlov emphasized to Korolev that the launch would have to be in time for the holidays "without fail."[3] The official order for the launch was issued on October 12, 1957, eight days after the launch of the first Sputnik.

Vacations were immediately cut short as Korolev ordered all his deputies back to Kaliningrad. They would have less than a month to bring the project to fruition. The options available to the engineers were slim: either prepare the biological version of the Object D satellite or create a completely new spacecraft. Because the former was still far from ready, they adopted a plan to make maximal use of the small PS-1 structure used for the first satellite. OKB-1 also had the advantage of a large database of experience in launching dogs and other animals on "vertical" trajectories into the upper atmosphere through the 1950s on modified versions of the R-1, R-2, and R-5 missiles. Engineers took a container originally earmarked for the next launch of the "biological" R-2A missile and used it as a basis for the new satellite, which was designated Simple Satellite No. 2 (PS-2). Once again, Korolev used as few outside organizations as possible. Chief Designer Semyon A. Alekseyev's Plant No. 918 at Tomilino, which specialized in high-altitude pressure suits, provided the suit for the dog, while the Leningrad-based Biofizpribor Special Design Bureau was tasked to build a feeding trough for the animal. Both organizations had participated in the same capacity in the vertical dog launch program of the 1950s. The Experimental Design Bureau of the Moscow Power Institute under Chief Designer Aleksey F. Bogomolov prepared the modest *Tral* ("trawl") radio transmitters for the communication of telemetry on the vital signs of the animal.[4] A slow-scan television system named Seliger was also built to transmit images of the dog in space; it had a capability of 200 lines per frame and ten frames per second.

Technical operations on the construction of the PS-2 formally began on October 10, 1957, just six days after the launch of the first Sputnik. The satellite, as it emerged in the following days, was a small stubby cylindrical container for a single dog, which contained life support systems and instruments for monitoring the life signs of the dog and the internal atmosphere of the capsule. The life support system included a "regeneration unit" containing chemical compounds, which absorbed carbon dioxide and excess water vapor. The system was designed to operate automatically. No provision was made to return the dog from orbit because neither the technology nor the time was available to prepare for such a mission. Doctors expected to put the animal to sleep with an automated injection of poison prior to oxygen depletion in the

2. Yaroslav Golovanov, *Korolev: Fakty i mify* (Moscow: Nauka, 1994), pp. 544–45. There are many contradictory accounts of the decision. Most, however, agree that Khrushchev suggested a launch for the holidays, and Korolev came up with the idea to put a dog in the satellite. Khrushchev had apparently told the six major chief designers (Barmin, Glushko, Korolev, Kuznetsov, Pilyugin, and Ryazanskiy) at a meeting in early October, "On the 7th of November, we will mark the fortieth anniversary of the 'Great October.' It would be a good idea to do something extra." See Col. M. Rebrov, "The Whiteness of Martian Seas . . ." (English title), *Krasnaya zvezda*, March 11, 1989, p. 4.

3. Golovanov, *Korolev*, pp. 547–48. Present at the meeting were Special Committee Chairman V. M. Ryabikov, Committee Deputy Chairman G. N. Pashkov, First Deputy Commander of the Directorate of the Commander of Reactive Armaments (UNRV) Lt. Gen. A. G. Mrykin, and Chief Designers V. P. Barmin, A. F. Bogomolov, S. P. Korolev, N. A. Pilyugin, and M. S. Ryazanskiy, as well as Korolev's "space" Deputy K. D. Bushuyev.

4. *Ibid.*, p. 548; G. Salakhutdinov, "Once More About Space" (English title), *Ogonek* 34 (August 18–25, 1990): 4–5; Yu. A. Mozzhorin *et al.*, eds., *Nachalo kosmicheskoy ery: vospominaniya veteranov raketno-kosmicheskoy tekhniki i kosmonavtiki: vypusk vtoroy* (Moscow: RNITsKD, 1994), p. 82; A. V. Ponomarev, "2 June—75 Years From the Birth of Academician A. F. Bogomolov (1913)" (English title), *Iz istorii aviatsii i kosmonavtiki* 59 (1989): 47–50.

life support system. The cylindrical container was crowned by a spherical object, identical in design to the first Sputnik, which housed the radio-telemetry systems, thermal systems, and power sources. A few scientific instruments were attached externally near the top of the booster core. These were for investigations of solar radiation in the ultraviolet and x-ray regions of the spectrum and for the study of cosmic rays. The total mass of the payload was 508.3 kilograms, a significant leap from the modest PS-1. Korolev's engineers designed the payload in such a way that it would remain attached to the central core of the R-7 booster throughout its time in orbit, thus enabling the satellite to use the same telemetry system as the rocket. This not only eliminated the development of a new telemetry system for the dog, but it would also help keep the temperature down in the dog container, a major concern for the designers. By October 18, a new R-7 ICBM for this next launch had been shipped to Tyura-Tam following a series of extensive tests at the assembly plant at Kaliningrad.[5] Korolev took an Aeroflot flight from Moscow eight days later, arriving back at the launch range via Tashkent.

Originally, there was a pool of ten dogs to choose for the flight, all of them trained at the Air Force's Institute of Aviation Medicine for previous upper atmospheric vertical flights. From a final three of Albina, Layka, and Mukha, biomedicine specialist Academician Vasiliy V. Parin selected Layka ("barker") to have the honor of being the first living being to reach orbit. The choice was primarily based on the dog's even temperament. Air Force doctor Vladimir I. Yazdovskiy recalls:

> *Layka was a wonderful dog. . . . Quiet and very placid. Before the flight to the cosmodrome I once brought her home and showed her to the children. They played with her. I wanted to do something nice for the dog. She had only a very short time to live, you see.*[6]

Albina, with two prior flight experiences, was named Layka's "double" for the mission. A group of six physicians, headed by Oleg G. Gazenko, assisted in an intensive training program for the three dogs in the days preceding the scheduled launch. Before flying to the launch site, Yazdovskiy and Gazenko operated on the two dogs. They attached wires connected to sensors to monitor respiration frequency over their ribs and under their skins. A portion of the carotid artery was also diverted into a piece of skin to record pulse and blood pressure.[7] Layka was put in the satellite container at mid-day on October 31, and by nighttime, the payload had been attached to the booster rocket, 8K71PS number M1-2PS. Temperatures at Tyura-Tam were very cold at the time, and the container was heated via a special hose attached to an air conditioner during the preparations for launch. Yazdovskiy, the *de facto* head of all biomedical operations, asked two of his assistants to keep a constant watch on Layka through the stacking procedures.

5. Yu. Biryukov, "From the History of Space Science: The Price of Decision—First Place (The First Satellites)" (English title), *Aviatsiya i kosmonavtika* no. 10 (October 1991): 37–39; Vasili Mishin and Boris Raushenbakh, "The Scientific Legacy of Sergei Korolev," in *History of the USSR: New Research. 5: Yuri Gagarin: To Mark the 25th Anniversary of the First Manned Space Flight* (Moscow: Institute of the History of Natural Science and Technology, USSR Academy of Sciences, 1986), pp. 117–18; Mozzhorin, *et al.*, eds., *Nachalo kosmicheskoy ery*, p. 82; Golovanov, *Korolev*, pp. 547–48; G. S. Vetrov, "On the Launch of the Second Artificial Satellite of the Earth" (English title), *Novosti kosmonavtiki* 23 (November 3–16, 1997): 50–54.

6. Golovanov, *Korolev*, p. 550.

7. The six physicians were I. S. Balakhovskiy, O. G. Gazenko (physiology), A. M. Genin (hygiene), A. A. Gyurdzhiyan (radiation), N. N. Kozakova, and A. D. Seryapin. Also involved in general preparations were Ye. M. Yuganov (vestibular apparatus) and A. R. Kotovskaya (overloads). See *ibid.*; Aleksandr Romanov, *Korolev* (Moscow: Molodaya gvardiya, 1996), p. 306.

Sputnik 2 is shown with its unique payload shroud at the launch pad at Tyura-Tam in November 1957. Warm air was piped into the capsule to keep the dog Layka comfortable amid the freezing temperatures. (files of Peter Gorin)

The 8K71PS booster lifted off on time at 0530 hours, 42 seconds Moscow Time on November 3, 1957, from the pad at site 1 at Tyura-Tam.[8] Although the dog's pulse tripled during the launch phase, all vital signs were normal. The PS-2 spacecraft, named the "Second Artificial Satellite" in the Soviet press, successfully entered a 225- by 1,671-kilometer orbit with an inclination of 65.3 degrees to the equator. The satellite payload remained attached to the central block of the R-7 vehicle throughout its orbital flight. Total mass in orbit was about six and a half tons, approximately one-thirteenth of which was the actual payload. Doctors monitoring Layka in the following days began to notice a significant rise in the internal temperature of the biological compartment, apparently a result of inefficiencies and malfunctions in the spacecraft's thermal control system. For almost the entire period of her flight, Layka suffered a modicum of discomfort because of these high temperatures. The poor dog finally succumbed to heat exhaustion on the fourth day of the mission on November 7. Later analysis on the ground based on incoming telemetry confirmed the suspicions of doctors that overheating had in fact caused her death.[9]

The Soviets revealed one striking piece of information unrelated to Layka many years later. The scientific instruments on the PS-2 had performed without any problems for a week and had detected evidence for the existence of a radiation belt around Earth. Soviet scientists on the ground who studied the data were, however, "circumspect in their interpretations" of the information.[10] In the end, the first U.S. satellite, Explorer 1, returned the same data a few months later, and the United States claimed one of the great discoveries of the early space age, the existence of a continuous band of radiation belts around Earth. The PS-2 spacecraft finally decayed from orbit on April 14, 1958, with its deceased passenger, having contributed to another long line of "firsts" in the Soviet space program.

8. Council of Veterans of the Baykonur Cosmodrome, *Proryv v kosmos* (Moscow: TOO "Veles," 1994), p. 176. Another source states that the launch was at 0722 hours Moscow Time. See Yu. P. Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya "Energiya" imeni S. P. Koroleva* (Korolev: RKK Energiya, named after S. P. Korolev, 1996), p. 92.

9. Yu. A. Mozzhorin, *et al.*, eds., *Dorogi v kosmos: I* (Moscow: MAI, 1992), p. 60; Golovanov, *Korolev*, p. 551. Some reports have suggested that the temperature rise was a result of the nonseparation of the central R-7 sustainer from the payload. See Biryukov, "From the History of Space Science"; K. V. Gerchik, ed., *Nezabyvayemyy Baykonur* (Moscow: Interregional Council of Veterans of the Baykonur Cosmodrome, 1998), p. 114.

10. Biryukov, "From the History of Space Science."

As the PS-2 was finding its way into the atmosphere, the engineers at OKB-1 were finally completing preparations to launch Object D, which had originally been slated to be the first Soviet satellite. Having been usurped from its place by the smaller PS-1 and PS-2 spacecraft, Object D was the last Soviet space project in existence at the time. The fact that government permission to allow work on Object D was not an endorsement for further space projects had become all too apparent by early 1958. There was, of course, little suspicion or knowledge in the West that all the Sputnik launches were either one-off efforts or hastily put-together projects resulting from the suggestions of a few anonymous men. In fact, the breadth and number of scientific instruments on board the spacecraft was literally a jolt to Western scientists. The 1,327-kilogram observatory made out of aluminum alloy was the first Soviet spacecraft to carry a "command radio-link" device for the control of instrumentation in orbit. There were twelve scientific experiments on board for the measurement and detection of:

- Primary cosmic radiation intensity
- The nuclei of heavy elements in cosmic rays
- Micrometeorites
- Atmospheric pressure
- Ion composition in the atmosphere
- The concentration of positive ions
- The magnitude of electric charges
- The intensity of electrostatic and magnetic fields
- The intensity of corpuscular solar radiation

The Tral multichannel telemetry system included a data recorder to store measurements out of the zone of communications visibility. Power was supplied by the first solar batteries used on a spacecraft, while internal temperature was controlled via circulating gaseous nitrogen. The useful payload of the sophisticated scientific observatory was 968 kilograms, and its scientific program was supported by a team of scientists from various disciplines, many of whom had been involved in mission planning since the project was approved in early 1956.[11]

Object D was launched by a modified R-7 ICBM named the 8A91 on April 27, 1958. The launch vehicle, however, broke up into pieces during the active portion of the trajectory at T+96.5 seconds because of resonant frequencies, thus destroying two and a half years' worth of labor.[12] Luckily for the scientists, OKB-1 had constructed an identical backup article with the same instrument complement. This craft was rumored to have been the subject of some political maneuvering prior to launch. There was reportedly some doubt about the functioning capabilities of the Tral-D data recorder built by the Experimental Design Bureau of the Moscow Power Institute. Korolev, under pressure from Khrushchev to launch the satellite in time to show support for the Italian Communist Party in the Italian elections, may have taken a gamble and opted to launch without verifying the operation of the device in question.[13]

11. Mishin and Raushenbakh, "The Scientific Legacy of Sergei Korolev," pp. 120–21; S. L. Nikolayev, "On the Work of M. K. Tikhonravov on the Creation of the First ISZ" (English title), *Iz istorii aviatsii i kosmonavtiki* 42 (1980): 51–61. The primary investigators included Sh. Sh. Dolginov, K. I. Gringauz, V. G. Istomin, V. I. Krassovskiy, L. V. Kurnosova, V. G. Kurt, Yu. I. Logachev, S. L. Mandelshcham, I. S. Shlovskiy, and S. N. Vernov.

12. Mozzhorin, *et al.*, eds., *Nachalo kosmicheskoy ery*, p. 65; Biryukov, "From the History of Space Science." One source says that the failure occurred at T+88 seconds. See Timothy Varfolomeyev, "Soviet Rocketry that Conquered Space: Part 1: From First ICBM to Sputnik Launcher," *Spaceflight* 37 (August 1995): 260–63.

13. Roald Z. Sagdeev, *The Making of a Soviet Scientist: My Adventures in Nuclear Fusion and Space From Stalin to Star Wars* (New York: John Wiley & Sons, 1994), pp. 156–58.

The launch of the second Object D took place successfully on May 15, 1958, by means of another 8A91 booster. The spacecraft entered an initial orbit of 1,881 by 226 kilometers at 65.2 degrees inclination. The Soviet press referred to the spacecraft as the "Third Artificial Satellite," later retroactively naming it "Sputnik 3." During its mission, ground controllers discovered that the data recorder did indeed fail, thus depriving scientists of information during periods when the satellite was not within communications view of ground stations. This had a repercussive effect on preventing scientists from confirming without doubt the existence of a radiation belt around Earth; there was simply no way to prove that the belt was continuous because of gaps in data. Despite the serious failure, there were 100,000 telemetric measurements and 40,000 optical observations conducted until communication was lost with the spacecraft on June 3, 1958. The mission provided a substantial amount of scientific and technological data in various disciplines.[14] Object D finally decayed from orbit on April 6, 1960, leaving behind the record of having been the first advanced scientific observatory launched into space.

The launch of these three satellites, although isolated from any macro-level space program, helped in many ways cement the important roles of the chief designers in the Soviet defense industry. Although all Soviet press reports touted the achievements of the Sputniks as those of the Communist Party of the Soviet Union, it was increasingly clear within the leadership that the efforts of these designers also served an important propaganda and public relations role for the Soviet state. All of the major chief designers benefited from this state of affairs, both in a tangible and intangible sense. Korolev and Glushko, the two most powerful Chief Designers, had the distinction of being the only ones labeled criminals of the state in their younger years. The fall of Beriya in 1953 and the subsequent denunciations by Khrushchev of Stalin's ruthless rule eventually set the stage for the formal "rehabilitation" for both. Glushko's original accusations had been corrected in October 1956, but it took much longer for Korolev, who had suffered much more. He had applied to the Soviet government in a letter dated May 30, 1955, to drop the five remaining criminal charges that still marred his record.[15] It would be the summer of 1957 before he would receive a reply from the USSR Chief Military Procurator. The letter merely stated that at a meeting of the Military Collegium of the USSR Supreme Court on April 18, 1957, the charges against him had been formally dropped, "due to the lack of any crimes."[16] While Korolev tried to put the dark chapters in his life behind, Glushko was not as amenable. One of their associates later recalled:

> *. . . Korolev had convinced himself that one should forget about Kolyma, prison, and all the rest, blot it out from memory and from the heart. Glushko [on the other hand] always remembered everyone and everything. He had saved many interesting documents. . . .*[17]

Korolev was bestowed with a doctor of technical sciences degree, the Soviet equivalent of a Ph.D., on June 29, 1957, even though he had not defended a dissertation.[18] Essentially an honorary title, it seems that Korolev did not use the title much in his writings. On December 18 of the same year, as a result of the huge successes of the first two Sputniks, he along with

14. *Ibid.*, p. 158; Christian Lardier, *L'Astronautique Soviétique* (Paris: Armand Colin, 1992), p. 113. For a summary of the results from Sputnik 3, see Nikolayev, "On the Work of M. K. Tikhonravov."

15. This letter is reproduced in full in N. L. Anisimov and V. G. Oppokkov, "Incident at NII-3" (English title), *Voyenno-istoricheskiy zhurnal* no. 11 (November 1989): 65–71.

16. Romanov, *Korolev*, pp. 269–70.

17. Col. M. Rebrov, "Specific Impulse" (English title), *Krasnaya zvezda*, August 26, 1989, p. 4.

18. Yu. V. Biryukov, "Materials from the Biographical Chronicles of Sergey Pavlovich Korolev" (English title), in B. V. Raushenbakh, ed., *Iz istorii sovetskoy kosmonavtiki* (Moscow: Nauka, 1983), p. 238. He was officially awarded the degree by the "High Certification Commission" on October 26, 1957, just twenty-two days after the launch of the first Sputnik.

several others, such as Chief Designers Barmin, Glushko, Kuznetsov, Pilyugin, and Ryazanskiy, Deputy Chief Designer Mishin, and Academician Keldysh, were named recipients of the Lenin Prize. Three of Korolev's key deputies—Bushuyev, Okhapkin, and Voskresenskiy—were bestowed the more prestigious Hero of Socialist Labor for their efforts.[19] Perhaps the most coveted of all honors came to Korolev and Glushko on June 20, 1958, when both were elected full Academicians of the USSR Academy of Sciences and thus befit of the highest level of stature in the scientific community. In truth, neither was a real scientist, and the promotion clearly would not have been approved by the Soviet scientific community had it not been for the recent successes in space. There were in fact many within the Academy of Sciences who privately scoffed at the promotions, bemoaning the influence of selective standards and political expediency. Along with Korolev and Glushko, the remaining four from the Council of Chief Designers—Barmin, Kuznetsov, Pilyugin, and Ryazanskiy—were promoted to Corresponding Members. Korolev's First Deputy Mishin also joined their ranks, an indication of the remarkable faith and trust Korolev had in his right-hand man. Mishin was the only deputy bestowed this honor.

The entry of the chief designers into the Academy of Sciences was extremely significant for the emerging space program because it provided a formal institutional setting from which to propose space projects outside of the conventional conduit of the defense industry.[20] It also allowed the slow but visible separation of the space program from the missile program, although in 1958 this division was admittedly somewhat indistinct given the lack of a plan for space exploration. Academician Keldysh, with connections to both the scientific community and the defense industry, was an indispensable ally to the space designers. A consummate scientist and mathematician of great repute, Keldysh, in some respects, legitimized the dreams and proposals of space exploration in the eyes of skeptical Academy of Sciences leaders. Furthermore, Keldysh had far more influence with government and the Communist Party than any of the major designers, including Korolev and Glushko. Almost all of Keldysh's work in the 1950s had been in support of defense projects, and even the military depended, to a great extent, on the talented mathematicians and scientists in his employ at both the Department of Applied Mathematics and NII-1.

There were also institutional changes in the Soviet government and Communist Party that entrenched the position of the chief designers. By 1957, after the so-called "Anti-Party Group Affair," the locus of power in the Soviet leadership shifted from the government to the Party. Those duties originally administered by the old Special Committee No. 2 in the 1940s eventually ended up in the Secretariat of the Central Committee of the Communist Party. Leonid I. Brezhnev, a forty-four-year-old apparatchik from Dnepropetrovsk in the Ukraine was appointed a member of the Secretariat as a new Secretary of the Central Committee in June 1957, having served the Party in senior positions in Kazakhstan. Roughly analogous to the Western concept of a cabinet, the Secretariat itself was typically composed of about a dozen individuals with specific responsibilities overseeing almost every area of activity on behalf of the Party.[21] The members of the Secretariat provided the all-powerful Presidium (later the Politburo) with analysis and recommendations. In many cases, the recommendations of the Secretariat member in

19. *Ibid.*, p. 239. The actual awards ceremony took place at the Kremlin on December 30, 1957. See Romanov, *Korolev*, pp. 307–08; Golovanov, *Korolev*, p. 551. Note that Korolev, the other chief designers, Mishin, and Keldysh had already been awarded the Hero of Socialist Labor in 1956 for the R-5M nuclear program. According to Mishin, Korolev had requested that he [Mishin] receive a second Hero of Socialist Labor in December 1957, but was refused only at the "highest level." See Mozzhorin, *et al.*, eds., *Dorogi v kosmos: I*, pp.

20. William P. Barry, "The Missile Design Bureaux and Soviet Piloted Space Policy, 1953–1974," draft of University of Oxford Ph.D. diss., 1995.

21. *Ibid.*; Peter Almquist, *Red Forge: Soviet Military Industry Since 1965* (New York: Columbia University Press, 1990), p. 20.

question were often pivotal in the final decision by the Presidium. After 1957, Brezhnev's portfolio in the Secretariat included "questions of the development of heavy industry and construction, the development and production of modern military technology and weapons, the equipment of the Armed Forces with them, and the development of cosmonautics" for the Central Committee and the Presidium.[22] This new role carved out in 1957 remained in existence throughout the next thirty years, and the holder of this post essentially acted as the *de facto* policy head of the Soviet space program. Curiously, it seems that Brezhnev, the first appointee to this post, did not have a very prominent role in determining space policy because the most important decisions were made by Khrushchev himself. What was significant, however, was that both Khrushchev and Brezhnev were very strong supporters of the missile industry, and Khrushchev in particular had been dazzled by the early successes of the Sputniks, thus creating a direct line from Korolev to Khrushchev on matters of future policy.

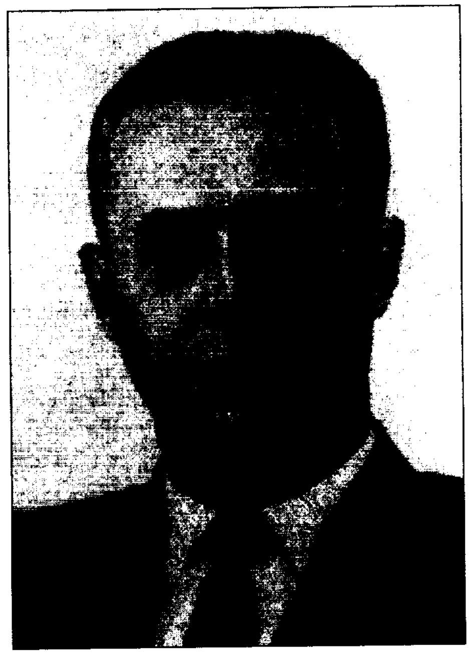
As power shifted into the Party apparatus, some of the most important supporters of the missile chief designers gravitated to higher positions in the defense industry, thus cementing support for the new space program. In particular, the first to benefit from the changes was Dmitriy F. Ustinov, Korolev's old "patron" from the 1940s. In December 1957, Khrushchev reorganized the Special Committee for Armaments of the Army and Navy, which had overseen the ballistic missile program since 1955, and created the new Military-Industrial Commission (VPK) to manage the *entire* Soviet defense industry; he put Ustinov in charge of the new governmental body. Staffed by the primary group of ministers in charge of the defense industry, VPK, after negotiation with the Soviet armed forces, managed the entire process of military procurement from research and development to production. On paper, its authority was limited to implementation, but because employees of VPK were responsible for drafting Party Central Committee decrees, the commission's jurisdiction extended to policy formulation.[23] Ustinov, in turn, made sure that the most important positions within the defense industry were occupied by individuals who owed their careers to him. In March 1958, Konstantin N. Rudnev became the new Chairman of the State Committee for Defense Technology, the "new" ministry overseeing the ballistic missile and space effort. Essentially, the old Ministry of Defense Industries with a new name, the State Committee had been created in January 1958 as part of a larger nationwide reform spurred by Khrushchev's goal to decentralize the Soviet economy. He set up a command system whereby "regional economic councils" (known in Russian as *Sovnarkhozes*) were established in key industrial cities such as Moscow, Leningrad, Gorky, and Sverdolsk.[24] Research and development institutions in the former Ministry of Defense Industry, such as NII-88 and OKB-1, were transferred at the time to the newly created State Committee.

22. Arthur J. Alexander, "Decision-Making in Soviet Weapons Procurement," *Adelphi Paper* 147/8 (Winter 1978/9): 1–64. For a detailed discussion of the role of the Secretariat in the defense and space industry, see pp. 11–12 in the same source.

23. V. Pappo-Korystin, V. Platonov, and V. Pashchenko, *Dneprovskiy raketno-kosmicheskiy tsentr* (Dnepropetrovsk: PO YuMZ/KBYu, 1994), p. 61; CIA Directorate of Intelligence, *The Soviet Weapons Industry: An Overview*, DI 86-10016 (Arlington, VA: Central Intelligence Agency, 1986), p. 14. VPK members in March 1958 included the following "ministers": K. N. Rudnev (Defense Technology), P. V. Dementyev (Aviation Technology), V. D. Kalmykov (Radio-Technical Industry), and B. Ye. Butoma (Ship Building). In addition, V. M. Ryabikov (Deputy Chairman, RSFSR Council of Ministers) and M. I. Nedelin (Deputy Minister of Defense for Reactive Armaments) were also members. The commission had one First Deputy Chairman (S. I. Vetoshkin) and two Deputy Chairmen (G. N. Pashkov and G. A. Titov). Finally, A. N. Shchukin, a respected radar expert, headed a "Scientific-Technical Council," which, among other things, approved new members of the commission.

24. John McDonnell, "The Soviet Defense Industry as a Pressure Group," in Michael McGwire, Ken Booth, and John McDonnell, eds., *Soviet Naval Policy: Objectives and Constraints* (Halifax, NS: Centre for Foreign Policy Studies, 1975), p. 90; Alexander G. Korol, *Soviet Research and Development: Its Organization, Personnel, and Funds* (Cambridge, MA: The MIT Press, 1965), p. 17.

The entire decentralization process had a repercussive effect of putting a greater share of the power over missile and space design and production into the hands of a new generation of bureaucrats, nurtured by Brezhnev and Ustinov, who were not located in Moscow.[25] The forty-seven-year-old Rudnev himself had served as director of NII-88 in the early 1950s and could be counted on to lend his support to Ustinov and Korolev at critical decision-making junctures. He was personally acquainted with all designers such as Korolev and Glushko and had also been a member of the State Commission for the R-7 launches. In his new position as the Chairman of the State Committee for Defense Technology, he was to play a much more "hands-on" role in the new space program, exceeding that of his predecessors. He was, in effect, the first industrial manager of the Soviet space program, akin to perhaps the role played by NASA administrators. By most recollections, he was very educated, accomplished, and sophisticated, although little is known about his personal life. An associate later described him as:



Konstantin Rudnev was Chairman of the State Committee for Defense Technology between 1958 and 1961. In that post, he effectively served as the first administrator of the emerging Soviet space program. He had served his apprenticeship in the early 1950s as Director of the famous NII-88 institute (files of Peter Gorin)

> *Unpretentious in his manner and attentive to people, he listened with enviable patience to the opinions of opponents without putting them into a rigid provisional framework. In a difficult moment . . . he managed to relieve the tension with a joke and he was witty, but short-spoken.*[26]

On paper at least, Korolev reported through the Chairman of the State Committee for Defense Technology (Rudnev), to the Chairman of the Military-Industrial Commission (Ustinov), to the Secretariat member in charge of defense industrial matters (Brezhnev), and finally to Soviet leader Khrushchev himself. By all accounts, this chain of command, especially in the case of new proposals, was merely a formality and rarely functioned as intended. Following the first launches of the R-7 and the Sputniks, Khrushchev regularly consulted with Korolev himself. The Council of Chief Designers seems not only to have exerted influence over programs that had been approved by Khrushchev, but also began to have some input into program commencements and approval. In particular, the council would often pass resolutions that were binding, albeit unofficially, for all the design bureaus and scientific-research institutes

25. McDonnell, "The Soviet Defense Industry as a Pressure Group," p. 116. One of those was an individual named S. A. Afanasyev, who was appointed to head the Leningrad *Sovnarkhoz* in May 1958, having served his apprenticeship as a directorate chief in Ustinov's ministry in the 1950s. Afanasyev's career would rise with Ustinov's, and he was to play an important role in the space program in the years to come.

26. Lt. Gen. Georgiy Aleksandrovich Tyulin, "Task for the Future; Notes of the State Commission Chairman" (English title), *Krasnaya zvezda*, April 2, 1988, p. 4.

involved. But in the end, it was always a question of Khrushchev's general assent or dissent. While Ustinov or Rudnev could hammer out the details, Khrushchev had the last word.

Fortunately for Korolev, the Soviet leader was clearly enamored of Korolev from 1956 through 1958. The remarkable support Khrushchev extended to Korolev at the time depended to a great extent on his achievements in building and successfully launching the R-7 ICBM. But the origins of the Khrushchev-Korolev relationship date back to February 1956 during Khrushchev's first visit to OKB-1 at Kaliningrad. As Khrushchev's son, one of those who accompanied the elder Khrushchev on that visit, later recalled, "The meeting with Korolev decisively influenced the thinking of my father. . . . After this visit father simply fell in love with Korolev, he was prepared to talk about him without end."[27] There were special perks to this change of heart, most notably demonstrated by allowing Korolev to call Khrushchev directly on matters, without having to go through "numerous bureaucratic obstacles."[28]

While the propaganda-type effects of Sputnik were clearly a boon to the Soviet leadership, the first and foremost goal on the Presidium's agenda was the achievement of strategic parity. Korolev had used the R-7 as a "Trojan horse" for his more outlandish dreams of space exploration, but he was also clever enough to know that the gains from the creation of the R-7 would not be unlimited. The next few years had Korolev toeing the fine line between appeasing those who wanted newer and better ICBMs and those who wanted the world to shudder in the face of Soviet accomplishments in space. In this sense, 1958 was a watershed year for Korolev and his associates on the Council of Chief Designers. The forces of institutions, politics, and personalities were in place for them to gradually create a new space program out of pieces of the missile program. The Object D, PS-1, and PS-2 projects had been short-lived, one-off programs intended to take advantage of the availability of the new R-7 ICBM to gain a foothold into space. It was now time to create a plan and a vision of a comprehensive program designed to put the Red Star firmly into space.

"I Favor Orbital Flight!"

Two themes stand out in all the proposals for artificial satellites sent to the government in the 1950s by Korolev and Tikhonravov: automated missions to the Moon and piloted flight into space. At every juncture, both engineers foresaw the two complementary projects as fundamental to the initial growth of the Soviet space program. Early Soviet conceptions for piloted spaceflight dated back to 1945–48, to Tikhonravov's short-lived VR-190 project for launching a human on a vertical flight to the upper reaches of the atmosphere. Later, when Korolev tasked doctors at the Air Force's Institute of Aviation Medicine in 1949 to develop systems to launch dogs into space, he viewed the effort only as a step to achieving the ultimate goal of human spaceflight.[29] The first vertical launches with animals in 1951 on the R-1B and R-1V rockets were thus not isolated projects for OKB-1, but rather the first concrete step in a larger thematic direction of piloted space exploration. These biological flights were followed from 1954 to 1956 by launches on the uprated R-1D and R-1Ye "scientific" missiles, further variants of the basic military R-1 rocket.

The flight profile that engineers developed for the R-1D launches was considerably different from that of the R-1B, and it clearly indicated a progression toward human as opposed to biological spaceflight. The rocket was launched to altitudes of 100 to 110 kilometers, at which

27. Sergey Khrushchev, *Nikita Khrushchev: krizisy i rakety: vzglyad iznutri: tom 1* (Moscow: Novosti, 1994), p. 112.

28. *Ibid.*, p. 104.

29. As early as 1951, OKB-1 may have drawn up preliminary plans for a small capsule to carry a person on a high-altitude vertical flight using the R-1B missile, which itself was used for the early dog launches. For a drawing of one of these conceptions of the R-1B, see Lardier, *L'Astronautique Soviétique*, p. 244.

point the dog cabin separated, going into a free-fall unstabilized trajectory. The dog seated on the right of the cabin ejected at altitudes of seventy-eight to eighty-four kilometers and used a parachute for landing during the following six minutes. The second dog was ejected at altitudes of thirty-nine to forty-five kilometers. Unlike the earlier flights, engineers dispensed with a pressurized cabin for the dogs and instead equipped each animal with its own life-support system in the form of a spacesuit. The aviation Plant No. 918 at Tomilino developed a mask-free suit, which included the suit itself, a detachable plexiglass helmet, an oxygen supply system, and a retractable tray on top of an ejection trolley. The last item carried the oxygen supply, the parachute system, and the physiological measurement equipment. Like the previous launches, a movie camera with a five- to six-minute supply of film recorded the dogs' reactions during various parts of the flight.[30] The total mass of the payload was 1,516 kilograms. In addition to the dog container, the R-1D carried two 130-kilogram scientific experiments packages from the Geophysical Institute of the USSR Academy of Sciences (GeoFIAN).[31] A group of twelve dogs, including flight veterans Albina, Malyshka, Kozyavka, and Tsyganka, was assembled to train for the launches, undergoing rigorous simulations with spacesuits in the cramped cabin.

The first R-1D missile lifted off on July 2, 1954, from Kapustin Yar with dogs Lisa and Ryzhik on board.[32] As planned, the first dog ejected out at an altitude of ninety kilometers, while the second was cast off at forty-five kilometers. Only two further launches were conducted in the series, in July 1954, and although none of the launches were completely successful, the engineers and physicians moved ahead with the use of another "new" missile, the R-1Ye. The latter was distinguished from its predecessor by the addition of a heavier complement of scientific experiments, including two 130-kilogram ejectable GeoFIAN strap-on containers. One of these, the DK-2, included five smoke candles whose ignition mechanism operated at various altitudes to measure wind direction. Unlike the R-1D, the R-1Ye main rocket body was also equipped with a system for allowing the recovery of the entire 4,286-kilogram frame. Four huge parachutes would reduce the rate of descent from 635 meters per second to a bearable seven meters per second.[33] The container for the dogs and the return profile remained exactly the same from the R-1D variant. The R-1Ye series was inaugurated with an early morning launch on January 25, 1955, carrying the dogs Albina and Tsyganka.[34] Engineers carried out

30. Yu. A. Mozzhorin *et al.*, eds., *Dorogi v kosmos: II* (Moscow: MAI, 1992), pp. 130–32, 137; M. V. Keldysh, ed., *Tvorcheskoye naslediye Akademika Sergeya Pavlovicha Koroleva: izbrannyye trudy i dokumenty* (Moscow: Nauka, 1980), p. 351; George E. Wukelic, ed., *Handbook of Soviet Space-Science Research* (New York: Gordon and Breach Science Publishers, 1968), pp. 18–19. The ejection system for the dog container was developed by N. M. Rudniy over a period of three years beginning in January 1951.

31. The primary scientific goals of these second series of vertical launches were: (1) research into the physical and chemical characteristics of air, measurement of the aerodynamic characteristics at high velocities and altitudes, and development of methods of determining the direction and velocity of the wind in the upper layers of the atmosphere; (2) determination of the physical processes in the ionosphere and the density of ionization at altitudes of 100 kilometers and research into altitudes of the D ionization layer and the distribution of voltage at the poles; and (3) research into the life activities of animals associated with the lifting of rockets to great altitudes and testing of systems for the rescue of the animals and a system of rescue of a payload with instruments. In addition, the R-1D rocket was said to be equipped with the STK apparatus and telemeasurement sensors for a special development program. See Keldysh, ed., *Tvorcheskoye naslediye Akademika*, p. 542.

32. Biryukov, "Materials from the Biographical Chronicles," p. 233; Lardier, *L'Astronautique Soviétique*, p. 81; Mozzhorin, *et al.*, eds., *Dorogi v kosmos: II*, pp. 135–36

33. Peter Stache, *Soviet Rockets*, Foreign Technology Division Translation, FTD-ID(RS)T-0619-88 (from unnamed source), Wright-Patterson Air Force Base, Dayton, Ohio, November 29, 1988, p. 219. This is a translation of Peter Stache, *Sowjetischer Raketen* (Berlin: Militarverlad der DDR, 1987). See also Keldysh, ed., *Tvorcheskoye naslediye Akademika*, p. 538.

34. Biryukov, "Materials from the Biographical Chronicles," p. 234; Evgeny Riabchikov, *Russians in Space* (Moscow: Novosti Press Publishing House, 1971), pp. 141–42.

at least five more launches with dogs by June 1956, confirming the selection of the basic design elements of the systems for ensuring the life support and rescue of the dogs.

The physicians involved in the program found that the test animals suffered no major changes in breathing and in their pulmonary and circulatory systems during the various phases of the flight. The failures in the R-1Ye program were apparently all associated with the rescue of the main body; all attempts to recover the rocket body failed because of the failures of the parachutes to withstand the shock of deployment.[35] Korolev, who summarized the results of the total of fifteen biological launches from 1951 to 1955, at a Moscow conference in April 1956, recalled that the series yielded "valuable, positive results" despite three major failures. He added, "The rockets met the numerous, highly complex, often vaguely formulated requirements constantly levied by our colleagues."[36]

The results from the R-1B, R-1D, and R-1Ye biological series of rockets were precisely what Korolev needed to move ahead with plans for human spaceflight. If the launch of an artificial satellite was his first overriding goal, then the launch of a human into space was without doubt the second important step to what he saw as fulfilling Tsiolkovskiy's original dreams of space exploration. It was during the R-1D launches with dogs in 1954 that the Soviet government received its first request to engage in piloted spaceflight. Tikhonravov's landmark document on artificial satellites clearly detailed a plan for immediate vertical launches of humans to 100 to 200 kilometers on existing rockets. A year later, in his annual report to the Academy of Sciences dated June 25, 1955, Korolev wrote:

> *[It is necessary to consider] the proposal to create a missile laboratory for the lifting of 1–2 researchers to altitudes of 100 kilometers and the development of a special system for the return of a laboratory with its crew to the Earth. The importance of such an experiment is huge not only from a scientific point of view, but also from the point of view of maintaining the USSR's priority in native missile technology. We know that if the necessary scientific and technological base for the accomplishment of the goal is created, in 1956 we will be able to start such flights. We ought not to forget that work in this direction is being carried out very intensively in the U.S.A.*[37]

In April 1956, at the All-Union Conference on Rocket Research into the Upper Layers of the Atmosphere, held under the aegis of the Academy of Sciences, Korolev responded to criticisms of human spaceflight:

> *There is the question as to whether or not vertical launches of a manned rocket . . . have any practicality for research . . . the effects of stress upon the human organism during rocket flight would not be for too long and would not be excessive even if the effects of acceleration would vary in terms of intensity as well as the direction of effect during var-*

35. Stache, *Soviet Rockets*, p. 219.

36. A portion of the text of Korolev's speech has been published as S. P. Korolev, "Research into the Upper Layers of the Atmosphere With the Aid of Long-Range Missiles" (English title), in Keldysh, ed., *Tvorcheskoye naslediye Akademika*, pp. 348–61. One failure was related to a malfunction in the power supply to the launch facility during a launch, while a second was caused by "a break in connection" that resulted in the "measuring head" separating prematurely during the ascent phase of the rocket. See the same source, p. 354. Of the three failures, two were in the R-1Ye series, and one was in the R-1B series.

37. The complete text of Korolev's report to the Academy of Sciences has been published as S. P. Korolev, "Account of Scientific Activities in 1954" (English title), in Keldysh, ed., *Tvorcheskoye naslediye Akademika*, pp. 344–46.

ious phases of the flight. This would, of course, still be very unpleasant. Still, it can now be said with some certainty that overstress will not stand in the way of manned rocket flight. . . . We feel that today prevailing difficulties can be overcome and manned rocket flight implemented. This will mean an immense expansion of research possibilities, aside from the pure significance of such flights.[38]

Few in the audience were aware that OKB-1 had already begun actual design work on a piloted spaceship using scientific versions of the R-1 and R-2 missiles.

At a restricted session of the 125th anniversary of the N. E. Bauman Moscow Higher Technical School, in September 1955, Korolev had presented his conceptions for vertical piloted spaceflight. He was remarkably forthright about his intentions:

Our mission is to ensure that Soviet rockets fly higher and farther than has been accomplished anywhere else up until now. Our mission is to ensure that a Soviet man be the first to fly in a rocket. And our mission is to ensure that it is Soviet rockets and Soviet spaceships that are the first to master the limitless space of the cosmos.[39]

The initial exploratory work on the project was carried out between April 1955 and May 1956 at OKB-1 under the technical leadership of engineer Nikolay P. Belov. Parallel work on the theme was also undertaken by Tikhonravov at NII-4. At a meeting in early 1956 to discuss the continuing vertical launches of dogs into space, Korolev proposed that dedicated work begin to replace dogs with humans. Enthusiastic to participate in this effort, a group of doctors at the Air Force's Institute of Aviation Medicine had sent formal requests to Vladimir I. Yazdovskiy, the department chief at the Institute of Space Medicine, to be considered as test subjects for the suborbital launches.[40] A small team, including Abram M. Genin, Ivan I. Kasyan, Aleksandr D. Seryapin, and Yevgeniy M. Yuganov, was established in March 1956, although it seems that they did little actual training for space missions.[41] Having been closely involved in the development of the flight instrumentation for the dog flights, these doctors were primarily engaged in the design of a capsule capable of carrying a human into space on a single-stage ballistic missile.

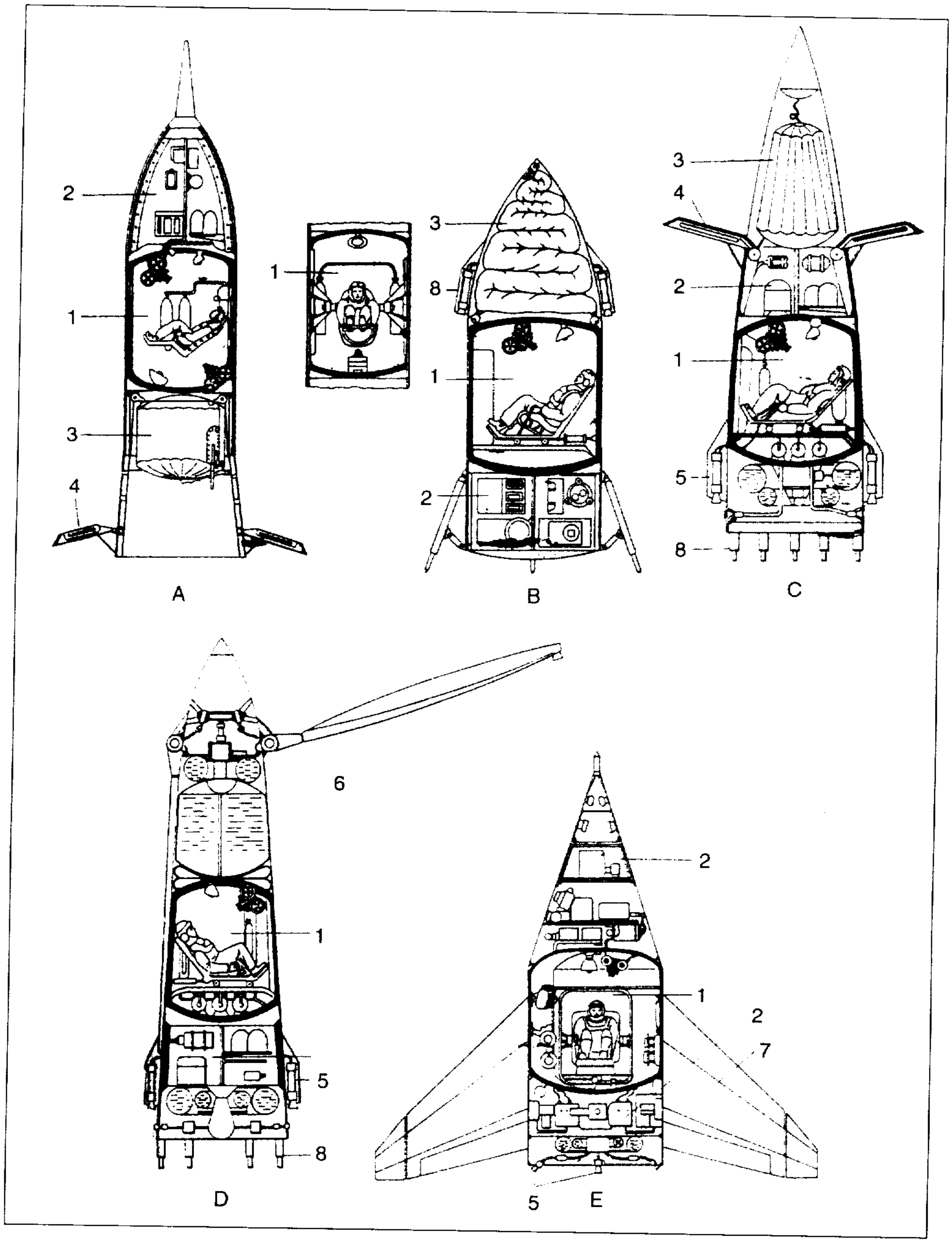
Belov's team at OKB-1 considered a common cabin design that would carry a pilot as the payload in a scientific variant of the military R-2 ballistic missile. The passenger would sit in a reclining seat surrounded by instruments and a camera to film the pilot's own reactions to flight conditions. Although a singular cabin design was considered, Belov's team studied at least five different methods of returning the capsule to Earth. The first variant used a parachute system triggered at a low altitude in much the same way as was used on the R-1B shots in 1951. Following separation from the main body of the rocket, the payload would deploy auxiliary air brakes as well as stabilizers to reduce deployment shock for the parachutes. Velocity would be reduced from 2,050 meters per second at the moment of separation from the rocket (forty kilometers) to 185 meters per second within forty-eight seconds and finally to just under one and a half meters per second at landing. Special thermal insulation would be developed for the air brakes. The second means of return used a reverse method. The point of separation from the

38. Korolev, "Research into the Upper Layers of the Atmosphere," pp. 359–61.

39. Golovanov, *Korolev*, p. 598.

40. Yaroslav Golovanov, "Cosmonaut No. 1: Selection" (English title), *Izvestiya*, April 2, 1986; Mozzhorin, *et al.*, eds., *Dorogi v kosmos: II*, p. 143; Lardier, *L'Astronautique Soviétique*, p. 120; V. P. Mishin, "Problems of the First Flight of a Man into Space" (English title), in *Gagarinskiye nauchnyye chteniya po kosmonavtike i aviatsii* (Moscow: Nauka, 1991), p. 22.

41. Lardier, *L'Astronautique Soviétique*, p. 121; Golovanov, *Korolev*, p. 598; Col. V. Gorkov, "History of the Space Program: Resident of Star Town" (English title), *Aviatsiya i kosmonavtika* no. 1 (January 1990): 20–23.



Beginning in 1955, OKB-1 studied five different types of spacecraft for sending a pilot on short hops into space on the R-2A missile. From top left to right are: (A) capsule with return by parachute and air brakes, the latter also for stabilization; (B) capsule with return by parachute and solid-propellant rocket engines; (C) capsule with return by parachute, stabilization by rocket engines and air brakes, and braking by air brakes and by rocket engines during terminal phase; (D) capsule equipped with helicopter-type rotors with rocket engines on the blade ends; and (E) spacecraft with wings for gliding return with the aid of stabilization engines. Legend: (1) capsule; (2) equipment; (3) parachute system; (4) braking and stabilizing surfaces; (5) position stabilizing nozzles; (6) rotor; (7) wings; and (8) braking engine. (reproduced from Peter Stache, Sowjetischer Raketen *(Berlin: Militarverlad der DDR, 1987))* main rocket body would be at a much higher altitude, but at a much lower velocity—that is, similar to the R-1Ye biological rockets. Auxiliary brakes would further reduce the velocity of descent to prevent parachute failures. The third conception was different from anything yet built and used small rocket engines to ensure stable positioning during the descent portion. The capsule would also use improved and larger air brakes in the upper portion of the spacecraft, as well as special brakes to reduce the landing shock for the passenger. This was an idea taken from Tikhonravov's VR-190 piloted rocket project in the 1940s.

The fourth and fifth variants for landing the capsule were perhaps the most ambitious and innovative. For the fourth system, OKB-1 engineers completely dispensed with the problematic parachutes, replacing them with seven-meter-diameter helicopter rotors fixed on the nose cone of the capsule. At the peak of its trajectory, the rotors would deploy and start moving in a circular motion by means of small rocket engines fixed to the tips. Stabilization during the descent would be ensured by additional control nozzles on the capsule. Engines for soft-landing were also installed at the base of the return capsule. The rotor idea was a design to which Korolev himself returned many times in the next few years, refusing to abandon what he considered its elegance. While the first four variants of return were based on the premise of a directly vertical flight into the upper atmosphere up to 200 kilometers, the fifth envisioned a true ballistic flight downrange about 600 to 1,000 kilometers, but also with a ceiling of 200 kilometers. The primary reason for taking this approach was the increased time of weightlessness—about fifteen minutes for the passenger. Korolev believed that such a ballistic suborbital flight could be accomplished without any problems if the return capsule was equipped with large delta-shaped wings. Stabilization and position control engines as well as aerodynamic rudders would aid during the descent of the pilot. Such a design would also lay the basis for the development of a supersonic transport vehicle capable of flying at velocities of 3,500 to 7,000 kilometers per hour.[42]

All of these various models would be launched on a modification of the R-2 missile, the scientific R-2A rocket. The old R-1 rocket, essentially a copy of the German A-4, had limited the range of investigations of the upper atmosphere to 100 kilometers. The introduction of the R-2 doubled this altitude, allowing the first investigations in what might be considered "true space." The draft plan for the R-2A rocket was completed in 1956 at OKB-1. The rocket, which was just under twenty meters long, would carry a payload weighing about 1,340 kilograms with two dogs as well as two 430-kilogram strap-on containers for scientific studies. The dog capsule itself had an internal volume of just under half a cubic meter and was in fact the prototype of the cabin used on the second Sputnik to carry Layka into orbit.[43] For the first time, accommodation was made for the ingestion of food by the animals during flight. This third generation of dog capsule dispensed with the catapult mechanism used in the previous series. Instead, the dogs, dressed in spacesuits, were strapped into separate chambers in a pressurized area in the nose cone. At the peak of the trajectory, the payload would separate and go into free fall. At five kilometers altitude, an improved recovery system with a series of three parachutes would deploy.[44] The design and development of the R-2A biological missile were carried

42. The details of all five designs were included in Korolev's speech at the N. E. Bauman Moscow Higher Technical School in September 1955 and are summarized in Stache, *Soviet Rockets*, pp. 261–71.

43. Lardier, *L'Astronautique Soviétique*, p. 82.

44. Stache, *Soviet Rockets*, p. 222. The following overall scientific goals were listed in the draft plan of the R-2A: (1) research into the chemical composition of air and measurement of air pressure at altitudes of 150–200 kilometers; (2) detection of solar ultraviolet radiation in the Lymankovskiy hydrogen series at 900–1,200 angstroms and photographing the surrounding areas; (3) research into the possibilities of survival and life support for animals lifted on the rockets to 200 kilometers; (4) testing of systems for rescuing the payload; and (5) determination of physical processes in the ionosphere and ionization density at altitudes of 150–200 kilometers. In addition, as in the R-1D program, the R-2A was said to be equipped with the STK apparatus and telemeasurement sensors for a special development program. See Keldysh, ed., *Tvorcheskoye naslediye Akademika*, p. 546.

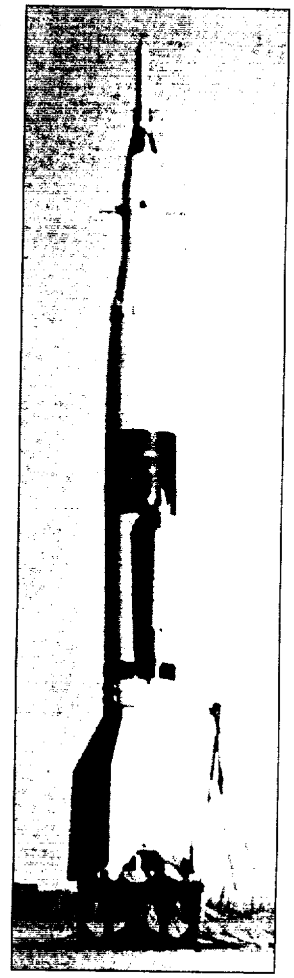
out in parallel with Korolev's studies on human rocket flight because both were to use the common R-2A rocket as a launch vehicle.

The first R-2A was launched successfully on May 16, 1957, from Kapustin Yar, the day after the first launch attempt of the R-7 ICBM. The two dogs on board, Ryzhaya and Damka, experienced a long six minutes of microgravity before returning safely to Earth after reaching an altitude of 212 kilometers. At least four more successful launches were carried out in the initial series, the last on September 9.[45] It was less than two months later that the same container was used to carry Layka into Earth orbit. These R-2A launches laid the groundwork for the piloted lobs into the atmosphere, but by late 1957, it seems that Korolev had been looking for other options. One of the original reasons for immediately commencing a piloted vertical program was the belief that an orbital satellite with a human on board would only be possible as late as 1964–66.[46] With the advent of the R-7 ICBM, these projections were drastically shortened by about five years. As Belov's group at OKB-1 continued work on crewed lobs into the atmosphere, it was increasingly clear, at least to Korolev, that the future lay elsewhere.

As with many of the new directions in the early Soviet space program, the most fruitful and groundbreaking work emerged from Tikhonravov's resourceful group, which had recently been transferred from NII-4 to OKB-1. On March 8, 1957, Korolev consolidated the work under Tikhonravov and established the new Department No. 9, comprised of about thirty young engineers. It was now the "planning department for development of space apparatus." That is, its focus was narrowed exclusively to space exploration—a significant event that in retrospect signaled the beginning of OKB-1's gravitation from creating missiles to designing spacecraft. In April, Tikhonravov facilitated some discussions among his team members about objectives on which they could focus. Three basic directions emerged:

- Continuing work on Object D, with expansion of work on a satellite capable of observation
- Initiating work on a biological satellite capable of carrying dogs in orbit for more than a day
- Developing a capsule for vertical flights of humans to altitudes of 300–400 kilometers

At the same time, Tikhonravov identified two future streams of work: the development of a piloted orbital spaceship and the creation of automated lunar exploration spacecraft.



This is one of the R-2A missiles, thirteen of which were launched between 1957 and 1960. Many of them carried biological containers with dogs to altitudes as high as 200 kilometers. A similar container was used to carry Layka into orbit on Sputnik 2. For a brief period, Korolev also planned to use the R-2A to launch humans on vertical hops into space. (files of Asif Siddiqi)

45. Biryukov, "Materials from the Biographical Chronicles," p. 238; Wukelic, ed., *Handbook of Soviet Space-Science Research*, p. 10.

46. A. Yu. Ishlinskiy, ed., *Akademik S. P. Korolev: Ucheniy, inzhener, chelovek* (Moscow: Nauka, 1986), p. 506.

Research on these topics had actually begun in November 1956, but it was consolidated in a document issued in April 1957, titled "A Project Research Plan for the Creation of Manned Satellites and Automatic Spacecraft for Lunar Exploration."[47] Still classified, the report laid the groundwork for the early piloted space programs in the Soviet Union.

This initial work in 1957 at OKB-1 helped limit the parameters of the future design of a piloted orbital spaceship. Engineers found that the mass of such a satellite could be as high as three to four tons and possibly five tons if the R-7 was augmented by an appropriate upper stage. They also made advances in methods for computing parameters of the heat stream on the surface of "a simple" body returning into the atmosphere at hypersonic velocities. Research between September 1957 and January 1958 was instrumental in narrowing down such factors as the mass of thermal protection and temperature ranges for various types of reentry bodies. Finally, scientists at Keldysh's Department of Applied Mathematics confirmed that with a ballistic reentry with zero lift, loads on a returning body would not exceed ten times the force of gravity.[48]

Korolev and Tikhonravov may have been primarily interested in Tsiolkovskiy's ideal of space exploration, but OKB-1 was still an organization funded by the Ministry of Defense. Tikhonravov's early work on piloted orbital spacecraft was in fact closely tied to goals more in line with those formulated by the military, a point strongly reflected in Tikhonravov's early conception for a satellite capable of "observation." Using the basic Object D frame as a starting point, in late 1956, Tikhonravov had begun work on two new variants of the satellite, Objects OD-1 and the OD-2; the "OD" stood for "oriented D." The OD-1 was a prototype of a military reconnaissance satellite with a passive orientation system, while the OD-2 was the prototype of a biological version for dogs with an active orientation system.[49]

It seems that the OD-1 reconnaissance satellite had the unofficial support of higher leaders, probably in the Ministry of Defense, although there was no formal approval for the work. Like most other early space projects, the momentum for the OD-1 came not from above but from below. Korolev and Keldysh had both signed a letter dated April 12, 1957, to the Council of Ministers on accelerating work on the OD-1. Later on July 2, Korolev apparently sent another letter to the government requesting approval to develop a photo-reconnaissance satellite using the OD-1 design.[50] Little information has been revealed on this early proposal. According to the design, the satellite was to use special recoverable film cassettes, which were designed by the Institute of Applied Geophysics of the Academy of Sciences. The S. I. Vavilov State Optical Institute, meanwhile, was tasked to develop the secret cameras for the spacecraft. The spacecraft itself consisted of two modules: a recoverable conical capsule carrying cameras and film and a large cylindrical instrumentation section with conical or spherical ends.[51]

47. *Ibid.*, p. 447; B. V. Raushenbakh, ed., *Materialy po istorii kosmicheskogo korablya "Vostok"* (Moscow: Nauka, 1991), p. 210; S. S. Kostin, "Some Aspects of Planning the 'Vostok' Space Ship" (English title), *Iz istorii aviatsii i kosmonavtiki* 42 (1980): 62–66; Timothy Varfolomeyev, "Soviet Rocketry that Conquered Space: Part 3: Lunar Launchings for Impact and Photography," *Spaceflight* 38 (June 1996): 206–08; Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p. 105.

48. Kostin, "Some Aspects of Planning the 'Vostok' Space Ship"; Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p. 105.

49. Raushenbakh, ed., *Materialy po istorii*, p. 210.

50. The text of the first letter has been published as S. P. Korolev, "Proposal for an Oriented Satellite of the Earth" (English title), in Keldysh, ed., *Tvorcheskoye naslediye Akademika*, pp. 373–74. See also Georgiy Stepanovich Vetrov, "The First Satellite: Historical Limits" (English title), *Novosti kosmonavtiki* 16 (July 28–August 10, 1997): 2–9.

51. Yuriy Mikhaylovich Frumkin, "Without the 'Secret' Stamp: The First Reconnaissance Satellite" (English title), *Aviatsiya i kosmonavtika* no. 3 (March 1993): 41–42; Yu. M. Frumkin, "Development of First Soviet Photoreconnaissance Satellite 'Zenit'" (English title), *Priroda* no. 4 (April 1993): 72–78.

The OD-2 biological variant apparently had less support, even among the engineering leaders within the space program. But it seems that research on this dog satellite had generated a modicum of discussion at various levels on the utility on human spaceflight. There were intensive discussions at the level of the Council of Chief Designers through 1958 on whether to even attempt human orbital spaceflight or whether to simply continue the more modest program aimed at vertical attempts. Some rejected ideas for piloted spaceflight based on concerns about the dangers of stress, weightlessness, meteors, reentry, and even cost. Others, including a number of chief designers on the council, believed that the optimal way would be to proceed at least initially with vertical hops to the upper atmosphere, as was being studied by Tikhonravov's team. A third faction within Korolev's OKB-1 proposed true suborbital launches with flights about 1,000 kilometers downrange, such as those studied by Belov's group, arguing that the experience from these modest launches would be adequate for the moment. Although it seems that Korolev had vigorously favored the latter two options during the mid-1950s, by 1958 his mood had become more ambitious and perhaps impatient.

Korolev's ideas were opposed by a number of major figures in the new space program during a meeting at the Academy of Sciences attended by representatives of various design bureaus, scientific-research institutes, the military, and the aviation medicine sector. Academician Norair M. Sisakyan, a leading biomedicine specialist who had been involved in the dogs-in-space program, cautioned about the publicity afforded to a potentially fatal attempt to orbit a pilot. Arkadiy S. Tomilin, the Chief of the Seventh Chief Directorate in the State Committee for Defense Technology, also opposed an orbital attempt, calling Korolev a "science fiction writer."[52] Korolev did, however, have the key support of not only Keldysh and Glushko, but also Maj. General Aleksandr G. Mrykin, Marshal Nedelin's chief specialist on space and missile issues and a very powerful figure in the military. Throughout 1958, these kinds of discussions were apparently quite common, but Korolev's headstrong support for orbital flight slowly emerged as a winner. As in the tremendous steps in the early evolution of the ICBM program, he believed that what was needed at that point were not incremental advances, but a significant leap in capabilities. Referring to the more modest approaches advocated by some of his associates, he was reported to have said at one meeting:

> *These are approaches with no future. We need spacecraft for flights around the Earth. Although gradual visits to space are effective, they are of no significance for science and for spaceflight. I favor orbital flight—we can achieve our goal without intermediate stages!*[53]

The Object K

On the morning of February 15, 1958, Korolev called Tikhonravov into his office and tasked him to begin formal work on a piloted orbital spaceship.[54] The vehicle would inherit the OD-2 designation originally kept for launching dogs into orbit. This project would continue in parallel with Belov's efforts to develop a suborbital piloted spacecraft. Tikhonravov appointed a talented thirty-two-year-old engineer in his department, Konstantin P. Feoktistov, to lead the engineering aspects of the effort. A protégé of Tikhonravov's, at the age of ten, Feoktistov was already making plans for exploring the Moon. In 1942, as a sixteen-year-old scout for Soviet

52. Romanov, *Korolev*, pp. 326–32; A. P. Romanov and V. S. Gubarev, *Konstruktory* (Moscow: Politicheskoy literatury, 1989), pp. 312–17. Note that a completely garbled and censored account of this meeting was reproduced in A. Romanov, *Spacecraft Designer* (Moscow: Novosti Press Agency Publishing House, 1976), pp. 38–42. Not only were the names disguised (Sisakyan becoming Stepnov and Tomilin becoming Koptelev), but conversations were so twisted beyond recognition, that in some cases the same person was having a conversation with himself in some passages!

53. Stache, *Soviet Rockets*, pp. 265–66.

54. Romanov, *Korolev*, p. 311.

partisan units during the Nazi invasion of the Voronezh region, he had been captured, shot, and left for dead. By a stroke of incredible luck, he had only been injured by the gunfire and waited until dark to crawl away to safety. In later years, he graduated from the N. E. Bauman Higher Technical School before finding work under Tikhonravov at NII-4. As the Chief of the Group for Planning Piloted Space Apparatus, he oversaw twenty young engineers at OKB-1 who began work in early 1958 on the design of a vehicle capable of carrying a human into orbit.[55]

Feoktistov's group began in March–April 1958 by addressing the problem of safely returning a capsule from orbit. In 1953, Timur M. Eneyev at Keldysh's Department of Applied Mathematics had conducted some of the earliest research on ballistic reentries of orbital vehicles. Eneyev's landmark work was used, in combination with theoretical work done the same year by Keldysh, Georgiy I. Petrov, Vsevolod S. Avduyevskiy, and others at NII-1, on the thermal characteristics of various materials for heat protection. The material eventually selected for the new spaceship was reinforced plastic of asbestos fabric.[56] During calculations for the thickness of this layer, one of the engineers, Konstantin S. Shustin, had mistakenly erred by a factor of two. Fortunately for the spaceship, Korolev had earlier demanded that the required thickness be multiplied by a factor of four for total safety (to fifty millimeters).[57] Feoktistov's group chose a simple ballistic means of reentry with no lifting surfaces. Many different landing systems were examined during this process, including Korolev's favorite helicopter rotor system. Korolev contacted the noted Soviet helicopter Chief Designer Mikhail L. Mil of OKB-329 on this issue, but he was less than enthusiastic. Mil told one of his deputies:

> *I simply don't want to get mixed up in this. Just imagine: a man flies into space, makes a couple of loops around the globe, the whole world applauds, and the superstar begins his return to the Earth and then—bang! Something happens to him. Who is to blame? We will be! No, we won't be taking part in this undertaking.*[58]

Also considered was a huge umbrella-type brake for landing. All these exotic ideas were eventually abandoned, and by April 1958, the engineers adopted a simple parachute system. In addition, because of the large mass of heat protection, the engineers decided at an early stage to return only a portion of the spacecraft from orbit—that is, there would be a special "descent apparatus" that would carry the lone passenger. This compartment would be attached in orbit to an instrument module.

The next major problem was also resolved in April and May: the shape of the descent apparatus capsule. Feoktistov's group examined several designs, including cones of different lengths and sizes, half spheres, and full spheres.[59] The last shape was finally chosen for three major reasons: a sphere would not require complicated attitude control devices during reentry to maintain dynamic stability. A sphere also offered increased internal volume relative to surface area. Finally,

55. Rex Hall, "Soviet Civilian Cosmonauts," in Michael Cassutt, ed., *Who's Who in Space: The International Space Year Edition* (New York: Macmillan, 1992), p. 291. The others in Feoktistov's group were K. S. Shustin, O. V. Surguchev, M. S. Florianskiy, G. Z. Davletshin, V. P. Kurayev, Ye. N. Lomonosova, V. G. Vartanyan (computations), A. A. Alimov, N. I. Beresnev, L. I. Dulnyev, A. A. Kochkin, V. Ye. Lyubinskiy, O. G. Makarov, V. I. Petrov, N. M. Tereshenkova, D. M. Ego (layout scheme, design elements, and so on), V. G. Suprun (life support systems), V. A. Yazdovskiy (measurement), P. V. Flerov, and Ye. N. Tsererin (landing system, program of experimental work). See Raushenbakh, ed., *Materialy po istorii*, p. 212.

56. N. Chentsov, "World Famous, But Secret in Every Way" (English title), *Nauka i zhizn* no. 2 (February 1991): 102–07; Lardier, *L'Astronautique Soviétique*, p. 121.

57. Lardier, *L'Astronautique Soviétique*, p. 121.

58. Golovanov, *Korolev*, p. 600.

59. One conception looked almost exactly like the Apollo Command Module.

spheres would be subject to lower thermal stresses because of the increased surface area. The engineers were aware that a more complex shape such as a cone would reduce g-loads during reentry as well as allow for some control at landing, but Korolev understood that these advantages were relatively unimportant in the face of the primary limiting factor—time. The selection of the shape of the descent apparatus, which was assumed to be the most difficult task, was evidently a breakthrough in the entire design process, and it was at this point that Korolev privately decided to propose and support the entire project at a governmental level.[60]

In early June, Tikhonravov and Feoktistov summarized the research done so far for Korolev, eliciting the latter's full approval. There were subsequent discussions in the next months with leading specialists from various other divisions at OKB-1. Then the four men primarily responsible for the work—Korolev (Chief Designer of OKB-1), Bushuyev (Deputy Chief Designer of OKB-1 for Space Technology), Tikhonravov (Chief of OKB-1's Department No. 9), and Feoktistov (Group Chief for Piloted Space Apparatus)—prepared and signed a formal and preliminary report on the research on August 18, 1958. The document, titled "OKB-1 Report. Materials on the Preliminary Work on the Problem of the Creation of an Earth Satellite with Humans on Board (Object OD-2)," was a nine-part thesis, plus an introduction and a conclusion, which included sections on:

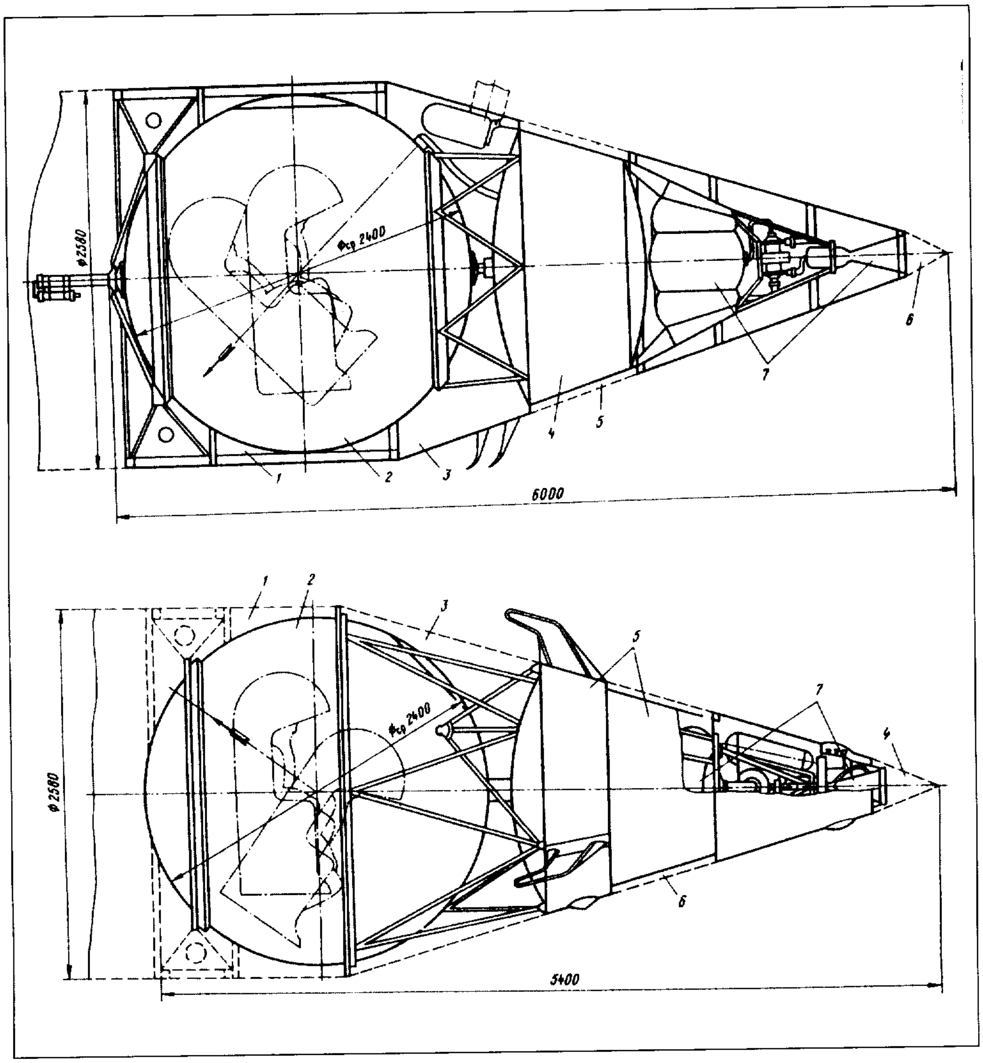
- Primary flight characteristics
- The layout scheme for Object OD-2
- The shape of the descent apparatus and problems of stability
- The composition of equipment, landing systems, and layout of the descent apparatus
- Heat protection of the descent apparatus
- Problems of heat cycles in orbit
- Control and orientation systems
- Tracking and communications
- The program of experimental work[61]

The paper contained four different possible variants of the piloted OD-2, all with a similar two-compartment configuration: the conical "instrument section" and the spherical "descent apparatus." The latter was a classic sphere of about two and a half meters diameter, which served as the crew compartment as well as the reentry module for the single passenger. All the variants were equipped with a large ejection seat for the crewmember to use during the descent to Earth's surface. In three of the variants, a large conical-shaped pressurized compartment, the instrument section, which housed all the electronics and control systems for the spacecraft, crowned this descent apparatus sphere. The conical section was evidently derived from the main body of the Object D scientific satellite launched as Sputnik 3, which suggests a lineage all the way back to Tikhonravov's original 1954 document on space exploration. In the fourth variant, the instrument section was in the form of a torus at the base of the sphere. All four conceptions had a large engine—the "braking engine unit"—at the apex of the cones, to perform reentry burns. Depending on the variant, the length of the sphere-cone combination was about four and a half to six meters. The diameter of the combination on the pad for all the versions was just over two and a half meters. The mass of the descent apparatus was just over three tons.[62]

60. Ishlinskiy, ed., *Akademik S. P. Korolev*, p. 506.

61. A slightly edited version of the document has been published as S. P. Korolev, K. D. Bushuyev, M. K. Tikhonravov, and K. P. Feoktistov, "OKB-1 Report. Materials on the Preliminary Work on the Problem of the Creation of an Earth Satellite With Humans on Board (Object OD-2)" (English title), in Raushenbakh, ed., *Materialy po istorii*, p. 20–119. Feotistov's "counterpart" for the reconnaissance satellite was Ye. F. Ryazanov, a veteran from Tikhonravov's group at NII-4.

62. *Ibid.*, pp. 41–49, 71.



Shown here are two conceptions of the Object OD-2 spacecraft, which was the first design for an orbiting piloted ship in the Soviet Union. Dating from August 1958, the OD-2 design was changed by early 1959 into the ship that was later named Vostok. Both of these conceptions incorporated a spherical return capsule for the lone pilot, a layout that was retained for Vostok. Note the conical instrument module on the right of each spacecraft, very much similar to the Object D satellite launched as Sputnik 3. (reproduced from B. V. Raushenbakh, ed., Materialy po istorii kosmicheskogo korablya "Vostok" *(Moscow: Nauka, 1991))*

From the writing in the document, it seems that variant number one was the favored version, a five- to five-and-a-half-ton spacecraft capable of ten days crewed orbital spaceflight. To account for a failure in the braking engine unit, the engineers had calculated that a circular orbit at 250 kilometers would allow the descent apparatus to reenter by normal decay after ten days, which was the length of safe operation of the on-board life support system. After reentry, the single passenger would eject out from the spherical capsule at an altitude of eight to ten kilometers and land separately from the main spacecraft. Although provisions were taken in case of a water landing, the descent apparatus was designed to touch down on land because this would provide a modicum of secrecy to the entire operation and also simplified rescue and survival procedures. Korolev had a strong dislike of parachute recovery systems, hence his preference for unusual methods of descent, but he agreed to a parachute system in this case because that would ensure a quicker design process. Ballistics calculations, however, proved that to ensure a soft-landing on Earth, parachutes of huge size as well as extra landing engines would be required, adding significant mass to the spacecraft. To circumvent the problem, the engineers decided to have the pilot eject at altitude. The descent apparatus would land separately.

A seven-part program of testing was identified in the document:

- Static testing on the ground for verifying the thermal protection, the engine unit, the life support system, the system of internal thermo-regulation, and the catapult system
- Air testing of the catapult system in various conditions
- Rocket testing of the catapult system in various conditions with the aid of mannequins on R-2 and R-5 rockets
- Verification of the thermal coating in natural reentry conditions
- The development of the spacecraft for carrying dogs on ballistic trajectories to 130–150 kilometers
- One or two launches of dogs into 250–300-kilometer orbits
- The launch of a human into a 250–300-kilometer orbit

According to the document, the engineers would not implement any design changes in the spacecraft following the automated flights because it would be difficult to predict the consequences of such actions on a crewed mission. If government approval was granted, Korolev envisioned a first piloted orbital launch by December 1960 at the earliest.[63]

Based on the August 1958 document, Korolev prepared an information package on the course of work on the OD-2 and had it circulated on September 15, 1958, to the other members of the Council of Chief Designers—Glushko, Pilyugin, Barmin, Ryazanskiy, and Kuznetsov—as well as to other senior officials in the government.[64] By this point, Korolev was faced with a dilemma: whether to focus on the reconnaissance satellite or the piloted spaceship. Continuing both programs simultaneously would tax the resources of his organization, thus perhaps delaying both efforts. Clearly, he preferred the piloted spaceship program, but that would posit him in the precarious position of ignoring the needs of the defense sector, a charge that was paramount to treason. Feoktistov recalls, "The battle in the OKB (a fierce one!) went on for several months and Chief Designers and other specialists from leading organizations who were to participate in this work were called in."[65] The real deciding factor, however, may have not been any internal consideration, but rather events thousands of kilometers from Kaliningrad, as the United States was beginning to take its first concrete steps toward piloted spaceflight.

In August 1958, President Eisenhower assigned the yet-to-exist formal successor to the National Advisory Committee for Aeronautics to develop and carry out the "mission of manned spaceflight."[66] On October 1, the National Aeronautics and Space Administration (NASA) formally came into existence and inherited that goal. Just six days later, NASA Administrator T. Keith Glennan approved plans for a piloted satellite project, and the primary responsibility of

63. *Ibid.*, pp. 116–18; Mikhail Rebrov, "A Star Traversing Cape Horn" (English title), *Krasnaya zvezda*, April 12, 1994, p. 2.

64. Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p. 633. The source mentions "directive organs," which was usually a euphemism for the Communist Party and the government.

65. Ishlinskiy, ed., *Akademik S. P. Korolev*, pp. 506–07.

66. Linda Neuman Ezell, *NASA Historical Data Book, Volume II: Programs and Projects 1958–1968* (Washington, D.C.: NASA Special Publication (SP)-4012, 1988), p. 99.

coordinating the program was delegated on November 5 to the Space Task Group based at the Langley Research Center in Virginia, headed by Robert R. Gilruth. Among the many luminaries of this resourceful group were Maxim A. Faget and Christopher C. Kraft, Jr., both of whom, along with Gilruth, would play some of the more pivotal roles in the early years of the U.S. civilian space program. The "human in space" project was officially designated "Mercury" on November 26, and by early January 1959, McDonnell Aircraft Corporation's bid for designing and producing the vehicle was accepted from a list of ten companies.[67]

These events in the United States did not pass without notice. The formation of NASA and Glennan's push for a piloted space project may have been pivotal during a meeting of the Council of Chief Designers in November 1958. Presentations were made on the suborbital program, the orbital spaceship, and the reconnaissance satellite. The council decided to move ahead first with the development of a piloted orbital spaceship. Work on the development of an automated reconnaissance satellite was moved to a secondary priority, and all efforts on suborbital piloted space programs ceased at this point after a full three years of research.[68]

Armed with unanimous recommendations for orbital flight and no doubt using the events in the Mercury program as added weight, Korolev took his case to the Communist Party and the government. On January 5, 1959, the Central Committee of the Communist Party and the USSR Council of Ministers issued a decree (no. 22-10ss) officially calling for biomedical preparations for a human spaceflight project.[69] This document, still classified, was the first government decree issued in support of a Soviet "human in space" program. Actual language for the specific development of a piloted *spaceship* was included in a second, more detailed decree (no. 569-264), which was adopted by the Soviet leadership on May 22, 1959.[70] Interestingly, this second secret decree was primarily focused on the approval of an automated reconnaissance satellite program, but Korolev, with the help of Keldysh and Rudnev, had managed to insert the following line at the end of the document: ". . . and also a satellite designated for a flight of a human."[71]

The work on the OD-2 piloted spaceship was significantly accelerated as a result of these decrees. There were, however, at least two major design decisions prior to the signing of the final technical specifications for the spaceship. In the original conception of the OD-2, the instrument section was a large cone-shaped compartment fitted on the forward end of the spherical descent apparatus. In the interest of maintaining mass constraints, instrumentation would be designed that could be mounted on the exterior of the instrument section for work in vacuum. Although Feoktistov himself supported this approach, by early 1959, Korolev opted for a more conservative path—one in which all the systems on the instrument section were installed *internally* in a pressurized compartment. In his opinion, this would significantly cut down on the time needed to design and develop instruments capable of working in open space.[72] The shape and configuration of the spacecraft also changed dramatically, with the instrument section now becoming a double-coned object fitted at the aft end of the sphere.

67. *Ibid.*, pp. 102, 139–40.

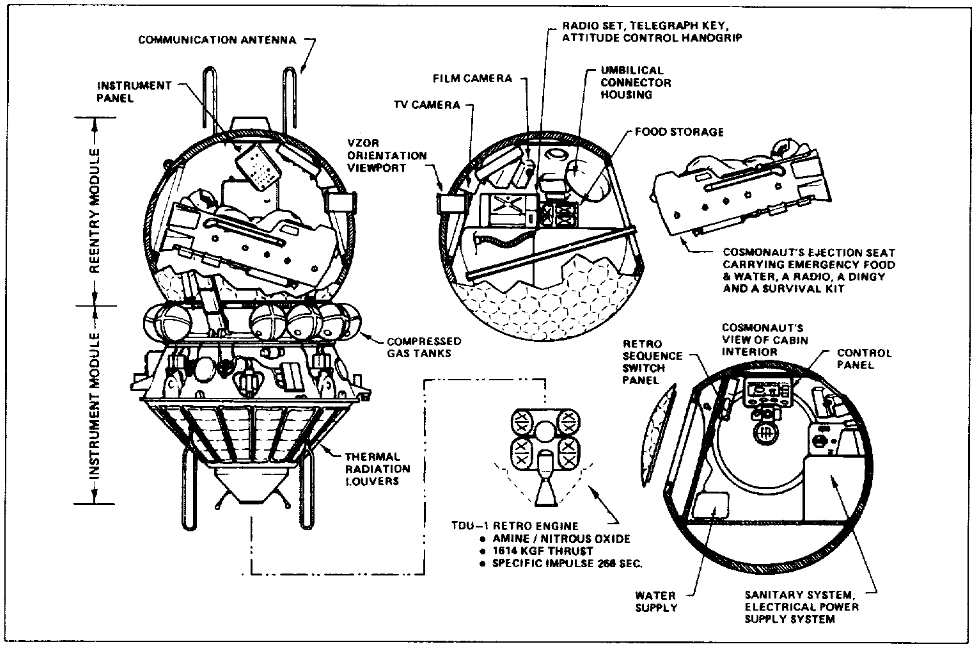
68. Raushenbakh, ed., *Materialy po istorii*, p. 212.

69. Gorkov, "History of the Space Program: Resident of Star Town." Korolev had evidently first raised the issue of "piloted" as a serious proposal to the government—that is, the Special Committee—in a memorandum in May 1957. Later in August 1958, he also managed to extract a show of support from NII-4 Director G. A. Tyulin. See Rebrov, "A Star Traversing Cape Horn."

70. S. Shamsutdinov, "Sixty Years for Yu. A. Gagarin" (English title), *Novosti kosmonavtiki* 5 (February 26–March 11, 1994): 5–7.

71. B. Ye. Chertok, *Rakety i lyudi: Fili Podlipki Tyuratam* (Moscow: Mashinostroyeniye, 1996), p. 424.

72. Ishlinskiy, ed., *Akademik S. P. Korolev*, p. 508.



This is the piloted variant of the Object K spacecraft that later was called Vostok. The Vostok ship consisted of two basic modules: a spherical reentry module ("descent apparatus") for launch and recovery of the lone pilot and an instrument module ("instrument section") to carry the systems necessary for flight implementation. (copyright David R. Woods)

The second change had more long-range repercussions. Partly because of the operational limitations of a passive orientation system and partly to conserve resources, the original OD-1 design for the reconnaissance satellite was abandoned. Instead, Korolev adopted the design of the biological OD-2 for the spy satellite.[73] Thus, the OD-2 became a dual-role spacecraft for military reconnaissance and human spaceflight, a common ancestry that was one of the more famous aspects of the early Soviet space program. Both missions required the recovery of portions of the satellite as well as a high degree of reliable systems operation; the use of a common bus would dramatically reduce the effort and time expended on an already overburdened OKB-1. The idea to merge the two disparate programs may even have been a strategy on Korolev's part to gain approval for the human spaceflight effort by using a reconnaissance satellite cover. The piloted program seems to have had little support from higher leaders, and in early 1958, it was still a very low-priority effort compared to the development of military ballistic missiles such as the R-7, the R-11M, the R-11FM, and the orbital reconnaissance satellite.

73. There are some inconsistencies as to exactly when the two designs were unified. In publishing the famous August 1958 report on the OD-2, the editor notes: "Minimum cuts [in the publication of the report] relate to the automated option of the satellite-ship, in which large-size photo-apparatus for survey of the Earth's surface were to be placed instead of the pilot. These options were later used as the basis of a separate program of development of the 'Zenit' photographic research satellite." See Raushenbakh, ed., *Materialy po istorii*, p. 212. This implies that the OD-2 design was already the basis for a common bus for both the piloted and reconnaissance satellite versions by August 1958. The official history of OKB-1, however, states that the unification occurred in 1959. See Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p. 99. The 1959 date may refer to the unification of the *new* design for the piloted spaceship (eventually used on the Vostok), which was markedly different from the OD-2.

As a result of these changes, the designers dropped the original OD-2 designation and instead named the spacecraft "Object K." The "k" stood for *korabl*, the Russian word for "ship." Four different variants were postulated, the 1K, 2K, 3K, and 4K. The first was earmarked as a common prototype for both the reconnaissance and piloted variants. The second and fourth were exclusively dedicated to photo-reconnaissance missions, while the third was designed for piloted spaceflight.

Korolev approved the "complex plan for experimental work" on the piloted spaceship on March 17, 1959, which led to the completion of the draft plan of the Object 1K the following month. Comprising "only a few tens of pages of text and sketches," it allowed the designers, instrument subcontractors, electricians, and test specialists to begin verifying the layout on mock-ups of the spacecraft.[74] Partly to have a dedicated facility for producing the new spacecraft, the Military-Industrial Commission institutionally transferred an old plant on the other side of Kaliningrad to OKB-1. During World War II, this plant and its associated Central Artillery Design Bureau had produced almost half the field guns in the Soviet Union, but as the missile age dawned in Russia, it was fast becoming an obsolete remnant of the past. By the mid-1950s, with a change of name to the Central Scientific-Research Institute No. 58 (TsNII-58), the organization had started mass production of fast neutron nuclear reactors for the Soviet economy. When Korolev needed an extra plant to focus on the development of new solid-propellant ballistic missiles as well as the production of new spacecraft, Ustinov agreed to give the plant and its personnel wholesale to the chief designer. On July 3, 1959, TsNII-58 was attached to OKB-1 as its "Second Territory." Korolev's engineers soon arrived with their drawings of the Object K, cementing the old artillery plant's giant leap into the future.[75] Deputy Chief Designer Bushuyev, the space systems chief at OKB-1, was transferred to manage operations at the plant, overseeing the manufacture of all spacecraft at Korolev's enterprise. The very first casings of the spherical descent apparatus rolled off the lines the following month.

The Object K spacecraft, as it emerged in 1959, was a two-section spacecraft with a mass of approximately 4.73 tons in its crewed variant. Of this, the descent apparatus was 2.46 tons, while the instrument section was 2.27 tons. The engineers informally called the descent apparatus *sharik* ("ball"). The overall length of the spacecraft without antennae was 4.4 meters, while the maximum diameter was 2.43 meters.

The spherical descent apparatus, which had an internal volume of just over one and a half cubic meters, was a single-seat capsule covered completely with heat-resistant coating to protect it during reentry. The thickness of the thermal coating varied between just over three and eleven centimeters, the latter on the side that would face the atmosphere during reentry. The two-and-three-tenths-meter-diameter capsule had three one-meter-diameter hatches, one for recovery parachutes, one for access to instrumentation, and one for entry and exit by the pilot. In addition, there were three portholes with refractory glass located on the module for the crewperson to carry out optical observations, two of which had controllable shutters to block out the Sun's rays. The bulk of the internal volume in the descent apparatus was taken by a large

74. For the "complex plan for experimental work," see Biryukov, "Materials from the Biographical Chronicles," p. 241. There is some confusion as to the date of completion of the 1K draft plan. One source says it was completed in April 1959. See Chertok, *Rakety i lyudi*, p. 423. Another source says late May 1959. See Ishlinskiy, ed., *Akademik S. P. Korolev*, p. 509. A third source says April 1960. See Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p. 108.

75. Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, pp. 67–68, 633; Chertok, *Rakety i lyudi*, p. 274; Ishlinskiy, ed., *Akademik S. P. Korolev*, pp. 326–27, 342–44, 348, 414; Sergey Khrushchev, *Nikita Khrushchev: krizisy i rakety: uzglyad iznutri: tom 2* (Moscow: Novosti, 1994), p. 410. Note that Khrushchev incorrectly implies that the absorption of the plant occurred in 1962.

ejection seat weighing 800 kilograms placed at an angle to the horizontal; it contained a spacesuit ventilation system, a catapult system, pyrotechnical devices, and parachute systems. The porthole directly forward of the pilot carried an optical device named *Vzor* ("view"), which would allow manual control over attitude. An instrument panel was located above the Vzor device, while there was a *Topaz* TV camera below it to provide internal views of the capsule during flight. The control panel had instrumentation for indicating air pressure, temperature, humidity, and composition, as well as pressure in the attitude control propellant tanks. Controls on the panel would also allow the pilot to carry out manual operation of the retrofire engine. A small partially visible rotating globe named *Globus* on the upper section of the instrument panel showed the pilot the spacecraft's location over the surface of Earth. The pilot's control stick, a food container, the air regeneration system, an electrical clock, a second Topaz TV camera for side views, a radio receiver, a sanitary system, and electrical supply sources were located on the right-hand side of the large ejection seat. Telemetry units and storage space for secondary equipment were located underneath the seat.

Initially, Korolev had pressured Chief Designer Ivan I. Kartukov at OKB-81 in Moscow, the leading designer of solid-propellant rocket accelerators for Soviet tactical missiles, to design a full-scale launch escape system with a tower similar to Mercury's. Kartukov's design, however, proved to be too heavy, and despite continuing pressure from Korolev, Kartukov refused to lighten his tower system, fearful that a less robust system would put the lives of pilots in danger. Korolev's engineers instead proposed using an ejection seat, which would serve as a means of escape in case of an emergency during launch up to the first forty seconds. In the event that the launch parameters deviated from accepted levels, a command from ground controllers could blow the hatch on the descent apparatus and eject the pilot in his seat out of the capsule. Although unable to produce a workable launch escape system, OKB-81 did participate in designing the complex hatch system for the ejection seat.

For internal atmosphere, Soviet biomedicine specialists selected a cabin pressure equivalent to 755–775 millimeters of mercury (mm Hg), or about one atmosphere, and a 79/21 nitrogen-oxygen composition (essentially the same as Earth's surface). This was in contrast to early U.S. designs, which had a cabin pressure of 258 mm Hg, about one-third of an atmosphere, and a pure oxygen environment. For Soviet engineers, the choice was driven by concerns for simplicity and shorter development time. While the oxygen-nitrogen system had the advantage of significantly lowering the danger from internal fires, unlike the American system, the pilot would, however, be exposed to the possibility of suffering from decompression in case the crewmember had to switch life support from the spacecraft to his or her suit. For oxygen replenishment, the Soviets chose a "chemical bed" system based on alkali metal superoxides, which would release oxygen as it absorbed carbon dioxide. A cooling and dessication unit consisting of a heat exchanger would ensure the required temperature and humidity in the cabin. Much of the technology for life support systems had come directly from the vertical flights of dogs into the upper atmosphere via modifications of the R-2 and R-5 missiles.

Communications with the spacecraft would be maintained by several systems. These included the *Signal* ("signal") system on 19.995 megahertz for the transmission of simple telemetry. The carrier was on-off keyed, with the key rate equal to the pilot's pulse rate and the off duration being proportional to the crew member's chest width for respiratory measurements. The system also multiplexed parameters for the retrofire burn. A second system named Tral-P1 would provide supplementary radio-telemetry capacity. For two-way voice communications between the spaceship and the ground, the lone pilot would use the *Zarya* ("dawn") system on VHF and UHF. Ground controllers also wanted to have a relatively constant video feed during the mission; this was the job of the Tral-T system, which would transmit images from the two Topaz TV cameras aboard the ship. For the landing stages of the mission, there were the *Peleng* ("bearing") system comprising a shortwave beacon for position determination during and after reentry and the *Raduga* ("rainbow") system for radio communications. Finally, there was the *Rubin* ("ruby") system for trajectory measurement during the flight.

The pressurized instrument section was composed of two cone-shaped compartments with their blunt ends facing each other. Its primary role was to carry instrumentation for ensuring piloted orbital flight. Made of an aluminum alloy, the main element of the module was a large engine for the retrorocket burn. Designated the Braking Engine Unit No. 1 (TDU-1), it had a vacuum thrust of 1.614 tons and was fed by 280 kilograms of an amine-based fuel and nitrous oxide. Maximum burn time would be forty-five seconds. Internally, the module contained the following systems: instrumentation for guidance, control, and orientation; units for "command-logic control"; an electrical supply system; apparatus for radio communications; telemetry instrumentation; and a programmed logic clock. The exterior contained tanks for a nitrogen-based attitude control system that used a dual system with eight nozzles each with a thrust of one and a half kilograms each. Additional systems on the outside included a solar sensor, a radiative thermal regulation system using blinds, and several small spheres housing oxygen for use in cases of emergency by the pilot. Eleven antennae protruded from various locations on the instrument section. Of these, three were for the Signal system, four were for the Zarya system, two were for telemetry, and two were for "radio-link" commands. The entire section was not designed for recovery and was to burn up in the atmosphere following separation from the descent apparatus.[76]

The TDU-1 would operate once during the mission. Prior to nominal reentry, the capsule would orient automatically by means of a solar sensor to align it to correct attitude. A traditional ballistic reentry would follow without any further attitude control. OKB-1 engineers designed the sphere in such a way that the center of gravity of the capsule was behind and below the pilot, thus ensuring the module would be in correct orientation to eject the crewmember in the seat at the correct angle. After reentry, at an altitude of approximately seven kilometers, bolts securing the pilot's hatch would sever explosively, blowing the cover away from the descending spacecraft. Just two seconds later, the crewmember and the couch would eject together with the aid of two powerful solid-propellant rockets, descending together to about four kilometers altitude, at which point the pilot would separate and land by parachute at a calculated impact velocity of five meters per second.

Both the Soviets and the Americans, while driven by many of the same considerations in building the first piloted orbital spacecraft, deviated philosophically in one important area. Soviet engineers designed Object K with the goal that an entire mission, from launch to landing, could be carried out without the pilot touching a single control inside the ship. While there was provision for a pilot to manually orient the vehicle and fire the retrorocket in case of an emergency, Soviet designers never considered the pilot on board anything more than a passenger. Although partly motivated by concerns about psychological stability of the pilot in outer space, this was primarily because it was not an aviation firm that was in the driver's seat, but rather OKB-1, which had only designed strategic ballistic missiles and a few high-altitude

76. V. P. Glushko, ed., *Kosmonavtika entsiklopediya* (Moscow: Sovetskaya entsiklopediya, 1985), pp. 65–66; K. P. Feoktistov, "The Development of Soviet Piloted Space Ships (Until the Early 70s)" (English title), in B. V. Raushenbakh, ed., *Issledovaniya po istorii i teorii razvitiya aviatsionnoy i raketno-kosmicheskoy nauki i tekhniki* (Moscow: Nauka, 1981), pp. 94–122; G. V. Petrovich, ed., *The Soviet Encyclopedia of Space Flight* (Moscow: Mir Publishers, 1969), p. 223; Mozzhorin, *et al.*, eds., *Nachalo kosmicheskoy ery*, pp. 272, 287; Ponomarev, "2 June—75 Years From the Birth"; Lardier, *L'Astronautique Soviétique*, pp. 122–23; R. F. Gibbons and P. S. Clark, "The Evolution of the Vostok and Voskhod Programmes," *Journal of the British Interplanetary Society* 38 (1985): 3–10; Edward Clinton Ezell and Linda Neuman Ezell, *The Partnership: A History of the Apollo-Soyuz Test Project* (Washington, DC: NASA SP-4209, 1978), pp. 64–67; Golovanov, *Korolev*, p. 621.

cabins for dogs. While a number of aviation enterprises made very significant contributions to the Object K effort, they worked as subcontractors to OKB-1. Furthermore, the heavy emphasis on automation may have also been an issue of control and reliability—that is, OKB-1 engineers not only did not trust a pilot's capability to function adequately, but they also wanted to design the craft, fly it, and land it all on their own. Undue automation of piloted space vehicles was an issue that would dominate the design of all Soviet crewed space vehicles and, some would say, have a negative impact on the course of events in the 1960s.

Activity in the Object K program intensified progressively through 1959. In late 1959, the first "boilerplate" spacecraft was delivered from the OKB-1 plant. Feoktistov recalls that "it was an awesome sight" to finally witness the creation of his design team's handiwork.[77] At the same time, Korolev assigned two of his most longtime associates, Petr V. Flerov and Arvid V. Pallo, to direct a series of landing tests of the descent apparatus to test out the critical parachute system. Flerov was quite possibly one of Korolev's most longstanding friends; they had met in the late 1920s when Korolev was flying gliders as a young man. For these drop tests, General Designer Oleg K. Antonov personally consigned a specially modified "pot-bellied" An-12 aircraft to OKB-1. Flerov and Pallo took a number of *shariks* to a military airfield at Saryshagan near Lake Balkhash and dropped the capsules from altitudes of 8,000 to 10,500 meters. The primary landing parachute itself, designed by the Scientific-Research Institute of the Parachute Landing Service, headed by Chief Designer Fedor D. Tkachev, had a maximum volume of 330 cubic meters and allowed touchdown at ten meters per second.[78] Of the five drop tests, one was an outright failure when the hatch failed to open, thus preventing seat ejection. The fifth and last *sharik* carried dogs. Although the touchdown was successful, the capsule unexpectedly rolled down the hills out of sight of rescuers. After a long search, Flerov and Pallo finally found the dogs "worn out but in one piece."[79] It was on April 10, 1960, that Flerov and Pallo returned from Saryshagan and reported back to Korolev that the parachute system was ready for flight. It was a critical milestone, which allowed him to make concrete plans for the first automated space missions of Object K.

The spacesuit and ejection system were developed and designed by Chief Designer Alekseyev's Plant No. 918, which had gathered significant experience during the vertical dog flights. There was much debate about the utility of a pressurized spacesuit during an orbital mission, with OKB-1 engineers believing that the redundant safety systems in the spacecraft would eliminate the need for a separate suit. Alekseyev, supported by several prominent biomedicine specialists, believed exactly the opposite. Despite the fact that inclusion of a suit would add more mass to the spacecraft, Korolev ultimately agreed to their demands and in mid-1960 decided to include a suit. Alekseyev's engineers eventually designed a suit, the SK-1 *Sokol* ("falcon"), which was completely autonomous from the spacecraft's air regeneration system. In case of depressurization, the suit could provide about four hours of backup support for a pilot. Of the eleven-and-a-half-kilogram mass of the suit, the helmet alone had a mass of just over three and a half kilograms. Tests of the new spacesuit and the ejection seat, both designed and built under Alekseyev, were carried out in July–September 1960 during eight drops from an Il-28 aircraft. One of the participants was famous Soviet parachutist Petr I. Dolgov, who was ejected at an altitude of 7,000 meters from the ejection seat.[80]

77. Ishlinskiy, ed., *Akademik S. P. Korolev*, p. 509.

78. Glushko, ed., *Kosmonavtika entsiklopediya*, p. 66. The designer at the institute in charge of parachute development was N. A. Lobanov.

79. Golovanov, *Korolev*, p. 605.

80. Lardier, *L'Astronautique Soviétique*, p. 122; V. Svergun and V. Ageyev, "The Road to 'Vostok'" (English title), *Aviatiya i kosmonavtika* no. 2 (March–April 1994): 42–43. Dolgov, a pilot at the famous M. M. Gromov Flight-Testing Institute, died in an unfortunate accident on November 1, 1962, during a parachute drop from 24,500 meters as part of the Volga program. See Yaroslav Golovanov, "Cosmonaut No. 1: Slander" (English title), *Izvestiya*, April 3, 1986, p. 6.

The life support system for the spacecraft was developed by OKB-124, headed by Chief Designer Grigoriy I. Voronin. At least fifteen full-scale tests of the system were conducted from 1960 to 1961 of durations between one and fifteen days, confirming the basic design selection of the system.[81] Once again, the experience with the dog flights proved to be critical in terms of meeting the given timeframe.

Korolev had originally envisioned the use of a powerful solid-propellant rocket engine for the retrorocket burn. An initial contract for the job had been assigned to NII-125, where another of his old prewar associates, Yuriy A. Pobedonostsev, was appointed to develop the engine. The contract stipulated a delivery by the first quarter of 1960. There was, however, much uncertainty with this effort, no doubt related to the poor state of advanced Soviet solid-propellant rocketry at the time. As insurance, Korolev's deputies Tikhonravov and Bushuyev recommended a parallel liquid-propellant effort.[82] The obvious choice for designing such an engine would have been Glushko's organization, but he was evidently not interested. As was often the precedent in such cases, Korolev turned to one of his most trusted associates, Chief Designer Aleksey Isayev of OKB-2. Clearly as talented and resourceful as Glushko, Isayev, however, lacked the former's unfettered ambition. A quiet man with an overwhelming drive for work, Isayev had stood in Glushko's shadow through the 1950s, although some of Isayev's original design schemes had been appropriated by Glushko for preliminary designs of the R-7 ICBM engines. Isayev's crowning achievement in the 1950s had been the development of an engine for the Soviet Union's first air defense missile, the V-300, for which in 1956 he received the Hero of Socialist Labor decoration, the USSR's highest civilian award.

Chief Designer Aleksey Isayev was responsible for the design of the majority of rocket engines for spacecraft in the Soviet space program. His first big contract in the space field was the design of the Object K (or Vostok) reentry firing engine, the TDU-1. His organization, OKB-2, also designed many other engines for air defense and long-range ballistic missiles. (files of Peter Gorin)

Isayev's design bureau had nominally been part of the old NII-88 but was separated into an independent organization, the new OKB-2, on January 16, 1959.[83] Just one month later, when Korolev entrusted Isayev with the retrorocket engine for Object K, Isayev was said to have come back to his design bureau and calmly announced to his senior staff: "[Korolev] has proposed that we quickly carry out one small but very important work: returning a human from space to the Earth."[84] Through the ensuing months, Korolev met with Isayev several times, asking him detailed questions on the development program for the TDU-1, but he never once recommended changes, thus implicitly entrusting enormous faith in Isayev's abilities. Within just

81. Lardier, *L'Astronautique Soviétique*, p. 122.

82. V. K. Kupriyanov and V. V. Chernyshev, *I vechernyy start . . .: rasskaz o glavnom konstruktorye raketnykh dvigateley Alekseye Mikhaylovichye Isayevye* (Moscow: Moskovskiy rabochiy, 1988), pp. 123–24.

83. *Ibid.*, p. 219. The independent OKB-2 was created by the merger of the old NII-88 OKB-2 and NII-88 OKB-3. The former had been headed by A. M. Isayev and the latter by D. D. Sevruk.

84. *Ibid.*, p. 125. The lead designer of the TDU-1 at OKB-2 was N. G. Skorobogatov.

seven months of receiving the task, Isayev's OKB-2 had begun ground test firings of the TDU-1 engine. The tests began on the evening of September 27, 1959, under the direction of Isayev's Deputy Vladimir G. Yefremov, culminating in a major failure on the fifth test because of a valve design error. After new valves were installed, the next ten tests were without mishaps, removing any doubts as to the design of the engine. On April 25, 1960, Isayev reported back to Korolev that the engine for the first piloted orbital spaceship was ready. It was less than a month prior to the launch of the first automated version of Object K.[85] The solid-propellant engine was never built.

The Object K program was the first large-scale project that opened the door to cooperation outside the design bureaus of the original members of the Council of Chief Designers. In fact, with the exception of Korolev's OKB-1, none of them had a major role in the design of the spacecraft. When Pilyugin's department at NII-885 refused to take on the job, Korolev contracted a team at NII-1 to develop the *Chayka* ("seagull") attitude control system for the vehicle. This team was headed by a forty-three-year-old vibrations specialist named Boris V. Raushenbakh, who had been conducting research since 1955 on the "controlled motion of space apparatus."[86] By 1959, Raushenbakh's small team had created the first Soviet attitude control system for the Ye-2A lunar probe, one of which, Luna 3, became the first spacecraft to take pictures of the far side of the Moon. Raushenbakh, a man of many talents, had led a remarkably interesting life and was one of the many in the space program who had known Korolev during his apprenticeship days at NII-3 in the 1930s. He was also one of those who had been sent off to the GULag. In March 1942, he had been arrested by the secret police simply for possessing a German surname. Having survived time at a labor camp where as many as ten prisoners were dying per day, he later worked for a few years at Bolkhovitinov's famous design bureau before returning to Moscow as a "free" man in 1948. Given his increased involvement with Korolev's projects, Raushenbakh's resourceful team was transferred wholesale from NII-1 to Korolev's OKB-1 on January 6, 1960.[87]

Attitude control was one of the most important elements of the Object K spacecraft, not the least because of the necessity to orient the vehicle in the correct direction to fire the main deorbit engine. Discussions on Object K's orientation system began in early 1959. Originally, Tikhonravov's team decided to simply use the Luna 3 system, which used the Moon as a point of reference to posit the vehicle in the correct attitude. This plan fell through when it became clear that the much brighter Sun would interfere with the light from the Moon. There were also potential complications caused by the different phases of the Moon as visible from Earth. By April–May 1959, OKB-1 finally issued a report selecting solar orientation as the chosen mode for Object K. When the system operated, it would posit the spacecraft such that the axis of the main retrorocket's nozzle would be toward the Sun—that is, the thrust would be directly in the direction away from the Sun. The biggest advantage of using the Sun was that optical sensors would not mistake the Sun for any other celestial body. For a nominal reentry, the Sun would have to be "ahead" of the spacecraft, in the sunrise phase, before its passage across the local zenith. There were also two other systems of orientation on the spacecraft: an automatic system, which responded to Earth's

85. Golovanov, *Korolev*, p. 614. In total, the TDU-1 engine underwent eighteen stripped-down firings, followed by sixteen full-scale ground firings.

86. V. P. Legostayev, "18 January—75 Years From the Birth of Soviet Scholar and Designer B. V. Raushenbakh (1915)" (English title), *Iz istorii aviatsii i kosmonavtiki* 64 (1990): 4–7.

87. *Ibid.*; Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p. 633; Golovanov, *Korolev*, pp. 572–74. While Raushenbakh's department was responsible for overall design, the actual Grif sensors for the attitude control system were manufactured by the Central Design Bureau No. 598 (TsKB-598).

infrared radiation and used a complex of sophisticated gyroscopic devices, and a manual system, which duplicated the solar system. For the latter, the pilot would use the Vzor optical device and observe the Earth moving below the center of the instrument. This would allow the pilot to control horizontal direction or yaw. Using a circular mirror, the pilot could also control pitch and roll.[88]

Given precedent, the radio and telemetry systems for the spacecraft would have been developed by Ryazanskiy at NII-885, but his existing workload necessitated bringing in several other organizations. NII-695, under Chief Designer Yuriy S. Bykov, designed the Signal, Peleng, Zarya, and Raduga telemetry-communications systems, while the Experimental Design Bureau of the Moscow Power Institute, under Chief Designer Aleksey F. Bogomolov, developed the Rubin trajectory measurement system and the Tral-P1 telemetry system.[89]

The original council members continued to provide systems for the launch vehicle: Glushko's OKB-456 provided engines; NII-885 of Ryazanskiy and Pilyugin designed the control systems; Barmin's GSKB SpetsMash modified the launch complex; and Kuznetsov's NII-944 developed gyroscopes. The creation of a launcher proved to be a long and complicated process for the Council of Chief Designers. By early 1958, the two-stage R-7 in its "space" variants, the 8K71PS and the 8A91, could at best lift 1,400 kilograms into low-Earth orbit. To satisfy the immediate requirements of launching lunar probes and piloted spacecraft, an increase of threefold over that weight was required. Proposals for building a new third stage for the basic R-7 booster had been tabled in the summer of 1957, and soon after, designers began work on two unrelated upper stage engines, one at Korolev's OKB-1 and one at Glushko's OKB-456.[90] By the end of 1957, the Council of Chief Designers had finalized plans for two new modifications of the R-7, the 8K72 and the 8K73 boosters. Both were to use the basic 8K71 R-7 ICBM augmented up by different upper stages for launching lunar probes and reconnaissance satellites. The Soviet government ratified the effort on March 20, 1958.

At the center of the decision to develop two different launch vehicles was a minor rift between Chief Designers Korolev and Glushko—an altercation that in less than five years would evolve into the most acrimonious and infamous battle within the Soviet space program. When plans for the upper stage engines for the R-7 were originally drawn up in mid-1957, Korolev assumed that any new engine would be fueled by the same combination of propellants as the booster proper—that is, liquid oxygen (LOX) and kerosene. Glushko, however, had been impressed by a new synthetic propellant named unsymmetrical dimethyl hydrazine (UDMH) developed for the first time in the Soviet Union by the State Institute for Applied Chemistry. According to the institute's data, the new component promised higher energy characteristics than the traditional LOX-kerosene combination. In a clear indication of his interests, in 1958,

88. B. V. Rauschenbach, "From the Development History of the Vostok Spacecraft," in J. D. Hunley, ed., *History of Rocketry and Astronautics, Vol. 20* (San Diego, CA: American Astronautical Society, 1997), pp. 156–57.

89. Mozzhorin, *et al.*, eds., *Nachalo kosmicheskoy ery*, pp. 272, 287; Ponomarev, "2 June—75 Years From the Birth"; Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p. 108. Others involved in the design of instruments for Object K included: NII-88 (the Mir-2 autonomous data recording device); TsKB-598 (the Vzor optical device and the Grif photo-electric sensors for the solar attitude control system); the M. M. Gromov Flight-Research Institute (the cockpit control panel); NII-137 (the explosive device for automated variants); NII-648 (the MRV-2M "radio-link" command systems); the All-Union Scientific-Research Institute for Power Sources (the power sources); NII-380 (the Topaz TV cameras); the Committee for State Security (KGB) and the Krasnogorsk Mechanical Plant (jointly the movie cameras for photography of Earth); and the State Scientific-Research Institute of Aviation and Space Medicine, the Biofizpribor Special Design Technology Bureau, the Scientific-Research Institute of Nuclear Physics of Moscow State University, and the Institute of Biomedical Physiology of the USSR Academy of Medical Sciences (jointly medicine, radiation dosimetric instrumentation, and food serving systems).

90. Vasiliy P. Mishin, ". . . He Said, "Here We Go!" English title), *Aviatsiya i kosmonavtika* no. 4 (April 1991): 13–14; Varfolomeyev, "Soviet Rocketry that Conquered Space: Part 3."

Glushko began the development of four new engines using UDMH, three in combination with nitrogen-derived oxidizers and the fourth in combination with LOX. It was the latter engine, the RD-109 with a vacuum thrust of just under ten and a half tons, which he intended to offer for use on the 8K73 lunar rocket. Korolev was not happy with this decision. His primary concern was time, and he strongly believed that Glushko would be unable to design, develop, and test the first Soviet rocket engine for work in vacuum with a completely new propellant combination by the deadline, which was late 1958. Despite entreaties to retain the LOX-kerosene combination, Glushko pursued work on the RD-109 engine. In this case, Korolev proved to be right. The tests of the engine were not finished in 1958, nor were they in 1959. Then the Council of Chief Designers formally abandoned any plans to develop the 8K73 lunar launch vehicle.[91]

Luckily for Korolev, there had been a second option, a small thrust engine (just over five tons) designated the RD-0105, developed in his own design bureau. Engineers under Mikhail V. Melnikov at the OKB-1 had already created the small steering thrusters for the R-7 first-stage engines, whose performance characteristics could be scaled to match those needed for an upper stage. Korolev, still needing a turbopump to complete the engine, was saved by the help of a new entrant to the space program. In 1957, he had been impressed by a report on the creation of a new restartable LOX-kerosene rocket engine developed in Voronezh at an aviation design organization, the OKB-154, headed by Chief Designer Semyon A. Kosberg.[92] The fifty-four-year-old Kosberg had little interest in space or rocketry in general, content in his place in the aviation sector, but he was eventually swayed by Korolev's persuasive arguments to collaborate with him on a new rocket engine capable of firing in vacuum. Thus, Korolev and Kosberg signed a memorandum of understanding at Kaliningrad on February 10, 1958, which called for the delivery of the new RD-0105 engine in time for the first lunar probe launch attempts.[93] The cooperation with an "outsider" was a slap in Glushko's face, but it worked in Korolev's favor. Combining a turbopump from Kosberg's organization with thrusters from Melnikov's group, the two design bureaus produced the RD-0105 engine in just nine months, ready for flight by August 1958. It was the first Soviet liquid-propellant rocket engine designed for use in vacuum.

The 8K72 rocket was fired nine times between September 1958 and April 1960 for the automated lunar probe program. Six of these launches were failures. The three successes were outstanding: the first probe to fly into solar orbit, the first human-made object to impact on another heavenly body, and the first probe to take pictures of the far side of the Moon. Calculations, however, proved that the lifting capacity of the 8K72, approximately four and a half tons into low-Earth orbit, would be just short of what was required for the piloted spaceship. Beginning in January 1959, Aleksandr S. Kasho, a senior engineer at OKB-1, thus led a team to modify the launcher to increase lifting capacity by 200 extra kilograms. A new upper stage engine was required. The original upper stage engine for the 8K72 had been a cooperative venture, but this time, Kosberg took the lone responsibility to improve the performance

91. Igor Afanasyev, "Absolutely Secret: N-1" (English title), *Krylya rodiny* no. 9 (September 1993): 13–16; T. Varfolomeyev, "Readers' Letters: On Rocket Engines from the KB of S. A. Kosberg, and Carriers on Which They Were Installed" (English title), *Novosti kosmonavtiki* 26 (December 18–31, 1993): 46–48; Varfolomeyev, "Soviet Rocketry that Conquered Space: Part 3"; "S. P. Korolev's Letter to the Deputy Chairman of the SSSR Council of Ministers L. V. Smirnov" (English title), *Nauka i zhizn* no. 4 (April 1994): 79–80. The other three engines developed by Glushko using UDMH were the RD-216, the RD-218, and the RD-219. The RD-109 was also known as the GDU-10, or article 8D79.

92. The particular engine was the RD-0102 for the Yak-27V aircraft. This was the first Soviet restartable liquid-propellant rocket engine running on LOX and kerosene. See Vladimir Rachuk, "Best Rocket Engines From Voronezh," *Aerospace Journal* no. 6 (November–December 1996): 30–33.

93. Golovanov, *Korolev*, pp. 559–60; Biryukov, "Materials from the Biographical Chronicles," p. 240; V. N. Ivanenko, "On the Life and Activities of S. A. Kosberg (on His 80th Birthday)" (English title), *Iz istorii aviatsii i kosmonavtiki* 49 (1984): 3–10.

characteristics of the engine, beginning work in September 1959. In the new version, the RD-0109 with a vacuum thrust of just over five and a half tons replaced the RD-0105 with a thrust of just over five tons.[94] To denote the difference from the 8K72 booster, a "k" was added to indicate use in the Object K program, thus becoming the 8K72K booster. This marginally modified launch vehicle had shorter burn times for all its stages, but compensated with the increased thrust of all engines, including the core. The total length with a new payload fairing for the piloted spaceship was more than thirty-eight meters, about five meters longer than the versions that launched the lunar spacecraft.

The piloted portion of the Object K program was one of three post-Sputnik space projects to emerge in the Soviet Union. Along with the military reconnaissance satellite effort and the lunar probe program, it allowed the USSR to gain a foothold in the cosmos. The United States also engaged in similar efforts, but by the end of the 1950s, the American civilian space program had a singular organizational platform, NASA, and a long-range vision that was far more integrative than any in the Soviet space program. The chief designers, led by Korolev, endeavored to keep pace with the institutional changes in the United States, with a flurry of letters and memos directed to the Soviet leadership. By 1960, change would come on the Soviet side, but with mixed results.

94. Varfolomeyev, "Soviet Rocketry that Conquered Space: Part 3." It is possible that there was a competitor variant to Kosberg's new RD-0109 engine.

CHAPTER SIX
ORGANIZING FOR THE SPACE PROGRAM

The piloted portion of Object K was afforded a modicum of priority by the Soviet defense industry in 1959 and 1960, but the lion's share of funding in the sector was still focused on the development of strategic offensive systems, primarily long-range ballistic missiles. The Soviet space program, as distinct from the Soviet missile program, was still in its infancy, and it was a difficult transition, which was unknown or misunderstood in the West. A top-secret CIA-sponsored intelligence report in August 1959 noted that:

> *There is no direct evidence on the priority assigned to the Soviet space program. From the launchings of the Sputniks, from statements by Soviet scientists and high government officials and from the fact that hardware was diverted from the high priority missile program, we believe the inference can be drawn that the Soviet space exploration program has been assigned a very high priority.*[1]

In 1959, there was, in fact, no official macro-level policy or priority on the Soviet space program. The defense management enterprises and the Central Committee Defense Industries Department, which had overseen ballistic missile development, were simply unprepared to make the transition from one to the other.

Pleas for Order

Engineering and scientific leaders such as Korolev, Keldysh, and Tikhonravov were seriously concerned about the lack of a coordinated policy on the Soviet space program. The launch of Sputnik in October 1957 prompted a flurry of discussions on the topic at the designer level, which eventually led these men to send a number of important letters and documents to the Soviet leadership. These appeals were formulated in two thematic directions—one aimed at establishing a management and industrial infrastructure to exclusively support a space program and the second aimed at establishing specific short- and long-range goals of such a program.

The first salvo on the organization theme came less than two months after the launch of Layka into space. In a letter titled "On the Establishment of New Powerful Industry for the Investigation of Cosmic Space," dated December 30, 1957, Korolev and Keldysh addressed both topics. Following the writings of Tsiolkovskiy very closely, the two listed the primary goals

1. U.S. Central Intelligence Agency, "Soviet Capabilities in Guided Missiles and Space Vehicles," National Intelligence Estimate 11-5-58, Washington, DC, August 19, 1958, as declassified February 15, 1995, by the CIA Historical Review Program, p. 27.

of a well-organized Soviet space program. These would be the development of oriented artificial satellites, the use of solar energy as a power source, the creation of satellites for photographing Earth's surface, the creation of space stations for extended use and the return of data from space, research on "a number of questions on orbiting the Moon," and "human flight across interplanetary space."[2] To facilitate these goals, the authors called for the establishment of new scientific-research institutes and design bureaus. As with many other letters of the time, it seems that the Soviet leadership did not respond favorably to the appeal. The first official governmental decree on the space program, on March 20, 1958, merely approved the automated lunar probe effort, without addressing any of the larger questions listed by Korolev and Keldysh.[3]

During the summer of 1958, Korolev and Tikhonravov prepared a more detailed appraisal of the goals of the Soviet space program.[4] This landmark document, also faithful to the Tsiolkovskiy vision, laid out the basis for much of the Soviet space effort during the 1960s, albeit with many delayed timeframes than originally proposed by its authors. Thematically, the letter was divided into four parts:

- Investigations using the R-7 and its three-stage modifications such as the 8K72
- Creation of new, more powerful launch vehicles
- Investigations using these new launch vehicles
- Basic scientific-research work for the development of interplanetary technology and search for newer achievements "in the road to the mastery of cosmic space."

The authors listed investigations using the R-7 and its three-stage modifications as:

- Creation of artificial satellites capable of:
    a. Photography of Earth with recoverable film cassettes (1958–60)
    b. Unlimited lifetimes and periods of operation (1961–65)
    c. Existing in highly elliptical orbits around Earth (1961–65)
- Creation of apparatus for investigations of the Moon, including:
    a. Ten to twenty-kilogram stations on the surface of the Moon (1958–61)
    b. Artificial lunar satellites for photography (1959–61)
    c. Satellites in elliptical orbit for circling the Moon and returning film cassettes back to Earth (1960–64)
- Creation of a piloted satellite with ballistic reentry in three stages (1958–60):
    a. Development of heat protection for the return apparatus
    b. Creation of test apparatus for suborbital testing
    c. Creation of a piloted satellite for operation up to ten days

2. This document has been reproduced in full as M. V. Keldysh and S. P. Korolev, "On the Establishment of New Powerful Industry for the Investigation of Cosmic Space" (English title), in V. S. Avduyevskiy and T. M. Eneyev, eds., *M. V. Keldysh: izbrannyye trudy: raketnaya tekhnika i kosmonavtika* (Moscow: Nauka, 1988), p. 241. The letter was said to have been sent to "directive organs," usually a euphemism for the USSR Council of Ministers and the Central Committee.

3. Yu. P. Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya "Energiya" imeni S. P. Koroleva* (Korolev: RKK Energiya, named after S. P. Korolev, 1996), p. 93.

4. This document has been reproduced in full in two difference Soviet sources. See S. Korolev and M. Tikhonravov, "Preliminary Considerations on the Prospects of the Mastery of Cosmic Space" (English title), in B. V. Raushenbakh, ed., *Materialy po istorii kosmicheskogo korabl "vostok"* (Moscow: Nauka, 1991), pp. 16–19. See also S. P. Korolev and M. K. Tikhonravov, "On the Prospects of Work on the Mastery of Cosmic Space" (English title), in M. V. Keldysh, ed., *Tvorcheskoye naslediye Akademika Sergeya Pavlovicha Koroleva: izbrannyye trudy i dokumenty* (Moscow: Nauka, 1980), pp. 405–08.

- Creation of a piloted satellite with return via gliding (1959–65)
- Research on opportunities for the exploration of Mars and Venus via automatic apparatus and returning to Earth's vicinity with photographic and other data (1959–61)
- Research on processes for bringing together two vehicles in orbit that would require preliminary scientific work (1962–66)

The second portion of the document addressed the development of new launch vehicles:

- Creation of a space booster with a payload of fifteen to twenty tons (ending in 1963 or 1964)
- Creation of ion and other engines for interplanetary flight and human flight to the Moon and nearest planets

In the third portion, Korolev and Tikhonravov addressed the use of the new launch vehicles enunciated above:

- Creation of a piloted satellite with one or two humans to develop conditions for extended piloted spaceflight and the establishment of satellite stations (1961–65)
- Creation of a spaceship using ion engines for piloted flight to the Moon and back to a station in Earth orbit (1961–65)
- Creation of automated spacecraft for investigations of Mars and Venus and their return to near-Earth space for research on the surface of the planets and testing long-distance radio communications (1963–66)
- Creation of "artificial settlements" in space with the following goals:
  a. Creation of near-Earth stations, work starting in 1962, for:
     (i) Studying prolonged weightlessness, artificial gravity, and effects on plants, humans, and animals
     (ii) Studying the effects of radiation on vegetation and living organisms
  b. Creation of near-Earth stations, work starting in 1962, for:
     (i) Assembly of "interorbital" vehicles
     (ii) Creation of a space transportation system with Earth
     (iii) Reception of "interorbital" vehicles

After accomplishing these objectives, the following two goals would be within reach:

- Flight of humans to Mars and Venus
- Flight of humans to the Moon and their return to Earth
- Construction of a continuously operating "station colony" on the Moon, on which preliminary work would begin in 1960

The fourth and final part of the document discussed exploratory work that scientists would carry out as part of research and development programs:

- Research on rockets propelled by chemical and nuclear propellants for lofting large payloads to Earth orbit and to the Earth-orbital stations (1959–60)
- Research on ion, plasma, and similar types of engines for use on interorbital transport spacecraft (1959–60)
- Research on rendezvous in orbit leading to experimental verification (1958–61)
- Research on technologies for orbital assembly of a space station in Earth orbit, using rocket stages as components of the station (1959–63)

- Research on closed-cycle life support systems and spacesuits (1960–65)
- Development of energy sources for Earth orbital stations and interorbital apparatus (1958–62)
- Research on radio communications over very long distances (1959–65)

In conclusion, Korolev and Tikhonravov added that the listed dates were preliminary and that there would undoubtedly be many other fields of scientific-research work that would accompany the enumerated goals.

Several important thematic directions emerge from closer inspection of the document. By early 1959, some of the more immediate goals were already part of ongoing programs, in particular the automated lunar probes, the human spaceflight effort, and the military photoreconnaissance program. As far as long-term objectives, Korolev and Tikhonravov clearly give a nod to Tsiolkovskiy's early theories, with a continued emphasis on Earth-orbital space stations acting as places of research as well as bases for the further exploration of space. In addition, in their vision of the future, piloted exploration of the planets is one of the central objectives. This particular theme would in fact dominate much of the long-term research at OKB-1 during the following five years as the Soviet space program was in the midst of expansion. It is noteworthy that for Korolev and Tikhonravov, who had been raised on a diet of Tsiolkovskiy and Tsander, a piloted lunar landing was not deemed important enough for short-term consideration but instead was consigned to second place *after* interplanetary missions.

Unlike many of Korolev's earlier letters to the government, there is nothing in the text in the document to suggest that the attainment of these goals would reap political dividends in a "space race" with the United States. The clear and well-thought out goals listed in the document were really the first concrete attempt by the designer faction to move ahead from isolated Sputniks and lunar probes to a rational and broad plan for the exploration of space.

Korolev and Tikhonravov signed the document and sent it to the Military-Industrial Commission on July 5, 1958. It is now clear that a number of key proposals in the report were discussed at a very high level over the course of the following year, although the specifics still remain classified. Superficial details are available of a meeting in Moscow in February 1959 to discuss nuclear propulsion for spacecraft, but the nature of debates on the larger issue of the conception and policy of a civilian and military Soviet space program still remain shrouded in mystery.[5] What is apparent is that by the summer of 1959, one year after having sent their letter, there had not been a single decree on long-term goals from the Communist Party and government. This lack of response may have been a catalyst for more action on Korolev's part.

In the early summer of 1959, he put his resources together with Academician Keldysh, certainly much more influential and powerful than Tikhonravov, and fired off three documents in succession to the Soviet leadership. The first one, dated May 20, 1959, was a letter proposing the addition to current plans of a project for designing an "apparatus for returning from orbit and landing on the Earth."[6] This was clearly in relation to the Object K program and referred primarily to the reconnaissance satellite with a few lines added on the piloted variant. Two days later, a decree was passed on both projects.

The second letter, sent only a week later on May 27, was much more comprehensive and exclusively addressed the immediacy of establishing formal institutional mechanisms for the new Soviet space program. The central proposition of the ten-point plan was to separate the ballistic missile effort from the space program:

5. The description of the 1959 meeting in Moscow can be found in A. P. Romanov and V. S. Gubarev, *Konstruktory* (Moscow: Izdatelstvo politicheskoy literatury, 1989), pp. 308–10.

6. Yu. V. Biryukov, "Materials from the Biographical Chronicles of Sergey Pavlovich Korolev" (English title), in B. V. Raushenbakh, ed., *Iz istorii sovetskoy kosmonavtiki* (Moscow: Nauka, 1983), p. 241. The letter remains classified.

> *At the present time, operations associated with the exploration of space are being conducted mainly by the same organizations that have been developing long-range missiles. This is undoubtedly favorable for progress of these operations. But now, since the objectives and scope of space exploration earmarked for the nearest future have become extremely broad, it is the right time to invite new forces and new organizations.*[7]

Specifically, the authors called for the creation of a Central Scientific-Research Institute for Interplanetary Research—a place where all future Soviet spacecraft would be designed. While Korolev's OKB-1 would retain the job of designing and building more powerful space launch boosters, the institute would be separate from the missile industry and focus exclusively on creating Earth-orbital satellites, piloted spaceships, and automated and piloted interplanetary vehicles. Korolev and Keldysh proposed that the new organization should be created on the basis of an existing aviation design bureau whose prior commitments would be transferred elsewhere.[8] In the authors' vision:

> *This organization could become in the future a scientific center of space exploration on an international scale, bearing in mind that the Soviet Union has achieved the first useful results in the field. These results could be fruitfully developed and extended in the future in cooperation with the socialist countries.*[9]

As part of a general restructuring of the missile and space sector, Korolev and Keldysh also called for the creation of seven other specialized institutes for (1) guidance and control systems, (2) long-range space communications, (3) radio-telemetry systems, (4) the development of power supply systems (including nuclear sources), (5) the design and manufacture of scientific instruments for spacecraft, (6) biomedical research on humans and animals in space, and (7) planetary sciences.

In ending their appeal, Korolev and Keldysh called for the creation of a management and directing mechanism, the Interdepartmental Scientific-Technical Council of the USSR Academy of Sciences headed by Keldysh, which would oversee the entire Soviet space effort. The closest thing to such an entity in the United States was perhaps the extinct National Advisory Committee for Aeronautics, which had recently been succeeded and replaced by the National Aeronautics and Space Administration (NASA). Putting Keldysh's name as head of this proposed council would clearly work in Korolev's favor, given Keldysh's clout with the upper echelons and his favorable support for Korolev's plans. There is nothing in the document to suggest, however, that Korolev would relinquish his influence over any new institution dedicated to the development of space vehicles. This document from May 1959 can in fact be seen from one perspective as a means to consolidate Korolev's hold on the emerging space program. At the same time, it was also a plea for order and rational thinking—that is, to separate the missile and space industries and establish a number of institutions exclusively dedicated to space exploration.

Korolev sent a third letter, still classified, to the government on July 13 of the same year "on considerations for the organization of work" on the space program.[10] The requests were important elements in the pursuit of establishing a separate space program in the Soviet Union,

7. The complete document, with disguised designations, has been reproduced as S. P. Korolev and M. V. Keldysh, "On the Development of Scientific-Research and Experimental-Design Work on the Mastery of Cosmic Space" (English title), in Keldysh, ed., *Tvorcheskoye naslediye Akademika*, pp. 409–12.

8. The aviation design bureau is unnamed in the document, but it was possibly OKB-256, headed by Chief Designer P.V. Tsybin, who was an old associate of Korolev's from the late 1920s.

9. Korolev and Keldysh, "On the Development of Scientific-Research," p. 411.

10. Biryukov, "Materials from the Biographical Chronicles," p. 241.

and Korolev took advantage of his peaking influence and power to propose some bold ideas, such as international cooperation, certainly a sensitive subject given the space sector's origins in the ICBM program. He had the support of sympathetic figures in powerful positions, such as Khrushchev, Ustinov, Rudnev, and Keldysh, patronage strong enough to quickly facilitate the launch of the first Sputniks, a series of launches in an automated lunar exploration program, and to gain the approval for a piloted satellite project. But this small window of opportunity did not last long. By 1959, a variety of factors had begun to erode the power of the Council of Chief Designers to force through a vigorous space program. The immediate response from the leadership to the series of letters in 1957 through 1959 remains unclear. When the government did take action on the space program, it ultimately fell far short of what Korolev and his associates desired.

On December 10, 1959, the Central Committee and the USSR Council of Ministers issued the very first decree, number 1386-618, on a macro-level policy on the Soviet space program.[11] Titled "On the Development of Research Into Cosmic Space," the decree was a modest first step in elaborating goals for the Soviet space program, albeit one with short-term goals. Evidently, only one of the May 1959 recommendations for institutional change proposed by Korolev and Keldysh was addressed in the decree: the document sanctioned the formation of the Interdepartmental Scientific-Technical Council for Space Research, an advisory body under the aegis of the Academy of Sciences to oversee thematic and project proposals on long-range space goals. Council members included senior officials from the design bureaus, institutes, scientific community, and military. Two designers from OKB-1—Korolev and his "space" deputy, Bushuyev—officially became members of the council's Presidium on January 13, 1960.[12]

The formation of the council, however, did not satisfy Korolev and Keldysh's call for an industry-wide reorganization. Perhaps armaments people Ustinov and Rudnev found Korolev's proposal to establish an organization in the *aviation* industry an anathema to their allegiances. The authors of the decree did, however, mention some of the points in the earlier July 1958 letter of Tikhonravov and Korolev. The government granted approval for the development of a four-stage variant of the R-7 for a series of automated missions to Mars, Venus, and the Moon, for piloted missions in the Object K spacecraft, and for exploratory studies on a heavy-lift booster.[13] The Ministry of Defense, the primary funding conduit for the design bureau system, was simply not interested in supporting a flourishing and long-range space program as outlined in the numerous letters to the leadership in the preceding two years. This clash over defense priorities was a theme that would grow much larger throughout the 1960s, but in 1959, it was the first indication to Korolev and the remaining members of the Council of Chief Designers that an indigenous space program was going to have a painful birth. What little funding was extracted would have to be continually justified on the basis of defensive needs, certainly a tricky proposition when one considers Korolev's ultimate goals of large space stations in Earth orbit servicing piloted interplanetary missions to Mars and Venus.

Within the defense sector, during the latter part of the decade, there had been a noticeable shift in Soviet strategy shifting from dependence on long-range aviation to ICBMs. This major

11. Raushenbakh, ed., *Materialy po istorii*, p. 210; G. Vetrov, "The Difficult Fate of the N1 Rocket" (English title), *Nauka i zhizn* no. 4 (April 1994): 78–80; K. Lantratov, "Russia to Mars!" (English title), *Novosti kosmonavtiki* 20 (September 23–October 6, 1996): 53–72; Georgiy Stepanovich Vetrov, "Development of Heavy Launch Vehicles in the USSR," presented at the 10th International Symposium on the History of Astronautics and Aeronautics, Moscow State University, Moscow, Russia, June 20–27, 1995.

12. B. V. Raushenbakh, ed., *S. P. Korolev i ego delo: svet i teni v istorii kosmonavtiki: izbrannyye trudy i dokumenty* (Moscow: Nauka, 1998), pp. 675–76.

13. Vetrov, "Development of Heavy Launch Vehicles"; B. Ye. Chertok, *Rakety i lyudi: Fili Podlipki Tyuratam* (Moscow: Mashinostroyeniye, 1996), p. 425; Lantratov, "Russia to Mars!."

shift, along with the advent of the R-7 ICBM and less powerful missiles from the Yangel design bureau, such as the R-12 and the R-14, necessitated a revamping of the existing command structure in the procurement and operation of ballistic missiles. Throughout the 1950s, the Ministry of Defense's control and influence over ballistic missile development was effected through its subordinate Chief Artillery Directorate in a department called the Directorate of the Commander of Reactive Armaments. Early proposals from various factions in the summer of 1959 addressed the anachronistic nature of having new generations of ballistic missiles in the control of artillery forces. Khrushchev elected not to follow the example set by the United States, where the U.S. Air Force controlled strategic missiles. Despite some significant opposition from within the Ministry of Defense, Khrushchev pushed through the formation of a new branch of the Soviet armed forces, the Missile Forces of Strategic Designation (RVSN), more commonly known as the Strategic Missile Forces. Signed into existence by a decree of the Communist Party and government on December 17, 1959, the Strategic Missile Forces inherited the control of all ballistic missiles in the Soviet Union.[14]

Marshal Nedelin, the fifty-seven-year-old military technocrat behind the successful missile buildup in the Soviet Union in the 1950s, was appointed the first Commander in Chief of the new service. Nedelin knew Korolev well. The latter regarded Nedelin very highly and was reported to have said that when it came to issues of quality control and delivery dates, Nedelin was a very principled and demanding customer.[15] All activities carried out by the Chief Artillery Directorate that were related to long-range missiles were transferred to the Strategic Missile Forces; by default, the Directorate of the Commander of Reactive Armaments also became a portion of the new Forces, thus bringing with it all its duties on operating space launch vehicles. Confusingly renamed the Chief Directorate of Reactive Armaments (GURVO), this growing department continued to handle all launch, tracking, and communications operations for Soviet spacecraft under the tutelage of its chief, Lt. General Anatoliy I. Semenov.[16]

Marshal Mitrofan Nedelin was the first commander of the Soviet Strategic Missile Forces. Through a long and distinguished career in the 1940s and 1950s, he had served in various capacities overseeing the procurement of the first long-range ballistic missiles into the Soviet armed forces. (files of Peter Gorin)

This unprecedented degree of control over the Soviet space program consolidated the position of the Ministry of Defense to affect space policy for decades to come. In the late 1950s and early 1960s, liaison with the space program was handled neither by Nedelin nor Semenov, but by two other officers in GURVO, both of whom would go on to play significant roles in policy formation and execution in the space program: Lt. General Aleksandr G. Mrykin and

14. The decrees on the formation of the RVSN are reproduced in I. D. Sergeyev, ed., *Khronika osnovnykh sobytiy istorii raketnykh voysk strategicheskogo naznacheniya* (Moscow: TsIPK, 1994), pp. 236–39. The Central Committee decree number was "Protocol No. 254," while the Council of Ministers decree number was 1384-615.

15. V. Tolubko, *Nedelin* (Moscow: Molodaya gvardiya, 1979), p. 176.

16. Sergeyev, ed., *Khronika osnovnykh sobytiy istorii*, p. 8; Yu. A. Mozzhorin *et al.*, eds., *Dorogi v kosmos: II* (Moscow: MAI, 1992), p. 117.

Maj. General Kerim A. Kerimov. The former was the First Deputy Commander of GURVO, while the latter was the head of GURVO's new Third Directorate, specially tasked to handle "client" operations related to launch vehicles, satellites, ground equipment, and command and control on behalf of the Strategic Missile Forces. This Third Directorate, created in September 1960, was the seed of the Russian Military Space Forces of the 1990s.[17] Mrykin, a man with a larger-than-life personality rivaling Korolev himself, was legendary for his hard-headed nature and inflammatory short temper—traits that terrified most officials who came into contact with him. He did, however, have close relationships with the members of the Council of Chief Designers, facilitating a relatively efficient mode of communication between the space and missile sectors.

What was remarkable about all four men—Nedelin, Semenov, Mrykin, and Kerimov—was that all had been involved in missile programs as artillery officers, starting with visits to Germany in 1945 during the famous operation to study the A-4. The stranglehold of these artillery veterans on the new Soviet space program was not transitory: artillery troops, later subsumed by the Strategic Missile Forces, launched every single Soviet missile and spacecraft, beginning with the first A-4 launches from Kapustin Yar in 1947 up to the end of 1991, when the USSR as an entity was formally dissolved. The ubiquity of the artillery men in the space program was not limited to the Strategic Missile Forces. In 1959, artillery veterans of the 1945 German visit headed several important institutes in the industry, including NII-4 and NII-88.[18] In the following years, they would also find positions in design bureaus and bureaucratic positions in ministries. This powerful lobby would pose a significant threat to Korolev's ideas of a grand space program.

Korolev in Trouble?

The conflict over defense spending was not the only threat to Korolev's plans. In 1958 and 1959, four different issues emerged in the discourse over the development of ballistic missiles, all of which involved Korolev. Although seemingly peripheral to the Soviet space program, the effects of these four factors were far reaching; together, they had an unprecedented cumulative effect on the course of human space exploration programs in the Soviet Union in the 1960s.

The primary competitor to Korolev's OKB-1 in the field of ballistic missiles was OKB-586 headed by Chief Designer Mikhail K. Yangel. In 1954, Yangel had inherited Korolev's efforts with storable propellants, turning a modest program into a full-fledged competitor to Korolev's own design bureau. Yangel's organization had rapidly developed the R-12 medium-range ballistic missile, which was formally declared operational on March 4, 1959.[19] Encouraged by the success of Yangel's first missile, the development of a second more powerful missile, the R-14, with a range of 4,500 kilometers, had been approved by the USSR Council of Ministers on July 2, 1958.[20] Both the R-12 and R-14 missiles used high-boiling storable components as

17. Yu. P. Maksimov, ed., *Raketnyye voyska strategicheskogo naznacheniya: voyenno-istoricheskiy trud* (Moscow: RVSN, 1992), p. 49. For a mention of the Third Directorate, see B. Ye. Chertok, *Rakety i lyudi: goryachiye dni kholodnoy voyny* (Moscow: Mashinostroyeniye, 1997), p. 154. See also V. V. Favorskiy and I. V. Meshcheryakov, eds., *Voyenno-kosmicheskiye sily (voyenno-istoricheskiy trud): kniga I: kosmonavtika i vooruzhennyye sily* (Moscow: Sankt-Peterburgskoy tipografii no. 1 VO Nauka, 1997), pp. 56–57. According to Kerimov, he headed "the directorate which handled the monitoring of the planning and manufacturing of space rockets and craft for flight in the automatic operation versions." See K. Issakov, "Breakthrough into the Unknown: Today is Cosmonautics Day" (English title), *Bakinskiy rabochiy*, April 12, 1988, p. 3.

18. By late 1959, NII-4 was headed by Maj. General A. I. Sokolov and NII-88 by Maj. General G. A. Tyulin, both artillery officers.

19. Sergeyev, ed., *Khronika osnovnykh sobytiy istorii*, p. 36. The first silo launch of the R-12 took place on August 31, 1959.

20. V. Pappo-Korystin, V. Platonov, and V. Pashchenko, *Dneprovskiy raketno-kosmicheskiy tsentr* (Dnepropetrovsk: PO YuMZ/KBYu, 1994), p. 61.

propellants, which had two major advantages over low-temperature cryogenic propellants such as liquid oxygen (LOX): they allowed missiles to be kept battle ready for long periods, and they permitted very quick preparations for launch. They also had some drawbacks; they were usually extremely toxic, dangerous to handle, and corrosive to traditional propellant tanks. Historically, Korolev had always preferred cryogenic combinations, primarily because they offered high specific impulse ratings and lifting efficiency, important factors for space launch boosters but much less relevant for military missiles. The first Soviet ICBM, the R-7, used a LOX-kerosene combination, a relatively efficient combination for space launch operations, but a poor choice for battle-ready missiles. In the best case, the R-7s took eight to ten hours to fuel and too much effort to keep ready. If a launch were canceled, a missile had to be emptied at the pad within ten hours, a dangerous situation for a rocket designed to be the first element of a Soviet strategic missile force. As early as August 1956, the all-powerful Council of Defense of the Politburo had adopted a decision to accelerate work on ICBMs that did *not* use cryogenic propellants.[21]

Concerns about propellants were compounded by the steep costs of building launch pads for the bulky R-7. Originally, the Ministry of Defense had proposed approximately fifty pads all over the Soviet Union, but the astronomical costs of such an endeavor quickly squelched any such plans. The R-7 itself went through a troublesome test regime. The first series began on May 15, 1957, and ended on July 10, 1958. Engineers incorporated improvements to the ICBM over the following year and conducted a second series of eight launches between December 24, 1958, and December 27, 1959.[22] Problems with the R-7 were slowly eliminated during these intensive tests, and the missile was officially declared an operational element of the Soviet armed forces on January 20, 1960. An improved version, the R-7A, with a lighter warhead and an all-inertial guidance system, became the standard version once it was declared operational in September of the same year.[23] Although it was the world's first ICBM, the R-7A was at best a very poor element of the strategic rocket forces. The costs of building launch pads, their visibility to overflying reconnaissance, the inordinate time to fuel the rocket, the use of cryogenic propellants, and the poor accuracy of the warhead were all reasons that prompted Khrushchev to drastically reduce plans to deploy the missile in large numbers. In the end, a total of four launch complexes were built, three of which were used as sites by strategic forces and the fourth for space launches.[24]

21. The Council of Defense meeting may have been in response to a proposal from Chief Designer V. P. Glushko on a new ICBM, the R-8, which would have used storable propellants instead of cryogenic pairings. Korolev was informed of the Council of Defense decision on October 16, 1956, by Marshall M. I. Nedelin. See Raushenbakh, ed., *S. P. Korolev i ego delo*, pp. 251, 664–65.

22. Yu. A. Mozzhorin *et al.*, eds., *Nachalo kosmicheskoy ery: vospominaniya veteranov raketno-kosmicheskoy tekhniki i kosmonavtiki: vypusk vtoroy* (Moscow: RNITsKD, 1994), p. 59. Of the eight launches during the second series, seven were successful. The first series-produced R-7 was launched on February 17, 1959, while the first fully fueled, operational R-7 was launched to the Pacific Ocean on October 22, 1959. See Biryukov, "Materials from the Biographical Chronicles," pp. 241–42.

23. Sergeyev, ed., *Khronika osnovnykh sobytiy istorii*, p. 37. The R-7A had a range of 12,000 kilometers. Authorization for the project was granted on July 2, 1958, the first launch was on December 23, 1959, and flight testing ended on July 7, 1960. See Maksimov, ed., *Raketnyye voyska strategicheskogo*, p. 47.

24. Of the four pads, two were at the Scientific-Research Testing Range No. 5 (NIIP-5) at Tyura-Tam at sites 1 and 31. Site 1 was for the early space launches. Construction of the latter was completed in late 1958, along with its own integration building at site 32. The remaining two pads were at a new site in northern Russia near the town of Mirnyy at NIIP-53. Officially called the Object Angara, the base was the site of two pads, the first of which was finished in 1959 (site 16) and the second of which was finished in 1961 (site 41). It was these two latter pads that constituted the main battle-ready R-7 pads. The first pad went on an alert status on December 15, 1959, a month prior to the order declaring the R-7 operational. See also Ye. B. Volkov, ed., *Mezhkontinentalnyye ballisticheskiye rakety SSSR (RF) i SShA* (Moscow: RVSN, 1996), p. 269.

The disappointment with the R-7 was a major blow to the limitless faith Khrushchev had placed on Korolev's abilities. It was the first of a number of factors that began to adversely affect the "open line" between the two, that had facilitated many of Korolev's early space plans. In May 1958, Khrushchev, at one of his many meetings with Korolev, had asked the chief designer about the possibility of finding a more efficient solution to the ICBM problem than the R-7. To Khrushchev's queries on storable propellants such as nitrogen tetroxide, Korolev merely replied that it would be impossible to build an ICBM using such components, invoking the difficulty of developing powerful engines using toxic components. Korolev's total insistence at using cryogenic propellants, no doubt stemming from his visions of space exploration, prompted him to propose a replacement for the R-7, a new missile called the R-9. Cryogenic propellants would still fuel the missile. Korolev promised to use high-speed pumps for quick preparations during battle, as well as super-cooled LOX to extend the time it could be maintained at flight readiness. In addition, the R-9 would only be half the mass of the cumbersome R-7. Khrushchev promised to think about the proposal but in general remained unsatisfied with Korolev. The Soviet leader confided in his son that Korolev appeared to be keener on achieving space records than work on defense.[25]

The day after the meeting with Korolev, Khrushchev called in Glushko. The latter was a strong believer in storable propellants, and Glushko had had problems with LOX for years. Beginning with his early work in 1930s, Glushko had consistently preferred storable propellants such as nitric acid, shying away from the vibration and combustion problems associated with more sophisticated cryogenic designs. Glushko told Khrushchev that an ICBM on storable propellants was possible to build and recommended Yangel as a potential contractor. He was particularly interested in a new combination of red fuming nitric acid and unsymmetrical dimethyl hydrazine, which would offer a potentially easy fix to the missile storage problems. Khrushchev took advantage of the advice and met with Yangel soon after. The latter, while conceding that using toxic propellants would be difficult, was completely amenable to the idea. The notion of creating an ICBM at OKB-586 had been one of Yangel's ultimate goals for some time. After the Council of Defense recommendation on building noncryogenic ICBMs, on December 17, 1956, the USSR Council of Ministers approved exploratory work on a new missile at Yangel's organization, called the R-16. Yangel received encouragement on his work when an independent panel approved the paper design of the missile in January 1958.[26]

Khrushchev's meeting with Yangel may have been pivotal in shifting "patronage" away from Korolev. Perhaps to be completely sure of any future action, he met with Korolev once again to hear his views on the propellant debate. Once again, Korolev repeated his views on what he considered "the devil's venom." Hearing that Khrushchev was considering giving Yangel the contract for a new ICBM with storable propellants, Korolev made an uncharacteristic offer. As Khrushchev later remembered, Korolev told him:

25. Sergey Khrushchev, *Nikita Khrushchev: krizisy i rakety: vzglyad iznutri: tom 1* (Moscow: Novosti, 1994), pp. 382–83. Note that there are contradictory reports that Korolev first proposed the R-9 ICBM idea to Khrushchev in September 1958. See Chertok, *Rakety i lyudi: goryachiye dni kholodnoy voyny*, p. 23.

26. Pappo-Korystin, Platonov, and Pashchenko, *Dneprovskiy raketno-kosmicheskiy tsentr*, p. 61. The Council of Ministers decree in December 1956 approved the development of the R-16 ICBM for a first launch by June 1961. Work on the theoretical aspects did not, however, begin until November 1957, after the initial series of R-7 launches. The draft plan for the missile was approved in January 1958, but clearly, there was some unexplainable delay in the program.

> *I propose that you give this acid-fueled [that is, storable propellant] missile project to me. Besides that, I will* also *make an oxygen-fueled missile that will be capable of nearly instantaneous action. This missile will not require any supplementary equipment, like those guidance stations that have to be located every five hundred kilometers along the missile's flight path.*[27]

Khrushchev was resistant to such an idea, but Korolev was insistent. Finally, the Soviet leader cut Korolev off sharply, reminding him that he was dealing with the Chairman of the USSR Council of Ministers. The meeting apparently had a profound effect on the close relationship between Korolev and Khrushchev, as their previous rapport gradually began to cool. Korolev had to increasingly resort to normal institutional mechanisms to get his big space plans approved instead of taking them personally to Khrushchev. Thus he became more constrained by the wishes of Ustinov, Brezhnev, Nedelin, and others whose primary concern was defense, not space. Perhaps the only asset Korolev had on his side at the time was Khrushchev's interest in using the space program as a means to advance his prestige and power. This, of course, put Korolev in the difficult position of having to justify his projects not only in terms of their military utility, but also their appeal to the imagination of the people of the world.

There was a more damaging secondary effect. Some have speculated that when Korolev heard that Glushko had decided to cooperate with Yangel on the new R-16 ICBM, it was a move that Korolev could neither forgive nor forget. While Glushko had developed engines for Yangel's modest R-12 and R-14 missiles, his support and involvement in a new competitive *ICBM* project of Yangel was apparently unforgivable. Glushko, having been in Korolev's shadow for decades, had been longing for independence and a way out from the series of troubling LOX engines he had been developing in difficulty for Korolev. It has been suggested that it was also perhaps jealousy that drove Glushko to switch sides to Yangel—jealousy at Korolev's unprecedented rise in twenty years, from GULag prisoner to preeminent space designer. It was Glushko, after all, who had written to Tsiolkovskiy as a young child and who had dreamed of space exploration when Korolev was still flying gliders at the local pilots club back in the Ukraine.[28]

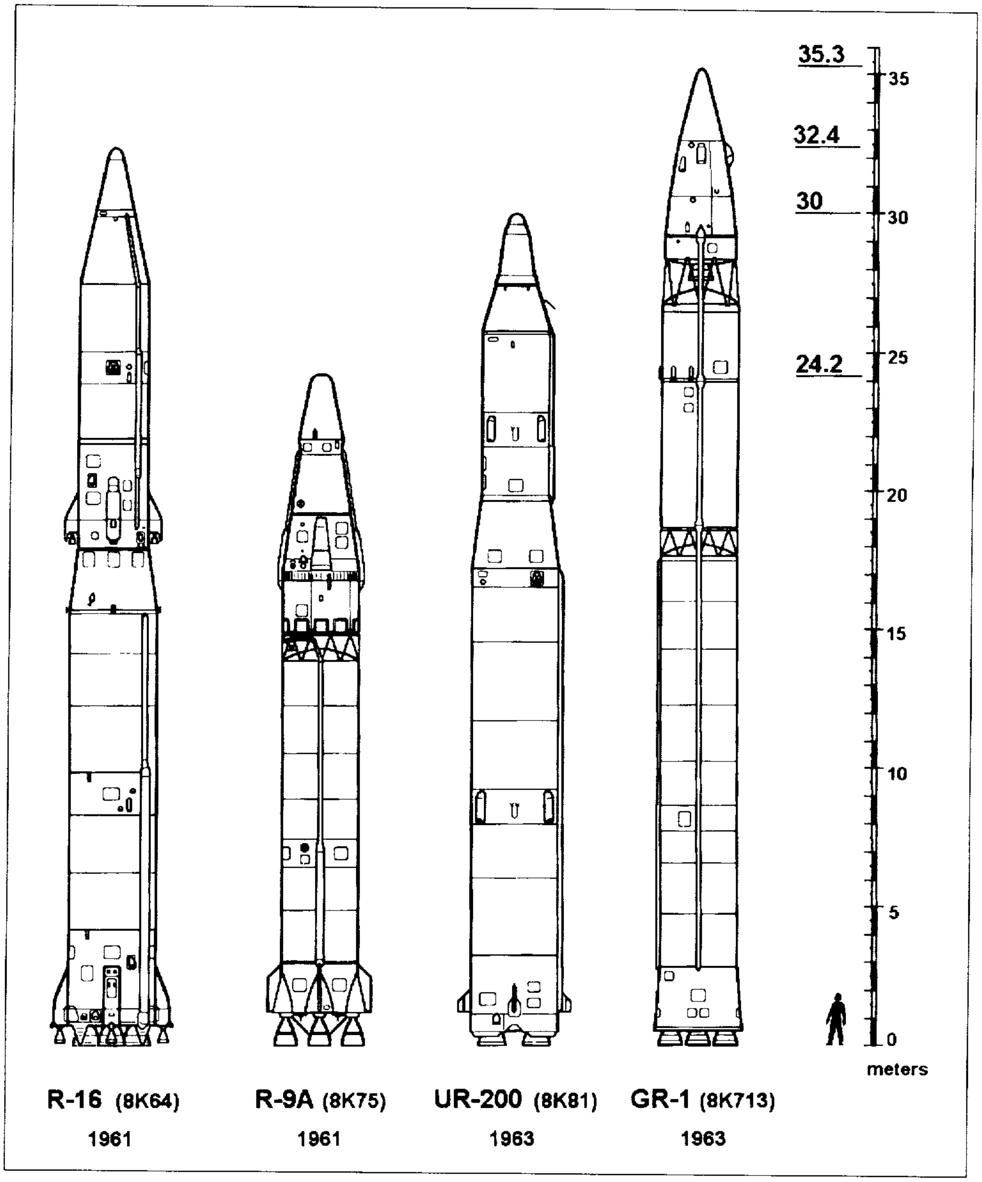
The break between Korolev and Glushko was neither sudden nor permanent, at least not during the R-9 discussions. The first cracks had begun to appear as early as 1954, during design work for the R-7, when Glushko had refused to design verniers for the missile. The acrimony broke into open conflict in the summer of 1957 during the series of R-7 launches, when there had been much finger-pointing about the causes of the failures. In one of his letters to his wife back in Moscow during that summer, Korolev provided a window into the relationship between the two giants of the Soviet space program:

> *[Glushko] arrived today and to everyone's amazement (mine included!), using the dirtiest language and the crudest phrases, began telling us all that our work was utterly worthless—and this, just half an hour after he arrived. This created a terrible impression on everyone. . . . His tirade, unfortunately, could not be considered criticism, certainly not friendly criticism, but simply mindless malice. I answered him calmly (you can imagine the nerves that that cost me!) and only criticized him for his intemperance and arrogance. [Pilyugin] demanded that we sit down and analyze his behavior, but is that really possible? If a person behaves in such a way but considers his own opinions "more intelligent than anyone else's in all issues without exception," then the only way that you can fight is with facts which refute all that he had blurted out.*[29]

27. Nikita S. Khrushchev, *Khrushchev Remembers: The Glasnost Tapes* (Boston: Little & Brown, 1990), p. 185. Author's emphasis.

28. For this line of interpretation, see Khrushchev, *Nikita Khrushchev*, pp. 382–83.

29. Yaroslav Golovanov, *Korolev: fakty i mify* (Moscow: Nauka, 1994), p. 708.



The evolution of long-range ballistic missile development in the Soviet Union in the post-Sputnik era. From the left are Yangel's R-16 (operational in 1961), Korolev's R-9A (1965), Chelomey's UR-200 (canceled), and Korolev's GR-1 (canceled). (copyright Peter Gorin)

With their unusually headstrong characters, their innate ambitions, and, perhaps most importantly, their differences over technical matters, it is not surprising that the two found themselves in serious conflict. The maturation of the missile and space programs finally broke whatever semblance of friendship they had developed over the years.

Yangel's R-16 ICBM project was officially approved by an official governmental decree on August 28, 1958. It would be a two-stage intercontinental missile with both stages using engines from Glushko's OKB-456, fueled by storable propellants.[30] The road to approving work on Korolev's R-9 was fraught with more difficulty. In April 1958, under severe pressure from Korolev, the six original members of the Council of Chief Designers, including Glushko, sent an official letter to the Military-Industrial Commission with a proposal to initiate the formal development of Korolev's missile.[31] Both Korolev and Glushko had motivations to cooperate on the new program—Korolev because Glushko essentially monopolized the development of high-thrust rocket engines in the Soviet Union, and Glushko because he was fearful of being excluded from a contract for a new ICBM project. By December of the same year, the two chief designers had agreed on the specifications for the two-stage missile.[32] Within weeks, Korolev was having second thoughts on Glushko's involvement. On March 7, 1959 he sent another letter to Ustinov and Rudnev proposing the development of *two* variants of the ICBM—one with Glushko's engines, called the R-9A, and one with nitric acid–kerosene engines designed by Isayev's OKB-2, called the R-9V. The latter option emerged for two reasons: it would be Korolev's stab at making a storable propellant rocket, and it would be insurance against Glushko's failure to develop a cryogenic engine.[33] The Soviet government declined to allocate resources for two versions of the rocket and, on May 13, 1959, issued an official decree approving R-9 development with only Glushko's engines.[34] The eighty-one-ton missile was to carry a two-ton warhead a full distance of 12,500 kilometers. Many of the performance characteristics of the R-9 were quite similar to the Martin Marietta Titan I ICBM, whose very existence was used by Korolev as justification for the R-9.

The program proved to be a Pandora's box of problems for Korolev. Put on the defensive by the military, Korolev had to continually defend his creation to a less than enthusiastic client, whose officials were quickly losing any interest in cryogenic ICBMs. OKB-1 First Deputy Chief Designer Mishin, who was the originator of the R-9 proposal, was instrumental in propping up Korolev's vehement opposition to storable propellants and enumerating the advantages of LOX. Mishin persistently supported LOX-based combinations and argued that given the resources, he could draw up technical plans to overcome the apparent deficiencies of LOX in the eyes of the military. He emerged with some remarkable technical solutions, including low-cost storage systems and high-speed pumps, which may have saved the R-9 program.[35]

Glushko, meanwhile, ran into severe problems with his chosen engines. The R-9 first stage required an engine with a thrust of about 140 tons at sea level. This high thrust level was, however, far in excess of any engine he had ever produced in his thirty years as an engine

30. Pappo-Korystin, Platonov, and Pashchenko, *Dneprovskiy raketno-kosmicheskiy tsentr*, p. 62. The engines were the RD-218 for the first stage and the RD-219 for the second stage. The propellants were unsymmetrical dimethyl hydrazine and red fuming nitric acid for both engines. Some sources state that government approval for the R-16 was granted on May 13, 1959—that is, in the same decree approving Korolev's R-9 missile. See, for example, Golovanov, *Korolev*, p 709.

31. This document, dated April 18, 1958, has been published in abridged form as "On Prospective Developments of Oxygen Missiles," in Raushenbakh, ed., *S. P. Korolev i ego delo*, pp. 249–51.

32. Glushko sent Korolev clarifications on performance ratings for his first-stage engines on December 9, 1958. Korolev sent a subsequent letter to the government and other chief designers on December 19. In it, he proposed a launch mass of seventy to seventy-five tons and a range of 12,000 kilometers for the mobile missile. See Raushenbakh, ed., *S. P. Korolev i ego delo*, p. 671. Note that Glushko had also proposed a variant of the R-9, known as the R-9B, using storable propellants (nitric acid–unsymmetrical dimethyl hydrazine), but Korolev apparently never took the idea very seriously.

33. Confusingly, Korolev also invited Yangel to participate in R-9V development. The R-9V would use four of OKB-2's engines of forty tons thrust each on the first stage. Yangel's OKB-586 would have responsibility for the general layout of the missile. See *ibid.*, pp. 595, 672.

34. I. Afanasyev, "The Mysterious 'Nine'" (English title), *Aviatsiya i kosmonavtika* no. 8 (August 1992): 34–35.

35. For a summary of Mishin's role in the R-9 LOX debate, see Chertok, *Rakety i lyudi: Fili Podlipki Tyuratam*, p. 217; Chertok, *Rakety i lyudi: goryachiye dni kholodnoy voyny*, pp. 27–28; James Harford, *Korolev: How One Man Masterminded the Soviet Drive to Beat America to the Moon* (New York: John Wiley & Sons, 1997), pp. 114–19.

designer. An attempt to build a similar single-chamber engine in the early 1950s had ended in complete failure. The new engine, the RD-111, also ran into serious problems. Like the R-7 engines, the new engine comprised four combustion chambers fed by the same turbopump. Unlike the earlier engines, however, the RD-111 had much higher chamber pressures (eighty versus sixty atmospheres), which, as it turned out, was the primary cause of high-frequency self-stimulated vibrations that tore the engines apart during ground tests.[36] Anticipating precisely such a situation, Korolev, with the approval of some key members in the government, had invited a new engine design organization to usurp Glushko's monopoly in the Soviet missile program: OKB-276, headed by forty-seven-year-old designer Nikolay Dmitriyevich Kuznetsov. Perhaps the most famous aviation engine designer of the era, Kuznetsov started his career in 1943 when he joined the Klimov Design Bureau as a Deputy Chief Designer, working on engines for Yakovlev and Petlyakov's fighter aircraft. On April 17, 1946, the Soviet aviation industry established a new design bureau at Plant No. 2 at Kuybyshev, to develop new turbojet engines for postwar airplanes. Three years later, Kuznetsov, then only thirty-eight years old, was appointed its Chief Designer. His organization went from strength to strength, making engines for some of the most famous Soviet airplanes of the 1950s, including the strategic Tu-95 bomber and the Tu-114 passenger aircraft.[37]

Unlike some other aviation chief designers, Kuznetsov was not the slightest bit interested in either the missile or the space industry. He had a well-established reputation as a designer of high-performance jet engines for Tupolev, Ilyushin, and Antonov, and he was not willing to jeopardize his standing by partaking in a high-risk endeavor in which he had no experience. But in the end, he was a victim of circumstance. By the late 1950s, the aviation sector as a whole was hit by hard times. As Khrushchev shifted his military strategy from aviation to missiles, numerous design enterprises found themselves without contracts to survive. In effect, the Soviet leader forced many of these organizations to make a radical shift in their design profiles. Kuznetsov was so resistant to shift his design bureau to the missile and space industry that he took the matter to Frol R. Kozlov, who was chairman of the Council of Ministers of the Russian Soviet Federated Socialist Republic. Kozlov and Kuznetsov enlisted the aid of Nikolay K. Kirichenko, possibly the most powerful man in the country after Khrushchev. However, the Soviet leader was not interested in Kuznetsov's arguments; he would have to shift to the rocketry industry, and that was it.[38]

Kuznetsov played right into Korolev's dilemma over the R-9 program. In November 1959, Korolev, alarmed by the delays in Glushko's engine development program, wrote to Secretary of the Central Committee Leonid Brezhnev, the nominal head of the Soviet space and missile program.[39] His request was unambiguous; first, he wanted Glushko ejected from the R-9

36. Chertok, *Rakety i lyudi: goryachiye dni kholodnoy voyny*, p. 33.

37. A. N. Ponomarev, *Sovetskiye aviatsionnyye kosntruktory* (Moscow: Voyennoye izdatelstvo, 1990), pp. 292–95. Kuznetsov was a Deputy Chief Designer at the V. Ya. Klimov Design Bureau (OKB-26) from 1943 to 1946 and a Chief Designer at the same organization from 1946 to 1949. He was appointed to his post as Plant No. 2 Chief Designer in 1949. See G. P. Svishchev, ed., *Aviatsiya entsiklopediya* (Moscow: Bolshaya Rossiyskaya entsiklopediya, 1994), p. 299. In June 1953, Plant No. 2 was renamed Plant No. 276, at which time the design bureau was named OKB-276.

38. Golovanov, *Korolev*, pp. 713–14. Korolev had been acquainted with Kuznetsov since about 1956–57, when the latter had begun exploratory work on rocket engines as part of the general redirection of work at the firm. See Igor Afanasyev, "N-1: Absolutely Secret" (English title), *Krylia rodiny* no. 9 (September 1993): 13–16. Kuznetsov's early work on rocket engines had been in cooperation with OKB-165 of Chief Designer A. M. Lyulka, another aviation engine enterprise, which had redirected its efforts to developing rocket engines for the ballistic missile and space programs.

39. This letter, dated November 25, 1959, has been reproduced in full as S. P. Korolev, "Letter to L. I. Brezhnev on Reorganization of Work on ZhRDs" (English title), in Raushenbakh, ed., *S. P. Korolev i ego delo*, pp. 284–85. By October 14, 1959, Korolev and Kuznetsov had finished a draft plan for the new variant of the R-9, designated the R-9M. The four NK-9 first-stage engines were from Kuznetsov's OKB-276, while second-stage engines would be from Isayev's OKB-2.

program, and second, he wanted to proceed using newcomer Kuznetsov's engines. Ustinov, the chairman of the Military-Industrial Commission, took a different view and supported Glushko's participation. Although Ustinov had for the most part been Korolev's supporter throughout the 1940s and 1950s, he was not, by any means, a blind ally of the latter. Ustinov's primary allegiance was to the military-industrial complex, not to any particular designer, and in 1959, Korolev's star in the missile industry was no longer rising. Under "strong pressure" from Glushko, Ustinov sided against Korolev; the latter would have to continue with Glushko's trouble-prone RD-111 engine. Although ground tests for Kuznetsov's engines continued for some time, this R-9 variant was never developed. Glushko, at least for the time being, maintained his monopoly over the design of high-thrust rocket engines in the Soviet Union.[40]

Nikolay Kuznetsov was the aviation designer based in Kuybyshev who joined forces with Sergey Korolev in 1958 to begin research on high-thrust cryogenic rocket engines for ICBMs. In later years, Kuznetsov would play a critical role in designing engines for the N1, the Soviet Moon rocket. (files of Peter Gorin)

The R-9/R-16 debacle in 1958 and 1959 brought four major issues to the forefront of the Soviet space program. The first was Khrushchev's loss of faith in Korolev as the best rocket builder in the Soviet Union; Yangel had taken that place. The second was Korolev and Mishin's full-fledged support of cryogenic propellants over storable propellants for both ICBMs and space launch vehicles. The third was the split between Glushko and Korolev over propellant selection. The fourth was the entrance of the Kuznetsov organization into the fray as a possible alternative to Glushko's monopoly in high-thrust rocket engine development. These four factors set the stage for the catastrophic dissension among the leading designers of the Soviet space program during the 1960s. In 1959, of course, the cumulative consequences of these factors could not be known. Korolev was at the peak of his influence. He had a strong support system within the Communist Party, the government, the military, and the Academy of Sciences. And he was building the first Soviet spaceship designed to carry humans into orbit. But as Korolev's monopoly in the missile business began to erode, his leading role in the piloted space program was also challenged in the late 1950s by three additional organizations led by prominent aeronautical engineers. All of these chief designers were "outsiders" from the aviation industry, and they entered the foray without a history in the armaments sector like Korolev. One of these men would compete fiercely with Korolev for the next decade.

40. Afanasyev, "The Mysterious 'Nine'"; Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, pp. 121–23; Harford, *Korolev*, p. 114. As early as January 18, 1960, State Committee for Defense Technology Chairman K. N. Rudnev sent a letter to Korolev (with a copy to D. F. Ustinov) ordering Korolev to proceed only with the Glushko variant of the R-9.

The Spaceplanes

Most histories of the early Soviet space program mention one human-in-space project from the late 1950s and early 1960s, the Vostok program, which paralleled NASA's Project Mercury. Declassifications in the early 1990s clearly show that Vostok was only one side of a much larger effort in human spaceflight. As in the United States, military piloted space proposals had also interested the Soviet government by the late 1950s. During this time, the aviation industry in the Soviet Union was facing its most severe challenge. A recent convert to the effectiveness of missiles, Khrushchev pushed through a number of reforms from 1957 to 1960, which effectively curtailed contracts for the majority of aviation design bureaus in the Soviet Union. Some organizations were even dissolved, and engineers were forced to look for work elsewhere. Having made the decision in 1946 not to engage in missile design, the leaders of the State Committee for Aviation Technology faced the consequences of their actions a decade later.[41] To sustain the well-being of their design bureaus, a number of chief designers from the aviation industry were forced to offer proposals related to missiles. Kuznetsov's OKB-276 and Kosberg's OKB-154, for example, joined with Korolev to work on his missiles and space launch vehicles. The Soviet Air Force, cognizant of the state of its reduced funding, also shifted its priorities to space issues at the time. A rare public showing of the Air Force's interest in such vehicles was illustrated in an article in its own daily newspaper, published soon after the launch of the first two Sputniks. The author, a V. Aleksandrov, described a "rocket-plane" capable of suborbital flights at speeds of 15,000 kilometers per hour and altitudes of 200 kilometers.[42] At the same time, a secret Air Force panel in late 1958 examined the primary thematic directions it should take during the following twenty-five years. Among other things, their report recommended two areas of further research:

- An early stage with aircraft flying at 6,000 to 7,000 kilometers per hour and altitudes of eighty to 100 kilometers for research into aerodynamic heating and flight dynamics at high speeds and altitudes
- A later stage with velocity and altitude increased to more than Mach 10 and 100 to 150 kilometers, respectively[43]

In its interest in spaceplanes, the Soviet Air Force also had help from the U.S. Air Force. The latter had been conducting studies on hypersonic vehicles for almost a decade, and a formal program, the Dyna-Soar project, was approved on October 10, 1957, less than a week after the launch of Sputnik. A three-step program was outlined, leading to the deployment of an orbital weapons system.[44] The progress in the Dyna-Soar program may have been the final catalyst for similar projects in the Soviet Union, the first of which was undertaken under fifty-two-year-old Pavel Vladimirovich Tsybin, an aeronautical engineer who had designed gliders in the late 1920s with Korolev. In the late 1940s, Tsybin had designed several high-speed "flying laboratories" that were powered by solid-propellant rocket engines. Based on this experience, on

41. For a summary of the aviation versus rocketry debate in the Soviet government in the late 1950s, see Khrushchev, *Nikita Khrushchev*, pp. 292–94.

42. V. Aleksandrov, "Rocket-Plane, the Aircraft of the Future" (English title), *Sovetskaya aviatsiya*, December 1, 1957. An English translation of the article can be found in *Soviet Writings on Earth Satellites and Space Travel* (Freeport, NY: Books for Libraries Press, 1958), pp. 196–99.

43. V. M. Petrakov, "Two Projects of V. M. Myasishchev," *Journal of the British Interplanetary Society* 47 (September 1994): 347–54.

44. For a detailed exposition on the events leading to the decision on the Dyna-Soar program, see Roy F. Houchin II, "Why the Air Force Proposed the Dyna-Soar X-20 Program," *Quest: The History of Spaceflight Magazine* 3 (Winter 1994): 5–12.

May 23, 1955, the Ministry of Aviation Industry established OKB-256 at Podberiozye (later Dubna), with Tsybin as its Chief Designer, to design and develop a supersonic ramjet-powered strategic bomber named RS. By 1956, this ambitious undertaking had split into two variants, one an air-launched bomber, named 2RS, and the other a reconnaissance variant, called 3RS. Construction and managerial delays eventually prompted Tsybin to focus exclusively on the supersonic reconnaissance aircraft, renamed RSR, which was comparable to the American SR-71A ("Blackbird"). The Soviet government formally approved the project on August 31, 1956. Within three years, test pilots were flying experimental models of the RSR.[45]

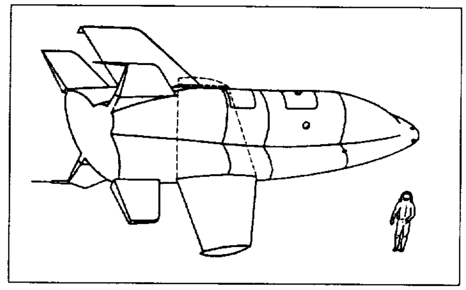
OKB-1 Chief Designer Korolev, still close to Tsybin, was aware of the latter's work and was particularly interested in the dynamics of the catapulted seat for the pilot, which Tsybin used on one of his "flying laboratories," the LL-1. At one of their meetings in 1958, Korolev asked Tsybin if he would be interested in conducting research on a reusable spacecraft that would return to Earth from space using lifting surfaces—that is, a spaceplane. Korolev specifically wanted something that could fit under the R-7's payload shroud. Tsybin, aware of the Air Force's recommendations and personally interested in the idea, agreed and established a group in his design bureau to study the problem.[46]

The predraft plan for this vehicle, the first true spaceplane in the Soviet space program, was signed by Tsybin on May 17, 1959, and resulted from at least a year's worth of research. The three-and-a-half-ton (at launch) spacecraft, called the Gliding Space Apparatus (PKA) in official documentation, was nine meters long and equipped with two large wings, which could be folded upwards during certain portions of the mission. The fuselage itself was three meters wide and protected by a shield composed of two layers of thermal insulation, one with an organic silicon compound and the second with ultra-fine fiber. The portions of the vehicle that were expected to be exposed to the greatest thermal stress—the forward portion of the shield and the leading edges of the horizontal control surfaces and rudders—were cooled by liquid lithium. Temperatures at these points were expected to reach as high as 1,200 degrees Centigrade, while other parts of the vehicle would be exposed to only 400 degrees. The two large wings were protected from heat stress by folding upward, thus entering a "shadow" region.

The main fuselage consisted of two pressurized compartments—a cabin for the single pilot and a compartment for instrumentation—both of which had additional thermal protection. The pilot's cabin had an ejection seat much like the LL-1 and Korolev's Object K spacecraft, a control panel, and additional support systems. The ejection seat had three different positions, depending on the phase of the mission: one for launch, one for work, and one for rest. The pilot would have viewing access to the exterior through two side-mounted large windows and a smaller one for astro-navigation purposes. As in the Object K spacecraft, in case of a launch failure at altitudes below 10 kilometers, the pilot could abandon the vehicle with the ejection seat. If a failure came later in the launch trajectory, the PKA would separate from the 8K72 booster, unfold its wings, and land. The instrument compartment contained the equipment and systems required for orbital flight and reentry.

45. Piotr Butowski, "Steps Towards 'Blackjack': Soviet supersonic intercontinental bombers before the Tu-160," *Air Enthusiast* 73 (January–February 1998): 36–49; Bill Gunston, *The Osprey Encyclopedia of Russian Aircraft: 1875–1995* (London: Osprey Aerospace, 1996), pp. 376–78; G. Amiryants, "Ivensen's 'Chayka'" (English title), *Aviatsiya i kosmonavtika* no. 4 (April 1990): 36–38. The RSR was eventually known as the R-020.

46. Mikhail Rebrov, "Recounted for the First Time: PKA, or Simply 'Lapotok'" (English title), *Krasnaya zvezda*, June 17, 1995, p. 4; Golovanov, *Korolev*, p. 765. On May 18, 1959, Korolev sent a letter to the State Committee for Defense Technology in which he formally proposed inviting OKB-256 to develop a "gliding apparatus." This letter has been reproduced as S. P. Korolev, "On Gliding Return from Orbit" (English title), in Raushenbakh, ed., *S. P. Korolev i ego delo*, pp. 271–72.



Pavel Tsybin's Gliding Space Apparatus (PKA) was the Soviet Union's first effort at designing a spaceplane. Its hinged wings were capable of attaining different angles for different phases of reentry. (copyright Igor Afanasyev)

Propulsion was provided through a bi-level system. A suspended propulsion system in the fairing and adjacent to the main fuselage shielding used two primary engines, with a thrust of 2.35 tons each, working on nitric acid and kerosene. One of these was the retrorocket, while the other was the "vernier," presumably for orbital corrections. The entire main propulsion system with a mass of about 780 kilograms would be discarded once retrofire had occurred at an altitude of ninety kilometers. A second system of propulsion was a set of three-kilogram thrust engines working on hydrogen peroxide for attitude control in orbit and for the descent.

The nominal mission length for the PKA was only twenty-four to twenty-seven hours, after which the spacecraft would de-orbit. Following reentry, it would use its uniquely shaped fuselage to provide lift. At an altitude of twenty kilometers and a velocity of 500 to 600 meters per second, the two wings would unfurl to their full span of seven and a half meters; control would be provided by the hydrogen peroxide thrusters throughout this phase. After a one-and-a-half-hour-long reentry, the 2.6-ton spacecraft would disembark on a runway at 180 to 200 kilometers per hour using bicycle-type ski landing gear, with the rear skis landing first.[47]

Tsybin's engineers built models of the spacecraft, which Korolev nicknamed *Lapotok* (a sandal made of bark) because it resembled the shape of a sandal, and subjected them to wind tunnel tests at the Central Aerohydrodynamics Institute (TsAGI) at Zhukovskiy, the premier Soviet aeronautics research institution. The development of special materials for the PKA was undertaken at the Moscow-based All-Union Institute of Aviation Materials. Tsybin was also able to enlist several key Soviet aeronautical engineers into contributing to the program, including aerodynamicist Sergey A. Khristianovich, thermodynamicist Vladimir A. Kirillin, and mechanics specialist Vladimir V. Struminskiy, all famous academicians in the country.[48] Despite the large amount of work, the program apparently never received the official sanction of the Soviet Party or government, and it may have been an effort pushed by the Air Force, then in search of a solution to difficult times. The Air Force never did see the PKA fly. By late 1959, Tsybin's engineers realized that the thermal protection problem was far more complex than had been anticipated. Tests in wind tunnels showed that the material of the special thermal shielding would have to be changed if the spacecraft was to endure thermal stress during reentry. Furthermore, the hinged sections of the wings were prone to retain heat within a "dead zone." These and other problems prompted the effort's termination.[49]

There may have been institutional problems, too. The downturn in the aviation industry led industrial leaders of the sector to close down a number of design bureaus; one of those was Tsybin's OKB-256. It is quite likely that poor research results in 1959 also prompted the chairman of the State Committee for Aviation Technology, Petr V. Dementyev, to suspend work on the RSR (later renamed the R-020) high-altitude reconnaissance plane, as military strategy was

47. Valentin Bobkov, "Space 'Sandal'" (English title), *Krylya rodiny* no. 11 (November 1991): 25; I. B. Afanasyev, "Unknown Spacecraft (From the History of the Soviet Space Program)" (English title), *Novoye v zhizni. Nauke, tekhnike: Seriya kosmonavtika, astronomiya* no. 12 (December 1991): 1–64; Rebrov, "Recounted for the First Time."

48. Golovanov, *Korolev*, p. 765. Khristianovich was the director of the Institute of Theoretical and Applied Mechanics of the Academy of Sciences, while Struminskiy was affiliated with TsAGI.

49. Afanasyev, "Unknown Spacecraft."

evolving more toward space-based reconnaissance. Thus the OKB-256's primary reason for existence also disappeared. On October 1, 1959, the enterprise was subordinated to another much more famous aviation design bureau, OKB-23 headed by Vladimir M. Myasishchev. By agreement with Korolev, the complete database on the PKA was handed over to a third firm, Artem I. Mikoyan's OKB-155, the builder of the famous MiG jet fighters. Tsybin himself was caught in the center of this maze of changes. He eventually found a place in 1961 at Korolev's design bureau as a deputy chief designer overseeing piloted space programs.[50]

The specialty of Myasishchev's OKB-23 was long-range bombers, but like other aviation design bureaus, it had begun to make overtures to the missile and space industry. One of its first forays into the long-range missile business was as part of the stiff competition with Semyon A. Lavochkin's OKB-301 to develop the first Soviet intercontinental cruise missile as an alternative to Korolev's R-7 ICBM. The two cruise missile projects, having officially begun in 1954, had progressed at different paces, with the Lavochkin model, known as the La-350 Burya, taking an early lead. By 1955, OKB-301 had built and tested an operational model of the AN-2Sh astro-navigation system for the missile aboard a Tu-16 bomber. Signals from the stellar sensors were transmitted to the plane's autopilot for more than four hours, enabling the aircraft to automatically correct deviations in its flight path to less than four kilometers accuracy. The following year, Lavochkin's engineers had finished construction of the first flight models of the two-stage cruise missile (at Plant No. 18 at Kuybyshev).[51]

Launch attempts of the Burya commenced on August 1, 1957, from the Air Force's test range at Vladimirovka in the Volga delta near Kapustin Yar, at exactly the same time when Korolev was testing his R-7 from Tyura-Tam. The initial series consisted of launches of only a live first stage and a ballast second cruise stage. The first three tests were complete failures; the missile was, in fact, completely destroyed on the second attempt on September 1. During a second phase of eight launch attempts beginning in March 1958, engineers studied the parameters of the boost stage prior to the separation of the dummy second stage. Only one flight was successful. A subsequent phase of four launch attempts proved to be much more encouraging. On one of these launches, on April 19, 1959, the Burya performed without problems on a thirty-three-minute jaunt into the skies over a distance of nearly 1,800 kilometers.[52]

Despite the relatively encouraging results, the La-350 Burya was a victim of its times. With the advent of the ICBM, this cruise missile was an anachronism. Because of its low flight altitude, eighteen to twenty-three kilometers, it was extremely vulnerable to defensive measures. It also took far too long, more than two hours, to reach its target. By comparison, ICBMs could do the same job in minutes. The Soviet government was also concerned that work on the Burya would divert resources from OKB-301's primary project, the long-range Dal anti-aircraft missile

50. The actual Plant No. 256, the location of one of the main design departments of OKB-256, was subordinated to the OKB-2-155 headed by Chief Designer A. Ya. Bereznyak, an organization with no connection to the ballistic missile or space industry. See Butowski, "Steps Towards 'Blackjack'"; Bobkov, "Space 'Sandal'"; Afanasyev, "Unknown Spacecraft"; Amiryants, "Ivensen's 'Chayka'"; Jacques Villain, ed., *Baïkonour: la porte des étoiles* (Paris: Armand Colin, 1994), p. 236; Rebrov, "Recounted for the First Time." As part of the research on the R-020, Tsybin had developed the NM-1 high-speed vehicle, which was flown thirty-two times starting in April 1959, albeit with poor results.

51. Boris V. Rauschenbach, "The 'Burya' Intercontinental Cruise Missile," presented at the 43rd Congress of the International Astronautical Federation, IAA-92-0187, Washington, DC, August 28–September 5, 1992; I. Afanasyev, "Without the Secret Stamp: Halt the Work, Destroy the Materials" (English title), *Aviatsiya i kosmonavtika* no. 6 (June 1993): 42–44.

52. V. Aslanov, "'Soviet Shuttle' of the 50s" (English title), *Apogey* 5 (June 1993): 1; Christian Lardier, "70 Years of Soviet Ramjets," presented at the 48th Congress of the International Astronautical Federation, IAA-97-IAA.2.3.03, Turin, Italy, October 6–10, 1997; Rauschenbach, "The 'Burya' Intercontinental Cruise Missile."

system for the city of Leningrad. On February 5, 1960, the Council of Ministers and the Central Committee issued a decree (no. 138-48) formally terminating all work on the Burya missile. By this time, nineteen examples of the missile had been manufactured, five of which remained unflown. The fate of OKB-301 took a further dive on July 9, 1960, when its patriarch, General Designer Lavochkin, died unexpectedly of a heart attack during missile testing of the Dal at Sary-Shagan. His successor, Mikhail M. Pashinin, retained the right to launch the remaining flightworthy models of the Burya. Three of the four launch attempts were spectacular. The last two in March and December 1960 were complete successes. Both missiles flew complete 6,500-kilometer flights to Kamchatka. All the remaining groundwork on the missile was, however, destroyed.[53]

Myasishchev's competitive M-40 Buran fared even worse. Flight tests of the missile were slated to begin in August 1957, but there were innumerable delays in the project, most apparently because of Glushko's engines for the first stage. Two models of the Buran were apparently manufactured at the giant Plant No. 23 at Fili, but the spectacular success of R-7 ICBM sealed its fate. One month after the launch of the first Sputnik, the Soviet government canceled the Buran project without a single launch.[54] It seems that the cancellation of the Buran did not deter Myasishchev. Although he had a plethora of advanced bomber projects at his design bureau by the late 1950s, unlike many other aviation designers, he was keen to diversify into the space and missile programs.[55] Myasishchev and Korolev had known each other for decades and had in fact worked together in the very same incarceration facility as prisoners during the early part of World War II. Myasishchev had been arrested for belonging to an aviation delegation that had visited the United States in the late 1930s. The two cooperated on a number of warplanes at the time and remained on good terms during the next fifteen years.

When Korolev was carrying out serious studies of human spaceflight on ballistic trajectories in late 1957 after the launch of the first Sputnik, Myasishchev began looking at designing a vehicle that could use aerodynamic surfaces during reentry. As with all aviation designers, Myasishchev had difficulty shifting his priorities to space. During a visit by Khrushchev to OKB-23 in August 1958, Myasishchev personally appealed for support to develop "rocket-plane" systems. Khrushchev replied, "Vladimir Mikhaylovich [Myasishchev], you are engaged [in] large themes in the field of aviation. This is your field. But questions of rocket technology are for *us* to decide and to provide."[56] Despite the negative response, Myasishchev's perseverance eventually paid off, and thus emerged the second spaceplane program in the Soviet Union.

OKB-23's reusable spaceplane project, which began in late 1957, was coordinated to a great degree with engineers at Korolev's OKB-1. Specifications of the R-7 ICBM were given to

53. Aslanov, "'Soviet Shuttle' of the 50s"; Lardier, "70 Years of Soviet Ramjets"; Afanasyev, "Without the Secret Stamp"; S. M. Ganin and V. I. Ivanovskiy, "The Multi-channel 'Dal' Anti-Aircraft Missile System of Great Range" (English title), *Nevskiy bastion* no. 1 (1998): 7–15.

54. V. Petrakov and M. Chernyshov, "Without the Stamp 'Secret': The Unknown Buran" (English title), *Sovetskaya rossiya*, April 10, 1991, p. 4; L. L. Selyakov, *Maloizvestnyye stranitsy tvorcheskoy deyatelnosti aviatsionnogo konstruktora Vladimira Mikhaylovich Myasishcheva* (Moscow: AO ANTK im. Tupoleva, 1997), pp. 109–12. The actual termination decree was issued on November 28, 1957.

55. Much of the OKB-23's resources were focused on the design of supersonic bombers, such as the M-30, M-31, M-32, M-33, and M-34, none of which were ever built. His most famous creation of the period was the M-50, a technology demonstrator for the M-52 supersonic bomber, whose first prototype flew on October 27, 1959. Other projects included the M-53 and M-55 (both supersonic airliners), the M-56 and M-57 (supersonic strategic bombers), the M-60 (a nuclear-powered bomber), and the M-70 (a flying-boat strategic bomber). See Butowski, "Steps Towards 'Blackjack'."

56. Petrakov, "Two Projects of V. M. Myasishchev."

Myasishchev's engineers, who determined the mass of a spaceplane (four and a half tons) as well as the optimal orbit (400 kilometers). Like Tsybin's PKA, OKB-23 project was also supported by the Soviet Air Force as a counterpart to the American Dyna-Soar, and for a brief period, there were actually two spaceplane projects in the USSR. Unlike Tsybin's brief stab at developing a hypersonic lifting body, it seems that Myasishchev's project was far more serious. Designated the M-48, the project was approved by the Soviet government and Communist Party in the same December 1959 resolution, which was the first macro-level policy statement on the Soviet space program. It thus became only the second fully sanctioned human spaceflight project in the Soviet Union. As with other efforts of such a scale, OKB-23 cooperated to a great degree with both OKB-1 and other research institutions, such as Keldysh's NII-1, which had pioneered research on high-altitude and high-speed aeronautics during the 1940s and 1950s, beginning with work on a Soviet version of the Sänger-Bredt antipodal bomber. OKB-23 also used its own rich database from the experience in designing the M-40 intercontinental cruise missile, especially in the area of thermal shielding. In March 1960, a delegation from OKB-23 visited Korolev's facility in Kaliningrad to acquaint themselves with progress on the Object K program as well as to facilitate the transfer of important technological innovations.[57]

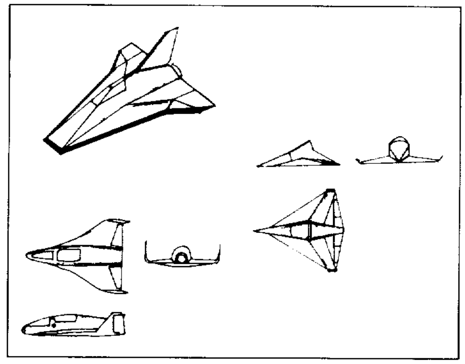
A governmental commission attached to the State Committee for Aviation Technology, the "ministry" overseeing the aviation industry, held a formal review of the project on April 8, 1960. Present were many leading experts from various aeronautics disciplines, who presented recommendations on the design of the M-48 spacecraft. Among the competing proposals was the use of a helicopter-landing scheme for the vehicle with a rotor diameter of eight meters. Other more traditional ideas revolved around using retractable or fixed wings, the use of liquid metal cooling, and the possibility of ballistic reentry. There was apparently much dissension on the issue of selecting a singular variant for the spaceplane, given that different aerodynamicists and aeronautical engineers argued for the benefits of their respective schemes. In a move clearly emphasizing the program's political importance, Deputy Chairman of the State Committee Aleksandr A. Kobzarev underscored the necessity of quickly developing an effective counterpart to the Dyna-Soar.

In the ensuing months, engineers proposed at least two major innovations in the development of the M-48. The thermal protection chosen for the vehicle was made of ultra-lightweight (for the time) ceramic foam characterized by its great fragility. Because it was necessary to have rigid wing surfaces, OKB-23 engineers chose to use thermal shielding in the form of tiles placed in layers with special adhesives. To ensure the safety of the shielding, they designed the ends of the tiles as conics and filled the spaces between them with quartz wadding impregnated with silicon resin. Tests of this configuration proved the soundness of this unusual design. A second innovation was the use of "electrodynamic analogs" to simulate behavior of the vehicle under different conditions. Thus the heat conductivity and thermal heat capacity of the construction was replaced by resistors, capacitors, and other electrical components. Resistances and potential differences at various points in the circuit simulated flight conditions, providing key information without resorting to actual flight testing. Engineers expended the most effort on the heat shielding, and they received several patents for the unique materials for different portions of the vehicle and the leading edge of the wings. At least 40 percent of the spacecraft was covered in special thermal protection.

Between March and September 1960, Myasishchev's engineers carried out intensive research on the final configuration of the M-48, leading to two final variants—one with a single fin at the rear (mass of 3.5 to 4.1 tons) and one with two fins at the tips of the wings (mass

57. *Ibid.*

of 3.6 to 4.5 tons). Although both spacecraft had similar performance characteristics, the former spacecraft was slightly longer (9.4 meters) than the latter (9.0 meters). Effective wingspan for both was seven and a half meters. The two-fin design, the smaller of the two variants, had a smooth outer contour resembling the Dyna-Soar, while the single-fin variant harked back to the paneled exterior of early proposals from Myasishchev in 1957–58. Unlike Tsybin's PKA design, neither of Myasishchev's spaceplane variants used hinged wings that could change their dihedral angles. Both spacecraft carried a cramped crew capsule for a single spacesuited pilot and an ejection seat. The mass of the seat and the pilot was limited to only 250 to 260 kilograms. The overall mass of the instrumentation amounted to 600 kilograms and included systems for navigation control, communications, life support, electrical power, and telemetry. Some parts of the apparatus for the M-48 were directly taken from Object K; these included the *Chayka* orientation system developed by NII-1 and the *Zarya* communications system developed by NII-695.



Three different conceptions of Vladimir Myasishchev's M-48 spaceplane project. At top is the single-fin variant from 1958 to 1960 with a detachable ablative leading front edge. At lower left (in three views) is an "elongated flying wing" dating from 1960, which was considered one of the most promising designs. At right (in three views) is one of the earliest conceptions of the M-48 from 1957 to 1958, which was later abandoned. (copyright Asif Siddiqi)

A nominal flight of the M-48 was to start on top of an 8K72 booster. In case of a booster malfunction, the pilot could eject from the stack at altitudes of up to eleven kilometers. After a daylong mission, the spacecraft would deorbit using a retrorocket engine with a thrust of 1.6 tons. At an altitude of forty kilometers, the pilot would begin controlled descent with a possible cross-range capability of 100 to 200 kilometers. The pilot would switch on a special turbojet engine at that point to provide final guidance. At an altitude of between five and eight kilometers, the pilot would eject from the vehicle in the ejection seat and land separately by parachute. The M-48 would then land independently at an airfield on skids. These skids were fairly small, with a length of 1.2 meters and a width of 0.25 meter.[58]

The M-48 spaceplane was not the only visible manifestation of Myasishchev's intentions of making a name for himself in the new space program. There were other major space-related efforts at OKB-23, including the development of a conical descent capsule with a diameter of two and a half meters that had a truncated asymmetrical shape and steering jets for reentry. Tested successfully in wind tunnels, this was apparently meant for a future crewed space project.

There was also a project to design a new powerful three-stage space launch booster designated the M-1. The first stage of the rocket would be a cluster of four parallel boosters, each with seven thirty-five-ton-thrust engines. The second stage would comprise four similar blocks and the third stage one block. Overall length was thirty-six meters. The 700-ton mass launcher would be capable of orbiting a twenty-ton payload into low-Earth orbit, about four times as much as Korolev's modest 8K72 launcher.[59] Unfortunately for Myasishchev, his bid for moving

58. *Ibid.*; Petrakov and Chernyshov, "Without the Stamp 'Secret'"; Mikhail Rebrov, "Work on the Theme No. 40, or Myasishchev's Spaceplane" (English title), *Krasnaya zvezda*, February 27, 1993, p. 6; Mikhail Rebrov, "Dark Journal, or the Sharp Twist of Fate" (English title), *Krasnaya zvezda*, December 9, 1995, p. 5.

59. Petrakov, "Two Projects of V. M. Myasishchev"; V. M. Petrakov, "From the History of the Development of Carrier-Rockets in the USSR" (English title), in *Trudy XXup chteniy, posvyashchennykh razrabotke nauchnogo nasladeniya i razvitiyu idey K. E. Tsiolkovskogo* (Moscow: RAN, 1994), pp. 166–81.

from bombers to spacecraft ran headlong into the face of certainly one of the most dominant figures in the early Soviet space program, Vladimir Nikolayevich Chelomey.

Enter Chelomey

Chelomey, like Myasishchev and Tsybin, was from the aviation industry. In his early career as a chief designer, his primary focus was air-launched anti-ship cruise missiles, a thematic direction he started by creating the first Soviet pulse-jet engine during World War II. By 1953, his design bureau, OKB-51, had produced a number of modifications of the German Fi-103 "flying bomb." These missiles, such as the 10X, the 10XN, the 14X, and the 16X, were tested with varying degrees of success at Kapustin Yar during the same years that Korolev was proving out his early rockets. Despite a modicum of success with the experimental research, none of them were ever accepted for operational use by the Soviet Air Force, not only because of technical limitations but also due to internal organizational conflicts within the military.[60] Chelomey's run with the cruise missiles came to an abrupt end on February 19, 1953, just two weeks before Stalin's death, when the Soviet leader signed a decree (no. 533-271) disbanding Chelomey's design bureau. The reason was political intrigue. One of Chelomey's primary competitors was Artem I. Mikoyan's MiG design bureau, OKB-155, which was competing with Chelomey to build coastal defense missiles. Mikoyan had a powerful ally in Sergey L. Beriya, the son of the dreaded Lavrentiy P. Beriya, who was the chief engineer at the Moscow-based KB-1, which produced the guidance systems for Mikoyan's KS-1 Kometa missile. Mikoyan and Beriya were able to push through a decision terminating work on all their competitors, including Chelomey.[61] Mikoyan not only inherited Chelomey's plant, but a number of his designers and his database of research.

Chelomey found a research position at NII-642 in Moscow, but he was clearly restless for better things. Undeterred by the major setback, he found enough support within the Ministry of Aviation Industry to regroup twenty of his former engineers on June 9, 1954, into a Special Design Group (SKG) based at the Plant No. 500 in Tushino. The team quietly resumed work on the ground-launched 10XN, one of his most promising cruise missiles.[62] Being an extremely ambitious man by nature, he was clearly not comfortable working on small projects. Unlike other designers of the era, he also considered himself more of a scientist than an engineer and was one of the few designers in the field who had the equivalent of a Ph.D. He had authored

60. For an exhaustive account of Chelomey's work during 1944–53, see Rostislav Angelskiy, "Like the German 'V' There Was the Russian 'Tenth X'" (English title), *Aviatsiya-kosmonavtika* 19(8) (August 1996): 27–40. See also Valeriy Rodikov, "The 'X's' of Vladimir Chelomey" (English title), *Krylia rodiny* (August 1989): 6–7; G. Yefremov, N. Bogolyubov, and P. Kotov, "From War to Space: Notes on General Designer V. Chelomey" (English title), *Krasnaya zvezda*, September 7, 1991, p. 5.

61. Angelskiy, "Like the German 'V'"; Khrushchev, *Nikita Khrushchev*, pp. 368–70; Valeriy Rodikov, "Im vremya dest tainstvennuyu znatnost. . .." in V. Shcherbakov, ed., *Zagadki zvezdnykh ostrovov: kniga pyataya* (Moscow: Molodaya gvardiya, 1989), pp. 13–14; Mikhail Rebrov, "'Akula' and Others: From the History of Winged Missiles" (English title), *Krasnaya zvezda*, February 5, 1994, p. 5; Yevgeniy Yerokhin, "When the 'Storm' Ended as the 'Still'" (English title), *Krylia rodiny* no. 10 (October 1995). The same order also terminated work on the R-1 Shtorm missile (at OKB-293 headed by M. R. Bisnovat) and the RAMT-1400 Shchuka missile (at GSNII-642 headed by M. V. Orlov).

62. Aleksandr Shirokorad, "Rakety nad morem" (English title), *Tekhnika i vooruzheniye* no. 11–12 (November–December 1997): 1–80; Gerbert Aleksandrovich Yefremov, "NPO Mashinostroyeniya Is Moving Into the High-Technology Market" (English title), *Vooruzheniye, politika, konversiya* 3 (1995): 31–37; M. Tarasenko, "35 Years for the OKB 'Vympel'" (English title), *Novosti kosmonavtiki* 8 (1998): 43–44. The Ministry of Aviation Industry signed an order dated May 19,1954, ordering the Plant No. 475 to resume the manufacture of 100 10XN missiles. This number was later reduced to fifty. See Angelskiy, "Like the German 'V'."

dozens of papers and a number of textbooks on such topics as aerodynamics, the theory of pulse-jet engines, and the phenomenon of vibration. Within the scientific community, he was highly respected; as a designer at Kapustin Yar, he was just as prone to be engaged in solving complex mathematical arcana as directing a launch. In this respect, he was exactly the opposite of Korolev, who had always been a "hands-on" technical person with a talent for managing. Chelomey, on the other hand, was a scientific prodigy of sorts, albeit with sometimes unrealistic but ambitious goals and less managerial skill than Korolev. Chelomey's gall and ambition continually surprised his closest colleagues, and the number of setbacks he would receive in his checkered career never once seemed to stunt his reach for resources and access to the top.

Clearly at the nadir of his career in 1954, Chelomey drew up a proposal for a new naval cruise missile. He approached a top admiral in the Navy, Pavel G. Kotov, and convinced him in a few hours that the Navy could not do without such a new and original weapon. By a stroke of fortune, the Ministry of Aviation Industry had also decided to establish a number of new design bureaus to focus on naval projects. A panel of famous scientists from the Academy of Sciences, including Keldysh, reviewed the naval cruise missile proposal and recommended it as a prospective direction of research. Chelomey also had a more powerful backer. Khrushchev recalled in his memoirs:

> *One day [Chelomey] asked me for an appointment to show me a model of a new missile he'd developed. He explained that it was a tactical missile like the German V-1 flying bomb, but it had special features: the wings could be folded up, and it could fit into a long barrel. When it was fired, the wings spread so that it looked like an airplane. I thought that the comrade had come up with an original and useful idea. . . .*[63]

There were some in the Ministry of Defense who opposed allowing Chelomey resources, but Khrushchev had the last word. In August 1955, Keldysh telephoned Chelomey and informed him that he had been assigned an empty tract of land with a tiny factory, the Reutov Mechanical Plant, located in the outskirts of Moscow. Here he would work on his pet design.[64] On Chelomey's personal request, much of his old database was returned to him from Mikoyan's design bureau. The group that Chelomey established there, by an official order on August 8, 1955, would eventually become one of the largest defense enterprises in the Soviet Union, the Experimental Design Bureau No. 52 (OKB-52).[65]

Between 1955 and 1958, Chelomey focused all his energies on his new missile, designated the P-5, which was tested in the North Sea from Soviet Navy submarines. He made an unprecedented and rapid rise from obscurity and by 1958 was vying for parity with the leading chief designers in the Soviet defense industry. His small design bureau had also expanded; a team of skilled engineers under Aleksandr D. Nadiradze was attached to OKB-52 in December 1957 to focus on solid-propellant missile research. The same Nadiradze would

63. Nikita S. Khrushchev, *Khrushchev Remembers: The Last Testament* (Boston: Little & Brown, 1974), p. 44.

64. Rodikov, "The 'X's' of Vladimir Chelomey," p. 14; Khrushchev, *Nikita Khrushchev*, pp. 371–72; Nina Chugunova, "V. N. Chelomey. Highlights of His Biography" (English title), *Ogonek* 4–5 (January 16–30, 1993): 24–29; Rebrov, "'Akula' and Others." The review panel for Chelomey's missile included M. V. Keldysh, A. A. Dorodnitsyn, and A. Yu. Ishlinskiy. For a short history of the Chelomey organization, see *Raketno-kosmicheskaya otrasl rossi* (Moscow: Assotsiatsiya sodeystviya kosmicheskoy nauke i tekhnike, 1996), p. b-134.

65. Not all of the Special Design Group relocated to the Reutov Mechanical Plant in August 1955. It was only after minor plant renovation in 1956 that all of Chelomey's team moved to Reutov from Tushino. See Yefremov, "NPO Mashinostroyeniya is Moving."

decades later design one of the most potent missiles in the Soviet arsenal, the so-called SS-20.[66] The P-5 missile itself had a mixed future. It was meant to be the first nuclear-armed Soviet naval missile, a counterpart to the U.S. Navy's Regulus. Chelomey's rocket, however, was cumbersome to prepare for launch and had poor accuracy.[67] Despite these weaknesses, the P-5 was declared operational on June 19, 1959, and Chelomey and a large number of his staff received important state awards, including the prestigious Hero of Socialist Labor for Chelomey himself. Later on July 3, 1959, he was named the general designer of his organization, a title that was more prestigious than the more common *chief* designer, but one that only existed in the aviation industry.

Apart from pure ambition and technical expertise, by this time Chelomey had a much more powerful ally. In March 1958, Khrushchev's son, Sergey Nikitich, joined the OKB-52 as a deputy chief of the department dedicated to guidance systems. By the younger Khrushchev's account, it had been his own decision to join Chelomey's design bureau, but it was obvious that Chelomey capitalized on the unexpected course of events. As one scientist in the space program later observed:

> *. . . Chelomey was an absolute master at using their personal triangle for the advancement of his ambitions. It is not that Chelomey got hints or requests from Nikita Khrushchev to promote his son. The stories I heard gave the completely opposite scenario. It was Chelomey who had taken the initiative.*[68]

Chelomey never hesitated to shower the Soviet leader with stories of his son's great technical expertise. The motives of both the older Khrushchev and Chelomey continue to remain obfuscated amid plaintive accusations of nepotism and outright jealousy in the eyes of other designers, but one fact is clear: the Soviet leader displayed a marked favoritism toward Chelomey by the late 1950s. Whether this was because of his son's unique position or merely whimsical is probably something that will never be known. The older Khrushchev did not hide his support of Chelomey. At a major display of military weaponry held at Kapustin Yar as part

66. Nadiradze's team had come from GSNII-642. This institute traced its lineage back to KB-2, which was established on May 13, 1946, to work on the German Hs-293A missile and later the RAMT-1400 Shchuka air-launched cruise missile. On December 15, 1951, KB-2 was combined with Plant No. 67 and renamed the State Union Scientific-Research Institute No. 642 (GSNII-642). Although its work on the Shchuka was discontinued in 1953, GSNII-642 continued work on other missile programs derived from the Shchuka. Chelomey's new OKB-52 was made a branch of GSNII-642 on November 6, 1957. Their positions evidently reversed on March 8, 1958. A subdivision from GSNII-642, SKB-2, was headed by Nadiradze. See Dmitriy Khrapovitskiy, ed., *Generalnyy Konstruktor Akademik V. N. Chelomey* (Moscow: Vozdushniy transport, 1990), p. 67. The solid-propellant theme was not pursued for very long at OKB-52 because Chelomey was apparently not interested in it. In 1958, Nadiradze's SKB-2 separated from Chelomey and was transferred to NII-1 within another ministry, the State Committee for Defense Technology, where it pursued the development of solid-propellant ballistic missiles. Nadiradze became the director of NII-1 in 1961 and went on eventually to develop a series of solid-propellant ICBMs for the Strategic Missile Forces. See Mikhail Rebrov, "When the Topol Bloomed . . . The Most Secret of the Designers" (English title), *Krasnaya zvezda*, February 25, 1995, p. 5; G. A. Yefremov, "Anniversary: V. N. Chelomey—80 Years" (English title), *Novosti kosmonavtiki* 12–13 (June 4–July 1, 1994): 68–70; Lardier, "70 Years of Soviet Ramjets"; Christian Lardier, "Solid Propellant Rockets in the Soviet Union," presented at the 49th International Astronautical Federation, IAA-98-IAA-2.3.09, Melbourne, Australia, September 28–October 2, 1998; R. Angelskiy, "Flying Shchuka" (English title), *Tekhnika i oruzhiye* no. 2 (1997): 9–16.

67. Steven J. Zaloga, *Target America: The Soviet Union and the Strategic Arms Race, 1945–1964* (Novato, CA: Presidio, 1993), p. 185; Shirokorad, "Rakety nad morem."

68. Roald Z. Sagdeev, *The Making of a Soviet Scientist: My Adventures in Nuclear Fusion and Space From Stalin to Star Wars* (New York: John Wiley & Sons, 1993), p. 202.

of the Operation *Bereza* in September 1958, Khrushchev made overt gestures in favor of Chelomey. As a participant recalled: "I noticed that when Khrushchev visited our static display, he spent a large portion of his time—50 minutes—studying Chelomey's stands, whereas he only devoted 10 minutes to the missiles designed by Korolev, Yangel, and others."[69] This was only six months after his son had joined OKB-52.

Chelomey's ascendance into the upper echelon would not be of any significance for Korolev or Yangel were it not for Chelomey's one crucial decision in 1958–59 to expand his horizons. Having spent the previous four years engaged in designing short-range tactical missiles for the Soviet Navy, Chelomey was well aware that the real prestige lay elsewhere—that is, in designing ICBMs and spacecraft. One of his early stabs at these themes was an ambitious idea to extend the capabilities of his naval cruise missiles by combining the benefits of winged and ballistic rockets. The Central Committee and the Council of Ministers issued a formal decree on July 2, 1958, permitting initial work on the development of winged-ballistic missiles at OKB-52.[70] After launch on a ballistic trajectory, the payload would reenter Earth's atmosphere in a capsule and release the winged missile, which, using its own wings and a jet engine, would guide its self-homing warhead, either conventional or nuclear, to its destination. The primary targets of these so-called "Aircraft Warheads" were evidently foreign battleships around the world. The slated range of the winged-ballistic missile was about 8,000 to 10,000 kilometers. It was during the research on this concept that Chelomey first expanded his reach from missiles into the space arena—specifically, the development of launch vehicles and spacecraft. As early as July 1959, he presented some initial space-related concepts to the powerful Defense Council of the Presidium of the Central Committee.

Based on the experience of developing cruise missiles and his exploratory composite winged-ballistic research, Chelomey's engineers began to study a wide range of problems. Unlike Korolev's entry into the space program, Chelomey began thinking big from the start. As Khrushchev's son later recalled:

> *[He] started with the most exotic: flight to the other planets. Chelomey fell for plasma engines . . . a spaceship untwisting itself in a spiral around the Earth until it would tear itself away from it . . . [and then] lay on a trajectory to Mars or Venus. Another idea resembled a ship: a winged rocket in a container would be carried above the atmosphere, do an intricate pirouette: diving into the stratosphere on wings and changing the trajectory, it would use supplementary engines to direct itself back into orbit. It would be able to fulfill missions of reconnaissance, photography, or carry out space-targeted bombings. But most of all Chelomey wanted to build a winged piloted ship. That would be highly maneuverable. He did not abandon the idea to the very last days of his life.*[71]

OKB-52's overall entry into the Soviet space program began under two broad themes called Kosmoplan ("Space Glider") and Raketoplan ("Rocket Glider"). Research on both tacks began in 1959. Admittedly, engineers used these names somewhat generically in the same way that Korolev's engineers named their first creations "space ships." In fact, Chelomey used the Kosmoplan and Raketoplan names precisely because they were different from Korolev's "space ships," to distinguish his own efforts from what he considered the pedestrian ways of Korolev's engineers.

69. Lt. Gen. Aleksey Kalashnikov, "Archives of 'Russian Armaments': Operation 'Bereza': This Was the First View of Our Missile Shield" (English title), *Krasnaya zvezda*, December 17, 1994, p. 6; Mozzhorin, *et al.*, eds., *Dorogi v kosmos: II*, p. 27.

70. E-mail correspondence, Igor Afanasyev to the author, November 23, 1997.

71. Khrushchev, *Nikita Khrushchev*, pp. 480–81.

In its initial conception, the Kosmoplan was an automated winged space vehicle designed to accomplish missions in deep space.[72] The spacecraft would perform its mission in three distinct phases:

- The Kosmoplan would be launched into a low-Earth orbit by existing or future launch vehicles.
- The Kosmoplan would slowly accelerate into a spiral trajectory around Earth using its own engines, and then accumulate sufficient speed to "shoot off" into a trajectory to the Moon, Mars, or Venus.
- After completing its mission, the Kosmoplan would return to Earth.[73]

It seems that Mars was a primary goal for the Kosmoplan. At the Red Planet, the spacecraft would use special cameras and probing sensors to study the planetary phenomena. Chelomey's engineers conceptualized a very unique reentry profile for the spaceplane. Just before reaching Earth's atmosphere, a conical apparatus, shaped somewhat like a folded umbrella, would extend out from the vehicle. Once the Kosmoplan entered the upper atmosphere at a slight angle to the horizontal, this unfurled "umbrella" would shield the spacecraft proper from thermal stresses. After atmospheric reentry, at a velocity of Mach 2, the Kosmoplan would jettison the "umbrella," and the plane would swerve appropriately and finally land at an airport landing strip.[74]

From a general perspective, the Kosmoplan theme encompassed only lunar and interplanetary flight, but confusingly, OKB-52 engineers also foresaw using the Kosmoplan in near-Earth space—that is, specifically, for missions in Earth orbit at altitudes of eighty-five to 105 kilometers for military reconnaissance missions. Thus, ultimately, Chelomey proposed two subclasses of the Kosmoplan, one for deep space missions and one for near-Earth orbital flight. Missions would originally begin with automated flights and then lead to piloted missions, especially in the near-Earth orbit variant. Ultimately, however, Chelomey's goal was a piloted expedition to Mars with a subsequent return and landing back on Earth.

Functionally, the Kosmoplan was divided into two major sections: a compartment for engine units and a return compartment. Taking into consideration the requirement for acceleration out of Earth orbit as well as the needs for aerodynamic braking near the atmosphere from low-Earth orbit, the engineers examined several different possible engine units for both subclasses of Kosmoplans. These included chemical liquid-propellant rocket engines, nuclear rocket engines, and electric rocket engines. After intensive analysis, Chelomey's engineers concluded that electric rocket engines with a nuclear power source would be optimal for achieving all of the possible goals of the Kosmoplan. The electric rocket engine would consist of mechanisms to convert a nuclear reactor's heat into electrical power, a plasma engine, and radiators to dissipate heat. The return compartment itself comprised a "braking container"—that is, a narrow cylinder that unfurled into the umbrella-shaped thermal shield for controlled aerodynamic reentry into Earth's atmosphere. Once the umbrella was discarded, the container would open up to reveal the spaceplane proper, an aircraft with folded delta wings, short in length but sharply swept back. The spaceplane would have its own turbojet engine for disembarking on conventional runways.

According to engineering analyses, the Kosmoplan design offered some significant advantages over standard ballistic spacecraft using chemical liquid-propellant rocket engines, such as

72. Interview, Gerbert Aleksandrovich Yefremov by the author, March 3, 1997.
73. E-mail correspondence, Igor Afanasyev to the author, November 28, 1997.
74. Igor Afanasyev, "Kosmoplan: Chelomey's Project" (English title), *Krasnaya zvezda*, August 26, 1995, p. 6.

those designed at the Korolev design bureau. For example, Chelomey believed that the useful payload of the Kosmoplan for a mission to Mars would be as high as 15 percent of the initial spacecraft mass at low-Earth orbit. There was, of course, also the benefit of reusability by returning the most valuable portion of the entire system back to Earth.[75]

The Raketoplan was slightly less ambitious than the Kosmoplan, but it was still a far leap from Korolev's modest Object K effort. The primary goal of the Raketoplan project was to transport payloads and people over intercontinental distances by reusable space vehicles—that is, it was meant exclusively for use in near-Earth space. Unlike the Kosmoplan, however, Chelomey believed that the Raketoplan could serve as some kind of futuristic space weapons bomber, something much akin to the Sänger-Bredt concept of years before. The Raketoplans would be launched vertically on conventional rockets and then perform suborbital ballistic flights with aerodynamic braking, maneuvering, and then landing at airports with a set of turbojet engines and landing gear. In their initial studies, OKB-52 engineers studied two-stage Raketoplan systems with both tandem and parallel staging. The second stage, the actual spaceplane, would fly the assigned mission, reaching velocities as high as eight kilometers per second.

OKB-52 studied two basic types of Raketoplans in 1959 and 1961, one for a range of 8,000 kilometers and one for a range of 40,000 kilometers. The modest version would be launched from pads located at latitudes close to Moscow and then, by flying over the North Pole, would be able to land at airfields at latitudes close to Washington, D.C. If the spacecraft was launched from even higher latitudes, then points as south as Cape Canaveral would come into its range of landing. The longer range model would be able to launch off any point in the Soviet Union and fly over the South Pole and up to any point in the United States, evading the radar systems of the North American Air Defense Command (NORAD). After its mission, the Raketoplan would land anywhere in the Soviet Union.

The two-stage design of the Raketoplan consisted of a winged first stage, which would return to a landing strip after it imparted sufficient velocity to the second stage. In one scenario, the single pilot in the first stage would use turbojet or ramjet engines fixed to the ends of the two wings to return to an airfield near the launch complex. The carrier aircraft had a range of 600 kilometers. In a second conception, the first stage would simply be a heavy glider. After launching the spaceplane into the upper atmosphere, this glider would land at an airfield about 600 to 800 kilometers from the launch pad. A special suspended jet engine installation would allow the first stage to return back to the launch area at subsonic speeds. The landing would be performed on wheels.

The spaceplane, or second stage, of the Raketoplan represented a hybrid of a rocket and a supersonic jet plane. The vehicle included propellant tanks for the fuel and oxidizer, intertank compartments with systems for tank pressurization, and a tail compartment with a liquid-propellant rocket engine. There was a pressurized sealed cockpit for the pilot at the forward end of the ship. The sweptback wings were attached to the middle part of the main fuselage. The aft part of the spaceplane included a cruciform tail assembly and a turbojet engine next to the main liquid-propellant rocket engine. Overall, given its primary mission of bombing enemy targets, OKB-52 engineers believed that it had one major advantage over intermediate-range ballistic missiles, such as Yangel's R-12 and R-14: the Raketoplan could maneuver in the atmosphere unlike missiles, which were preprogrammed with a trajectory prior to launch. No doubt, the fact that the Raketoplan system was completely reusable added to its attractiveness as a new weapon of the Soviet armed forces.[76]

75. Correspondence, Igor Afanasyev to the author, November 28, 1997.
76. *Ibid.*

These grand proposals from Chelomey would probably have sunk into obscurity, by 1959, had it not been for Chelomey's support system within the Communist Party, the government, and the military. First and foremost, he had access to Khrushchev personally on a regular basis, on a par with Korolev's own influence with the Soviet leader. In the Party, he could count on Ivan D. Serbin, the chief of the Defense Industries Department in the Central Committee, who served as somewhat of a watchdog within the defense sector, making sure that the Party's official policy was being carried out in "proper" ways. Serbin remains one of the least talked about individuals in the history of the Soviet space program, a situation that is completely disproportionate to the remarkable power he wielded over almost a quarter of a century. He was apparently a terrifying figure to many, thus inheriting the nickname "Ivan the Terrible" during his tenure as Party *apparatchik* for the defense sector. Very little is known about his background; his biographies merely state that he began working in the innards of the Party in 1942, rising to his current position in February 1958. He was forty-eight years old at the time.[77]

Ivan Serbin was the chief of the Central Committee's Defense Industries Department from 1958 to 1981. More commonly known as "Ivan the Terrible," he was the doctrinal watchdog for the Soviet missile and space programs, wielding considerable influence over not only personnel changes, but also policy. (files of Peter Gorin)

Within the government, Chelomey also had the strong unequivocal support of Petr V. Dementyev and Aleksandr A. Kobzarev, the chairman and deputy chairman, respectively, of the State Committee for Aviation Technology. Dementyev had been one of those who had decided in 1945 to relinquish missiles to the armaments industry, but with Chelomey's strong reach for missiles and space, he no doubt saw Chelomey as a way out from the near-catastrophe that was facing the aviation sector. Chelomey also had very powerful enemies, primarily in the person of Dmitriy F. Ustinov, the chairman of the Military-Industrial Commission. Ustinov's initial dislike of Chelomey was understandable: Chelomey was coming from the aviation industry into the missile business, which had been dominated by people such as Korolev and Yangel who had been nurtured under Ustinov within the armaments industry. For Ustinov, this was an unacceptable intrusion into his affairs. During Khrushchev's reign in power, there was, however, little Ustinov could do. Although he was the chairman of the Military-Industrial Commission—certainly one of the most powerful jobs in the Soviet defense industry—Ustinov had to answer to Serbin and ultimately to Khrushchev. It was a no-win situation. Chelomey, very much aware of the "Ustinov problem," completely bypassed normal institutional means and usually took his proposals straight to Khrushchev, thus ensuring that they would be given a fair look without an outright rejection from Ustinov.[78]

77. Edward L. Crowley, Andrew L. Lebed, and Dr. Heinrich E. Schulz, eds., *Prominent Personalities in the USSR* (Metuchen, NJ: The Scarecrow Press, 1968), p. 547.

78. Telephone interview, Sergey Nikitich Khrushchev by the author, October 10, 1996.

Korolev himself was predictably protective of his domain. As Chelomey began to make inroads into the arena of space, Korolev was dismissive of his plans, calling them "a circus" of ideas.[79] Sometime in 1959, soon after Korolev's successful lunar mission to the far side of the Moon, Chelomey sent two of his leading deputies, Gerbert A. Yefremov and Valeriy Ye. Samoylov, to meet with Korolev to discuss his future plans. When the two explained that Chelomey was interested in multiple-use spacecraft as part of a complex system of orbital operations, Korolev was aghast. According to Yefremov, Korolev replied at one point: "Why do we need such a system at the present time? Right now all this is fantastic. In space right now it's necessary to solve [more specific] goals, for example like . . . photographing the far-side of the Moon."[80] By Yefremov's account, it was apparently at that point that the discourse between the two designers started to degenerate into competition instead of cooperation.

Chelomey, undeterred by Korolev's criticisms, took his complex plan for space exploration straight to the top at a meeting in early April 1960. The general designer had been eager to meet with Khrushchev to discuss his plans for some time. During a short vacation in Crimea, Khrushchev took the opportunity to invite not only Chelomey, but also several important players involved in the development of Soviet naval missiles.[81] There were three main problems on the agenda: the next generation of naval cruise missiles, problems with gyroscopes in naval missiles, and the question of future anti-satellite systems.

After discussions on naval missiles, Khrushchev allowed Chelomey to present his plans for space. Chelomey came prepared with a plethora of charts and diagrams and began expounding on a plan for a large-scale Earth-orbital complex made of space stations, winged reusable transport ships, communications satellites, cargo spacecraft, and huge orbital space factories. The Raketoplan-Kosmoplan idea was at the crux of much of his presentation, and Chelomey expounded clearly that one of the major problems of developing such systems would be adequate thermal protection, which would take years to perfect. This first segment was followed by his offering for a military space complex at the core of which was a battle station equipped with nuclear projectiles in revolving turrets. Khrushchev was apparently getting bored at this point by this overtly ambitious plan, and Chelomey quickly changed the subject to more modest plans—in particular, a system for recovering hostile satellites from orbit for inspection. Once again, one of the central tenets of his plans was a winged vehicle with a large payload bay for stowing captured satellites. Moving on, he described another space-based system for intercepting incoming ICBMs, probably the first-ever discussion at a high level in the Soviet Union on a strategic defense program paralleling the American "Star Wars" program of the 1980s. Chelomey also presented conceptions of new automated space-based anti-satellite and ocean reconnaissance systems, the kind that would allow operational capability by 1962–63.[82]

Chelomey finished his prepared speech and then asked Khrushchev for authority to develop his own space launch vehicle. Khrushchev's interest perked up when Chelomey explained that his space launcher would be designed in such a way that it could *also* be used as a new efficient ICBM. Since about 1958, the general designer had explored several conceptions of launch vehicles (such as the A-300) and ICBMs (such as the A-200) in preparation for this

79. Khrushchev, *Nikita Khrushchev*, p. 480.

80. G. A. Yefremov, "Where *'Salyut'* Started" (English translation), in Khrapovitskiy, ed., *Generalnyy Konstruktor Akademik V. N. Chelomey*, p. 8.

81. Those present included: B. Ye. Butoma (Chairman of the State Committee for Ship Building), V. N. Chelomey (General Designer of OKB-52), P. V. Dementyev (Chairman of the State Committee for Aviation Technology), Admiral S. G. Gorshkov (Commander in Chief of the Military-Naval Fleet), N. S. Khrushchev (First Secretary of the Central Committee), S. N. Khrushchev (Deputy Chief of an OKB-52 Department), and V. I. Kuznetsov (Chief Designer of NII-944). See Khrushchev, *Nikita Khrushchev*, pp. 484–85.

82. *Ibid.*, pp. 485–89.

moment. The A-200 ICBM, later renamed the UR-200, was the center of Chelomey's proposals. The rocket, in its space launch version, would have a payload capability of three to four tons to low-Earth orbit, putting it in a lighter class than concurrent Soviet launch vehicles such as Korolev's 8K72 and 8K72K boosters for the Object K program.[83] In typical fashion, Chelomey elected not to use the traditional "R" index normally reserved for all previous Soviet long-range missiles, but introduced the "UR" index, standing for "universal missile" in Russian. This was a direct reference to his idea that such missiles would have dual use as space launch vehicles *and* ICBMs. The "200" was a rough estimate of the total launch mass of the new rocket.

Chelomey wanted approval for the Raketoplan, the Kosmoplan, the UR-200, as well as two automated military systems, an anti-satellite system named "IS" ("Satellite Destroyer") and a radar ocean reconnaissance satellite system named "US" ("Guided Satellite"). There was also the question of the huge battle stations in orbit, but all of this no doubt overwhelmed Khrushchev. His son recalls that after hearing Chelomey's prognosis about war in space, all the attendees sat there "looking depressed [and] made no comment."[84] While Khrushchev declined to approve the more ambitious and outlandish plans, the Soviet leader did see a point in forging ahead with work on the UR-200 ICBM as a competitor to new missiles from the Korolev and Yangel design bureaus. He also evidently found the IS anti-satellite proposal worthy of further consideration. His son later wrote that at the end of the meeting, "Father began talking about how important the proposed program seemed to him. If war reached into space—he thought Chelomey's arguments were very convincing—then we must not allow ourselves to be caught unprepared."[85] Chelomey's boss, Chairman Dementyev, also piped in, cautiously supporting Chelomey's grand plans.

All Chelomey needed were the resources to carry out his program. In an incredibly shrewd move, he took advantage of Khrushchev's favorable impressions and explained that to carry out such large-scale work, he would need some additional help, maybe another design bureau or a production plant. Playing on Khrushchev's anathema toward strategic aviation, this ploy worked. Dementyev suggested that there was Myasishchev's excellent design bureau in Fili with its adjacent production factory, Plant No. 23, which could be very useful for Chelomey. It was well known that Khrushchev had been unhappy for a while with the performance of Myasishchev's bombers. After a cursory discussion on the poor results of some of Myasishchev's products, Khrushchev told Dementyev to draw up the appropriate governmental decree to transfer Myasishchev's design bureau and his plant, wholesale, to Chelomey. Thus, the April 1960 meeting was the effective death knell not only for Myasishchev's bombers, but also his radical spaceplane design, the M-48.

In a strange irony, Myasishchev had been involved in a project to design a new ICBM *with* Chelomey. In 1958 and 1959, during the latter's initial exploratory studies for a new generation of missiles, Chelomey had signed a preliminary agreement with Myasishchev and another aviation designer, Pavel O. Sukhoy of OKB-51, to develop a new two-stage ICBM for the Strategic Missile Forces. Myasishchev would build the first stage, while Sukhoy would be responsible for the second stage. Chelomey would build the warhead container. At some point in the autumn of 1960, ballistics reviews by Myasishchev's designers proved that there were fundamental flaws in the design submitted by Chelomey. At a meeting to discuss the issue, Myasishchev's deputies were critical of the proposal as a whole, which no doubt angered the proud Chelomey. As one of Myasishchev's engineers recalled: "After that meeting the fate of OKB-23, and

83. Dmitriy Khrapovitskiy, "Absolutely Unclassified: The Ground Waves of Space Politics" (English title), *Soyuz* 15 (April 1990): 15.

84. Khrushchev, *Nikita Khrushchev*, p. 490.

85. *Ibid.*, p. 492.

personally of V. M. Myasishchev was determined. Moreover, it was stated that Myasishchev was a jet expert but now, of necessity, [suddenly] a rocket expert."[86]

In Chelomey's view, Myasishchev had stepped over the line. It was, however, too late for him. On October 3, 1960, by Central Committee and Council of Ministers decree no. 1057-434, Myasishchev's design bureau was formally renamed OKB-52 Branch No. 1; all his bomber projects were terminated. His space projects, such as the M-48 spaceplane, the crew return capsule, and the M-1 launch vehicle, fared no better. Myasishchev was forced to stand by and witness as his entire database of research, accumulated over almost a decade, was handed out part and parcel to two other design organizations, Sukhoy's OKB-51 and Tupolev's OKB-156. His personnel remained behind at the old design bureau haunts to wait for new orders from Chelomey.[87] Myasishchev was apparently offered the luckless job of working under Chelomey as head of Branch No. 1, but he refused and instead moved out of the whole design business into pure science research as the new director of TsAGI, the most important aeronautics research institution in the Soviet Union.[88] Chelomey meanwhile inherited a completely new organization, its excellent engineering staff, as well as one of the largest production facilities in the USSR, Myasishchev's Fili plant. While yet to make a concrete stab at the piloted space program, Chelomey had left no doubt about the breadth of his ambitions.

The Big Space Plan

Chelomey was not the only one thinking big at the time. All of the several long-range plans that Korolev had submitted to the government through 1959 required the development of huge and powerful launch vehicles to support large-scale space operations. Preliminary studies on heavy-lift launch vehicles began in the Soviet Union in 1956. In August of that year, Glushko had circulated a proposal to all the other major chief designers and to then–Minister of Defense Industries Ustinov about a new booster based on the R-7 design, but with each block having two 100-ton-thrust engines, thus having a total thrust of 1,000 tons. He had expected a preliminary paper project on the issue to have been completed by November of the following year, but work on the R-7 ICBM had precluded serious inquiry.[89] Korolev had also inaugurated such studies at his own design bureau. The first mention of such a vehicle in OKB-1 archives is dated September 14, 1956, and describes a vehicle with a launch mass of 1,000 tons. The question was once again discussed at a meeting of the Military-Industrial Commission on July 15, 1957, with the unanimous recommendation that future heavy-lift boosters *not* use the cluster configuration used on the R-7. The designers agreed that LOX should be used as oxidizer because it provided higher specific impulse than storable propellants.[90] The issue was considered premature at the time, but the commission approved further preliminary research on the topic. OKB-1 plans for 1959–60 also mentioned a similar project, and in December 1959, the gov-

86. Petrakov, "Two Projects of V. M. Myasishchev"; Petrakov, "From the History of the Development of Carrier-Rockets."

87. S. A. Zhiltsov, ed., *Gosudarstvennyy kosmicheskiy nauchno-proizvodstvennyy tsentr imeni M. V. Khrunicheva. 80 let* (Moscow: GKNPTs Khrunichev, 1997), p. 52; Petrakov and Chernyshov, "Without the Stamp 'Secret'"; Selyakov, *Maloizvestnyye stranitsy tvorchesko*, pp. 114–15.

88. V. A. Fedotov, "The Scientific-Research Activities of V. M. Myasishchev" (English title), *Iz istorii aviatsii i kosmonavtiki* 50 (1984): 3–13; Christian Lardier, *L'Astronautique Soviétique* (Paris: Armand Colin, 1992), p. 152.

89. Vetrov, "Development of Heavy Launch Vehicles."

90. *Ibid.*; Vetrov, "The Difficult Fate of the N1 Rocket." There was also a meeting of the Council of Chief Designers on the same day addressing similar topics. One source states that the specifications for the new booster were a launch mass of 1,000 to 2,000 tons and payload values of forty to ninety tons. See R. Dolgopyatov, B. Dorofeyev, and S. Kryukov, "At the Readers' Request: The N1 Project" (English title), *Aviatsiya i kosmonavtika* no. 9 (September 1992): 34–37.

ernmental decree on the space program included a clause authorizing exploratory studies at OKB-1 on the topic of heavy-lift boosters.

The effort to determine the specifications for the next generation of Soviet launch vehicles was, in more than one way, intrinsically connected with the qualitative nature of the future of the Soviet space program. The December 1959 decree on space had hesitantly approved a number of projects, but far less than what Korolev had been lobbying for. But between December 1959 and mid-1960, there was a remarkable turnaround in the manner in which the Soviet leadership viewed their space program. Soviet space historians themselves have been unable to clearly explain the abrupt shift. One respected Russian space historian, Georgiy S. Vetrov, has suggested that the about-turn was prompted primarily by actions not in the USSR, but by one individual in the United States, Democratic Senate Majority Leader Lyndon B. Johnson of Texas. Johnson had played a major role in the formation of NASA, and he continued to criticize the seemingly ineffectual actions of the Eisenhower administration through the years after Sputnik. As chairman of the Senate Aeronautical and Space Sciences Committee, he had authored a memorandum on the use of the arena of space in the interest of national defense, which had alarmed the Soviets. In a statement typical of the period, Johnson told the Democratic Caucus in 1958 that:

> *Control of space means control of the world. . . . There is something more important than the ultimate weapon. That is the ultimate position—the position of total control over Earth that lies in outer space . . . and if there is an ultimate position, then our national goal and the goal of all free men must be to win and hold that position.*[91]

Later, in February 1960, Johnson had been primarily responsible for increasing the NASA budget request for the 1961 fiscal year by a figure of $168 million. Statements by Herbert F. York, the Director of Defense Research and Engineering at the Department of Defense, advocating a strong military component to the U.S. space program, were also evidently viewed with much alarm by the Soviets.[92]

Prompted by NASA's long-range plans for space exploration, Khrushchev found a sudden interest in the Soviet space program. On January 2, 1960, he summoned the primary motivators of the space program—Korolev, Glushko, Keldysh, and Pilyugin—and unexpectedly asserted that Soviet successes in space were no less important than military rockets. Korolev quoted Khrushchev's exact words the next day when he met with Keldysh, other chief designers, and all his principal deputies: "Your affairs are not well. You should quickly aim for space. There's broad and all-out levels of work in the U.S.A. [in this field] and they'll be able to outstrip us."[93]

During the following month, it was clear that the basic thematic direction of the Soviet space program was going to be military. Believing that pronouncements of Johnson and York were symptomatic of the military nature of the U.S. space program, the Soviet leadership wanted to compensate for the overtly "civilian" nature of the December 1959 space plan. Thus, proposals were floated in early 1960 for a plethora of different military projects. As with the U.S. space program, most of the proposals were centered around the development of a heavy-lift launch vehicle. In a rush to receive approval in this window of opportunity, both Korolev and

91. *Lyndon Johnson & The American Dream* (New York: Harper & Row, 1976), p. 145, referenced in Harford, *Korolev*, p. 252.

92. David Baker, *The History of Manned Spaceflight* (New York: Crown Publishers, 1985), pp. 50–51; Vetrov, "The Difficult Fate of the N1 Rocket"; interview, Georgiy Stepanovich Vetrov by the author, January 9, 1997. In July 1960, York had threatened the Saturn program with cancellation because he believed that the project had no military utility.

93. Chertok, *Rakety i lyudi: Fili Podlipki Tyuratam*, p. 318.

Glushko offered up wildly differing proposals for heavy boosters. Unlike Korolev, who favored a qualitative leap in design, Glushko, in 1959 and 1960, had explored the possibility of using the R-9 ICBM as the basis for a heavy-lift launch vehicle. His conservative approach was to cluster together seven R-9s as the first stage and four as the second stage. The launch mass of the booster would be 1,500 tons. A subsequent version would replace the R-9's standard RD-111 engines with more powerful ones and have a launch mass of 2,000 tons.[94] In an April 1960 letter to Korolev on the proposal, Glushko ended on a dramatic note: ". . . any other decision [other than proceeding with the R-9-based launcher] will strike a blow to the priority and prestige of Soviet attempts to conquer space. . . ."[95] Korolev was not impressed, and he sent back an official letter the following month evidently rejecting Glushko's proposal.

For almost two months beginning early February 1960, Korolev ensconced himself with his leading deputy chief designers—Vasiliy P. Mishin, Sergey S. Kryukov, and Boris Ye. Chertok—to hammer out the details of a new "big space plan." Initially, the four explored a 1,600-ton booster with a nuclear engine as the second stage. This idea, although tempting, was tempered by the uncertainty about nuclear propulsion technology at the time.[96] As a result of these studies, the men enumerated three preliminary operational goals for the new launch vehicle:

- Defense-related projects in low-Earth orbit
- The creation of a global system of space-based communications and weather-forecasting satellites
- The exploration of the Moon and the inner planets[97]

Although all the studies were carried out internally at OKB-1, the final recommendations of the group were apparently circulated to all the principal chief designers in March stating that OKB-1 had finalized all the primary requirements and operational characteristics and missions of the new booster. This initial proposal recommended using LOX propellants for all stages of the launch vehicle as well as nuclear, electric, and liquid hydrogen engines for the upper stages. Kryukov, responsible for assessing different configurations of a new launch vehicle, explored more conventional ideas of both longitudinal and transverse staging. The designers finally decided to dispense with the old cluster scheme as in the R-7 ICBM and proposed a tandem three-stage design. Initially, they agreed on a very broad range of specifications: launch mass of 1,000 to 2,000 tons and payload capability to low-Earth orbit of forty to eighty tons. Under pressure from Mishin, and with objections from Kryukov, Korolev agreed to invite other engine designers to participate in developing the booster—in particular, Chief Designer Kuznetsov of OKB-276, who had made a failed bid to develop engines for Korolev's R-9 ICBM. Apart from boosters, the designers produced an extensive list of plans for the piloted space program, such as developing ships with electric engines and systems for orbital assembly.

94. Vetrov, "Development of Heavy Launch Vehicles"; M. Rudenko, "The Moon Slips Away: Chronicles of an Unknown Race" (English title), *Ekonomika i zhizn* 45 (November 1991): 19. The latter source has a slightly different description of Glushko's new booster. According to one of Glushko's deputies, M. I. Osokin, Glushko proposed that "the first stage . . . would comprise of [sic] six blocks of the same diameter arranged in a circle, of the R-7 or the R-9, but augmented in length and having the RD-111 engine from the R-9 installed in each block. The central block, also augmented, would have one RD-111 engine installed, but for high altitude use and high altitude firing. . . ." The two Glushko proposals were known as the R-10 and the R-20, respectively, and both used the LOX-unsymmetrical dimethyl hydrazine propellant combination.

95. Rudenko, "The Moon Slips Away."

96. Chertok, *Rakety i lyudi: Fili Podlipki Tyuratam*, pp. 344–45.

97. Dolgopyatov, Dorofeyev, and Kryukov, "At the Readers' Request: The N1 Project."

When Glushko first saw the plan, he immediately rejected Kuznetsov's participation in developing the booster and evidently made an aborted attempt at getting Yangel to offer a competitive proposal. Eventually, he changed his mind and sided with the remaining council members.[98] By early April, Korolev prepared a draft of his proposal in the form of an official Central Committee and Council of Ministers decree, which he sent to the Military-Industrial Commission with the agreement of eight chief designers. Within days, he decided to completely revise his conceptions when he realized that his future in space would depend heavily on Chelomey's rising ambitions.[99] Perhaps with knowledge of Chelomey's recent meeting with Khrushchev in Crimea, Korolev ceded some of his monopoly over the new Soviet space program. In a revamped version of his draft decree, dated May 30, 1960, Korolev grudgingly included Chelomey's design bureau as a leading player in the *piloted* space effort. OKB-1 retained its griphold on the development of a super heavy-lift launch vehicle. Korolev met with Khrushchev in early June 1960 to explain the booster proposal. He emphasized both its military utility as well as more grandiose plans for the exploration of the Moon, Mars, and Venus. The payload capability would be ten times more than any existing booster, and Korolev promised that the booster would be ready by 1963, if given the necessary resources. In a departure from common practices, Korolev named his new projected series of boosters, "N," denoting *nosityel*, the Russian word for "carrier."

The Central Committee and the USSR Council of Ministers signed the "big space plan" into law on June 23, 1960, as decree number 715-296. Titled "On the Creation of Powerful Carrier-Rockets, Satellites, Space Ships and the Mastery of Cosmic Space in 1960–67," it was the blueprint for the Soviet space program in the 1960s.[100] Although the actual decree remains classified, Korolev's original draft for the "big space plan" has been published; it seems that many, if not all, of the original points from Korolev's plan were enthusiastically approved by the Soviet Communist Party and government following Khrushchev's sudden about-turn on the space program. The draft itself remains a remarkable record of the stunning ambition of the early Soviet space program. The eleven-point decree had four major sections:

- Enumeration of the major thematic directions of work
- Enumeration of timeframes for future activities
- Robotic exploration
- Earth satellites[101]

The core of the plan was the OKB-1 proposal to develop a series of heavy boosters to support various military and civilian programs. Tailored to fit a variety of missions, a general upper payload limit of seventy to 100 tons to a 300-kilometer orbit was specified in the decree. Launch mass would vary between 1,000 to 2,000 tons, depending on the variant. Engineers would carry out initial planning and design work for the boosters during 1960–62, concurrent with research

98. Chertok, *Rakety i lyudi: Fili Podlipki Tyuratam*, p. 345.

99. The text of the first version of the plan, dated April 12, 1960, has been reproduced in full as "Planning Decree of TsK KPSS and the Council of Ministers for the Future Mastery of Cosmic Space" (English title), in Raushenbakh, ed., *S. P. Korolev i ego delo*, pp. 289–93. Korolev's attached cover letter, dated April 7, 1960, is also reproduced in the same source on pp. 287–89. The eight chief designers were V. P. Barmin, A. F. Bogomolov, V. P. Glushko, N. D. Kuznetsov, V. I. Kuznetsov, A. M. Lyulka, N. A. Pilyugin, and M. S. Ryazanskiy.

100. Vetrov, "The Difficult Fate of the N1 Rocket"; N. P. Kamanin, *Skrytiy kosmos: kniga pervaya, 1960–1963gg* (Moscow: Infortekst IF, 1995), p. 19.

101. The Korolev proposal for the decree, dated May 30, 1960, has been published as "Planning Decree for TsK KPSS and Council of Ministers" (English title), in Raushenbakh, ed., *S. P. Korolev i ego delo*, pp. 295–301. Korolev's cover letter with the decree, published as "Letter to S. I. Vetoshkin and K. N. Rudnev" (English title), is in the same source on pp. 294–95.

on a new generation of chemical, nuclear, liquid hydrogen, and low-thrust electric rocket engines. In addition, the decree called for the development of new control, guidance, and communications systems, new launch complexes, ground command and control systems, anti-satellite battle systems, long-duration piloted spacecraft, and "systems for solving defense-related goals" by using navigation, geophysical, communications, and weather satellite systems. A large portion of the decree was clearly dedicated to military goals, reflecting the Soviet government's newfound interest in militarizing this new frontier. The decree called for the creation of a "military space station" not only for space-based reconnaissance but also full-fledged battles in space. Smaller "military satellite-ships" would conduct radar reconnaissance and have the capability to inflict damage to both earthly and space-based targets. Korolev added a paragraph proposing that these new rocket boosters could also be used to "significantly promote the development of peaceful science and culture," including the creation of radio and television broadcasting, weather, navigation, astronomy, and geophysical satellite systems.

The second portion of the document addressed specific projects. OKB-1 listed specifications for its new generation of heavy-lift boosters. There would be two launch vehicles:

Booster	Timeframe	Payload to Low-Earth Orbit	Payload to the Moon
N1 (or 11A51)	1960–62	40–50 tons	10–20 tons
N2 (or 11A52)	1963–67	60–80 tons	20–40 tons

The N2 vehicle would use liquid hydrogen, ions, plasma, and nuclear engines in its upper stages. These rockets would allow three new *piloted* projects to be implemented, all also developed by OKB-1:

Project Designation and Description	Period	Goals (all would have crews of two to three cosmonauts)
Object KS (piloted heavy satellite ship)	1961–63	Reconnaissance and anti-satellite missions; would also have a "civilian" variant
Object KL (piloted lunar ship)	1961–64	Circumlunar and lunar orbital missions
Object KMV (piloted interplanetary ship)	1962–65	Circumplanetary missions to Mars and Venus

Among the projects addressed in the second portion of the decree were the development of robotic probes to the Moon, Mars, and Venus and new uprated launch vehicles using the R-7 and R-9 ICBMs. Draft plans for both new launch vehicles would be ready by 1961, with flights initiated the following year. The third part called for the further development of the existing Object K spacecraft in four versions: for piloted missions in 1960 and 1961, for automated photo reconnaissance from 1961 to 1963, for scientific research in 1960 through 1962, and for rendezvous and docking in orbit in 1961 through 1963. All would be launched by R-7–based launch vehicles. Korolev also included a point on the development of a scientific satellite named Elektron to study Earth's radiation belts. Three subsections detailed new developments in small Earth-orbiting satellites for communications, meteorology, and scientific research given to other organizations, such as Yangel's OKB-586.[102] All this was to be accomplished from 1960 to 1967, with OKB-1 as the primary contractor for most of the projects.

In retrospect, it is clear that the decree was hastily put together, wildly ambitious, and remarkably unrealistic. Attempting to take advantage of the favorable conditions that existed for a few months in 1960, the Council of Chief Designers proposed a macro-level plan that completely ignored the limitations of national economic resources as well as organizational barriers. The latter was of particular importance because few of the institutional changes recommended by Korolev and Keldysh, in their 1959 letter to the government, were addressed in the decree. The space program remained an arm of the defense industry, and its future course remained intertwined in the needs, policies, and actions of individuals whose first priority was much more earthly in nature. Thus, such grandiose goals as *piloted* flight to the Moon and planets, which had no obvious military utility, generated zero interest from the primary financiers of the space program, the Ministry of Defense.

Like Korolev, Chelomey had also proposed a mix of "civilian" and military space programs. Government officials had evidently worked on the details of Chelomey's specific programs after the important April 1960 meeting with Khrushchev in Crimea:

- An automated Kosmoplan (Object K) would be developed for flight to the Moon, Mars, and Venus, capable of returning to Earth on a conventional runway. The spacecraft would use high-energy liquid propellant, nuclear, plasma, and ion engines. Two variants were projected, one with a mass of ten to twelve tons and a more advanced twenty-five-ton model for flight in 1965 or 1966.
- A draft plan would be completed by 1962 for a new space launch vehicle with a mass of 600 tons for launching the Kosmoplan.
- A naval reconnaissance satellite (Object US) would be developed in 1962 through 1964 to aid in targeting Chelomey's P-6 anti-ship missile against U.S. naval assets.
- A Raketoplan (Object R) would be developed for Earth-orbital flights, capable of landing on any conventional airfield. The spacecraft would have a mass of ten to twelve tons and a flight range of 2,500 to 3,000 kilometers. The robotic variant would be ready by 1960 or 1961, the piloted variant between 1963 and 1965, and the military anti-satellite variant between 1962 and 1964.[103]

These and other projects from Chelomey were the subject of a second decree (no. 715-295) issued on the very same day as Korolev's "big space plan." In Chelomey's case, the actual decree approved the creation of the piloted spaceplane, the Raketoplan, whose primary mission

102. "Planning Decree for TsK KPSS and Council of Ministers," *op. cit.*; Boris Arkadyevich Dorofeyev, "History of the Development of the N1-L3 Moon Program," presented at the 10th International Symposium on the History of Astronautics and Aeronautics, Moscow State University, Moscow, Russia, June 20–27, 1995; M. Chernyshov, "Why Were Soviet Cosmonauts Not on the Moon?" (English title), *Leninskoye znamya*, August 1, 1990, p. 3. There is one source that purports to contain descriptions from the *actual* decree. See Golovanov, *Korolev*, pp. 710–11. According to this source, the details of the decree were slightly more ambitious, including the development of an Earth-orbital spaceship for crews of two to three people, automatic lunar satellites, and automatic lunar landers that would return to Earth. Also listed were research on carrying out piloted expeditions to the Moon to investigate its terrain, the selection of sites for establishing lunar settlements, and, after construction of such a base, the creation of a transport system for the Earth-Moon-Earth route. At the same time, a spaceship would be developed for crews of two to three people to carry out orbital missions to Mars and Venus, which among other things would select locations for future research bases on the surface. After these bases were established, regular interplanetary flight of crews would begin. A separate paragraph was allegedly also dedicated to launching automatic spaceships to the outer planets—in particular, Jupiter.

103. "Planning Decree for TsK KPSS and Council of Ministers," *op. cit.*

was to conduct anti-satellite missions in Earth orbit.[104] Additional decrees in October 1960 and March 1961 dramatically bolstered Chelomey's presence in the Soviet space program by formally initiating his works on the "IS" robotic anti-satellite spacecraft system, the "US" naval reconnaissance system, and the UR-200 ICBM/space launch vehicle.[105]

Chelomey's overt pandering to military interests clearly played in his favor. Within a span of less than a year, Chelomey had entered as a serious competitor to Korolev in almost every area of the space and missile programs—from ICBMs to piloted spacecraft, from interplanetary probes to military space systems. Chelomey's new empire was not limited to future creations but also to more earthly assets, such as the absorption of the Myasishchev design bureau, OKB-23, and its associated Plant No. 23, in October 1960. At the same time, the June 1960 decree also allocated huge amounts of funds to begin large-scale construction at OKB-52's premises at Reutov.[106]

The climate of the Soviet space program changed dramatically in the course of the three years after the launch of the first Sputnik. From a few isolated projects in 1957, by 1960 it was poised to expand into a large-scale undertaking far in excess of what was planned in the United States at the time. The internal nature of power and influence had also evolved. Where Korolev once was the only player in the game, there was fragmentation and competition. In the Western sense of the word, competition had the connotation of a proactive plurality of opinions, which fostered creativity and efficiency. In the centralized and socialist Soviet system, with resources restricted by the needs of the defense sector, it gave rise to chaos.

In 1957, Korolev had a singular vision of a Soviet space program moving across the great expanse. By 1960, Chelomey had made his entry with a plethora of competitive proposals, which in some cases were diametrically opposed to those of Korolev. Korolev's favored engine designer, Glushko, had arrived as a powerful force of his own, but estranged from his former friend. Finally, Yangel had taken Korolev's place as the favorite missile designer, thus shifting allegiances in the military, the primary financiers of the space program. All this, of course, happened behind a wall of secrecy. Only the best and the brightest were shown to the public. In that respect, the crowning achievement of the public Soviet space program was still to come.

104. *Ibid.*

105. There is evidence to suggest that the Soviet government may have approved preliminary research on the IS, US, and UR-200 systems in the same June 1960 decree. See Sergey Khrushchev, *Nikita Khrushchev: krizisy i rakety: uzglyad iznutri: tom 2* (Moscow: Novosti, 1994), p. 50. Note that the author states that the decree in support of these programs was in *July* 1960, not June 1960. This seems to be a typographical error. The robotic "IS" satellite program was officially initiated by a Communist Party and government decree on October 3, 1960. See Raushenbakh, ed., *S. P. Korolev i ego delo*, p. 680; N. S. Simonov, *Voyenno-promyshlennyy kompleks SSSR v 1920–1950-ye gody: tempy ekonomicheskogo rosta, struktura, organizatsiya proizvodstva i upravleniye* (Moscow: ROSSPEN, 1996), p. 301. The "US" program was approved by two decrees, on March 16, 1961 (no. 420-174), and on June 3, 1962. See Mikhail Rudenko, "Designer Chelomey's Raketoplans" (English title), *Vozdushniy transport* 48–49 (1995): 8–9. The development of the UR-200 ICBM/launch vehicle was officially approved by decrees on March 16, 1961, and August 1, 1961. See I. Afanasyev, "35 Years for the 'Proton' RN" (English title), *Novosti kosmonavtiki* 1-2 (1998): 45–48.

106. Yefremov, "NPO Mashinostroyeniya is Moving."

Chapter Seven
Gagarin

In the three years from 1958 to 1960, a continuous series of proposals and counterproposals set the stage for establishing policy directions for the new Soviet space program. If, at the time of the first Sputnik, the space program was a minor offshoot of the ballistic missile effort, then by 1960 it began to emerge as a separate field ready for exploitation and support. Because of its origins in the rocketry program, the military's involvement in the space effort continued to be pervasive. The piloted component of the Soviet space program had in fact risen hand-in-hand with the development of the first Soviet reconnaissance satellite. And when it came time to select volunteers for the first outbound voyages into space, it was once again the armed forces that served as a pool for qualified individuals.

The Cosmonauts

Discussions on the type of passengers to be used for the first orbital space missions began concurrently with the January 1959 decree calling for biomedical preparations for human spaceflight. Four months later, representatives from the military, the science sector, and the design bureaus met at the offices of the Academy of Sciences, under Vice-President Keldysh's supervision, to discuss means and standards for selecting volunteers for the space missions. The attendees considered individuals from a variety of professional backgrounds, such as aviation, the Soviet Navy, rocketry, and car racing. It was at the insistence of Air Force physicians that Keldysh approved a plan to narrow the pool to only qualified Air Force pilots. The doctors convincingly argued that Air Force training, which included exposure to hypoxia, high pressure, g-loads along various axes, and ejection seat experience, would all be relevant to training for space missions.[1] One other factor may have also affected the decision to choose pilots. In April 1959, NASA selected its first astronauts, all seven coming from aviation backgrounds in the American armed forces.

The Soviet Air Force issued a document at the time, titled "Directive of the General Staff of the [Air Force] for the Selection of Cosmonauts," which entrusted a Deputy Commander-in-Chief of the Air Force, Col. Gen. Filipp A. Agaltsov, with the administrative duties to carry out the task. Agaltsov's job was made easier by the fact that the space medicine group at the Air Force's Institute of Aviation Medicine had had a long history of involvement in the rocketry business. Led by the ubiquitous Lt. Col. Yazdovskiy, this team developed basic and initial requirements for the candidates in coordination with OKB-1 engineers. At an early meeting to

1. Yu. A. Mozzhorin *et al.*, eds., *Dorogi v kosmos: II* (Moscow: MAI, 1992), p. 144.

discuss these specifications, Chief Designer Korolev presented the specifications for the would-be "cosmonauts." The men, and only men were considered, were to be between twenty-five and thirty years of age, no taller than 1.70 to 1.75 meters, and with a weight no more than seventy to seventy-two kilograms—all requirements sufficient to allow for accommodation in the small 3KA capsule, the piloted variant of Object K. Korolev was candid about the skills of these would-be cosmonauts:

As has been repeatedly demonstrated in our automated flights and those with animals on board, our technology is such that we do not require, as the American Mercury project does, that our early cosmonauts be highly skilled engineers. The American astronauts must help control the rocket systems at every stage of the flight.[2]

While this was strictly not true, it was an indication of the depth to which automation was an intrinsic factor in the early Soviet piloted space program. During the entire selection phase, Korolev emphasized repeatedly that one of the primary criteria for the pilots would be the necessity to carry out precisely programmed functions—a requirement that in truth left the candidates with much less control than they would have had flying a simple aircraft. The final specifications for the future cosmonauts were frozen by June 1959 in a document approved by three Air Force institutions—the Institute of Aviation Medicine, the Central Scientific-Research Aviation Hospital, and the Central Commission for Aviation Medicine—as well as the USSR Academy of Sciences and the USSR Academy of Medical Sciences.[3]

Yazdovskiy's team at the Institute of Aviation Medicine, being a large group of physicians with a variety of interests, had been organized into different departments for the selection process, with sections for general physiology, psychology, life support systems and hygiene, and the actual selection of candidates. Yazdovskiy appointed Nikolay N. Gurovskiy and Yevgeniy A. Karpov, two Air Force physicians, to oversee the candidate selection process.[4] Groups of doctors in pairs were then sent to a number of major Air Force bases in the western Soviet Union. Doctors at the bases were also consulted on the issue, and by August, the selection process had commenced with inspections through the records of more than 3,000 pilots. Most were eliminated at an early stage because of height, weight, and medical history. Grounds for exclusion, based on the last criterion, included certain diseases such as chronic bronchitis, angina, predisposition to gastritis and colitis, renal and heptic colic, and pathological shifts in cardiac activity. The remaining pilots were then interviewed beginning September 3 with questions on their health, goals, moods, work, and quality of life. Even at this point, none of the volunteers were aware of the nature of the mission, which was disguised under the euphemism of "special flights." Gurovskiy recalled later:

The conversation [with the pilots] had nothing whatsoever to do with space. Some officers had no idea what we were getting at and why we had come, while others on the contrary got the point immediately and asked permission to consult with their family.

2. Yevgeni Karpov, "Beginnings," in Viktor Mitroshenkov, ed., *Pioneers of Space* (Moscow: Progress Publishers, 1989), p. 18.

3. Mozzhorin, *et al.*, eds., *Dorogi v kosmos: II*, p. 147.

4. Each doctor at the institute was assigned a specialty in the field of space biomedicine in preparation for piloted missions. They were: V. I. Yazdovskiy (chief), O. G. Gazenko (physiology), A. M. Genin and A. D. Seryapin (hygiene and life support systems), F. D. Gorbov (psychology), and N. N. Gurovskiy and Ye. A. Karpov (selection and preparation of cosmonauts, which was the Department 7 at the institute). Apart from the Air Force's Institute of Aviation Medicine, the Central Scientific-Research Aviation Hospital (TsNIAG) and the Central Commission for Aviation Medicine (TsVLK) were also involved in the preliminary stages of cosmonaut selection.

We had to absolutely forbid this: it was a new, top-secret project, and the prospectus had to make the decision himself, without outside assistance.[5]

Just over 200 individuals passed this early screening and were then sent in groups of twenty for further testing at the Central Scientific-Research Aviation Hospital in Moscow. Testing under the "Theme No. 6" program formally began on October 3. Scores of individuals dropped out of the race at this point as the resilience and will of the young Air Force pilots faltered in the face of the extremely demanding and rigorous tests. Apart from further interviews, there were a number of physical tests. One involved spinning the pilot in a stationary seat to test the vestibular apparatus. Another subjected the volunteers to low pressure in a barometric chamber. A third was a classical centrifuge to test high gravity loads. It seems that original plans called for a small group of seven or eight pilots, but Korolev insisted on tripling this number because he wanted a group much larger than the NASA astronaut team. At the end of 1959, a team of doctors approved twenty men to serve as candidates for the first team of cosmonauts.[6] They were told to return to their units to await further orders.

On January 11, 1960, Soviet Air Force Commander-in-Chief Marshal Konstantin A. Vershinin formally signed plans to establish a center exclusively dedicated to the training of the cosmonauts for the upcoming piloted flights. The directive called for the use of an old two-story building situated on the premises of the M. V. Frunze Central Airfield on Leninskiy Prospekt in Moscow. Institutionally, the new center, officially called the Cosmonaut Training Center (TsPK), was subordinated to the Air Force's Institute of Aviation Medicine. The thirty-eight-year-old Karpov, who had been involved in cosmonaut selection, was appointed the first Director of TsPK by official order on February 24.[7] The initial staff at the facility numbered about 250. Although the new center was nominally under the control of physicians, the Air Force General Staff ultimately exercised total supervision of all cosmonaut affairs via one high-ranking officer who would become one of the most prominent personalities in the history of the Soviet human space program, Nikolay Petrovich Kamanin.

A lieutenant general in the Soviet Air Force, Kamanin was well known to the Soviet populace even before the existence of the Soviet space program. As a twenty-five-year-old pilot in February 1934, he had led a daring rescue mission to the Arctic to save the crewmembers of the ship *Chelyushkin*, who had been stranded on floating ice.[8] For this particular act, Kamanin had the distinction of being the very first Soviet citizen bestowed with the "Hero of the Soviet Union" title, an honor reserved for great acts of bravery. By the late 1950s, Kamanin was serving as the first deputy chairman of a voluntary youth organization dedicated to training boys and girls for future service in the armed forces. Clearly, his stature as a famous public aviator was crucial to his appointment because it seems that he had not been involved in any significant high-priority military projects in his entire career. He was relieved of his previous duties at

5. Col. V. Gorkov, "History of the Space Program: Resident of Startown" (English title), *Aviatsiya i kosmonavtika* no. 1 (January 1990): 20–23.

6. Mozzhorin, *et al.*, eds., *Dorogi v kosmos: II*, pp. 147-148; Christian Lardier, *L'Astronautique Soviétique* (Paris: Armand Colin, 1992), pp. 125–26. The selection commission included V. I. Yazdovskiy, N. N. Gurovskiy, Ye. A. Karpov, and F. D. Gorbov from the Institute of Aviation Medicine and K. F. Borodin, I. I. Bryanov, Ye. A. Fedorov, and M. D. Vyadro from TsNIAG and TsVLK.

7. Gorkov, "History of the Space Program"; V. Ponomarenko and I. Alpatov, "Our Contemporaries: The Source of Cosmonautics" (English title), *Aviatsiya i kosmonavtika* no.12 (December 1990): 38–39. Karpov's deputies at TsPK were Air Force officers N. F. Nikersayov (political worker), Ye. Ye. Tselikin (director of flight training), V. V. Kovalev (head of the training section), and A. I. Susuyev (head of the logistics section). TsPK's "real" designation was the military unit no. 26266.

8. Pavel Popovich and Alexander Nemov, "Galactic Secrets," in Mitroshenkov, ed., *Pioneers of Space*, pp. 200–01.

the time and officially appointed the Deputy Chief of the Air Force's, General Staff for Combat Preparations. His duties included supervising the selection, training, and administration of the new cosmonauts and reporting directly to the high command of the Air Force, including Commander-in-Chief Marshal Vershinin.[9] Although the junior Karpov officially headed the Cosmonaut Training Center, it was effectively the fifty-one-year-old Kamanin who controlled its most important activities. For the following ten years, no Soviet cosmonaut would get off the ground without his blessing.

On February 25, Kamanin formally approved the final short list of twenty candidate cosmonauts selected by the end of 1959. These young men, along with seven others across the world, represented the first group of people to prepare for voyages into outer space. The twenty were:

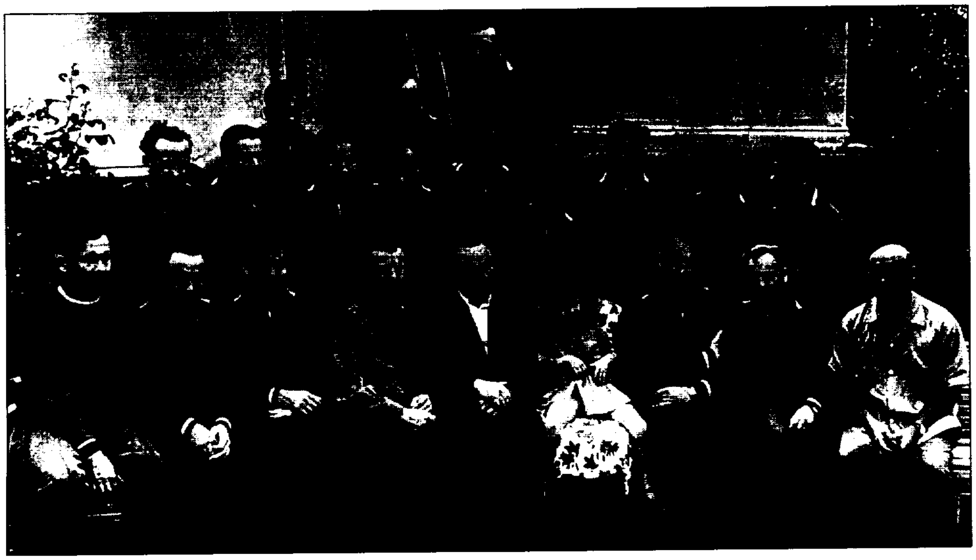
- Senior Lieutenant Ivan N. Anikeyev (twenty-seven years old)
- Major Pavel I. Belyayev (thirty-four)
- Senior Lieutenant Valentin V. Bondarenko (twenty-three)
- Senior Lieutenant Valeriy F. Bykovskiy (twenty-five)
- Senior Lieutenant Valentin I. Filatev (thirty)
- Senior Lieutenant Yuriy A. Gagarin (twenty-five)
- Senior Lieutenant Viktor V. Gorbatko (twenty-five)
- Captain Anatoliy Y. Kartashov (twenty-seven)
- Senior Lieutenant Yevgeniy V. Khrunov (twenty-six)
- Captain Engineer Vladimir M. Komarov (thirty-two)
- Lieutenant Aleksey A. Leonov (twenty-five)
- Senior Lieutenant Grigoriy G. Nelyubov (twenty-five)
- Senior Lieutenant Andrian G. Nikolayev (thirty)
- Captain Pavel R. Popovich (twenty-nine)
- Senior Lieutenant Mars Z. Rafikov (twenty-six)
- Senior Lieutenant Georgiy S. Shonin (twenty-four)
- Senior Lieutenant German S. Titov (twenty-four)
- Senior Lieutenant Valentin S. Varlamov (twenty-five)
- Senior Lieutenant Boris V. Volynov (twenty-five)
- Senior Lieutenant Dmitriy A. Zaykin (twenty-seven)[10]

Of the group, five had not met the age criteria of being between 25 and 30, but this condition was waived because of their performances in the selection procedures. Two in particular, Belyayev and Komarov, were the most educated and experienced members of the team, having already graduated from Air Force academies. Because of the age restriction, none of the selected were test pilots, unlike some of their U.S. colleagues. Komarov had some experience as a test engineer flying new aircraft, but the most experienced pilot, Belyayev, had accrued only 900 hours of flying time. Others such as Gagarin had flown only 230 hours. Only one pilot, Popovich, had flown what was then considered a high-performance aircraft, the MiG-19.[11] To a large extent, this was a direct result of the high degree of automation in Soviet piloted

9. Kamanin nominally reported to four Air Force officers: his immediate superior Air Force General Staff Chief Col. Gen. P. I. Brayko, Air Force Deputy Commander-in-Chief Col. Gen. F. A. Agaltsov, Air Force First Deputy Commander-in-Chief Marshal S. I. Rudenko, and Vershinin.

10. "At the Request of the Readers: Detachment of Air Force's Cosmonauts" (English title), *Aviatsiya i kosmonavtika* no. 5 (May 1990): 46–47.

11. Yaroslav Golovanov, *Korolev: Fakty i mify* (Moscow: Nauka, 1994), p. 605; Rex Hall, "Soviet Air Force Cosmonauts," in Michael Cassutt, ed., *Who's Who in Space: The International Space Year Edition* (New York: Macmillan, 1993), p. 210.



The original 1960 group of cosmonauts is shown in a photo from May 1961 at the seaside port of Sochi. The names of many of these men were considered state secrets for more than twenty-five years. Sitting in front from left to right: Pavel Popovich, Viktor Gorbatko, Yevgeniy Khrunov, Yuriy Gagarin, Chief Designer Sergey Korolev, his wife Nina Koroleva with Popovich's daughter Natasha, Cosmonaut Training Center Director Yevgeniy Karpov, parachute trainer Nikolay Nikitin, and physician Yevgeniy Fedorov. Standing the second row from left to right: Aleksey Leonov, Andrian Nikolayev, Mars Rafikov, Dmitriy Zaykin, Boris Volynov, German Titov, Grigoriy Nelyubov, Valeriy Bykovskiy, and Georgiy Shonin. In the back from left to right: Valentin Filatyev, Ivan Anikeyev, and Pavel Belyayev. Four cosmonauts were missing from this photograph. Anatoliy Kartashov and Valentin Varlamov had both been dropped from training because of injuries. Valentin Bondarenko died in a training accident a few months before. Vladimir Komarov was indisposed. The original photo was taken by I. Snegirev. (files of Asif Siddiqi)

spaceships; there was simply no requirement for significant piloting experience or skill at that point. The candidates had to be intelligent, comfortable with high-stress situations, and most of all physically fit.

In late February 1960, twelve of the twenty selected cosmonaut candidates arrived for final medical tests at the Central Scientific-Research Aviation Hospital. It was there on March 7 that Marshal Vershinin gave a welcome speech, which one witness characterized as "parting words prior to departure on a long, difficult journey."[12] The same day, Kamanin signed final orders officially inducting them into the cosmonaut team and instructing them to return to their Air Force units, settle all pending matters, and then arrive at the new training center. Orders for the remaining eight trainees were signed between March 9 and June 17, 1960, after which all twenty were permanently stationed at the center.[13] Training classes for the candidates began at 0900 hours Moscow Time on March 14 with an introductory lecture from physician Yazdovskiy. During the initial four months, the training was evenly divided between a heavy emphasis on academic disciplines and general daily physical fitness regimes. The latter included two hours

12. Gorkov, "History of the Space Program."

13. The first twelve to officially join the team on March 7, 1960, were Anikeyev, Bykovskiy, Gagarin, Gorbatko, Komarov, Leonov, Nelyubov, Nikolayev, Popovich, Shonin, Titov, and Volynov. Khrunov joined on March 9, Zaykin and Filatyev joined on March 25, Belyayev, Bondarenko, Rafikov, and Varlamov joined on April 28, and Kartashov joined on June 17. Their official orders were signed by Commander-in-Chief of the Soviet Air Force Marshal K. A. Vershinin. See V. Semenov, I. Marinin, and S. Shamsutdinov, *Iz istorii kosmonavtiki: vypusk I: nabory v otryady kosmonavtov i astronavtov* (Moscow: AO Videokosmos, 1995), p. 12.

of intensive calisthenics per day initially conducted at the Central Army Stadium in Moscow. In later months, a dedicated exercise facility was built on the premises of the training center itself. To provide a distinct link between the spacecraft they would be flying and their training, three times a week, various engineers from OKB-1 and other leading space firms served as part-time lecturers at the center, teaching classes covering rocket-space systems, space biomedicine, navigation, radio communications, geophysics, and astronomy.[14]

Parachute training, which prepared the cosmonaut-trainees for both emergency and nominal mission events, was commenced on April 13, when most of the pilots were flown to the Saratov region near Engels to begin jumps from a converted An-2 aircraft. Within about six weeks, each had made approximately forty to fifty jumps, and became acclimated to landing on water and land, from high and low altitudes, and in nighttime conditions.[15] At the same time, trainee Bykovskiy became the first individual to undergo a fifteen-day-long test in the TBK-12 anechoic chamber, beginning April 6, to simulate the effects of complete psychological isolation. Other medical testing included the use of the *Khilov* swing to test the vestibular apparatus, the *Barani* and *Rotor* rotating armchairs, a low-pressure barometric chamber to simulate altitudes of up to twelve kilometers, a centrifuge capable of inducing up to ten g's, and a thermal chamber to subject the trainees to temperatures up to seventy degrees Centigrade for one or two hours. Regular medical tests were administered before and after each exercise. Not surprisingly, of all the training regimes, the cosmonauts were most resistant to the medical and endurance tests, and it apparently took much convincing for them to agree to subject themselves to the never-ending series. To maintain their piloting skills, the trainees were allowed to fly MiG-15UTI trainer aircraft under the supervision of Mark L. Gallay, one of the most renowned test pilots in the Soviet Union, on loan from the prestigious M. M. Gromov Flight-Research Institute at Zhukovskiy. Under Gallay's direction, the trainees flew parabolic trajectories to simulate microgravity for periods up to thirty seconds in specially equipped Tu-104 aircraft.[16]

Because of the space limitations of the existing facilities for training, the Air Force tasked the staff at the new center to explore the possibility of moving to a location more amenable to the needs of cosmonaut training. Officers initially recommended two potential sites near Moscow: one at Balashikha and the other near the Tsiolkovskiy Railway Station at Shelkovo. After assessing the pros and cons, the Air Force decided to move the entire training program to the latter area because of its isolated location and large area. The proximity to several key facilities, including OKB-1, a large housing complex, the Academy of Sciences, and the Monino airfield were also important factors in the selection. The staff of the training center and the cosmonauts formally relocated to the new location on June 29, 1960.[17] This new suburb of Moscow, about the thirty kilometers northeast of the capital city, was renamed Zelenyy ("Green"). The location is known, however, by its more recent name Zvezdniy Gorodok ("Starry Town" or "Star City"), the site where Russian cosmonauts and American astronauts trained during the 1990s and will be training in the early 2000s for flights to the Russian space station *Mir* and the International Space Station.[18]

14. In the initial stages, lecturers from OKB-1 included K. D. Bushuyev, K. P. Feoktistov, M. K. Tikhonravov, B. V. Raushenbakh, V. I. Sevastyanov, and Ts. V. Solovyev. Biomedicine lectures were initially given by O. G. Gazenko, V. V. Parin, and V. I. Yazdovskiy. See Mozzhorin, *et al.*, eds., *Dorogi v kosmos: II*, p. 150; Golovanov, *Korolev*, p. 610; A. Yu. Ishlinskiy, ed., *Akademik S. P. Korolev: Ucheniy, inzhener, chelovek* (Moscow: Nauka, 1986), p. 471.

15. Lardier, *L'Astronautique Soviétique*, p. 126; Golovanov, *Korolev*, p. 610. The parachute training was directed by TsPK instructors I. M. Dzyuba, M. I. Maksimov, N. K. Nikitin, A. K. Starikov, and K. D. Tayurskiy.

16. Vladimir Yazdovsky, "They Were the First," *Aerospace Journal* no. 2 (March–April 1996): 69–71; Lardier, *L'Astronautique Soviétique*, pp. 122, 126–27.

17. Gorkov, "History of the Space Program."

18. The location was renamed Zvezdniy Gorodok on October 28, 1968

As the basic training for the trainees neared completion, a rudimentary spacecraft simulator named the TDK-1, the first of its kind in the Soviet Union, was built at the M. M. Gromov Flight-Research Institute to allow training in various mission modes.[19] Because doctors believed that it would be inefficient to train all twenty men on one simulator at this early phase, Korolev, Karpov, and Kamanin recommended that the center staff select a core group of six pilots who would undergo accelerated training. This group would carry out the first piloted flights, while the remaining fourteen would continue basic training and fly at a later time. Some such as Volynov, who was too broad-shouldered, and Shonin, who was too tall, were not considered for the primary group. Komarov, who was clearly the strongest candidate, being an engineer and a capable pilot, would have been included on the team had it not been for a cardiac anomaly that doctors inadvertently detected during a training exercise. The Air Force eventually drew up a short list of six names on May 30, 1960. Informally titled "The Vanguard Six," they were Gagarin, Kartashov, Nikolayev, Popovich, Titov, and Varlamov. To meet with them, Korolev visited the center for the first time on June 18.[20] The cosmonauts had first learned of his existence only three months earlier, although even then he was simply referred to as the "chief designer" to conceal his identity. The Vanguard Six in turn repaid the honor with a visit to the OKB-1 premises the following month, thus for the first time seeing the spacecraft they were destined to fly.

The core group of six cosmonauts suffered their first casualties, both coincidentally in July 1960, soon after moving to the new location at Zelenyy. On July 16, following a centrifuge test of up to eight g's at TsPK, physicians discovered a reddening of trainee Kartashov's spine. Subsequent centrifuge tests confirmed the original diagnosis of hemorrhages, which implied weaknesses in his blood vessels. An otherwise completely healthy person, Kartashov was immediately dropped from the Vanguard Six, although he remained at the center continuing basic training with the other cosmonauts. Despite entreaties from his close friends, such as Titov, Kartashov was eventually dismissed from the team in April 1962 without having been assigned to any missions. Little more than a week after Kartashov's accident, on July 24, a second trainee from the inner six, Varlamov, was involved in a swimming accident at the Medvezhiy Lakes while swimming with two other pilots, Bykovskiy and Shonin. During a dive, Varlamov hit the bottom of the lake with his head and injured his spine. Following diagnosis, he was found to have a displaced cervical vertebra, which disqualified him from further training.[21] Nelyubov and Bykovskiy, respectively, took the positions of Kartashov and Varlamov. Bykovskiy was apparently favored because of his slight appearance, low weight, and high tolerance for g-loads.[22] Thus by the end of July, six men were in line to compete for the grand prize of being the first Soviet citizen in space: Gagarin, Bykovskiy, Nelyubov, Nikolayev, Popovich, and Titov. If all went according to Korolev's plan, one of them would also have the distinction of being the first person in space.

19. The simulator was designed and built by the State Experimental Design Bureau of the Flight-Research Institute (SOKB LII), headed by Chief Designer S. G. Darevskiy.

20. Rex Hall, "The Soviet Cosmonaut Team 1956–1967," *Journal of the British Interplanetary Society* 41 (1988): 107–10. A brief description of this first meeting can be found in Ishlinskiy, ed., *Akademik S. P. Korolev*, pp. 490–91.

21. Kartashov officially resigned from the cosmonaut team on April 7, 1962, following which he became a test pilot for the Ministry of Defense. He worked for many years at GSOKB-473 of O. K. Antonov before retiring. Varlamov officially resigned from the cosmonaut team on March 6, 1961. After his resignation, he served as a deputy chief of the center's spaceflight control post and later as a chief instructor. He died on October 2, 1980, the result of a brain hemorrhage.

22. Golovanov, *Korolev*, pp. 616–17; Yazdovskiy, "They Were the First."

Korabl-Sputnik

The testing program for the first Soviet piloted spacecraft began in 1960. By that time, the ship was given an actual name: Vostok ("East"). By April, OKB-1 engineers under Bushuyev and Tikhonravov had completed the draft plan for the first version, designated the 1K (or Vostok 1), essentially a "boilerplate" variant for testing the primary spacecraft systems in orbit. Also mentioned in the draft plan were the 2K (Vostok 2) and the 3K (Vostok 3). The former would be the automated reconnaissance satellite, while the latter would be the actual piloted spaceship. There was considerable pressure to accelerate the Vostok 3 schedule, primarily because of the stream of news on Project Mercury. By the early summer of 1960, NASA officials were expecting to fly the first *suborbital* piloted Mercury not before January 1961. This deadline marked an informal target for OKB-1; for Korolev in particular, it was absolutely imperative that the first piloted Vostok be in orbit prior to a *suborbital* Mercury. The "end of 1960" deadline was specified in an official document from the Soviet government, dated June 4, 1960, titled "On a Plan for the Mastery of Cosmic Space"; all testing for a piloted Vostok flight would be completed by December 1960.[23]

The testing program to support the attainment of this goal involved not only launching automated Vostok 1 and Vostok 3 capsules, but also firing a series of short-range missiles into the upper atmosphere to prove out various elements of the life support system and biological support instrumentation. While none of these lobs into space used the actual Vostok spacecraft, the flights made an important contribution to the progress of the Vostok program as a whole. Most of these launches were announced publicly by the Soviet media as being extensions of the IGY scientific program of 1957–58. Two different types of missiles were used for these experiments, the R-2A and the R-5A, both "scientific" variants of military ballistic missiles. At least five successful biological launches of the R-2A in 1957 were followed by six more from July 1959 to September 1960, all to altitudes of approximately 212 kilometers. Each carried two dogs.[24] A more advanced but less intensive program of launches was undertaken by the R-5A, which allowed the time in weightless conditions for the passenger dogs to be doubled. Four launches were carried out between February and October 1958, each carrying two dogs to altitudes of about 470 kilometers, a world record for a single-stage ballistic missile.

The success of the vertical launches of these missiles helped reinforce the confidence in the overall Vostok program. From a political standpoint, however, the piloted project was still in competition with more pressing military goals. Since late 1958, OKB-1 had been concurrently working on the parallel reconnaissance satellite effort designated Zenit. Although initially there was implicit support to emphasize the piloted portion, by early 1960, perhaps prompted by the changing strategic positions between the two superpowers, the Soviet government expressed increased impatience in the timetable for the surveillance project. At a meeting on January 9, 1960, Military-Industrial Commission Chairman Ustinov reminded the leaders of OKB-1 that "there was no goal more important at the present time" than the reconnaissance program.[25] The criticism was clearly aimed directly at Korolev's idealistic enthusiasm for piloted spaceflight, and it also underlined the growing rift between civilian and military goals in the Soviet space program. When the Council of Chief Designers had originally decided in late 1958 to bestow a higher priority to Vostok than Zenit, the Ministry of Defense was still

23. Yu. P. Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya "Energiya" imeni S. P. Koroleva* (Korolev: RKK Energiya, named after S. P. Korolev, 1996), p. 109.

24. This second series was inaugurated on July 2, 1959, and ended on September 22, 1960. See George E. Wukelic, ed., *Handbook of Soviet Space-Science Research* (New York: Gordon and Breach Science Publishers, 1968), p. 17. There were two additional failures in the program out of a total of thirteen launches.

25. B. Ye. Chertok, *Rakety i lyudi: Fili Podlipki Tyuratam* (Moscow: Mashinostroyeniye, 1996), p. 319.

relatively unsure of the requirement of space-based reconnaissance. That position had drastically changed in less than two years, possibly exacerbated by the launches of the U.S. spy satellite CORONA under the cover-name Discoverer.

The Vostok program as a whole achieved a significant milestone in the early summer of 1960, as the first flight-ready article was transported to Tyura-Tam for launch. Supervising the test program for Vostok was yet another *ad hoc* "State Commission," this one originally established to oversee the series of ongoing R-7A ICBM launches. Marshal Nedelin, the Commander-in-Chief of the Strategic Missile Forces, served as commission chairman, his presence underlining the unbridled influence of the military over a "civilian" project.

The first Vostok 1 article readied for launch was a subvariant designated the 1KP (or Vostok 1P), with the "p" denoting that it was a simple ("prostoy") spacecraft not designed to be recovered from orbit. The spacecraft had no thermal shielding for the spherical descent apparatus and no life support system. Instead of the large ejection seat that would carry a pilot, the spacecraft carried a mock-up of the contraption to simulate the correct loads. Unlike later Vostok spacecraft, two solar panels shaped like semicircles were installed on a boom heading out forward from the descent apparatus. This system, designated *Luch* ("ray"), would provide power to the spacecraft as an experiment to evaluate the effectiveness of solar power over chemical batteries.[26] The primary goal of the mission was to test the basic elements of the vessel, in particular the complex *Chayka* orientation system, which would put the spacecraft in the proper attitude for reentry. Although the vehicle would burn up on reentry, telemetry data would indicate whether the spacecraft had been properly angled. Total spacecraft mass was 4,540 kilograms.

Engineers began arriving at Tyura-Tam on April 28, 1960, in preparation for the flight, which was planned for early May. There were numerous problems with the Chayka system that threatened to delay the mission. Engineers delivered a flight-ready system several days late and installed it on the spacecraft only on May 5. Continuing anomalies with the system forced Marshal Nedelin to reschedule the launch on May 15, exactly three years after the first R-7 launch. It was an early morning launch with the Sun shining brightly in the sky when the 8K72 launch vehicle raced toward orbit with its Vostok 1P payload. The vehicle successfully entered a 312- by 369-kilometer orbit at an inclination of sixty-five degrees. As soon as they received news of successful orbital insertion, the senior members of the State Commission gathered to draw up a communiqué for the Soviet press. There was some indecisiveness over what to call the vehicle in the open media; Korolev livened the discussion by suggesting the use of the word *korabl* (ship): "There are sea ships, river ships, air ships, and now there'll be space ships!"[27] Although the term "space ship" was used for the first time in the official TASS news agency announcement on the mission, the craft itself was simply designated *Korabl-Sputnik* ("satellite-ship"). There was no indication that the mission had any relevance to a piloted space effort.

The flight, planned to last three or four days, proceeded without incident, with successful tests of the electrical and power source systems. Reentry, the most critical juncture of the mission, was scheduled for the early morning of May 19. Prior to the scheduled firing of the TDU-1 engine, the control group at Tyura-Tam (Group T) had detected anomalies in the primary system of attitude control, which used the infrared sensor. Although the system as a whole seemed to be functioning fine, the sensor itself was not responding correctly. The Tyura-Tam team reported the problem to the control group at Moscow (Group M), but the designer

26. The solar panel system was designed by the All-Union Scientific-Research Institute of Current Sources (VNIIT) headed by N. S. Lidorenko. See Lardier, *L'Astronautique Soviétique*, p. 123.

27. Chertok, *Rakety i lyudi*, p. 385. The other attendees were L. A. Grishin, A. Yu. Ishlinskiy, and M. V. Keldysh.

of the system, Boris V. Raushenbakh, refused to agree to Group T's recommendation to use the backup system of orientation. OKB-1 Deputy Chief Designer Boris Ye. Chertok, who was the head of Group T, quickly called a meeting at Tyura-Tam and reached a consensus that the primary system *not* be used, in favor of the still-operating solar-based *Grif* sensor. He then passed this recommendation on to Moscow. Although it seems that Korolev agreed with Chertok at first, he gave in after persuasive arguments by Keldysh and Raushenbakh to go ahead with the primary system. Unfortunately, on the sixty-fourth orbit, the primary system malfunctioned, and the fourteen thrusters working on compressed nitrogen (ten kilograms thrust each) inserted the spacecraft in the exact wrong attitude. The TDU-1 retrorocket automatically fired on time at 0252 hours Moscow Time, but the spacecraft, instead of reentering the atmosphere, was boosted into a new high orbit of 307 by 690 kilometers. The descent apparatus eventually decayed more than five years later on October 15, 1965. Korolev, indignant at the control error, slapped reprimands on several of his engineers, including Vostok designer Feoktistov.[28]

After a short investigation of the malfunction, OKB-1 opted to remove the infrared system from the Vostok 3A piloted variant of the spacecraft. Those spacecraft would instead be equipped with two systems: a solar-based automatic system and a manual system using Earth's horizon. The second Vostok 1 spacecraft readied for launch, while having the old set of orientation systems, was far more advanced than its modest predecessor; it was equipped with an operational life support system and a means of recovery. Two dogs, Chayka and Lisichka, were trained to fly into orbit on board. Korolev was particularly fond of Lisichka, a feeling that was evidently mutual; the usually calm dog would invariably become animated when Korolev would visit during prelaunch operations. The two dogs were launched on July 28, 1960, but the mission went awry right from the beginning. Just nineteen seconds after launch, the booster began "to fork to one side" as a result of a fire and a breakdown of the combustion chamber in one of the strap-on engines (in Blok G). The inert strap-on broke away from the main vehicle, and the booster eventually exploded into pieces at T+28.5 seconds. Although the descent apparatus separated from the stack, the explosion killed both passengers.[29]

The accident forced serious consideration for testing a launch escape system on the 8K72 booster. Tikhonravov's department, responsible for the design of the spacecraft, proposed a system in late August that would ensure that any on-board cosmonaut would have the capability to abort the mission at four different stages of the ascent to orbit. The first forty seconds of the launch were considered the most dangerous portion, and in the case of a booster malfunction, the pilot would eject from the capsule via a catapult and land separately by parachute.[30] The addition of a launch escape system as well as the change in orientation systems were unusual for a program whose flight testing had already *begun*. The Vostok program indeed had the odd distinction of being perhaps the only piloted space program whose draft

28. *Ibid.*, pp. 386–87; "The Program of Research Successfully Completed. TASS Communiqué on the Movements of the Korabl-Sputnik" (English title), *Pravda*, May 21 1960; Ishlinskiy, ed., *Akademik S. P. Korolev*, p. 513. The burn time of the engine was about twenty-six seconds, implying that the TDU-1 was shut down before a full burn, or it was also the victim of a malfunction.

29. Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p. 111; Chertok, *Rakety i lyudi*, p. 389; S. Shamsutdinov, "Sixty Years for Yu. A. Gagarin" (English title), *Novosti kosmonavtiki* 5 (February 26–March 11, 1994): 5–7; Timothy Varfolomeyev, "Soviet Rocketry that Conquered Space: Part 3: Lunar Launchings for Impact and Photography," *Spaceflight* 38 (June 1996): 206–08; S. P. Korolev, "On the State of the Experimental Work on 'Vostok' Ship" (English title), in B. V. Raushenbakh, ed., *Materialy po istorii kosmicheskogo korablya "Vostok"* (Moscow: Nauka, 1991), pp. 136–45. Note that the last source states that the failure occurred on July 23, 1960.

30. Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p. 113. Note that in Korolev's 1961 document summarizing the Korabl-Sputnik launches, he stated that the system was installed on all Vostok flights following the July 1960 accident, which implies that such a system was used on the August 1960 launch. See Korolev, "On the State of the Experimental Work," p. 136.

plan—that is, the technical document specifying its design—continually evolved over the period of the project.[31] This was no doubt attributable to the time constraints set in part by plans for Project Mercury.

The next Vostok 1 mission was set to carry two new dogs, Belka and Strelka, into orbit. Along with the dogs, there were numerous other biological specimens. The pressurized cabin contained twelve mice, insects, plants, fungi, cultures, seeds of corn, wheat, peas, onions, microbes, strips of human skin, and other specimens. In addition, there were twenty-eight mice and two white rats outside the ejection seat, but within the descent apparatus. Two internal TV cameras, developed by NII-380, would provide views of the dogs during the spaceflight. The spacecraft itself was fully equipped with a functioning catapult, a life support system, and parachutes. The launch, originally set for August 15, was delayed because of problems with an oxygen valve in the booster, but the dogs were finally sent on their way with a successful launch at 1144 hours 6 seconds Moscow Time on August 19. Upon successfully entering its 306- by 339-kilometer orbit at 64.96-degree inclination, the spacecraft was named the "Second Korabl-Sputnik." Total mass in orbit was about 4,600 kilograms. News of the launch was immediately relayed to the Hall of Columns during the minutes when judges were considering the sentence for American Francis Gary Powers, who was shot down by a Soviet S-75 missile system in May of the previous year.

Throughout the one-day mission, doctors continuously monitored the medical condition of the dogs while various parameters of the life support system were given a rigorous workout. Because there were two cameras aboard the spacecraft, Yazdovskiy's biomedical support group was able to observe the reactions of the dogs while in flight. The pictures coming back were not encouraging. Initially, the dogs appeared deathly still, and without the incoming data stream on their life signs, it would have been impossible to tell if they were alive or not. Later they became more animated, but their movements seemed convulsive. Belka squirmed and finally vomited on the fourth orbit. Yazdovskiy silently watched the video and gloomily reported to the State Commission that a flight with a cosmonaut be limited to one orbit and no longer. There were simply too many unknowns about the effects of weightlessness on the human organism.[32] A number of scientific experiments were carried out during the mission, including those for the detection of cosmic rays and the monitoring of high-energy emissions in the ultraviolet and x-ray wave lengths.

Telemetry showed that the infrared orientation system had failed once again. After a busy night verifying its capabilities, engineers recommended using the backup solar orientation system. The latter system performed without any anomalies on the spacecraft's eighteenth orbit, and the descent apparatus successfully entered Earth's atmosphere at the correct angle. The catapult system operated on schedule and ejected the cabin with the dogs in the mock-up of the ejection seat. The cabin landed safely by parachute only ten kilometers from the designated point of touchdown in the Orsk region in Kazakhstan after a one-day, two-hour spaceflight. Belka and Strelka thus became the first living beings recovered from orbit. The spacecraft itself was only the second object retrieved from orbit; the American Discoverer 13 had preempted Korabl-Sputnik 2 by nine days.[33] Doctors found both dogs in good condition despite the

31. The draft plan for the Vostok 3A spacecraft (the piloted variant) was officially completed on July 31, 1961, well after the first piloted orbital spaceflight.

32. Golovanov, *Korolev*, p. 622.

33. Discover 13 was a CORONA reconnaissance satellite diagnostic mission without on-board cameras. Note also that one source suggests that the descent apparatus of the Korabl-Sputnik 2 spacecraft landed as much as 200 kilometers from its target site. See Mozzhorin, *et al.*, eds., *Dorogi v kosmos: II*, p. 46.

concerns during the mission. Extensive physiological tests proved that there had been no fundamental changes in their health.

This particular flight of the Vostok 1 spaceship was a watershed moment and verified almost all the primary elements of the spacecraft design. Korolev returned to Moscow on August 28 to hear reports from Deputy Chief Designer Bushuyev and Group Chief Feoktistov on the progress of the design of the Vostok 3A piloted variant. Very satisfied with the work done, Korolev, in coordination with the other leading chief designers involved in the program (Glushko, Ryazanskiy, Pilyugin, Barmin, Kuznetsov, Bogomolov, Isayev, Kosberg, Alekseyev, and Yazdovskiy), prepared a document titled "Basic Status of the Development and Preparation of the Object 3KA (The Piloted Space Ship 'Vostok-3A')," which included listings and descriptions of all the major systems on the spaceship as well as a cyclogram for a nominal flight with contingency plans for all possible failures.[34]

The importance of the document, dated September 7, 1960, was not so much for its technical details, but because of the remarkable concern for safety of the pilot that comes through in each section of the report. One section is completely devoted to enumerating the redundancies and safety measures for each of the spacecraft's major systems, from the critical orientation systems to the tiny pyrotechnical cartridges on the ejection hatch. Finally, in what must have been Korolev's personal touch, the authors emphasized that previous management practices in the missile industry would no longer hold for the Vostok project because failure was an unacceptable outcome. The complete Vostok system consisted of a six-unit three-stage launch vehicle with as many as thirty-three thermally, statically, and dynamically loaded systems, such as turbopumps, for the rocket engines. The spacecraft itself consisted of 241 vacuum tubes, more than 6,000 transistors, fifty-six electric motors, and about 800 relays and switches interconnected by about fifteen kilometers of cable, in addition to 880 plug connectors having up to 850 contacts *per* connector. Clearly, the entire system could not be regarded as failure-proof. Here Korolev used his managerial technique to emphasize to each chief designer, plant director, and military operations manager that the life of a cosmonaut depended on his or her part of the work. The chain of responsibility was delegated down to the lowest ranked worker in the assembly shop. The eleven signatories of the document indirectly represented 123 organizations, including thirty-six plants, that were participating in the project.[35]

The preparation of this document proved to be the catalyst for a state-level intervention in the program. Three days later, on September 10, the ten most powerful leaders in the Soviet defense industry (led by Ustinov) and the armed forces, along with the six original core members of the Council of Chief Designers, signed and sent a document on the Vostok program to the Central Committee of the Communist Party. Declassified finally in 1991, the letter for the first time formally set a timetable for accomplishing the first piloted spaceflight. It began:

> *The successful launch, space flight, and landing of the spacecraft (the object "Vostok-1") sheds new light on the dates for performing a piloted flight into cosmic space. An analy-*

34. This document has been reproduced in its entirety as S. P. Korolev, V. P. Glushko, M. S. Ryazanskiy, N. A. Pilyugin, V. P. Barmin, V. I. Kuznetsov, A. F. Bogomolov, A. M. Isayev, S. A. Kosberg, S. M. Alekseyev, and V. I. Yazdovskiy, "Basic Status of the Development and Preparation of the Object 3KA (The Piloted Space Ship 'Vostok-3A')" (English title), in Raushenbakh, ed., *Materialy po istorii kosmicheskogo*, pp. 125–28.

35. Raushenbakh, ed., *Materialy po istorii kosmicheskogo*, p. 213. There was also another document titled "Regulations for the 3KA," which was issued in December 1960 and specified production and design responsibilities for each chief designer, plant director, and so on. See Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p. 565.

sis of the telemetric measurement data received during the flights of the "Vostok-1" suggests the possibility of creating normal living conditions for a human during space flight.[36]

The authors recommended that one or two further Vostok 1 flights be carried out in October–November 1960, followed by two automated missions of the Vostok 3A variant in November–December 1960. By December 1, the cosmonauts training for their mission would be ready, and a full-scale piloted flight could be accomplished in a Vostok 3A in December, in time to beat a Mercury launch. Unlike all earlier Soviet space projects, the fact that this document was signed by ministerial heads rather than the standard deputy ministers clearly underlines the importance with which the Soviet leadership viewed the program. If in 1959 there was some hesitation on the part of the government to fully commit to a piloted space program, by the end of 1960, those concerns had no doubt been overridden by the imminent threat of Project Mercury. Having consistently taken the lead in the early space race, the Soviet Union was forced to make efforts to continuously maintain that preeminence. Despite the national priority in strategic missiles, space had become an arena not only for military applications but also simply national pride. In a sense, the chest-beating self-congratulatory euphoria that had followed the launches of Sputniks and Lunas pushed the Soviet government into maintaining the image of the new advanced Soviet state. It was a race that they had started and were in no position to call off.

The petition by the sixteen leaders of the Soviet space program was received in the Central Committee of the Communist Party—that is, by Nikita S. Khrushchev and Frol R. Kozlov. Both approved the plan and issued a top-secret reply dated October 11, listing each of the ministerial jurisdictions of the signatories:

1. The proposal of the USSR Council of Ministers State Committee of Defense Technology, the USSR Council of Ministers State Committee on Radio-Electronics, the USSR Ministry of Defense, the USSR Council of Ministers State Committee for Ship Building, the USSR Council of Ministers State Committee for Aviation Technology, and the USSR Academy of Sciences, which has been examined and approved by the Commission of the Presidium of the USSR Council of Ministers for Military-Industrial Issues, on the preparation and launch of a spacecraft (the object "Vostok-3A") with a man on board in December of 1960, is approved, because it is a task of great importance.[37]

Thus the stage was set for the launch of the first human into space in the last month of 1960. It was an ambitious timetable. There was no precedent for the rapid pace of the schedule—OKB-1 had managed to conduct three launch attempts in three months in the summer of 1960, and that rate would have to be almost doubled. The decision was clearly made after

36. An edited version of this letter was published in V. Belyanov, L. Moshkov, Yu. Murin, N. Sobolev, A. Stepanov, and B. Stroganov, "Yuriy Gagarin's Star Voyage: Documents from the First Flight of a Human into Space" (English title), *Izvestiya TsK KPSS* 5 (1991): 101–29. The signatories to the document were (in order of their signatures): D. F. Ustinov (Chairman of the Military-Industrial Commission), R. Ya. Malinovskiy (Minister of Defense), K. N. Rudnev (Chairman of the State Committee for Defense Technology), V. D. Kalmykov (Chairman of the State Committee for Radio-Electronics), P. V. Dementyev (Chairman of the State Committee for Aviation Technology), B. Ye. Butoma (Chairman of the State Committee for Ship-Building), M. I. Nedelin (Commander-in-Chief of the Strategic Missile Forces), S. I. Rudenko (Deputy Commander-in-Chief of the Air Force), V. M. Ryabikov (Deputy Chairman of the RSFSR Council of Ministers), M. V. Keldysh (Vice-President of the USSR Academy of Sciences), S. P. Korolev (Chief Designer of OKB-1), V. P. Glushko (Chief Designer of OKB-456), M. S. Ryazanskiy (Chief Designer and Director of NII-885), N. A. Pilyugin (Chief Designer of NII-885), V. P. Barmin (Chief Designer of GSKB SpetsMash); and V. I. Kuznetsov (Chief Designer of NII-944).

37. This decree of the Central Committee of the Communist Party and the USSR Council of Ministers has been reproduced in full in *ibid.*, p. 103. The title of the document was "On the Object 'Vostok-3A'."

exhaustive discussion, and there is no evidence to suggest that Korolev would have approved such a timetable if he did not think it was realistic. The plans of the Soviet government were, however, suddenly and tragically thwarted by one of the worst-ever disasters in the history of rocketry, a dark reminder of the perils of the new technology at its disposal.

Disaster and Delays

On the evening of October 24, Korolev called OKB-1 senior engineer Arkadiy I. Ostashev into his office to give him some important information. The chief designer had just received a call from Tyura-Tam on restricted communications lines from his Deputy Yevgeniy V. Shabarov concerning a major accident at the launch range in which Ostashev's older brother, Yevgeniy, had been involved.[38] Still unaware of the scale of the accident, Korolev immediately permitted the younger Ostashev to fly to the launch site. The magnitude and catastrophic nature of the accident only became clear to Korolev through the night as more and more reports arrived from both Tyura-Tam and indirect sources in Moscow. The disaster was beyond the comprehension of even the most darkest nightmares, and it involved a rocket designed not by Korolev, but by his rival, Chief Designer Yangel.

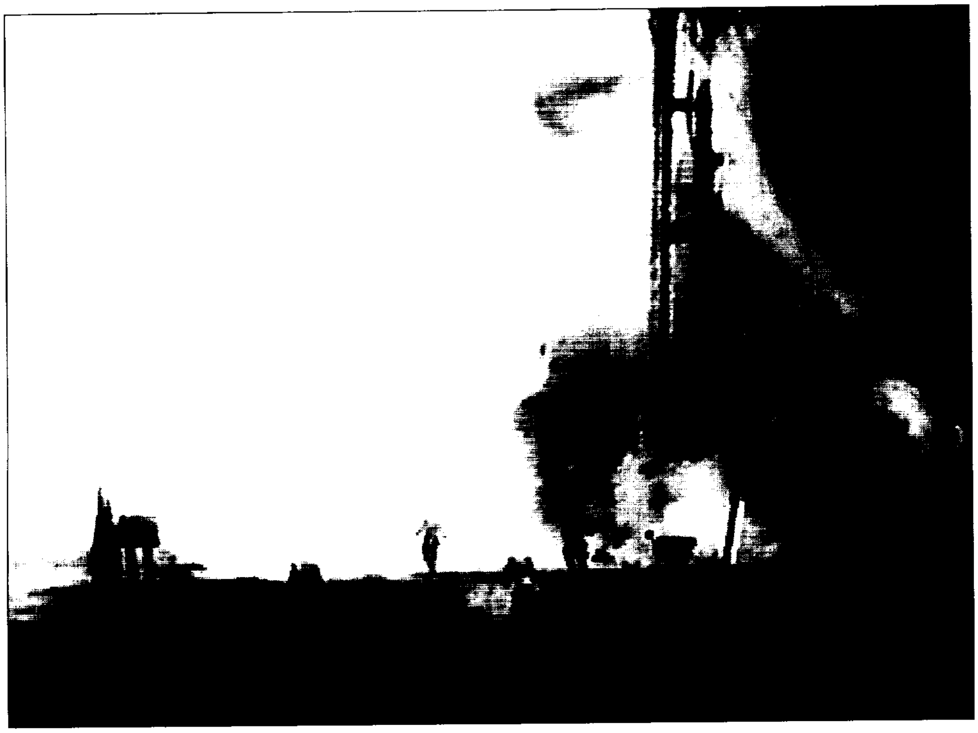
Offering up stiff competition to Korolev to design a new generation of ICBMs, Yangel had brought his first offering, the R-16, to the launch pad in mid-October for its first launch. After the relative failure of Korolev's R-7 as an operational ICBM, there was a tremendous amount of import focused on bringing Yangel's new R-16 to operational status. It would finally give the Soviet Union an active and large-scale strategic deterrent backing up the Khrushchev's bluster and bragging about Soviet might. Days before the planned launch, the Soviet leader, in a speech at the United Nations, had boldly stated that strategic rockets were being produced in the Soviet Union "like sausages from a machine," a claim that was clearly not true in the case of ICBMs.[39] Numerous important officials were at Tyura-Tam to witness the first launch, including Strategic Missile Forces Commander-in-Chief Nedelin, who also chaired the State Commission for the R-16.

Fueled by storable, hypergolic, and highly toxic propellants, there had been much difficulty prior to launch, especially in fueling procedures, which caused great consternation at the site. The first launch was originally set for October 23, but a major propellant leak that evening forced a postponement to the next day. On the orders of the State Commission, all repairs to the missile were carried out in a fully fueled state, creating a remarkably dangerous situation at the pad. The repairs were successfully completed through the night, and all prelaunch operations proceeded as planned until thirty minutes prior to the set launch time on October 24. At this point, there were still approximately 200 officers, engineers, and soldiers near the pad, including Marshal Nedelin, who scoffed at suggestions that he leave the pad area. "What's there to be afraid of? Am I not an officer?," he was reported to have asked.[40] By a fateful stroke of luck, Yangel himself was convinced to enter a safe bunker to smoke a last cigarette by Maj. General Aleksandr G. Mrykin, Nedelin's point man for missiles and space. Mrykin was apparently thinking of quitting smoking, and he had decided to smoke his last cigarette right then. It was at that moment, exactly thirty minutes prior to the scheduled launch, that the missile suddenly exploded on the pad, releasing an expanding inferno of destruction around the pad area.

38. Chertok, *Rakety i lyudi*, p. 396.

39. Steven Zaloga, *Target America: The Soviet Union and the Strategic Arms Race, 1945–1964* (Novato, CA: Presidio, 1993), p. 195.

40. S. Averkov, "Top Secret: Explosion at Baykonur Cosmodrome: Only After 30 Years Are We Learning the Truth About the Death of Marshall Nedelin and a Large Group of Rocket Specialists" (English title), *Rabochaya tribuna*, December 6, 1990, p. 4.



This still from a film of the R-16 explosion shows the expanding fireball around the missile as pad workers desperately tried to flee the scene of the catastrophe. Approximately 130 people perished as a result of the explosion, many of whom were identified only by medals on their jackets or rings on their fingers. (copyright Rudy, Inc., via Quest *magazine)*

Within seconds, the rocket broke in half and fell on the pad, crushing any one who might have still been left alive. At that point, the fire and the heat increased in intensity as all the propellants ignited in a crescendo. Some people were simply engulfed in the fire, while others who managed to run in a burning state succumbed to the toxic gases within minutes. Technicians remained hanging from their harness from special cranes as their bodies burned. Deputy Chairman of the State Committee of Defense Technology Lev A. Grishin, who had been standing next to Nedelin, managed to jump over a high railing, run across the molten tarmac, and jump to the high gate of the ramp from a height of three and a half meters, breaking both legs in the process to reach safety. Tragically, he succumbed to his burns soon after he was taken to the hospital.[41] As the temperature raged to around 3,000 degrees, people just simply melted in the firestorm, many being reduced to ashes.

Through the ensuing days, workers began the gruesome task of identifying bodies. A special commission headed by Yangel was formed immediately to investigate the accident. The failure had evidently occurred when the second stage of the R-16 had spuriously started firing on the pad because of a control system failure, thus igniting the propellants in the first stage. This control system, developed by the Kharkov-based OKB-692, had lacked a circuit to block spurious commands from reaching the second stage. It took fourteen hours of torment before the

41. Grishin was still alive four days after the disaster, on October 28. At the time, his injuries were listed as "2nd, 3rd, and 4th degree burns on the face, head, neck, left half of the thorax. Open fracture in both bones of right and left shins. Left lower extremity amputated from the middle third of the shin."

young Ostashev identified his brother. Nedelin himself was identified only by his Gold Star medal attached to his uniform. OKB-692 Chief Designer Boris M. Konoplev, the talented guidance systems engineer who was among the rising stars in the Soviet missile and space program, was identified by his height, having been one of the tallest men at the pad. All told, 126 individuals died in the blast, including senior military officials, deputy chief designers, and numerous soldiers.[42] The entire incident was kept under tight wraps, and Marshal Nedelin was said to have died in an aircraft accident, a piece of fiction that the Soviets officially maintained until early 1989. The prohibition on discussing the disaster among the survivors was not lifted until 1990, thirty years following the tragedy.[43]

The R-16 disaster was a devastating blow to the Soviet missile program. Although it did not have any direct connection to the piloted space effort, there was clearly a repercussive delay on the Vostok program. Many of the same design organizations, such as OKB-456 (Glushko), NII-944 (Kuznetsov), NII-88 (Tyulin), and NII-229 (Tabakov), had major contributions to both the R-16 and Vostok projects. Marshal Nedelin, apart from his role as Commander-in-Chief of the Strategic Missile Forces, had also chaired several important State Commissions, including Vostok, thus capping his fifteen-year-long role as one of the most important figures in the growth of the Soviet missile and space programs. Kirill S. Moskalenko, the fifty-eight-year-old Commander of the Moscow Military District, was brought in as the new commander of the Strategic Missile Forces. He had the unusual distinction of being one of the men to participate in NKVD Chairman Beriya's execution in December 1953. Konstantin N. Rudnev, forty-nine, the industrial leader of the space and missile program, took Nedelin's place as the chair of the State Commission for Vostok.[44] It was the peak of Rudnev's ten-year rise to influence as one of the top industrial managers in the Soviet Union. His first job in the rocketry effort had been as director of the famous NII-88 in the early 1950s.

It would be more than two weeks following the R-16 disaster that active work on the Vostok effort resumed again. By this time, it was clear that the original schedule for a piloted flight in December 1960 was unrealistic. In a letter dated November 10, Ustinov, Keldysh, Korolev, Rudnev, and Moskalenko asked the Central Committee for formal permission to launch two Vostok 1 precursor craft prior to commencing testing of the piloted Vostok 3A variant.[45] In the best-case scenario, a first piloted flight could not be carried out before late February 1961. By this time, NASA was also looking at the first suborbital flight in early spring. Thus, despite the delays associated with the R-16 disaster and other technical problems, there was still a slim margin of safety in the new schedule.

42. Chertok, *Rakety i lyudi*, p. 397. There are still many discrepancies in reports of the final human toll of the R-16 disaster, ranging from a lower limit of ninety-two to an upper limit of 165. By October 28, seventy-four people had been identified as dead. A number of previously classified important documents related to the disaster were published in 1994. These included the original communiqué sent by Yangel to Moscow minutes after the disaster, a preliminary accident report by the technical commission on the day after the accident, and lists of those who had been identified (both deceased and injured) by October 28. See I. D. Sergeyev, ed., *Khronika osnovnykh sobytiye istorii raketnykh voysk strategicheskogo naznacheniya* (Moscow: TsIPK, 1994), pp. 240–63.

43. There are numerous Russian language sources that describe the incident. The ones primarily used in the above narrative were: Averkov, "Top Secret: Explosion at Baykonur Cosmodrome"; Col. A. Radionov, "The Time Has Come to Tell: It Happened at Baykonur: At the First Launch of the New Rocket. How Marshall Nedelin Died. The Memory of the Living" (English title), *Krasnaya zvezda*, October 24, 1990, p. 2; A. Bolotin, "Site Ten" (English title), *Ogonek* 16 (April 15–22, 1989): 10–14. For a recent English language account of the R-16 disaster, see Asif A. Siddiqi, "Mourning Star," *Quest* 3 (Winter 1994): 38–47.

44. Zaloga, *Target America*, p. 99; Chertok, *Rakety i lyudi*, p. 411.

45. This letter is reproduced in full, but with disguised designations, as D. F. Ustinov, M. V. Keldysh, S. P. Korolev, K. N. Rudnev, and K. S. Moskalenko, "On Launches of the 'Vostok-A' Korabl-Sputnik" (English title), in V. S. Avduyevskiy and T. M. Eneyev, eds., *M. V. Keldysh: izbrannyye trudi: raketnaya tekhnika i kosmonavtika* (Moscow: Nauka, 1988), pp. 355–56.

Permission to launch the two Vostok 1 spacecraft, the fourth and fifth in the series, was granted almost immediately by the Central Committee, which allowed processing at the OKB-1 plant and at Tyura-Tam to pick up speed. Both spacecraft were identical to the ship launched in August, save for the omission of the infrared orientation system that had been the source of so many problems on the previous missions.[46] The first one was launched without incident on December 1, 1960, into an orbit exactly mimicking the one planned at the time for an actual piloted mission: 180 by 249 kilometers at a 64.95-degree inclination. Aboard the satellite, called the Third Korabl-Sputnik in the Soviet press, were two dogs, Pchelka and Mushka. Total mass in orbit was 4,563 kilograms. There was apparently improved biomedical instrumentation on board, as well as a different set of instruments for cosmic and radiation studies.

The flight went well, and there were twelve successful communications sessions for telemetry reception. After about twenty-four hours in orbit, on the seventeenth orbit, the main TDU-1 engine was to fire to initiate reentry. Unfortunately, there was a malfunction in the stabilization system of the engine; the resulting firing was far shorter than had been planned. Although the spacecraft would still reenter, computations showed that the landing would overshoot Soviet territory. The spacecraft made one and a half more orbits, after which the descent apparatus with the dogs separated from the rest of the vehicle. An additional communications session with the craft confirmed the failure of the TDU-1. At this point, a special and unusual system was called into operation—one that was installed to address this precise situation. During earlier mission planning, there had been much concern about the possibility of having a spacecraft land off course and on "foreign territory." Given the extreme secrecy and xenophobia of the missile and space programs, the only option for designers was to install a self-destruct system aboard the vehicle to destroy the "evidence" before recovery by non-Soviet parties. Designed by NII-137, the system for the emergency explosion of the object was designed to detonate if the on-board g-sensor did not detect reentry at the assigned moment. Mercifully, such a system was only earmarked for the Vostok precursor missions and not for any actual piloted craft. In the case of Korabl-Sputnik 3, the system went into operation at the beginning of reentry and destroyed the spacecraft along with its hapless passengers.[47] At the time, the Soviet press merely announced that because of the incorrect attitude, the descent apparatus had burned up on reentry.

The problem with TDU-1 was identified quickly by "adopting means for ensuring normal work of the Braking Engine Unit," and the next Vostok 1 spacecraft was brought to the launch pad at site 1 in the third week of December. There was a slight change in the booster-spacecraft stack for this flight. All earlier Korabl-Sputnik missions had used the 8K72 launch vehicle also used for the Luna launches. This particular flight would be the first to use a slightly modified variant designated the 8K72K, which substituted the RD-0109 (just over five and a half tons) for the RD-0105 (just over five tons) as the third orbital insertion stage.[48] The nominally increased thrust would allow a slightly higher mass planned for the piloted variant. Thus, the fifth Vostok 1 spacecraft, carrying the dogs Kometa and Shutka, was sent on its way at 1045 hours Moscow Time on December 22, 1960.[49] The first two stages of the 8K72K booster

46. Korolev, "On the State of the Experimental Work."

47. *Ibid.*; Chertok, *Rakety i lyudi*, pp. 411–12. Although the system was not used on any piloted Vostok mission, it was standard on all variants of the Vostok spacecraft for reconnaissance missions.

48. Varfolomeyev, "Soviet Rocketry that Conquered Space: Part 3." The first tests of the 8K72K variant may have occurred earlier. There were two suborbital launches related to the R-7 (or R-7A) on July 5 and 7, 1960, during which the payloads were deposited in the Pacific. See Lardier, *L'Astronautique Soviétique*, p.. 122; *A Chronology of Missile and Astronautical Events*, prepared for the Committee on Science and Astronautics, U.S. House of Representatives, 87th Cong., 1st sess. (Washington, DC: U.S. Government Printing Office, March 1961), p. 119.

49. N. P. Kamanin, *Skrytiy kosmos: kniga pervaya, 1960–1963gg* (Moscow: Infortekst IF, 1995), p. 9. Note that this source suggests that the names of the dogs were Zhemchuzhnaya and Zhulka.

performed without fault, but the new third stage engine prematurely cut off at T+425 seconds because of the destruction of the gas generator in the engine. The emergency escape system went into operation, and the spacecraft successfully separated as its flight trajectory described an arc across the Soviet Union. The payload reached an altitude of 214 kilometers and landed about 3,500 kilometers downrange from the launch site in one of the most remote and inaccessible areas of Siberia, in the region of the Podkamennaya Tunguska River close to the impact point of the famed Tunguska meteorite. By the late hours of December 22, rescue forces began to detect signals from the descent apparatus, and a search party led by Korolev's old friend, Arvid V. Pallo, was dispatched to try and locate the capsule.

The rescue mission turned out to be one of the most harrowing episodes of the time. Once the rescue group was dropped at the general area of the landing site two days late on December 24, Pallo and his associates found themselves in waist-deep snow. By having aircraft fly in the direction of the object, they managed to reach the capsule. Once the team found the spacecraft, they had to approach it with extreme care because the emergency explosive system was to automatically detonate the vehicle sixty hours after landing. By the time they reached the spacecraft, it had already been sixty hours, but the capsule had still not exploded, forcing them to disengage the explosive in minus-forty-degree Centigrade temperatures. They later discovered that the cabling in the explosive system had burned through, neutralizing the bomb. Although both hatches on the descent apparatus had been discarded, the ejection seat had remained within the spherical capsule instead of ejecting out with the dogs. Later investigation showed that during ejection, the seat had slammed into the side of the exit porthole and remained within the spacecraft. Pallo and his deputy returned to the site the next day, and the dogs were finally taken out of the capsule, a little cold but alive, and flown to safety, arriving in Moscow on December 26. Bringing the descent apparatus itself back to Moscow proved to be much more difficult as they used a variety of strategies to literally drag the capsule through kilometers of snow. At one point, Pallo's team had to terminate all rescue operations and spend the night in the middle of the ice and snow when the temperature dropped to minus sixty-two degrees Centigrade. It was the first week of January 1961 before the vehicle finally arrived in Moscow.[50] Despite Korolev's entreaties that the failure be announced in the Soviet press, the State Commission vetoed the idea.

An analysis of the launch abort on December 22 showed that there were a number of major anomalies on the mission. Following the booster third-stage failure, the Vostok 1 craft was to separate into its component descent apparatus and instrument section modules. This never happened. The two capsules severed their connections only because of the thermal heating on reentering the atmosphere. Furthermore, the ejection seat was to have shot out of the capsule two and a half seconds after the hatch was jettisoned; on this mission, both events occurred simultaneously, causing the craft to deform from the shock of the failed ejection.[51] Then there was the fortuitous failure in the self-destruct system. All of these, for obvious reasons, were not encouraging. The Korabl-Sputnik program now had two major failures in a row. The State Commission's provisional date of February 1961 for a piloted flight was no longer viable. At a meeting of the commission on January 5, 1961, Deputy Chief Designer Bushuyev laid out a schedule for the forthcoming months. As per earlier plans, the next two launches in the series were to be automated flights of the actual piloted variant, the Vostok 3A. The first would fly on February 5 and the second on February 15–20.[52] Contingent upon their successes, the commission would approve a piloted mission.

50. Mozzhorin, *et al.*, eds., *Dorogi v kosmos: II*, pp. 47-51; M. Rebrov, "But Things Were Like That—Top Secret: The Painful Fortune of the N1 Project" (English title), *Krasnaya Zvezda*, January 13, 1990, p. 4.

51. Kamanin, *Skrytiy kosmos*, p. 10.

52. *Ibid.*, p. 11.

The Road to Vostok

The training of the core group of six cosmonaut-trainees selected as a pool for the first piloted mission reached a turning point in January 1961. By that time, all six had finished final regimes in simulators lasting three days, as well as full-scale parachute and recovery training. Over two days in mid-January, the six—Captain Bykovskiy, Lieutenant Gagarin, Lieutenant Nelyubov, Captain Nikolayev, Captain Popovich, and Lieutenant Titov—took their final exams to assess their degree of readiness. A special interdepartmental commission under Lt. General Kamanin's supervision would review the results of the tests and recommend the most likely candidates for the very first mission.[53] On January 17, each candidate spent forty to fifty minutes in a simulator at the M. M. Gromov Flight-Research Institute describing the operation of the spacecraft, its instruments, and various phases of a mission, after which the members of the commission asked specific questions. Particular attention was devoted to the operation of the TDU-1 engine and spacecraft orientation, both of which had failed at various times in the previous Korabl-Sputnik missions. On the first day, Nikolayev, Popovich, Gagarin, and Titov received grades of "excellent," while Bykovskiy and Nelyubov were given "very good" scores. The following day, the candidates took a written exam, which completed the program. The results were collated soon after, and the commission recommended the following order for using the trainees in flights: Gagarin, Titov, Nelyubov, Nikolayev, Bykovskiy, Popovich.[54] This particular series of tests helped narrow down the pool of cosmonauts for the first mission to the three best candidates: Gagarin, Titov, and Nelyubov. Although nontechnical factors such as psychological characteristics and ideological issues would narrow the three men down to one for the very first mission, all three would travel to Tyura-Tam in a few months.

Even at this early stage, the twenty-six-year-old Yuriy Gagarin seemed to be the clear favorite. He had come from working-class origins in the Smolensk region west of Moscow, graduating from secondary school in 1949. He spent the following few years in various technical institutes before joining the Orenburg Higher Air Force School in 1955. Until his selection as a cosmonaut-trainee, he had served as an active duty pilot at Zapolyarniy, north of the Arctic Circle. By all accounts, he was a very likable and intelligent individual, and he had fortuitously made an extremely favorable impression on Korolev the first time the cosmonauts had met the chief designer in mid-1960. Although there has been a tendency to hero-worship the young man, even those less prone to hyperbole had nothing but positive things to say about him. Cosmonaut Khrunov later remembered that:

> *Gagarin was extraordinarily focused, and when necessary, very demanding of himself and of others. Which is why I think that concentrating on that famous smile of his might miss the mark entirely and might even diminish the image of who he really was.*[55]

53. The members of the commission were: Maj. General A. N. Babiychuk (Chief of the Soviet Air Force Medical Service), Lt. General V. Ya. Klokov (Institute of Aviation and Space Medicine), V. I. Yazdovskiy (Institute of Aviation and Space Medicine), Colonel Ye. A. Karpov (Director of TsPK), Academician N. M. Sisakyan (Department of Biological Sciences of the USSR Academy of Sciences), K. P. Feoktistov (OKB-1), S. M. Alekseyev (Chief Designer of Plant No. 918), and M. L. Gallay (test pilot at the M. M. Gromov Flight-Research Institute). In addition, Flight-Research Institute Director N. S. Stroyev was present during the tests. See Kamanin, *Skrytiy kosmos*, p. 12; L. N. Kamanin, "A Minute's Readiness Has Been Announced . . ." (English title), *Znamya* no. 4 (April 1989): 134–46.

54. The remaining eleven active cosmonauts—Anikeyev, Belyayev, Filatyev, Gorbatko, Khrunov, Komarov, Leonov, Rafikov, Shonin, Volynov, and Zaykin—took their test on April 4, 1961. Out of a total possible of "5," Komarov and Leonov received 5+, Anikeyev, Filatyev, Shonin, and Volynov received 5, and Belyayev, Gorbatko, Khrunov, and Rafikov received 4. See Golovanov, *Korolev*, p. 633.

55. *Ibid.*, pp. 628–29.

OKB-1 engineer Raushenbakh recalls that "Gagarin would never try to ingratiate himself, nor was he ever insolent. He was born with an innate sense of tact." In an early evaluation of his personality dating from August 1960, when he was simply one of twenty men in training for a flight, a commission of Air Force doctors wrote with remarkable unambiguity of Gagarin's positive attributes:

> *[M]odest: embarrasses when his humor gets a little too racy; high degree of intellectual development evident in Yuriy; fantastic memory; distinguishes himself from his colleagues by his sharp and far-ranging sense of attention to his surroundings; a well-developed imagination; quick reactions; persevering, prepares himself painstakingly for his activities and training exercises; handles celestial mechanics and mathematical formulae with ease as well as excels in higher mathematics; does not feel constrained when he has to defend his point of view if he considers himself right; appears that he understands life better than a lot of his friends.*[56]

When the cosmonaut group had carried out an informal and anonymous survey to see whom among the cosmonaut group they would like to see fly first, all but three of the twenty named Gagarin. Apart from his high qualifications, he also satisfied the Communist Party's unwritten criterion that the first Soviet person in space be from a completely Russian and working-class background.

German Titov, twenty-five years old at the time, had grown up in the Kosikhinskiy District in Altay Territory before entering the Kacha Higher Air Force School in 1953. Following his graduation in 1957, he served as an active duty pilot in the Leningrad District. He struck many as being the most worldly and well read of the six, and he was noted for rebelling against what he called "silly questions" during the selection processes in 1959.[57] The youngest of the six, he had performed excellently and without problems throughout the past year in training and was a close competitor of Gagarin. The last of the three, the twenty-six-year-old Grigoriy Nelyubov, was perhaps the most talented and qualified of the group of six. Raised in Crimea, he had graduated from the Yeisk Higher Air Force School in 1957 and served as a MiG-19 pilot with the Black Sea Fleet. Soon after selection as a cosmonaut, he had consistently demonstrated his expertise as one of the top members of the group of twenty. He also had influential supporters at OKB-1; Department Chief Raushenbakh was said to have supported Nelyubov's candidacy to be the first Soviet person in space. On the negative side, Nelyubov was also extremely outspoken and individualistic. For Air Force overseer Kamanin, a diehard old-school Stalinist, Nelyubov's otherwise remarkable record in training was neutralized by his direct and critical nature. Gagarin, who was "quiet in character," was a far more suitable candidate from an ideological perspective.[58]

In terms of preparing for the first Vostok mission, the training of cosmonauts was only the tip of the iceberg of a mammoth undertaking. Tracking requirements for a piloted mission were a lot more stringent than for the modest Sputniks in the years before, and the military NII-4 institute was once again tasked with coordinating the establishment of a network to support the new project. The original seven communications points spread out across the Soviet Union (at Tyura-Tam, Makat, Sary-Shagan, Yeniseysk, Iskhup, Yelizovo, and Klyuchi) to support the early satellite program were augmented by six new stations (at Leningrad, Simferopol, Tbilis,

56. *Ibid.*, p. 629.
57. Rex Hall, "Soviet Air Force Cosmonauts," in Cassutt, ed., *Who's Who in Space*, p. 266.
58. *Ibid.*, p. 251; Golovanov, *Korolev*, p. 630.

Kolpashevo, Ulan-Ude, and Moscow).[59] Although the Soviet Union stretched close to two and a half times more in width than the contiguous United States, there were clear limitations to monitoring space missions from a single landmass, especially given the heightened requirements of a piloted mission. Perhaps reluctant to negotiate treaties as NASA did to station tracking points on foreign soil, the Soviets instead resorted to fully equipped self-contained naval vessels stationed all over the world. The first generation of Soviet overseas tracking ships—*Sibir, Suchan, Sakhalin,* and *Chukotka*—were stationed originally to monitor ICBM nose cone impacts and later for mission-critical events of the Korabl-Sputniks. These ships were commissioned as part of the officially named Pacific Ocean Hydrographic Expedition No. 4. These were augmented in August 1960 by a newer second generation stationed in the Atlantic that were built specifically for the Vostok, lunar, and interplanetary programs: *Dolinsk, Ilichevsk,* and *Krasnodar.* The duration of communications contact between each surface point and the orbiting spacecraft was limited to five to ten minutes, with an altitude envelope reaching out to 1,500 to 2,000 kilometers.[60]

For the early piloted space missions, NASA opted to use a control center at the launch site at Cape Canaveral. While the Soviets maintained such a control point at Tyura-Tam, the nerve center for all the early piloted Soviet spaceflights was in the Bolshevo suburb of Moscow at the premises of the military NII-4. It was here that the so-called Command-Measurement Complex Center was located, under direct control of the Strategic Missile Forces. The center was staffed primarily with officers from NII-4 and headed from July 1959 by Colonel Andrey G. Karas, a veteran of the early Kapustin Yar launches. Ballistics and computational support during missions were provided by three different computation centers, each with its own operations group—one at NII-4 and two in the Academy of Sciences. Although Karas was nominally the head of the entire Command-Measurement Complex, the day-to-day technical operations were handled by Colonel Amos A. Bolshoy, a military scientist who would play a prominent role in controlling all early Soviet piloted missions by providing the State Commission with recommendations on mission-critical events.[61] The fact that this position, roughly analogous to the Western concept of a flight director, was occupied by a colonel in the Strategic Missile Forces was merely another symptom of the outgrowth of the Soviet space program from the ballistic missile effort. This was one of the reasons that until the 1970s, the Soviets steadfastly refused to identify the location of its primary control center for the early piloted space program. Apart from command and control, the Soviet Air Force accepted the burden of organizing recovery forces for landing cosmonauts. The huge armada consisted of twenty-five aircraft (twenty Il-4s, three An-12s, and two Tu-95s) as well as ten helicopters. In addition, seven separate parachute teams were established to quickly reach a returned cosmonaut to provide firsthand medical support.[62]

59. Yu. A. Mozzhorin, *et al.*, eds., *Nachalo kosmicheskoy ery: vospominaniya veteranov raketno-kosmicheskoy tekhniki i kosmonavtiki: vypusk vtoroy* (Moscow: RNITsKD, 1994), p. 272. Each of these centers was called a Scientific-Measurement Point (NIP), and each had a separate number: NIP-1 (Tyura-Tam), NIP-2 (Makat), NIP-4 (Yeniseysk), NIP-5 (abandoned in 1958), NIP-6 (Yelizovo), NIP-7 (Tyura-Tam), NIP-8 (not built), NIP-9 (Leningrad), NIP-10 (Simferopol), NIP-12 (Kolpashevo), NIP-13 (Ulan-Ude), and NIP-14 (Moscow).

60. *Ibid.*, pp. 265, 272–73. See also B. A. Pokrovskiy, *Kosmos nachinayetsya na zemlye* (Moscow: Patriot, 1996), pp. 341, 345–46. A fourth ship to the "second generation," *Aksay*, was added in September 1962. See also Lardier, *L'Astronautique Soviétique*, pp. 122–23.

61. Bolshoy was replaced by P. A. Agadzhanov in the mid-1960s. See Pokrovskiy, *Kosmos nachinayetsya na zemlye*, pp. 239, 365; "On the Scientific-Technical Activities of Yu. A. Mozzhorin (On the 70th Year of His Birth)" (English title), *Iz istorii aviatsii i kosmonavtiki* 60 (1990): 4–11.

62. Lardier, *L'Astronautique Soviétique*, p. 123; Kamanin, *Skrytiy kosmos*, p. 39. There were also apparently three Il-18 teams headed by V. M. Pekin, M. A. Chernovskiy, and G. P. Perminov. Among the physicians who were part of the parachute teams was B. B. Yegorov, later to be the first physician in space. The commander of the search and rescue service was Air Force Lt. General A. I. Kutasin.

Through January and February 1961, there were intensive preparations for the launches of the remaining two Vostok precursor missions. Each of these spacecraft would be identical to the actual piloted variant, save for the fact that each would carry a single dog into orbit. A life-size mannequin would be strapped into the main ejection seat, while the dog would be put in a container separate from the ejection mechanism. Unlike the previous dog flights, the missions were to last a single orbit—that is, exactly the same as planned for the first human flight. The preparations leading up to a piloted launch were not smooth by any means. At a meeting of the State Commission presided by Rudnev on February 22, schedules were laid down for the two preliminary missions. The first Vostok 3A with a mannequin would be launched in the first days of March *prior to* completion of ground testing and the elimination of all defects in the model; the second Vostok 3A would reach orbit only after full-scale ground testing was completed. The problems with the first spacecraft were limited to anomalies in the life support and ejection systems, certainly important elements for a biological satellite.[63] At a meeting on February 27, Chief Designers Semyon A. Alekseyev (Plant No. 918) and Grigoriy I. Voronin (OKB-124), responsible for the ejection mechanism and life support systems, respectively, approved a detailed plan for testing these systems for the second Vostok 3A spacecraft. In particular, Voronin had introduced a new air conditioning system, which had to undergo a complete thirteen-day test to simulate the contingency of having a cosmonaut in orbit for that length of time in case of retrorocket failure.

On March 2, OKB-1 Group Chief Feoktistov and his assistant Oleg G. Makarov, both destined to be cosmonauts themselves in later years, prepared a detailed set of instructions for the pilot of the first mission, which included courses of actions for various stages of the mission as well as a number of different emergency situations. The two engineers took provisions to include instructions for manually altering the attitude of the spacecraft in orbit and conducting a completely manual retrofire, both of which were not planned for execution during a nominal mission. The finished document was passed on to Korolev, Keldysh, Bushuyev, and Voskresenskiy, who all significantly shortened the list, arguing that during the first mission, the pilot should not actively control any instrument on the spaceship. A vigorous fight was put up by Kamanin, test pilot Gallay, and physician Yazdovskiy, who argued that the cosmonauts were extremely well trained and could be expected to perform any assigned tasks without problem. In the end, after a long discussion with Academician Keldysh on the merits of human control of a space vehicle, Korolev and the others backed down, and the original lengthy set of instructions was formally approved. Although the first cosmonaut would have the choice of manually controlling certain systems, all members of the State Commission were in agreement that the activities of the pilot should be as conservative as possible. The only concession to scientific research was the inclusion of dry seeds, *drosophila*, and lysogenic bacteria as part of the payload for biomedical studies.[64]

In early March 1961, several leading designers and high-ranking Strategic Missile Forces officials left Moscow for the city of Leninsk near Tyura-Tam to direct the preparations for the two upcoming automated missions.[65] A total of thirty to forty days would be spent during this period at the launch site to test every system of the third spacecraft, the one that would carry a human, and its launch vehicle. By this point, the first Vostok 3A was scheduled for March 9, and the second for late March at the earliest. The pressure was building on the Soviets as Project Mercury seemed to be close to a piloted launch. The option to launch the first Vostok 3A with-

63. Kamanin, *Skrytiy kosmos*, p. 21.

64. *Ibid.*, p. 23; Wukelic, *Handbook of Soviet Space-Science Research*, p. 54.

65. K. Isaakov, "Breakthrough into the Unknown: Today is Cosmonautics Day" (English title), *Bakinskiy rabochiy*, April 12, 1988, p. 3. The town of Zarya next to the Tyura-Tam launch site was renamed Leninsk on January 28, 1958. See Ivan Borisenko and Alexander Romanov, *Where All Roads Lead to Space Begin* (Moscow: Progress Publishers, 1982), p. 22.

out the benefit of full-scale ground testing was clear evidence that OKB-1 was not only trying to keep up with its own timetable, but aiming to outrun its chief rival thousands of kilometers away. Back in the United States, in mid-February, NASA's Space Task Group had recommended moving ahead with a suborbital piloted mission on the next Mercury-Redstone attempt. In a last-minute move that seems pivotal in retrospect, Wernher von Braun, on the advice of his booster specialists, argued that an additional automated Redstone flight was necessary before certification for a human launch. Von Braun's recommendation was accepted, thus pushing the first launch of an astronaut from April 25 to early May.[66]

For Korolev, whose decades-old competition with von Braun was only exceeded by his intense urge to be first, this window proved propitious. Korolev proposed to First Secretary Khrushchev that the first piloted mission could be launched in late April to coincide with the celebrations for May Day. The Soviet leader was, however, categorically against timing such a major space mission with a national holiday, no doubt concerned about the possibility of a catastrophic failure. Instead, Khrushchev asked Korolev to move the launch either forward or backward. Thus, the option was clear: the chief designer informally set the first piloted Vostok launch for mid-April. In a curious twist, Khrushchev himself announced on March 14 during an interview widely reported in the West: "The time is not far off when the first (Soviet) spaceship with a man on board will soar into space."[67]

The first human-rated Vostok 3A spacecraft lifted off successfully at 0929 hours Moscow Time on March 9, 1961, and entered a 183.5- by 248.8-kilometer orbit inclined at 64.93 degrees to the equator. The spacecraft was called the Fourth Korabl-Sputnik in the Soviet press. A small pressurized sphere in the spacecraft carried the dog Chernushka ("Blackie") together with forty white and forty black mice, several guinea pigs, reptiles, plant seeds, human blood samples, human cancer cells, micro-organisms, bacteria, and fermentation samples. Unlike the previous dog flights, the main ejection seat was taken up by a life-sized mannequin (Ivan Ivanovich) fully dressed in a functional SK-1 *Sokol* spacesuit. Additional mice, guinea pigs, microbes, and other biological specimens were placed in the mannequin's chest, stomach, thighs, and other parts of the "body."[68] This virtual menagerie of animals and plants was the subject of intensive biomedical experimentation during the single orbit flight. An unnamed designer of the Vostok later revealed an interesting aside to the mission:

> *[T]he main purpose was to ensure reception of voice transmissions from [the ship]. We rejected a numerical countdown, fearing Western radio stations would monitor the human voice and raise a clamor throughout the world alleging that Russia has secretly put a man into orbit. A song also aroused objections because it would be said in the West that "the Russian" cosmonaut had lost his head and started singing! It was then decided to tape a popular Piatnitsky Russian choir, and when the dummy, clothed for purposes of decency in a white smock, suddenly sang like a choir, it was very funny.*[69]

In rehearsal for the exact sequence of events on an actual piloted flight, the retrorocket TDU-1 engine fired on time for just under forty-two and a half seconds. Almost ten seconds later, the instrument section separated from the descent apparatus, the latter making a ballistic reentry into the atmosphere. The mannequin was safely ejected out of the descent apparatus

66. David Baker, *The History of Manned Spaceflight* (New York: Crown Publishers, 1985), p. 65.

67. *The New York Times*, March 15, 1961, p. 8; Sergey Khrushchev, *Nikita Khrushchev: krizisy i rakety: uzglyad iznutri: tom 2* (Moscow: Novosti, 1994), p. 97.

68. Mozzhorin, *et al.*, eds., *Dorogi v kosmos: II*, pp. 141–42.

69. R. F. Gibbons and P. S. Clark, "The Evolution of the Vostok and Voskhod Programmes," *Journal of the British Interplanetary Society* 38 (1985): 3–10.

after reentry, while the main capsule with the dog landed separately by parachute. The mission had lasted only one hour, forty-six minutes. The two objects from the spacecraft settled down about 260 kilometers northeast of Kuybyshev in the middle of a large open field covered by snow. There was apparently some delay in having an OKB-1 representative get to the main capsule to neutralize the self-destruct system. The rescue team led by Lt. General Kamanin elected to take the dog out of the capsule before the arrival of the OKB-1 expert to prevent the dog from freezing to death.[70]

The unequivocal success of Korabl-Sputnik 4 was a clear boost to the fortunes of the Vostok program, which had lacked a completely trouble-free mission since August 1960. The euphoria over the flight was, however, marred to some extent by a tragedy that struck the cosmonaut team in the most unexpected of ways. On March 23, just two days before the launch of the last Vostok 3A precursor, cosmonaut-trainee Bondarenko was on the tenth day of a fifteen-day exercise in an isolation chamber at the premises of the Institute of Aviation and Space Medicine in Moscow. The chamber contained 50 percent oxygen at a reduced pressure to simulate the atmosphere of a spaceship, and it was completely soundproof to test the effects of isolation. Upon completion of some medical tests at the conclusion of his isolation period, Bondarenko removed the sensors attached to his body and with a cotton-wool pad soaked in alcohol cleaned the places where they had been attached. Without looking, he threw the cotton pad away, and the latter landed on the ring of a live electric hotplate. It immediately caught on fire, and the flame blazed up in the oxygen-rich atmosphere. At first, instead of ringing the alarm, Bondarenko tried to put the fire out himself, but his woolen training suit caught fire. The doctor on duty, Mikhail A. Novikov, tried to open the door as soon as he became aware of the fire, but this operation took several minutes, by which time Bondarenko was completely burnt. As he was dragged out of the chamber, he reportedly kept repeating, "It was my fault, no one else is to blame."[71]

The chief physician at the nearby hospital where Bondarenko was taken recalled later that the cosmonaut's "body was totally denuded of skin, the head of hair; there were no eyes in the face—everything had been burnt away. It was a total burn of the severest degree."[72] Bondarenko finally died at 1500 hours Moscow Time on March 23, eight hours following the accident, of shock resulting from burns. It was the very first death of a space trainee in the history of the space program. Just twenty-four years of age and the youngest trainee on the team, he was buried in his birthplace of Kharkov, where his parents lived. His wife Anya and their son Sasha remained behind at Zelenyy, supported by a special pension as a result of a direct order from Minister of Defense Marshal Rodion Ya. Malinovskiy.[73] News of the accident was completely suppressed in the interest of morale, especially considering that the first piloted Vostok mission was then scheduled in less than three weeks. It is not clear whether any of the other cosmonaut-trainees were told about the tragedy at the time, or several weeks later. As it happened, the accident or even the existence of Bondarenko was not revealed until 1986 as part of a series of articles in the newspaper *Izvestiya* celebrating the twenty-fifth anniversary of the first piloted Vostok mission.

Preparations for the last precursor mission continued with the Bondarenko tragedy firmly in mind. The six core cosmonauts flew to Tyura-Tam on March 17 to witness the prelaunch operations of the next Korabl-Sputnik, where they engaged in some last-minute training

70. Kamanin, *Skrytiy kosmos*, pp. 25–26.

71. *Ibid.*, pp. 33–34; Yaroslav Golovanov, "Cosmonaut No. 1: Slander" (English title), *Izvestiya*, April 3, 1986, p. 6; Golovanov, *Korolev*, p. 633.

72. Vladimir Golyakovsky, *Russian Doctor* (New York: St. Martin's/Marek, 1984), p. 130.

73. Golovanov, "Cosmonaut No. 1: Slander." The order was signed on May 15, 1961, and included the following: "Furnish the family of First Lt. Bondarenko with everything they need, as befits the family of a cosmonaut."

exercises. The trainees completed a variety of tests, including a question-and-answer problem session with Korolev. There was a minor delay of the launch because of a problem with the on-board communications apparatus, but this proved to be unimportant. Launch operations were also halted briefly because of a failure in a sensor on the third stage of the booster, and on orders from Chief Designer Kosberg, workers rapidly replaced the unit. Prior to launch, controllers conducted communications tests between the blockhouse near the pad and the spacecraft to simulate conditions on a crewed mission. Kamanin, Korolev, and cosmonaut trainee Popovich took turns testing the system. Popovich had been assigned to serve as the prime communicator during the launch, analogous to the "capcom" role in the U.S. space program.[74]

The spacecraft, named the Fifth Korabl-Sputnik in the Soviet press, was successfully launched at 0854 hours Moscow Time on March 25, just two days after Bondarenko's death. The 4,695-kilogram vehicle carried another coterie of animals and biological samples, including the dog Zvezdochka ("Starlet") on a single-orbit mission. Orbital parameters were 178.1 by 247 kilometers at a 64.9-degree inclination, close to what was slated for the piloted flight. The mission was uneventful, and all reentry procedures were conducted without problems. As with several of the previous missions, the recovery of the animals and the mannequin was delayed by bad weather. The descent apparatus and the ejection seat landed during a heavy snowstorm, causing difficulties in locating the exact touchdown point. By the time that a group of engineers from Plant No. 918 reached the site, it had been twenty-four hours since the landing. After several hours traveling on horse-drawn sleighs over the one-and-a-half-meter-deep snow, the rescuers finally reached the descent apparatus with the dog, and they eventually found the mannequin in a nearby forest. The neighboring villagers were apparently very suspicious of the recovery teams, suspecting that they might do some harm to the "man" that had landed by parachute. The villagers finally retreated when they were shown conclusive proof that the "man" was indeed just a mannequin.[75] Academy of Sciences Vice-President Aleksandr V. Topchiyev summarized the results of the five successful Korabl-Sputniks in a press conference in Moscow on March 28. In attendance were not only Soviet and foreign journalists, but also Gagarin, Titov, and other cosmonauts in the front row of the audience. No one, of course, had any knowledge that one of them was slated to fly in a spacecraft within days.[76]

The safe landing of Korabl-Sputnik 5 effectively cleared the way for the launch of the first piloted Vostok spacecraft. For Korolev and Tikhonravov, this would be the apex of their long careers in rocketry, which began thirty years before with the amateur GIRD team in a basement in Moscow. In a fitting move, Korolev invited some of the original GIRD veterans to his offices at Kaliningrad in March 1961, a month prior to the first scheduled piloted launch. It was a surprise reunion for the guests, punctuated by much reminiscing, although they had little idea of Korolev's real work because of its classified nature. Near the end of the conversation, Korolev, speaking of the fruitful work at GIRD, added that "now we have come very far!" He invited the guests to a nearby assembly shop. Nikolay I. Yefremov, one of the GIRD veterans, later described the trip:

> *When we walked into the spacious, well-lit shop, we immediately saw our long time dream. Sergey Pavlovich [Korolev] introduced it, literally introduced it as if it were a living thing, the beautiful rocket. Off to the side, on a special pedestal, we saw the cockpit of the spacecraft prepared for manned flight. It was the "Vostok" spacecraft.*[77]

74. Kamanin, *Skrytiy kosmos*, pp. 29–33, 34–35.
75. "Vostok Program, 1961–1963," *Russian Space History* (New York: Sotheby's, 1993), description for lot 11.
76. Golovanov, *Korolev*, p. 625.
77. Ishlinskiy, ed., *Akademik S. P. Korolev*, pp. 164–65.

Even in the hectic days leading to the first Vostok flight, a link was underlined between the pioneering work in the 1930s and the Soviet space program of the 1960s. After thirty years of postulating and hypothesizing, the reality of human spaceflight was only a few days away.

Gagarin in Orbit

After the Korabl-Sputnik 5 mission, Korolev returned to Moscow on the evening of March 28. The following afternoon at a meeting of the State Commission presided over by Chairman Rudnev, Korolev presented the results of the complete Vostok program and declared readiness to launch a human into orbit on the next Vostok 3A spacecraft.[78] Later in the evening, the leading members of the State Commission met once again to draw up a formal document requesting permission from the Communist Party to launch a human into space. For the first time, a high-ranking official from the Committee for State Security (KGB), its First Deputy Chairman, Petr I. Ivashutin, was present.[79] The memorandum, addressed to the Central Committee and classified "Absolutely Secret," began:

> *In accordance with the decree of the Central Committee of the KPSS and the USSR Council of Ministers of 11 October 1960 on the preparation and launch of a space ship with a human, all the necessary work on ensuring human flight into cosmic space has been finished at the present time. . . . Two "Vostok-3A" satellite-ships have been prepared for this purpose. The first ship is at the [launch] range, and the second is being prepared for launch. Six cosmonauts are prepared for the flight. The satellite-ship with a human on board will be launched for one orbit around the Earth and will land on the territory of the Soviet Union on a line running through Rostov-Kuybyshev-Perm.*[80]

A section of the document detailed contingency procedures in the case of unforeseen events:

> *For the orbit chosen for the satellite-ship, in the event that the ship's system for landing on the Earth fails, the ship can descend by natural breaking in the atmosphere over the course of 2–7 days, with a touchdown between latitudes of 65° north and south. In the event of a forced landing in foreign territory or the rescue of the cosmonaut by a foreign ship, the cosmonaut has appropriate instructions. In addition to a ten day supply of food and water, the cosmonaut's cabin is outfitted with a portable emergency supply of food and water that will last for 3 days, and also means of radio-communications and the "Peleng" transmitter whose signals can be used to determine the landing site of the cosmonaut. The satellite-ship is not equipped with a system for emergency destruction of the Descent Apparatus.*[81]

The issue of installing a self-destruct system on the ship was discussed at length during the meeting. All those present, with the sole exception of KGB representative Ivashutin, strongly opposed including such a system on a piloted vehicle. Ivashutin only backed down when all

78. The document presented by Korolev is the previously referenced "On the State of the Experimental Work." A second document, titled "The Orientation System of the 'Vostok' Satellite-Ship," was also signed by Korolev on the same day. This document has also been reproduced in Raushenbakh, ed., *Materialy po istorii kosmicheskogo*, pp. 133–35.

79. According to Kamanin, *Skrytiy kosmos*, pp. 38–39, those present at this meeting were: S. P. Korolev (Chief Designer of OKB-1), G. I. Voronin (Chief Designer of OKB-124), S. M. Alekseyev (Chief Designer of Plant No. 918), L. I. Gusev (Director of NII-695), M. V. Keldysh (Vice-President of the USSR Academy of Sciences), P. I. Ivashutin (First Deputy Chairman of the KGB), S. I. Rudenko (First Deputy Commander-in-Chief of the Soviet Air Force), and N. P. Kamanin (Deputy Chief of the Air Force General Staff for Combat Preparations).

80. This document has been reproduced in full in Belyanov, *et al.*, "Yuriy Gagarin's Star Voyage," pp. 103–04.

81. *Ibid.*, p. 104.

the other members refused to go along.[82] The State Commission also took pains to carefully detail the manner of publicity given to the mission by the Soviet media. There was no attempt by the members to obfuscate or lie about a potential failure, despite the almost paranoid secrecy of the space program. Every attempt was made to give precedence to the safety of the cosmonaut over other political considerations, such as having to admit failure:

> *We consider it advisable to publish the first TASS report immediately after the satellite-ship enters orbit for the following reasons:*
> *(a) if a rescue becomes necessary, it will facilitate rapid organization of a rescue;*
> *(b) it precludes any foreign government declaring that the cosmonaut is a spy with military goals.*
> *If the satellite-ship does not enter orbit because of insufficient speed, it can land in the ocean. In that case, we also consider it advisable to publish the TASS report, so as to facilitate rescue of the cosmonaut.*[83]

There had also been discussion for some time on what to actually call the spaceship in the open press. One side proposed retaining the Korabl-Sputnik name for the mission, merely listing it as the next in the series—that is, the Sixth Korabl-Sputnik. It was Tikhonravov who passionately argued that such a momentous mission not be referred to by such a generic designation. Instead, he proposed disclosing the top-secret "Vostok" name in the TASS report.[84] Korolev agreed, and the State Commission ratified this position. The memorandum from the State Commission for Launch ended with the following: "We request permission to launch the first Soviet satellite-ship with a human on board and approval for the preparation of planning the TASS communiqués."[85] The flight was set between and April 10 and 20, 1961. The document was signed by Military-Industrial Commission Chairman Ustinov, State Commission Chairman Rudnev, defense industry "ministers" Kalmykov, Dementyev, and Butoma, Academician Keldysh, Strategic Missile Forces Commander Moskalenko, Air Force Commander Vershinin, Air Force representative Kamanin, KGB representative Ivashutin, and Chief Designer Korolev.[86]

82. Kamanin, *Skrytiy kosmos*, p. 39.
83. Belyanov, *et al.*, "Yuriy Gagarin's Star Voyage," pp. 104–05.
84. Mikhail Rebrov, "Was This Just a Tragicomedy?" (English title), *Krasnaya zvezda*, June 1995.
85. Belyanov, *et al.*, "Yuriy Gagarin's Star Voyage," p. 105.
86. Note that K. N. Rudnev was also the chair of the State Committee for Defense Technology, the "ministry" overseeing the ballistic missile and space programs. V. D. Kalmykov was the chair of the State Committee for Radio-Electronics, P. V. Dementyev was the chair of the State Committee for Aviation Technology, and B. Ye. Butoma was the chair of the State Committee for Ship-Building. It is apparent from the list that some important changes had been made since the original decree on Vostok in October 1960. Marshal Moskalenko had taken the place of the deceased Marshal Nedelin as Commander-in-Chief of the Strategic Missile Forces, thus maintaining a high-level representation from the old artillery lobby. The Air Force had gained in strength with two members on the commission. Air Force Deputy Commander-in-Chief Marshal Rudenko was replaced in favor of Commander-in-Chief Marshal Vershinin and Lt. General Kamanin. Rudenko was, however, still closely involved in preparations for the flight, but the importance of the mission perhaps necessitated the inclusion of Vershinin. Kamanin's "promotion" is noteworthy in retrospect for it hints at his rapidly rising influence. For obvious reasons of security, KGB representative Ivashutin had been added to the commission, and this underscores the importance with which the Communist Party viewed the project. The notable omissions from the core group from October 1960 were Soviet Minister of Defense Malinovskiy, former Sputnik State Commission Chairman Ryabikov, and the rest of the Council of Chief Designers. Malinovskiy probably relinquished his role to Moskalenko and Vershinin. The omission of Ryabikov is somewhat puzzling because he had been involved in the missile and space programs since 1946, rising to the very powerful position of chair of the so-called Special Committee by 1955, thus overseeing even his former boss Ustinov. With alliances in the defense industry continually changing, it seems that Ryabikov's road to power had reached a plateau by 1960. At the time of the first Vostok mission, he was the chair of the Council of National Economy of the Russian Soviet Federated Socialist Republic, certainly a "demotion" from his previous roles in the defense industry.

The memorandum was formally addressed to the Central Committee of the Communist Party, which on paper was composed of a very large group of individuals. In practice, however, especially in the case of such a high-priority project, only two individuals were involved in the final go-ahead: Nikita S. Khrushchev and Frol R. Kozlov. The latter had inherited the top Communist Party position for the space, missile, and defense sectors in the Secretariat in July 1960.[87] From then on, as the member of the Party "cabinet" responsible for important policy decisions on the space program, Kozlov only had one person who could overrule his word. As the new Secretary of the Central Committee for defense and space, he helped define and reinforce a position that had been handled unevenly at best by his predecessor Leonid Brezhnev, who after Kozlov's promotion found himself in a largely ceremonial post.

On April 3, three days following receipt of the State Commission memorandum, the following "Strictly Secret" decree titled "On the Launch of the Space Satellite-Ship" was issued by the Presidium (later the Politburo) of the Central Committee:

> *1. The proposal of Ustinov, Rudnev, Kalmykov, Dementyev, Butoma, Moskalenko, Vershinin, Keldysh, Ivashutin, and Korolev on the launch of a satellite-ship "Vostok-3A" with a cosmonaut aboard is approved.*
> *2. The plans for TASS to announce the launch of the space ship with a cosmonaut aboard an Earth satellite is approved, and grants the Commission for Launch the right, if necessary, to introduce updates on the results of the launch and the Commission of the Presidium of the USSR Council of Ministers for Military-Industrial Issues, the right to publicize it.*[88]

The actual TASS communiqués were authored by the military NII-4 under the supervision of institute Deputy Director Colonel Yuriy A. Mozzhorin. The preparation of the news report was a strangely surreal process, as remembered by Mozzhorin years later:

> *In order not to lose time for writing and transmitting the necessary texts of the communiqués to radio and television, these communiqués were prepared at our institute, with the agreement of S. P. Korolev and the leadership, and sent in advance to radio, television, and TASS in sealed envelopes. In the case that [the cosmonaut] successfully entered orbit, they would receive a signal authorizing them to open them, and write down the orbital parameters [which would be communicated] by telephone, and the information would then be publicized internationally. There were also two more packets of material with the above [envelope] . . . with . . . communiqués for unfortunate [outcomes]. [The first one was] brief—in the event of death of the cosmonaut during insertion into orbit or at liftoff. The second one was in case of not having reached orbit, but having landed in some foreign territory or in the equatorial regions of the world's oceans. This contained an appeal to all governments, in particular the government on whose territory the cosmonaut had landed, requesting them to render assistance for [his] search and return.*[89]

87. Michael Tatu, *Power in the Kremlin: From Khrushchev's Decline to Collective Leadership* (London: Collins, 1969), pp. 88–89. Note that Kozlov's appointment into the Secretariat was announced on May 5, 1960, although his predecessor Brezhnev was not formally released from his prior duties until July 1960.

88. Belyanov, *et al.*, "Yuriy Gagarin's Star Voyage," p. 105. Note the curious omission of Kamanin's name from the Communist Party decree, although he was a signatory to the original request. The Commission of the Presidium of the USSR Council of Ministers for Military-Industrial Issues was more commonly known as the Military-Industrial Commission (VPK).

89. Mozzhorin, *et al.*, eds., *Nachalo kosmicheskoy ery*, p. 276.

The official Communist Party approval for the launch may have been the last *de facto* step in getting a human into space, but technical problems with the Vostok spaceship continued to thwart the possibility of a launch on time. On March 24, OKB-124, responsible for the life support system, reported at a meeting of the State Commission that there were serious limitations in the air drying units of the Vostok 3A spaceship. Long-duration tests on location at the Institute of Aviation and Space Medicine had proved that impregnated lignin in the system began to leak after absorbing a certain amount of moisture, resulting in large amounts of brine forming inside the spacecraft. At a second meeting on March 28, OKB-124 Chief Designer Voronin vehemently defended his system, claiming that the lithium chloride would be harmless to the cosmonaut. A competitive proposal by institute doctor Abram M. Genin to use a newer drying system on the vehicle was the subject of much debate.[90]

The problem with the life support system remained unresolved when Korolev flew into Tyura-Tam from Moscow late on April 3. The six core cosmonauts arrived on the afternoon of April 5 as part of a group of three chartered Il-14 airplanes, followed by State Commission Chairmen Rudnev the following day. Leaving behind their wives back in Moscow, the cosmonauts were instructed to tell their spouses that the launch was set for April 14, three days later than actually intended—to reduce worry. The first meeting of the full State Commission at Tyura-Tam took place immediately after Rudnev's arrival, at 1130 hours Moscow Time, at which point the primary issue of discussion was the life support system and the results of additional testing of the spacesuit and ejection system. Chief Designer Voronin reported, somewhat unconvincingly, that the suspect drying unit was completely ready for a contingency ten-day mission. Because an actual nominal flight was to last only an hour and a half, concerns were somewhat allayed; there would simply not be enough time for brine to form in the spacecraft.[91] The commission also approved cosmonaut trainer Mark L. Gallay's proposal to have the cosmonaut candidates conduct training sessions in the actual flight-ready spacecraft rather than a backup one. These tests were carried out on April 7 without incident by Gagarin and Titov, by then the primary contenders for the flight. Nelyubov, the third candidate, was considered out of the running.

The State Commission conclusively addressed the question of who would fly the first mission at a meeting on April 8. Lt. General Kamanin, as overseer of the cosmonaut team, clearly had a major role in the selection. Both Gagarin and Titov had performed without fault during training, with Gagarin edging out Titov in the January 1961 examinations. Although Gagarin was a marginal favorite, Kamanin apparently began to lean toward Titov in the final days leading up to the launch. On April 5, he wrote in his personal journal:

> *Both are excellent candidates, but in the last few days I hear more and more people speak out in favor of Titov and my personal confidence in him is growing too. . . . The only thing that keeps me from picking [Titov] is the need to have the stronger person for a [second] one day flight.*[92]

While Kamanin himself may have been a key player in the selection, there has been much speculation in the West that the final choice was in fact made by "higher ups," as one would expect in a highly centralized society such as the Soviet Union. Days before the scheduled launch, photographs and biographies of Gagarin and Titov were evidently sent to the Defense

90. Kamanin, *Skrytiy kosmos*, pp. 34–38; Yu. A. Mozzhorin *et al.*, eds., *Dorogi v kosmos: I* (Moscow: MAI, 1992), pp. 61–62.

91. Golovanov, *Korolev*, p. 637; Kamanin, *Skrytiy kosmos*, pp. 43–45; Neville Kidger, "Yuri Gagarin's Immortal Day," *Spaceflight* 33 (April 1991): 124–29.

92. Kamanin, *Skrytiy kosmos*, pp. 44–45; Bart Hendrickx, "The Kamanin Diaries 1960–1963," *Journal of the British Interplanetary Society* 50 (January 1997): 33–40.

Department of the Central Committee, the curator of the space program. Each candidate had two photos, one in civilian clothing and one in military attire. Here a number of Party apparatchiks mulled over their files and reported to Ivan D. Serbin, the feared head of the Defense Department. Serbin then showed the photographs to Kozlov, who in turn showed them to Khrushchev. Upon seeing the photos, the Soviet leader was reported to have said, "Both pairs are excellent! Let them decide for themselves!"[93] A noted Russian aerospace historian, Yaroslav K. Golovanov, suggests that the only reason such a convoluted procedure was carried out was simply to allow the Party apparatchiks to be able to say that the decision had been made at the "highest level."

In the end, at the State Commission meeting on April 8, Kamanin stood up and formally nominated Gagarin as the primary pilot and Titov as his backup. Without much discussion, the commission approved the proposal and moved on to other last-minute logistical issues. It was assumed that in the event Gagarin developed health problems prior to liftoff, Titov would take his place, with Nelyubov acting as *his* backup. The launch date was limited at the meeting to April 11 or 12. Orbital parameters would be 180 by 230 kilometers, and the mission would last a single orbit. There was some discussion on the idea of registering the mission as an absolute world record. In the interest of maintaining the ever-pervasive secrecy, some members of the commission, in particular Moskalenko and Keldysh, opposed having sports commissioners involved. In the end, the commission decided not to disclose the launch site or the type of launch vehicle, but to file documents with international organizations to establish a world record. Although the mission would be completely automated, commission members proposed giving the codes to unlock the manual orientation system for reentry in an envelope to the cosmonaut. In case of a failure of the automatic system, the cosmonaut would open the sealed envelope and activate the manual system.[94] The meeting ended with a decision to hold a last session, more as a formality, two days later.

The following day, Kamanin invited Gagarin and Titov privately to his office and announced to them that Gagarin was going to fly and that Titov would serve as his backup. When asked years later how he felt, Titov replied, "Why even ask! Painful or not—it was at least unpleasant."[95] The two men relaxed the rest of the day as prelaunch procedures for the 8K72K booster continued at the Assembly-Testing Building. Remarkably, Korolev and his principal deputies Mishin and Chertok were at the same time involved in the first critical launch of the new R-9 ICBM from nearby site 51. It was an extremely high-priority program for not only OKB-1 itself but also the Soviet Union as a whole, and one wonders how hectic operations at Tyura-Tam must have been during this second week of April 1961.[96] The first R-9 launch took place on April 9, just three days prior to Gagarin's slated launch from site 1.

The following day at 1100 hours, a large meeting of the State Commission took place at a site overlooking the banks of the majestic Syrdarya River. This session was simply a formality, primarily for the Soviet press, but it was open to many curious workers who had not yet had a glimpse of the cosmonauts. In attendance were seventy people, including chief designers (such as Korolev, Glushko, Pilyugin, Barmin, Ryazanskiy, Kuznetsov, Isayev, Kosberg, Alekseyev, Voronin, Bykov, and Bogomolov), ministers, Air Force officers, Strategic Missile Forces officers, and representatives from the Communist Party and the Academy of Sciences, as well as the six core cosmonauts. Chief Designer Korolev, State Commission Chairman Rudnev, Strategic

93. Golovanov, *Korolev*, pp. 634–35.

94. *Ibid.*, p. 638; Kamanin, *Skrytiy kosmos*, pp. 46–47; Lardier, *L'Astronautique Soviétique*, p. 129.

95. Golovanov, *Korolev*, p. 638.

96. Vassily Mishin, "He Would Make You Work to the Best of Your Ability," *Aerospace Journal* no. 6 (November–December 1996): 76–78; Chertok, *Rakety i lyudi*, pp. 432–33.

Missile Forces Commander Moskalenko, and Cosmonaut Training Center Director Karpov all made short but dramatic presentations on the impending mission, followed by thank-you speeches by Gagarin, Titov, and Nelyubov. At the end, Kamanin singled out Gagarin to become the first human to go into space. The young cosmonaut gave an acceptance speech, which was cut short in the middle when a movie cameraman let it be known that his film had inadvertently run out. Gagarin repeated his entire speech so that it could be recorded again.[97] Earlier in the morning, the 8K72K booster had been moved to the pad at site 1. The launch was set for the morning of April 12, 1961. Engineers had calculated the exact launch time, 0907 hours Moscow Time, because it would afford the best solar illumination for the orientation system's sensors somewhere over Africa right before retrofire.

The day before the launch, OKB-1 engineers Raushenbakh and Feoktistov briefed Gagarin and Titov for an hour and a half on various mission events. Raushenbakh recalled later that he was still having trouble coming to terms with the magnitude of what was going on:

> *I looked at [Gagarin] and in my mind I understood that tomorrow this kid was going to awaken the whole world. But at the same time I just could not make myself believe that tomorrow something would happen which the world had not yet seen—that this First Lieutenant sitting in front of us would tomorrow become the symbol of a new epoch. I would start giving him instructions, such as, "Turn this on, don't forget to switch this on,"—all these normal, pedestrian, even boring remarks, and then I would become silent and some sort of internal imp would begin whispering to me, "This is all a bunch of crap. You know that nothing of this sort is going to happen tomorrow."*[98]

Being at the center of everything, the cosmonauts were perhaps less conscious of their centrality in this vortex of events. Witnesses remember Gagarin smiling the whole day, happy that he had been chosen for the mission. The cosmonauts also visited the pad to meet the young soldiers, officers, and sergeants who had worked on the rocket the past few days. It was a pragmatic managerial move—one that not only lifted morale among the lower rank workers, but also played a role in instilling a sense of responsibility, both among the cosmonauts and the work teams. Gagarin and Titov were assigned to a special cottage near the pad area, which had previously been the late Marshal Nedelin's place of choice to stay at Tyura-Tam. That night, they had a light meal with Lt. General Kamanin and were asleep by 2130 hours when Korolev quietly visited to check up on the two. Physicians attached sensors to both cosmonauts to monitor their vital systems during the night. In addition, unbeknown to both, special strain gauges were attached to their mattresses to monitor whether the trainees had had a fitful night of tossing and turning.[99] As it turned out, both men slept remarkably peacefully.

Korolev did not sleep at all that night. Among the many worries on his mind, perhaps the most troubling was the prospect that the rocket's third stage would fail during the ascent to orbit, depositing the Vostok spacecraft in the ocean near Cape Horn on the southern tip of Africa, an area infamous for its constant storms. The chief designer had demanded that there be a telemetry system in the launch bunker at Tyura-Tam to confirm that the third stage had worked as planned. If the engine worked nominally, the telemetry would print out a series of "fives" on tape; otherwise, there would be a series of "twos." Despite all the precautions, all

97. Kamanin, *Skrytiy kosmos*, pp. 48–49; Golovanov, *Korolev*, p. 638.

98. Golovanov, *Korolev*, p. 640.

99. *Ibid.*, p. 641. The primary physicians in charge of Gagarin and Titov at the time were I. T. Akulinichev and A. R. Kotovskaya. The strain gauges were designed by engineers I. S. Shadrintsev and F. D. Gorbov.

the testing, and all the preparations, Korolev still had his doubts. One military officer recalled, "For some reason, it was just Cape Horn that would not give Korolev a moment's peace."[100]

Prelaunch pad operations at site 1 began at 0300 hours on April 12, just before dawn, as controllers began taking their stations not only at Tyura-Tam, but all over the Soviet Union. A very brief readiness review meeting of the State Commission at 0600 hours ended with an "all prepared" conclusion, after which the members dispersed to various duties. Gagarin and Titov themselves had been woken up half an hour earlier by Cosmonaut Training Center Director Karpov and presented with a bunch of early wild flowers, a gift from the woman who had previously owned the cottage. After a short breakfast with food from a tube (meat paste, marmalade, and coffee), a group of doctors led by Yazdovskiy, almost ten years after he had led the first historic flight of dogs from the deserts at Kapustin Yar, examined the cosmonauts. Two assistants helped Gagarin and Titov don their bulky *Sokol* spacesuits—first a pale blue pressurized suit, followed by a bright orange coverall. Titov was the first to suit up to prevent Gagarin from overheating because the suits depended on external power sources for the cooling fans, which were only on the transport bus. Within an hour of waking up, both cosmonauts were on the bus, accompanied by eleven other individuals, including cosmonauts Nelyubov and Nikolayev and two cameramen who recorded the entire trip.[101] The jaunt was short, and there was apparently much joking between Gagarin and the rest. Numerous photos of that short bus ride show a sometimes pensive Gagarin, seemingly unaffected at being at the center of this massive undertaking.

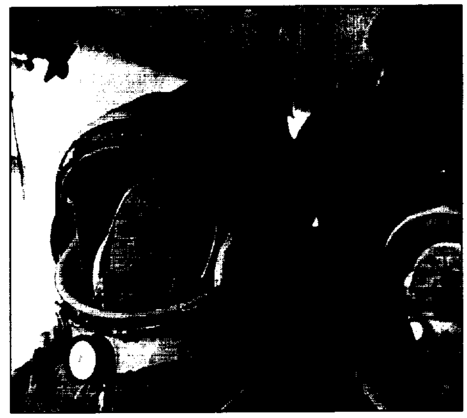
On arrival at the pad, Gagarin and Titov were greeted by Korolev, Keldysh, Kamanin, Moskalenko, State Commission Chairman Rudnev, and other officials. By all accounts, Korolev clearly looked fatigued and tired as he quietly watched Gagarin say his final goodbyes. As onlookers stood around, Gagarin turned to Rudnev and reported very briefly that he was ready for the mission. One of the more enduring myths of the flight was that before he took the elevator up to the top of the rocket, Gagarin made a farewell speech. Soviet-era journalists for years outdid each other by putting together and embellishing disjointed quotes from Gagarin with sugar-coated melodramatic flourishes, such as "I was seized by a total lifting of all my spiritual forces, with all of my being I heard the music of nature. . . ." To this day, documentaries often play a tape of Gagarin speaking to the assembled crowd at the base of the booster, but this speech was in fact taped much earlier, in Moscow, when Gagarin was essentially forced to utter a stream of banalities prepared by anonymous speechwriters. Similar speeches by Titov and Nelyubov were also taped.[102] After last-minute embraces with Rudnev, Moskalenko, and Korolev, Gagarin was escorted to the service elevator, where he halted and waved excitedly one last time before the two-minute ride to the top. Titov was left behind, thus separating the futures of these two men—one into history and one into posterity.

Vostok lead designer Oleg G. Ivanovskiy helped Gagarin into the spacecraft, who switched on the radio communications system at 0710 hours. For the next two hours, he chatted effusively with Korolev and "capcom" cosmonaut Popovich. Kamanin, Chief Designer Bykov, and

100. Mikhail Rebrov, "A Star Traversing Cape Horn" (English title), *Krasnaya zvezda*, April 12, 1994, p. 2.

101. Golovanov, *Korolev*, pp. 644–55. The individuals apart from Nelyubov and Nikolayev who were on the bus were TsPK Director Ye. A. Karpov, Plant No. 918 Chief Designer S. M. Alekseyev, F. A. Vostokov, V. I. Svershchek, G. S. Petrushin, Yu. D. Kilosanidze (all from Plant No. 918), physician L. G. Golovkin, and cameramen V. A. Suvorov and A. M. Filippov.

102. *Ibid.*, p. 649. The prepared speech included the following passage: "Dear friends, you who are close to me, and you whom I do not know, fellow Russians, and people of all countries and all continents: In a few minutes a powerful space vehicle will carry me into the distant realm of space. What can I tell you in these last minutes before the launch? My whole life appears to me as one beautiful moment. All that I previously lived through and did, was lived through and done for the sake of this moment." See Evgeny Riabchikov, *Russians in Space* (Garden City, NY: Doubleday & Company, 1971), p. 19.



A pensive Yuriy Gagarin is in the bus on the way to the launch pad on the morning of April 12, 1961. Behind him, seated, is his backup, German Titov. Standing are cosmonauts Grigoriy Nelyubov and Andrian Nikolayev. (files of Asif Siddiqi)

Commission Chairman Rudnev also took the mike on occasion to wish him well. The main command bunker, comprising several rooms, was walking distance from the actual launch pad. On the day of the launch, officials had set up a small table with a green tablecloth specifically for Korolev in the main room. Here there would be a two-way radio and a single red telephone for giving the password to catapult the cosmonaut in case of an emergency during the first forty seconds of the launch. Only three people knew the password: Korolev, his Deputy Leonid A. Voskresenskiy, and Colonel Anatoliy S. Kirillov, a Strategic Missile Forces officer who had recently been appointed to head the First Directorate at Tyura-Tam—that is, the division responsible for launch operations. His predecessor had been killed in the recent R-16 disaster. For Voskresenskiy, it was the culmination of a long career as Korolev's deputy for flight testing. His exploits in testing the German A-4s at Kapustin Yar in the 1940s were by then part of legend. Apart from Korolev, Voskresenskiy, and Kirillov, the three men primarily responsible for directing the launch, others in the main room included Mark L. Gallay, the renowned Soviet test pilot who had assisted cosmonaut training. Korolev apparently allowed him to witness the launch, not for his piloting skills, but because Gallay was an accomplished author—one who could chronicle the events for those who did not have the fortune to actually be present. Most of the members of the State Commission, as well as senior engineers such as Glushko and Feoktistov, were housed in a second room called the "guest room" of the bunker. In the third room, Chief Designer Ryazanskiy served as head of telemetry systems.[103] Gagarin's call sign was *Kedr* ("Cedar"), while the ground call sign was *Zarya-1* ("Dawn-1"), most likely named as such because of the same designation of the primary voice communications system on Vostok.

At 0750 hours, the hatch was closed, but one of the contacts indicated that it was not pressed down properly. Three engineers at the top of the rocket removed all thirty screws in the hatch and shut the hatch a second time when all the indicators were positive. This action took almost an hour, and the technicians finally left the vicinity of the Vostok about thirty minutes prior to the scheduled launch. An excerpt from the communications from Kedr to Zarya-1 shows that despite the risks involved, there were attempts to alleviate some of the tension:

0814 hours

Popovich:	*Yuriy, you're not getting bored there, are you?*
Gagarin:	*If there was some music, I could stand it a little better.*
Popovich:	*One minute.*

0815 hours

Korolev:	*Station Zarya, this is Zarya 1. Fulfill Kedr's request. Give him some music, give him some music.*
Popovich:	*Did you read that? Zarya answers: We'll try to fulfill your request. Let's have some music or I'll get bored.*

103. Others in the main room included OKB-1 engineer B. A. Dorofeyev, Air Force officer N. P. Kamanin, NII-885 Chief Designer N. A. Pilyugin, cosmonaut "capcom" P. R. Popovich, and NII-885 Deputy Chief Designer V. P. Finogenov. See *ibid.*, pp. 647–48.

0817 hours

Popovich:	*Well, how is it? Is there music?*
Gagarin:	*No music yet, but I hope there'll be some soon.*
Korolev:	*Well, they gave you music, right?*
Gagarin:	*Not yet.*

0819 hours

Korolev:	*Of course, that's the way musicians are; now they're here, now they're there, but they don't do anything very fast, as the saying goes, Yuriy Alekseyevich.*
Gagarin:	*They gave me love songs.*[104]

At T (launch) minus fifteen minutes, Gagarin put on his gloves and ten minutes later closed his helmet. The tower was taken away from the pad at the same time. By this time, the tension was clearly rising, and Korolev and Voskresenskiy both took tranquilizer pills to calm their hearts. The record of the 8K72K booster was not something that instilled confidence. Up to that time, there had been sixteen launches of the R-7 with the Blok Ye third-stage combination, which was to send Gagarin to orbit. Of those sixteen launches, six had failed because of faults in the R-7, while two had failed because of the Blok Ye itself—that is, a success ratio of exactly 50 percent. In the case of the seven Vostok spacecraft flown, two spacecraft had failed to reach orbit because of booster malfunctions, while two others had failed to complete their missions.[105] For an endeavor that theoretically required a 100-percent guarantee of success, if the past record was any indication, the potential for an accident was significant on Gagarin's mission.

While Korolev and Voskresenskiy may have needed to calm their selves down, Gagarin, removed in some way from the hubbub of activity at the pad, was as calm as ever:

0841 hours

Kamanin:	*How do you read me?*
Gagarin:	*I read you well. How do you read me?*
Kamanin:	*Your pulse is 64, respiration 24. Everything is going normally.*
Gagarin:	*Roger. That means my heart is beating.*[106]

Gagarin's pulse rate reached an excited 157 beats per minute seconds before liftoff, although his tone remained completely calm. Finally, at exactly 0906 hours, 59.7 seconds on April 12, 1961, the Vostok spacecraft lifted off with its twenty-seven-year-old passenger, Senior Lieutenant Yuriy Alekseyevich Gagarin. His first exuberant words were: "We're Off!"[107]

Korolev, Voskresenskiy, and Kirillov had the abort codes in case the 8K72K booster did not achieve nominal performance, but the launch trajectory was on target. For the first few minutes after launch, Gagarin reported feeling the g-loads on him rise, but he gave no indication of any lack of comfort. In fact, he maintained his sense of humor:

104. Belyanov, *et al.*, "Yuriy Gagarin's Star Voyage," p. 110.
105. Riabchikov, *Russians in Space*, p. 21; Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p. 113.
106. Belyanov, *et al.*, "Yuriy Gagarin's Star Voyage," p. 111.
107. *Ibid.*

0909 hours

Korolev:	*T plus 100. How do you feel?*
Gagarin:	*I feel fine. How about you?*[108]

At T+119 seconds, the four strap-on boosters of the base R-7 missile separated, allowing the center sustainer to continue to fire. The payload shroud separated from the Vostok spaceship exactly fifty seconds later as planned. At about five g's, Gagarin reported some difficulty in talking, saying that all the muscles in his face were drawn and strained. The g-load steadily increased until the central core of the launcher ceased to operate and was detached at T+300 seconds.[109] Following the separation of the spent core and strap-ons, the RD-0109 upper stage engine ignited to accelerate the craft to orbital velocity.

Korolev was literally shaking through all of this, having obsessed over the possible landing in the ocean south of Cape Horn if the upper stage failed. The incoming telemetry began to stream in a series of "fives," indicating all was fine. Then, suddenly, the numbers changed to a series of "threes." There were brief seconds of terror—a "two" was a malfunction, but what was a "three"? After a few agonizing seconds, the numbers reverted back to "fives." Engineer Feoktistov remembers that "these interruptions, a few seconds in length, shortened the lives of the designers."[110]

During the powered leg of the flight, Gagarin's pulse reached a maximum of 150 beats per minute. Although Popovich was officially the "capcom" for the mission, Korolev's excitement most likely got the better of him, and he took over communications personally for a good portion of the ascent to orbit, constantly asking Gagarin about his well being:

0910 hours

Korolev:	*The fairing has been jettisoned, everything is normal. How do you feel?*
Gagarin:	*. . . Nose fairing jettisoned. . . . I see the Earth. The g-load is increasing somewhat. I feel excellent, in a good mood.*
Korolev:	*Good boy! Excellent! Everything is going well.*
Gagarin:	*I see the clouds. The landing site. . . . It's beautiful. What beauty! How do you read me?*
Korolev:	*We read you well, continue the flight.*[111]

Orbital insertion occurred finally at T+676 seconds just after shutdown of the third-stage RD-0109 engine. For the first time in history, a human being had escaped the bonds of Earth's gravity and entered outer space. Initial orbital parameters for the Vostok spaceship were 175 by 302 kilometers at a 65.07-degree inclination to the equator. The orbit was much higher than had been planned for the flight; the apogee was about seventy kilometers over the planned altitude, indicating a less than stellar performance for the launch booster. When the parameters were reported back to Tyura-Tam from the flight control center at NII-4 in Moscow, no doubt there was some anxiety because the higher orbit could have resulted in a longer mission given retrofire failure.

Immediately after entering orbit, Gagarin reported that he was feeling excellent and vividly described the images outside his porthole. In his secret postflight report, he recalled his feelings of being the first human being to experience prolonged microgravity:

108. *Ibid.*, p. 112.
109. Gibbons and Clark, "The Evolution of the Vostok and Voskhod Programmes."
110. Rebrov, "A Star Traversing Cape Horn."
111. Belyanov, *et al.*, "Yuriy Gagarin's Star Voyage," p. 112.

I ate and drank normally. I could eat and drink. I noticed no physiological difficulties. The feeling of weightlessness was somewhat unfamiliar compared with Earth conditions. Here, you feel as if you were hanging in a horizontal position in straps. You feel as if you are suspended. Obviously, the tightly fitted suspension system presses upon the thorax. . . . Later I got used to it and had no unpleasant sensations. I made entries into the logbook, reported, worked with the telegraph key. When I had meals, I also had water. I let the writing pad out of my hands and it floated together with the pencil in front of me. Then, when I had to write the next report, I took the pad, but the pencil wasn't where it had been. It had flown off somewhere. The eye was secured to the pencil with a screw, but obviously they should have used glue or secured the pencil more tightly. The screw got loose and flew away. I closed up my journal and put it in my pocket. It wouldn't be any good anyway, because I had nothing to write with.[112]

Once the orbital parameters had been accurately determined, controllers at NII-4 sent the numbers to news agencies in Moscow, instructing reporters to open their secret envelopes. Because of simple gross inefficiency, the Soviet news agency TASS was unable to announce the launch until almost an hour after Gagarin took off. Everyone back at Tyura-Tam was bewildered, unsure as to why the news was not on the radio despite assurances that it would be so. Finally, a full fifty-five minutes after launch, famous Soviet radio personality Yuriy B. Levitan announced:

The world's first satellite-ship "Vostok" with a human on board was launched into an orbit about the Earth from the Soviet Union. The pilot-cosmonaut of the spaceship satellite "Vostok" is a citizen of the Union of Soviet Socialist Republics, Major of Aviation Yuriy Alekseyevich Gagarin.[113]

U.S. intelligence services were already cognizant of the mission prior to the announcement. An electronic intelligence station in Alaska had picked up transmissions from the spacecraft, just twenty minutes after launch. Further real-time interceptions of communication thirty-eight minutes later clearly showed a human moving inside the spacecraft.[114]

Most of Gagarin's single orbit was spent observing the view through the porthole and the systems in the craft itself. No experiments were planned for the mission, and no anomalies were detected during his time in orbit. Because of physicians' concerns about the adverse effects of weightlessness on the psychology of the cosmonaut, precautions were taken to ensure that the cosmonaut could not control the spacecraft and endanger his life. A special six-digit code was programmed on a special "logic clock" to lock the controls on the ship; Gagarin was not told three of the missing digits. If the Vostok was to lose its ground command link, then Gagarin could unseal a special envelope that contained the code (1-2-5) and thus unlock the controls. Otherwise, all the flight actions took place automatically or were controlled by the ground.

When contact with Zarya-1 at Tyura-Tam was lost about seven minutes after launch, Gagarin maintained contact with Zarya-2 at Kolpashevo and Zarya-3 at Yelizovo.[115] Prior to

112. *Ibid.*, p. 119.

113. "Tass Communiqué on the World's First Flight of a Human into Cosmic Space" (English title), *Pravda*, April 13, 1961. This report has also been published in Raushenbakh, ed., *Materialy po istorii kosmicheskogo*, p. 146.

114. Dwayne Day, "Those Magnificent Spooks and their Spying Machines," *Spaceflight* 39 (March 1997): 98–100.

115. The communicators at Zarya-2 were Air Force Lt. Colonel G. I. Titarev and military unit no. 32103 representative Lieutenant B. V. Seleznez. The communicator at Zarya-3 was Air Force Colonel M. F. Karpenko. In addition, communications were also maintained with the station at Khabarovsk (Air Force Colonel M. P. Kaduskin) and in Moscow (Desna) at NII-4 (Captain V. I. Khoroshilov).

retrofire, the Vostok ship was oriented to the correct attitude using the solar sensor system, resulting in three commands to fire the small thrusters. The TDU-1 retrorocket system successfully fired at 1025 hours, and Gagarin noted the status of all the systems, recording his comments on a tape recorder because he was out of range of ground communications:

> *The braking rocket fired for exactly 40 seconds. During that period, the following occurred. As soon as the braking rocket shut off, there was a sharp jolt, and the craft began to rotate around its axis at a very high velocity. The Earth passed in the "Vzor" from top right to bottom left. The rate of rotation was about 30 degrees per second, at least. I was an entire "corps de ballet": head, then feet, head, then feet, rotating rapidly. Everything was spinning around. Now I see Africa (this happened over Africa), next the horizon, then the sky. I had barely enough time to cover myself to protect my eyes from the Sun's rays. I put my legs to the porthole, but didn't close the blinds.*[116]

Following the firing of the retrorocket engine, the large instrument section of the vehicle was to separate from the spherical descent apparatus, with the latter descending into the upper layers of the atmosphere. It was precisely at this point that the only major malfunction occurred on the mission:

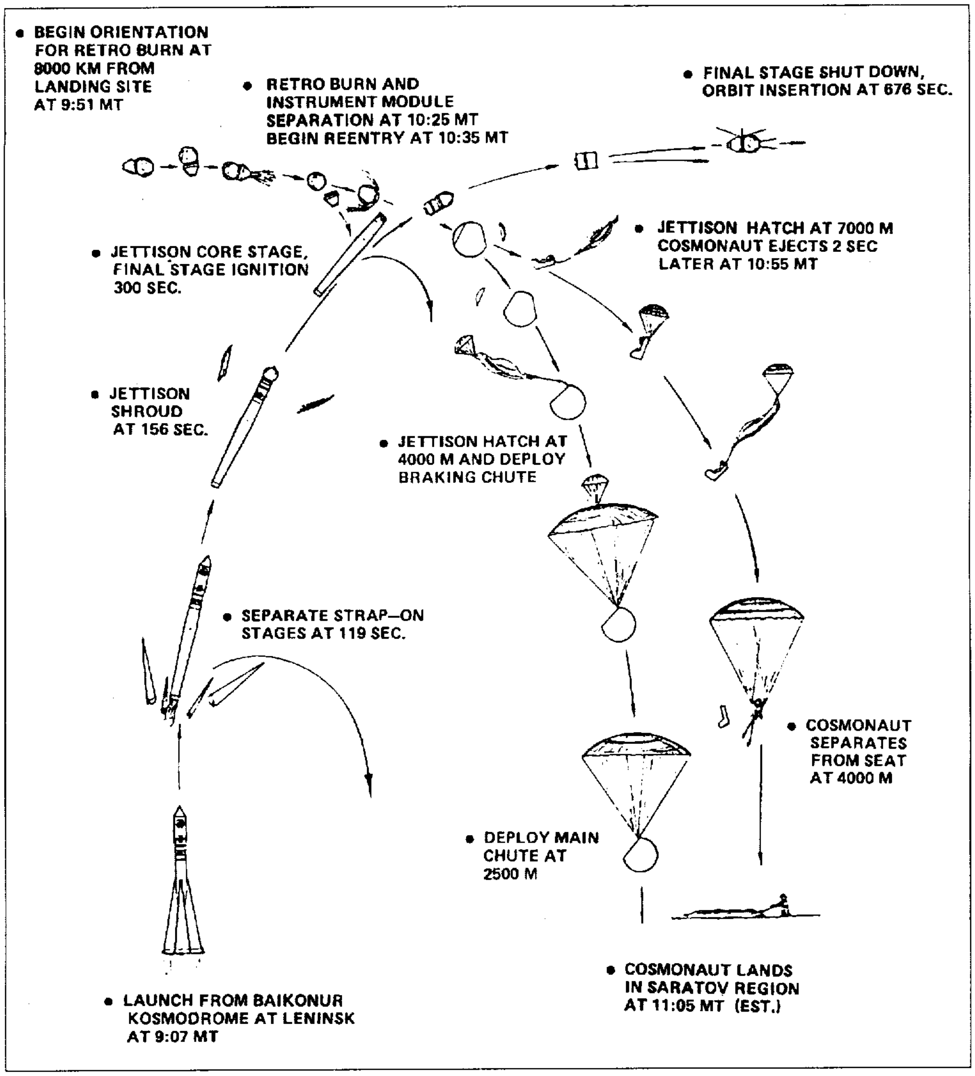
> *I wondered what was going on and waited for the separation. There was no separation. I knew it was scheduled in 10 to 12 seconds after actuation of the retrorocket. When it was actuated, all the lights of the control board went out. I felt that more time had passed, but there was no separation. The light panel "Landing-1" failed to go out.*[117]

The separation mechanism, comprising four metal strips that came together in a single lock, evidently released the two modules on time, but the compartments remained loosely connected by a few cables; the heavier descent apparatus remained below the lighter instrument section as the combined spacecraft reentered the atmosphere. Although the situation was of serious concern, it does not now seem that Gagarin's life was in jeopardy, as suggested by some Western analysts when this incident was finally revealed in 1991. Gagarin, who was clearly cognizant of the situation, remained remarkably calm:

> *. . . still no signs of separation. The "corps de ballet" continues. I thought that something had gone wrong. I checked the time on the watch. About two minutes had passed but there was no separation. I reported through the [high-frequency] communications channel that the [retrorocket] had worked normally. I estimated that I would be able to land normally anyway, because the distance to the Soviet Union was six thousand kilometers and the Soviet Union was about eight thousand kilometers long. That meant that I could land before the Soviet far east. So I decided not to make much ado about that. I used the telegraph key to transmit the "VN" message meaning "all goes well."*[118]

Separation finally occurred at 1035 hours, approximately ten minutes later than intended, saving the spacecraft from a dangerous tumbling reentry. Gagarin's description of a ballistic reentry, the first such in history, was vivid and full of illuminating details:

116. Belyanov, *et al.*, "Yuriy Gagarin's Star Voyage," p. 120.
117. *Ibid.*
118. *Ibid.*, pp 120–21.



This is the mission profile for Yuriy Gagarin's pioneering flight into space. (copyright R. F. Gibbons)

Suddenly a bright purple light appeared at the blind edges. The same purple light could be observed in the small opening of the right-hand porthole. I felt oscillations of the spaceship and burning of the coating. I don't know what caused the crackling sounds: whether it was the structure or because of the heat-resistant casing expanding as a result of the heat, but I heard crackling sounds. The frequency was approximately one crackling per minute. Generally, I felt the temperature was high. . . . Next the overloads began to rise gradually. The ball was constantly oscillating along all axes. As the load factor was reaching its peak, I could see the Sun. Its rays penetrated into the cabin through the porthole of hatch 1 and the right-hand porthole. By the reflected rays of the Sun I could tentatively determine how the spaceship was rotating. By the time the load factor reached its peak, the spaceship oscillations reduced to 15 degrees. At that moment I felt that the load factor reached about 10g. There was a moment for about

2 or 3 seconds when the instrument readings became blurred. My vision became somewhat greyish. I strained myself again. This worked, and everything assumed their proper places.[119]

At an altitude of 7,000 meters, the main descent apparatus parachutes opened, and then hatch number one shot off from the capsule. Gagarin was shot out of the craft, still in his seat, just two seconds later. Looking down at the land, he immediately recognized that the region of landing was near the Volga River. He separated from his seat, and his personal parachute then opened. He recalled later:

When I was parachute training, we had jumped many times over this very site. We had flown much here. I recognized the railroad, a railroad bridge over the river, and a long spit of land extending far into the Volga. I thought that was probably Saratov. I was landing in Saratov.[120]

Ground control spent several minutes in tension following reentry, when communications were cut off. Soon after the command for retrofire occurred, Korolev telephoned Khrushchev, who was at the holiday resort at Pitsunda, telling him that "the parachute has opened, and he's landing. The spacecraft seems to be OK!" Khrushchev asked excitedly, "Is he alive? Is he sending signals? Is he alive? Is he alive? . . ."[121]

Gagarin, very much alive, landed relatively softly in a field next to a deep ravine at 1055 hours, just one hour and forty-eight minutes following launch. The landing point was twenty-six kilometers southwest of the town of Engels in the Saratov region, close to the village of Smelovka. Immediately after landing, he had some trouble opening up the air valve in his spacesuit, and it took him six whole minutes of wrestling before he was able to breathe natural air. His first concern was reporting that he was safe:

I had to do something to send a message that I had landed normally. I climbed a small hill and saw a woman with a girl approaching me. She was about 800 meters away from me. I walked to her to ask where I could find a telephone. So I was walking to her, when I saw that the woman was slowing down and the girl was going away from her and running back. When I saw that, I began to wave my hands and shout: "I'm a friend, I'm Soviet!" She told me that I could use the telephone in the field camp. I asked the woman not to let anyone touch my parachute while I was going to the camp. As we approached the parachutes, we saw a group of men, about six all in all—tractor drivers and mechanics from the field camp. I got acquainted with them. I told them who I was. They said that news of the space flight was being transmitted at that moment over the radio.[122]

Eventually, rescue teams arrived and drove him to a military unit not far from Engels, where he received a telegram of congratulations from Khrushchev and reported officially by telephone to Air Force Commander-in-Chief Vershinin on having completed his assigned mission. Vershinin's deputy, Col. General Agaltsov, was the first high-ranking space official to meet the cosmonaut, and after further cursory congratulatory phone calls from Khrushchev and Brezhnev, Gagarin was quickly escorted out to seclusion at Kuybyshev in the Zhiguli Hills on the Volga.

119. *Ibid.*, p. 121.

120. *Ibid.*, p. 122.

121. M. Rebrov, "The Difficult Path to April 1961, or Why We're Not Finding Out the Entire Truth About the Flight of Yu. Gagarin Until Today" (English title), *Krasnaya zvezda*, March 28, 1992, p. 3.

122. Belyanov, *et al.*, "Yuriy Gagarin's Star Voyage," p. 122.

Back at Tyura-Tam, once news arrived that Gagarin was safe, the tensions that had pervaded the entire mission instantly dissipated. After a short meeting of the State Commission, champagne was passed around amid much mutual congratulations. Korolev was completely beside himself, laughing and smiling for the first time in days, excited and animated beyond what many of this colleagues had ever seen from him. The members of the commission flew to the landing site to inspect the descent apparatus; witnesses remember that Korolev could simply not take his eyes off the capsule, touching it and checking it all over. After the inspection, they flew off to Kuybyshev to finally meet with Gagarin, who had just minutes before been promoted from a senior lieutenant directly to major. Upon seeing the Korolev, Gagarin reported quietly, "All's well, Sergey Pavlovich, things are just fine." According to one journalist, Korolev was so beside himself with the shock of euphoria that he was speechless: "[He] had no clue what to say or how to reply [to Gagarin]."[123]

During the next morning, there was an official and final meeting of the *ad hoc* State Commission, during which Gagarin described his entire flight in great detail, a narrative that was preserved on tape. Following the monologue, commission members asked him a series of questions on various aspects of the flight. On April 19, Marshal Vershinin formally presented the transcripts of both sessions to the Central Committee. Both were classified "Top Secret" and unavailable to researchers until 1991, thirty years after the mission.[124]

Earlier on April 14, Gagarin returned to Vnukovo Airport in Moscow while thousands of onlookers cheered him on. A procession of scores of automobiles finally led the way to Red Square, where Khrushchev, Brezhnev, Kozlov, and other leaders of the Soviet state basked in the unqualified success of the first mission into space by a human. It was a moment unlike any other in Soviet history, quite possibly the absolute zenith of the more than forty years of Soviet achievements in space. Derided for years by the West for its backwards technology and antiquated customs, the Soviet Union had abruptly taken one of the most important steps in the history of humankind, the first voyage of a human into space. It was a day full of hyperbole from thousands of people on the streets, but anything less would not have done justice to it. Korolev, the chief architect of this achievement remained, as ever, anonymous among the multitudes. He traveled several cars behind the leading motorcade in a nondescript vehicle, prevented from wearing his previous state awards on his lapel for fear that Western agents would suspect something. Such was the curious and perhaps sad legacy of a powerful and great nation, unencumbered by notions of political freedom.

The flight of Yuriy A. Gagarin will undoubtedly remain one of the major milestones in not only the history of space exploration, but also the history of the human race itself. The fact that this accomplishment was successfully carried out by the Soviet Union, a country completely devastated by war just sixteen years prior, makes the achievement even more impressive. Unlike the United States, the USSR had to begin from a position of tremendous disadvantage. Its industrial infrastructure had been ruined, and its technological capabilities were outdated at best. A good portion of its land had been devastated by war, and it had lost about 25 million citizens. Thus, comparisons of the uncannily close race between the two superpowers in the early years after Sputnik are in some ways flawed by the absence of context. In the crudest of terms, it was a devastated totalitarian society with old-fashioned machines competing against an intact and democratic one equipped with far better technology. Both exercised the political imperative to explore space, but it was the totalitarian state that overwhelmingly took the lead.

123. Golovanov, *Korolev*, pp. 654–56.
124. Both have been reproduced in full in Belyanov, *et al.*, "Yuriy Gagarin's Star Voyage," pp. 117–28.

The Secret World

The first human in space, Yuriy Gagarin, seems very happy in this photo from 1961, taken soon after his historic mission. (NASA photo)

In attempting to maintain a tight shroud of secrecy around the Vostok mission and the space program as a whole, Soviet officials went to great and sometimes ludicrous levels of effort. Having told the full story of his flight to the State Commission, Gagarin was later forced to partake in a gross obfuscation of the truth. To satisfy international standards for an aerospace record for a piloted orbital flight, the passenger was required to take off and land in the same vehicle. Gagarin, of course, parachuted out of his descent apparatus prior to touchdown. Soviet authorities went to great lengths to conceal this fact, in many cases forcing Gagarin to blatantly lie during various press conferences. The first conclusive admission came ten years later in 1971, by which time Gagarin's flight was widely accepted as an international record.[125] The press conferences themselves were exercises in control and secrecy. A transcript from Gagarin's first postflight press conference illustrates the sometimes comic aspects of Gagarin's unenviable job:

Question:	*When were you told that you were the first candidate?*
Gagarin:	*I was told in good time that I was the first cosmonaut.*
Question:	*You said yesterday that your fellow pilot-cosmonauts are prepared for another cosmic flight. How many are there? Are there more than a dozen?*
Gagarin:	*In accordance with the plan to conquer cosmic space, pilot-cosmonauts are being trained in the country. I believe that there are more than enough to undertake important flights. . . .*
Question:	*When will the next spaceflight take place?*
Gagarin:	*I think that our scientists and cosmonauts will undertake the next flight when it is necessary.*[126]

As was typical during the aftermath of the first Sputnik launch, a number of important academicians were used for elucidating some of the technical aspects of the mission, thus implying that they were in some way connected to the facilitation of the mission. The most prominent of these was Academician Anatoliy A. Blagonravov, whose official title was Academic Secretary of the Department of Technical Sciences of the USSR Academy of Sciences. The sixty-six-year-old machine sciences expert had some tenuous ties to the space

125. To the knowledge of this author, the first reliable confirmation that Gagarin indeed landed in his capsule was in Riabchikov, *Russians in Space*, p. 36.

126. Peter Smolders, *Soviets in Space* (New York: Taplinger Publishing Co., 1973), p. 115.

establishment, but his high-visibility trips to various congresses cemented the myth that he was in some manner one of the leaders of the entire effort.

Forced to formally report a launch location for the Vostok spacecraft, the Soviets also created the fiction of a great new spaceport named "Baykonur." A few days following Gagarin's mission, a team led by Maj. General Kerimov, the head of the Third Directorate in the Chief Directorate of Reactive Armaments of the Missile Forces, prepared a document to submit to the International Astronautical Federation on the details of the mission. Prohibited from mentioning Tyura-Tam, Kerimov and his assistants picked the small settlement of Baykonur, 370 kilometers northeast of the actual launch site.[127] Although Western observers were quickly able to identify the real location with the aid of tracking data, the Soviets continued to insist on the Baykonur name for the launch area for close to thirty years. At first amused by the sudden fame of their native town, the inhabitants of the actual city of Baykonur tried to use the confusion over names to their own advantage. They put in orders for all sorts of scarce raw materials, such as cement and wood, to officials in Moscow, all of which they received in vast quantities. Moscow officials later stopped all such disbursements once they realized that they were the victims of a shrewd scam.[128] In a twist of which George Orwell would have been proud, the "Baykonur Cosmodrome" designation eventually came into accepted usage even among workers at Tyura-Tam. In 1996, the town of Leninsk was officially renamed Baykonur, the center of the Baykonur Cosmodrome.

Gagarin's flight had a large-scale repercussive effect on the growing space industry. Awards and promotions were liberally handed out to numerous important individuals, while space as a component of the ballistic missile program began to acquire an independent character. By an order dated June 17, 1961, 6,938 men and women were honored with various awards, including a number with the Hero of Socialist Labor, the highest and most prestigious national civilian honor in the Soviet Union. Characteristically, the Soviet press only named seven of the almost 7,000, all of them high officials in the Communist Party and government. The seven who were named for the Hero of Socialist Labor were Khrushchev (for the third time), Kozlov, Brezhnev, Ustinov (for the second time), Rudnev, Kalmykov, and Academician Keldysh (for the second time). Among those who remained unnamed, five of them were chief designers receiving the award for the second time. Korolev, Glushko, Barmin, Pilyugin, Kuznetsov, and Yangel were invited to the Kremlin at a secret ceremony on June 20.[129]

Concurrent with the bestowal of these honors, a major reshuffle in the Soviet space industry took place. At the apex of these changes was the replacement of the chairman of the State Committee for Defense Technology, the "ministry" with control over the space program. The Soviet press announced on June 10, 1961, that Committee Chairman Konstantin N. Rudnev

127. Mozzhorin, *et al.*, eds., *Nachalo kosmicheskoy ery*, pp. 320–21. The others involved with Kerimov in making the decision were Colonel A. A. Maksimov (GURVO) and Major V. D. Yastrebov (NII-4). See also Jacques Villain, ed., *Baïkonuor: la porte des étoiles* (Paris: Armand Colin, 1994), p. 47.

128. Golovanov, *Korolev*, p. 642.

129. Of the ninety-five people who received their Hero of Socialist Labor awards for the first time were the following chief designers or institute directors: S. M. Alekseyev (Plant No. 918), Yu. S. Bykov (NII-695), L. I. Gusev (NII-695), G. Ya. Guskov (NII MikroPribor), A. G. Iosifyan (NII-627), S. A. Kosberg (OKB-154), N. A. Krivoshein (TsKB TyazhMash), V. P. Makeyev (SKB-385), I. A. Rosselevich (VNII-380), N. A. Semikhatov (NII Avtomatiki), V. G. Sergeyev (OKB-692), V. S. Shpak (GIPKh), G. M. Tabakov (NII-229), and G. I. Voronin (OKB-124). Among the major omissions from the list were Chief Designers M. S. Ryazanskiy (NII-885) and A. M. Isayev (OKB-2). Both had, however, received the Hero of Socialist Labor in 1956, although Ryazanskiy was the only member of the original Council of Chief Designers who had not been bestowed the honor a *second* time in 1961. See Christian Lardier, "Soviet Space Designers When They Were Secrets," presented at the 47th International Astronautical Federation, IAA-96-IAA.2.2.09, Beijing, China, October 7–11, 1996; Albert Parry, *The New Class Divided: Science and Technology Versus Communism* (New York: Macmillan, 1966), p. 110; Golovanov, *Korolev*, p. 660.

had been released from his post and would chair the State Committee for the Coordination of Scientific Research, the "ministry" overseeing pure science in the Soviet Union. Rudnev, having played a leading role in facilitating the Vostok program, was in effect moved directly out of the so-called defense industry structure, thus relinquishing any further direct role in the space program. In an ironic twist, *The New York Times* reported his new appointment, suggesting that Rudnev had been appointed "coordinator of the Soviet Union's rocket and space programs" when it was exactly the reverse.[130] Rudnev's vacating of the defense technology post caused a row of individuals to move up, positing them as key players in the space program during the 1960s. Rudnev's own replacement was an unlikely choice, a forty-five-year-old former electrical engineer named Leonid V. Smirnov, who was without doubt the fastest rising star within the Soviet defense industry. He had served for almost ten years as the director of the mammoth State Union Plant No. 586, where the USSR manufactured most of its ballistic missiles. In mid-1959, during a visit to the plant site at Dnepropetrovsk in the Ukraine, Khrushchev had been unusually impressed with Smirnov's work.[131] While this visit no doubt played a pivotal role in his rapid promotion in the following years, Smirnov also owed his every promotion to the powerful Ustinov, who had begun to populate various defense industry positions with his protégés, building a support system that played to his advantage for many years.

Smirnov himself vacated the post of First Deputy Chairman of the State Committee for Defense Technology, thus allowing the promotion of Maj. General Georgiy A. Tyulin to fill that position.[132] Tyulin had served as the director of the important NII-88 from August 1959 until his new appointment. One of the most ubiquitous persons in the history of the Soviet space program, the artillery officer was reportedly a close supporter of Korolev's. The appointment of an artillery officer to such a high position in the defense industry was clearly a strong indication of the artillery lobby's ambitions to dominate the space program. Tyulin's appointment was, in fact, the first of many in which high-ranking artillery officers were moved from the Ministry of Defense directly to high managerial positions within the defense industry—that is, from the client sector to the design sector. This not only cemented their influence on both sides, but it prevented other armed services such as the Air Force from making inroads to control the space program.

The second artillery officer to move from the client side to the design side was Colonel Yuriy A. Mozzhorin, the individual who had directed the development of the Soviet ground-tracking network in support of ICBMs and satellites. On the recommendation of both Korolev and Tyulin, Mozzhorin took over the latter's vacated post as director of NII-88 on July 31, 1961.[133] During the years that Korolev's OKB-1 had been subordinated to NII-88 in the 1940s and 1950s, the institute had served as the *de facto* center of long-range ballistic missile developments in the Soviet Union. This responsibility had been somewhat diluted after 1956, when OKB-1 became an independent institution, because the locus of activity had moved from NII-88 to OKB-1. As a research institute instead of a design bureau, however, NII-88 continued basic research into many new technologies that were eventually used on space vehicles and

130. "Rudnev Heads Soviet Space Drive," *The New York Times*, June 11, 1961.

131. V. Pappo-Korystin, V. Platonov, and V. Pashchenko, *Dneprovskiy raketno-kosmicheskiy tsentr* (Dnepropetrovsk: PO YuMZ/KBYu, 1994), p. 67; John McDonnell, "The Soviet Defense Industry as a Pressure Group," in Michael McGwire, Ken Booth, and John McDonnell, eds., *Soviet Naval Policy: Objectives and Constraints* (Halifax, NS: Centre for Foreign Policy Studies, 1975), p. 120; Sergey Khrushchev, *Nikita Khrushchev: krizisy i rakety: vzglyad iznutri: tom 1* (Moscow: Novosti, 1994), p. 433.

132. I. V. Kostryukov, "The Development in TsNIIMash of Branch Experimental Bases for the Development of Rocket-Carriers and Space Apparatus" (English title), *Iz istorii aviatsii i kosmonavtiki* 60 (1990): 41–55.

133. "On the Scientific-Technical Activities of Yu. A. Mozzhorin"; Yu. A. Mozzhorin, "The Central Scientific-Research Institute of Machine-Building—The Main Center for Soviet Rocket-Space Industry" (English title), *Iz istorii aviatsii i kosmonavtiki* 60 (1990): 20–40; Letter, A. A. Yeremenko, Chief of the Public Affairs Department of TsNIIMash, to the author, April 14, 1994.

boosters. By the late 1950s, under Tyulin's command, the entity gradually established a mandate for focus on applied themes rather than pure science. At the time of Mozzhorin's appointment to the directorship post in 1961, NII-88's agenda took a dramatic turn. No longer consigned exclusively to research and development efforts, the institute assumed a pivotal role in the formulation of Soviet space policy. An official decision of the government in 1961 designated NII-88 as the "primary science institution" in the Soviet space program.[134] The scope of responsibilities of NII-88 were summarized by a Soviet space historian using rhetorical questions:

> *What rocket-space hardware is needed? Which areas need to be developed first? Which of the systems proposed by the chief designers need to be developed and which need to be refused?. . . All that [was] worked out . . . under the supervision of Yu. A. Mozzhorin.*[135]

Yuriy Mozzhorin was the director of NII-88 from 1961 to 1990. During that period, NII-88 served as the "primary scientific institution" in the Soviet space program. Mozzhorin was personally responsible for rejecting or recommending to the government dozens of proposals from various chief designers. (files of Peter Gorin)

Thus, although the space chief designers were not officially subordinate to Mozzhorin, by the force of his new responsibilities, he would have the duty of recommending or rejecting proposals and then submitting them to the ministerial level.

The mind-boggling confusion of hierarchy that was the Soviet space program in the 1960s was tempered only by the institutional loopholes that allowed design bureaus and chief designers to push their programs through informal channels. The research and development process in the Soviet space industry and in the defense industry as a whole originated in four possible ways, by:

- Having the military identify a need for a capability and forward a request called a "tactical-technical requirement" to the ministry in question, in this case the State Committee for Defense Technology
- Having the chief designer of a particular design bureau propose a project in the form of a ten- to twenty-page "predraft plan"
- A combination of the first two—that is, having the chief designer cooperate with the military to develop a tactical-technical requirement simultaneously with a predraft plan
- A political imperative—that is, a directive from the Communist Party.[136]

134. M. V. Tarasenko, *Voennyye aspekty Sovetskoi kosmonavtiki* (Moscow: Nikol, 1992), p. 17.

135. A. A. Maksimov, "People of Science: A Veteran of the Space Program" (English title), *Zemlya i vselennaya* no. 6 (November-December, 1990): 30-31.

136. William P. Barry, "The Missile Design Bureaux and Soviet Piloted Space Policy, 1953-1974," draft of University of Oxford Ph.D. diss., 1995.

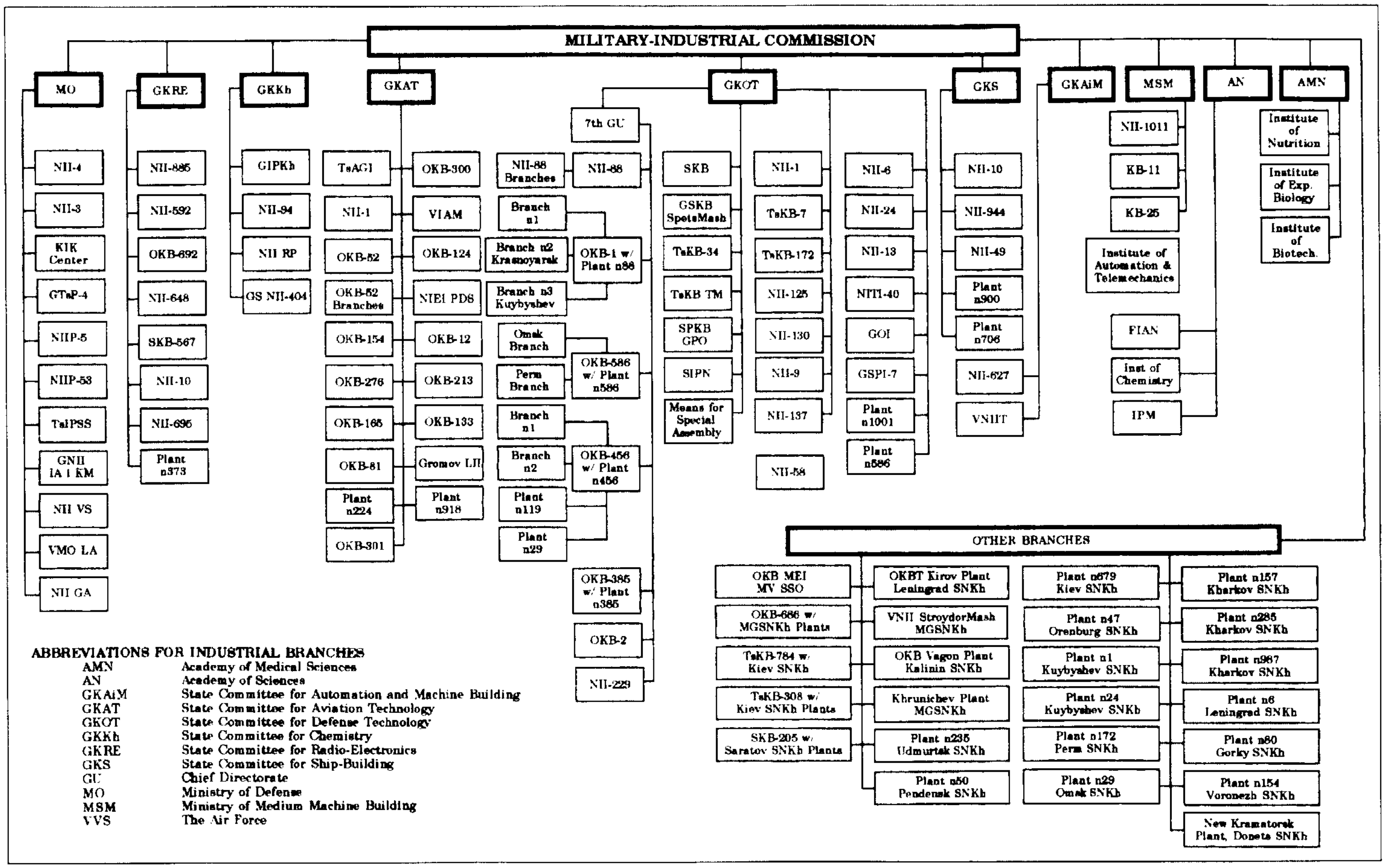
In the case of the space program, it is now becoming clear that the second mode of operation was the most prevalent—that is, the most powerful chief designers, principally Korolev, Chelomey, Glushko, and Yangel, essentially drove space policy with a plethora of proposals in the form of predraft plans. At this point, a number of similar bodies, called scientific-technical councils, would come into play to review the plans and recommend a particular approach.

The number of scientific-technical councils was another indication of the way in which checks and balances were instituted in the space program. There was usually such a council in each design bureau to review proposals, there was one in NII-88, and there was one in the State Committee for Defense Technology. Within the military itself, there were at least three councils with relevance to the space program—one in the Ministry of Defense General Staff headed at the time by artillery Col. General Nikolay N. Alekseyev, one in the Strategic Missile Forces headed during the 1960s by Maj. General Viktor P. Morozov, and one in NII-4, which was responsible for devising the tactical-technical requirements. Finally, as the space program began to emerge as an independent entity from the ballistic missile effort, the government created a unique body called the Interdepartmental Scientific-Technical Council for Space Research within the USSR Academy of Sciences in 1958.[137] Headed by Academician Keldysh, who had assumed the position of academy president on May 19, 1961, soon after Gagarin's flight, the council included representatives from the major space design bureaus and institutes, NII-4, the Strategic Missile Forces, and the Soviet Air Force. In the case of actual spacecraft proposals, it was this council rather than the others that had the final say, usually after a review period by the other bodies. The presence of military officers on the academy's council ensured a strong military component in each "civilian" proposal.

The result of the council review process was only a recommendation, albeit one that had the support of major players. The recommendation was then passed on to the ministry level, and eventually to the powerful Military-Industrial Commission headed by the all-watching Ustinov. Party support, indispensable for any program, was usually ensured by the appropriate chief designer prior to this point, usually with a meeting with Khrushchev or Kozlov. Given the sanction of Khrushchev or Kozlov, the project was formally approved by a joint decree of the USSR Council of Ministers and the Central Committee of the Communist Party. The program then would be managed under Ustinov, who was something of a genius in working through the paper-logged Soviet system. A "draft plan" for the project—that is, a detailed technical document describing the vehicle and its characteristics—was prepared during the process, often before official approval, perhaps to elicit interest from the military. In many cases, the scientific-technical councils were used to screen draft plans from competing proposals before being passed on to the top. The draft plan served as the final document from which the design bureau, in cooperation with its plant, produced the first experimental models of the spacecraft or launch vehicle.

The entire process of Soviet space policy was, of course, not derived from a formal hierarchical process. Unlike other defense industries, the space program was driven to grow by the powers of the leading chief designers. Thus, the approval or rejection of a project was often a function of the relationship that the chief designer had with key members of the Communist Party and government, in particular Khrushchev, Kozlov, and Ustinov. Even at that level, it was a complex process influenced by the fortunes of certain individuals. For example, Khrushchev strongly supported both Chelomey and Korolev, while Ustinov was a "patron" of both Korolev and Glushko and hated Chelomey; Kozlov meanwhile had a marked aversion to Korolev. The story of the

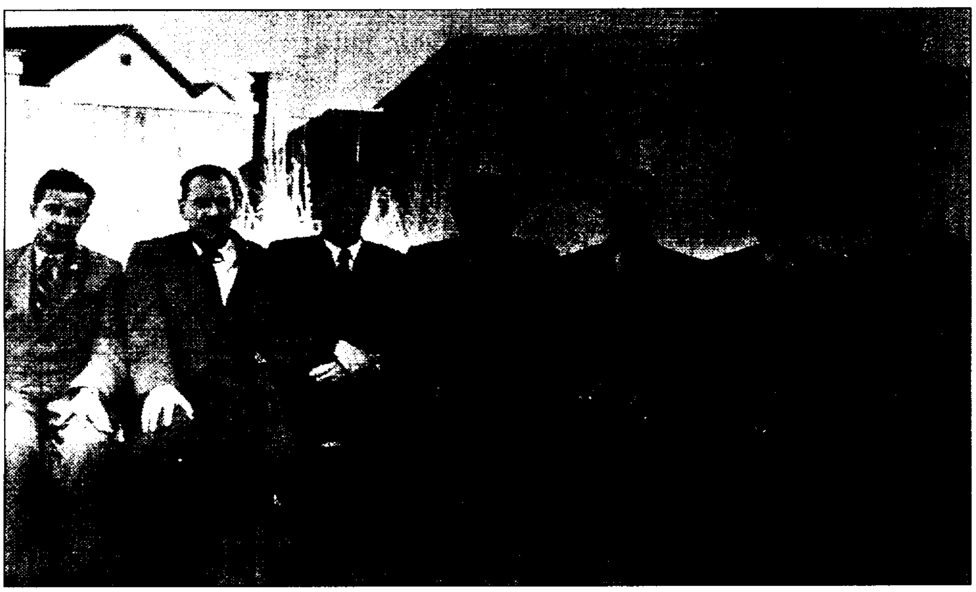
137. *Ibid.*; Mozzhorin, *et al.*, eds., *Dorogi v kosmos: II*, pp. 101, 103; Sergeyev, ed., *Khronika osnovnykh sobytiye*, pp. 85–86; V. S. Avduyevskiy and M. Ya. Marov, "Mstislav Vsevolodovich Keldysh and Space Research" (English title), *Zemlya i vselennaya* no. 3 (May–June 1991): 46–52.



The organization of the Soviet ballistic missile and space industry in 1961. (copyright Asif Siddiqi)

Soviet space program was thus in many ways a story of interpersonal rivalries and political expediency. Clogged by a rigorous process of review and unending red tape, there were many worthy proposals that simply fell by the wayside as the fortunes of chief designers rose and fell.

The important chief designers were clearly Korolev, Glushko, Yangel, and Chelomey, but it would be an oversimplification to suggest that others had no say. For example, the other members of the original Council of Chief Designers, while not performing in the capacity of "primary contractors" for space vehicles, could often derail or provide critical support to a project. In 1961, the Soviet government passed a decree defining the rights and status of the Council of Chief Designers, ensuring that the decisions of the body were binding to all the concerned ministries and agencies.[138] These decisions were most likely related to operational actions, such as to force a subcontractor to deliver on time or to approve a particular launch, rather than actual policy. On purely technical issues, the council operated in a fairly democratic manner in the early years. For example, if a problem occurred in a given engineering area, a meeting of the council would be held at the particular design bureau that had specialty over the problem in question. Although Korolev presided over the meetings, the chief designer whose expertise covered the matter most appropriately resolved each disagreement in technical matters. Chief Designer Barmin has recalled, however, that "we never, I should emphasize, never turned the council into a trade-union meeting of sorts, in which decision was made by a mechanical majority of votes."[139] Thus, the veto of Pilyugin or Barmin on a particular issue could bring a matter to a standstill regardless of whether Korolev or Glushko believed otherwise.



This photo of the Council of Chief Designers dates from 1959 during control of a Luna mission to the Moon. From the left are Aleksey Bogomolov, Mikhail Ryazanskiy, Nikolay Pilyugin, Sergey Korolev, Valentin Glushko, Vladimir Barmin, and Viktor Kuznetsov. Most reproductions of this picture have Bogomolov on the left cropped off because he was not one of the original members of the council from the 1940s. (files of Asif Siddiqi)

138. B. Konovalov, "Dash to the Stars" (English title), *Izvestiya*, October 1, 1987, p. 3; B. Konovalov, "Lessons of the First Satellite" (English title), *Izvestiya*, September 29, 1987, p. 3.

139. Konovalov, "Lessons of the First Satellite."

In the original 1959 letter of Korolev and Keldysh to the government on organizing for the space program, they had laid out a number of potential options, all of which implied a formal separation of the space program from the ballistic missile program. The central tenet of their proposal was the formation of a dedicated scientific research institution focused exclusively on the exploration of space. By 1961, even after the euphoria surrounding Gagarin's flight, few of their proposals were implemented. The only visible manifestation that the Soviet leadership was interested in space as separate from military policy was the formation of the *ad hoc* Interdepartmental Scientific-Technical Council for Space Research within the Academy of Sciences. OKB-1, the most dominant space organization in the immediate post-Sputnik era, continued to maintain its multitude of ballistic missile programs as its primary *raison d'être*. Augmented by the addition of a number of subsidiaries and branches in the recent past, Korolev was overseeing about 15,000 employees in 1961, far more than any other design bureau in the field.[140] OKB-1 also served as a tool for foreign policy. In August 1958, a group of senior engineers from the design bureau were sent to China, along with some R-2 missiles, to assist the Chinese ballistic missile program. Although the team returned to the Soviet Union in early 1960, the exchange was a significant boon to Chinese aspirations to develop a strategic force and to aid in the emergence of the future Chinese space program.[141]

A Day in the Life

Gagarin's flight had been a singular event in the planning of the Vostok program. Although there were orders for the manufacture of many more Vostok spacecraft, actual plans for subsequent piloted missions were remarkably vague. Unlike the Mercury effort in the United States, the Soviet program essentially advanced in stops and starts. From the outside, all of the missions, of course, seemed as if they were parts of a well-planned program, but in truth the missions were formulated as the project advanced. Vague plans for the second piloted Vostok flight dated back to early 1961, when conceptions were focused on a daylong mission. These ideas were the subject of vigorous discussion at the Sochi resort on the Black Sea in mid-May, where Korolev, his wife, all the cosmonauts, physicians, Air Force officers, and cosmonaut trainers

140. The first OKB-1 branch was located at Ostashkov-3 on the island of Gorodomlya, where the German scientists captured after the war developed their own missile proposals. This subsidiary, called OKB-1 Branch No. 1, was established in 1957 to design gyroscopes. See Margarita Shii, "Secrets of Island N: What Are They Doing on the Island of Gorodomlya? Some Say They Are Producing Bacteriological Weapons, Others—Strategic Missiles" (English title), *Novoye vremya* 30 (July 1993): 16–17. A second subsidiary, OKB-1 Branch No. 2, was established on June 4, 1959, at Plant No. 1001 in Krasnoyarsk-26, under the leadership of Deputy Chief Designer M. F. Reshetnev, to oversee the manufacturing of the R-9 ICBM. On December 18, 1961, the branch was formally separated from OKB-1 and became the independent OKB-10. Its initial focus was design and manufacturing oversight over ICBMs, but in 1962, it began to design and develop its own satellites. In later years, as NPO Prikaldnoy mekhaniki, it became one of the largest developers of satellites in the world, focusing primarily on communications satellites. See S. Golotyuk, "Anniversaries: After Thirty Years and a Thousand Satellites (On the Anniversary of the Launch of the First Spacecraft Developed at the NPO Applied Mechanics at Krasnoyarsk-26" (English title), *Novosti kosmonavtiki* 17 (August 13–26, 1994): 42–43. The third subsidiary of OKB-1 was established at Kuybyshev to produce the R-7 ICBM. On April 3, 1958, the manufacturing of the missile was moved to the State Aviation Plant No. 1. Later on July 23, 1959, the Serial-Design Department No. 25 was established on the premises of the plant to oversee R-7 manufacturing and upgrades. On July 17, 1960, this department became OKB-1 Branch No. 3 under the leadership of Deputy Chief Designer D. I. Kozlov. The latter had earlier served as the "lead designer" of the R-5 and R-7 missiles. See V. M. Drebkova, "On the Anniversary of the TsSKB" (English title), *Novosti kosmonavtiki* 15 (July 16–29, 1994): 43–44. An additional branch, although not designated as such, was established on July 3, 1959, at Kaliningrad at the former Central Scientific-Research Institute No. 58 (TsNII-58). It was headed by OKB-1 Deputy Chief Designer K. D. Bushuyev. See Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p. 633.

141. A. V. Ponomarev, "24 April—20 Years From the Launch of the First Chinese Rocket-Carrier 'Long March-1' with the Satellite 'China-1'" (English title), *Iz istorii aviatsii i kosmonavtiki* 64 (1990): 30–33.

went on a well-earned vacation after Gagarin's mission. In the process of formulating plans for the following mission, discussions ended in a deadlock as Korolev insisted that the flight last a complete day. On the other side, Kamanin, the biomedicine specialists, and the cosmonauts themselves were inclined toward a more modest three- to four-orbit flight with a landing in eastern Soviet Union. Buoyed by the success of Gagarin, and unwilling to carry out what he saw as only an incremental advance, Korolev refused to back down. Unknown to anyone present at Sochi, Korolev was so sure that his one-day proposal would be approved that he had already summoned Deputy Chief Designer Bushuyev to Sochi to begin preparations for the longer plan.[142]

The conflict eventually spilled over to the General Staff level within the Soviet Air Force, which had nominal control over the cosmonauts. Air Force Deputy Commander-in-Chief Agaltsov convened a meeting in June with some of the most prominent physicians in the space medicine field: Oleg G. Gazenko, Nikolay N. Gurovskiy, Norair M. Sisakyan, Vasiliy V. Parin, Vladimir I. Yazdovskiy, Yevgeniy M. Yuganov, and others. Also in attendance were the six core cosmonauts and Cosmonaut Training Center Director Karpov. All the physicians unanimously supported the triple-orbit (or five-hour) option; even Gagarin, who had recently been named the commander of the cosmonaut group, offered his full support. When Korolev heard the news, he was indignant. The matter was eventually taken to the ministerial level and decided by State Committee for Defense Technology Chairman Smirnov. Korolev had his way: the mission was planned for a full twenty-four hours and seventeen orbits.[143]

Titov, Gagarin's backup for the first mission, was considered a natural choice for the flight. Said to have been a much more sophisticated and worldly person than the shy and uncomplicated Gagarin, Titov was one of the most well-read and astute cosmonauts on the team, as adept as quoting Hemingway as he was in the technical arcana of rocketry. His individualistic streak lent itself to many a conflict with the cosmonaut physicians, who were as notorious in their search for problems to bar candidates from flight as the ones in the United States. In selecting Titov's own backup, the most likely choice would have been Nelyubov, but Titov apparently had been irritated by Nelyubov's constant wishes to move ahead in the cosmonaut roster. Kamanin dropped him from consideration and instead moved in Nikolayev as the backup. This would be the first of many times that Nelyubov would be the center of a "personality conflict." In early June 1961, a new State Commission, headed by Smirnov, convened to discuss details of the flight, tentatively approving Titov and Nikolayev as the likely candidates. The launch was provisionally set for August, only two months later.[144]

Once all the parties agreed on the length of the mission, Keldysh, Korolev, Kamanin, and Mozzhorin signed a detailed technical document on mission objectives on July 7, 1961.[145] The primary goal of the mission would be the accomplishment of an orbital piloted space mission lasting seventeen orbits with a landing on the start of the eighteenth. In addition, six specific objectives were listed:

142. Kamanin, *Skrytiy kosmos*, p. 56; Golovanov, *Korolev*, p. 666.

143. Golovanov, *Korolev*, pp. 667–68. Gagarin had been appointed commander of the military unit no. 26266 (the cosmonaut team) on May 25, 1961. See Sergey A. Voevodin, *VSA053*, October 23, 1994, newsletter on the Internet.

144. Golovanov, *Korolev*, p. 666; William Shelton, *Soviet Space Exploration: The First Decade* (New York: Washington Square Press, 1968), pp. 102–04; Aleksandr Romanov, *Korolev* (Moscow: Molodaya gvardiya, 1996), p. 420.

145. This document has been reproduced in full as M. V. Keldysh, S. P. Korolev, N. P. Kamanin, and Yu. A. Mozzhorin, "On the Flight of the 'Vostok-2' Space Ship" (English title), in Avduyevskiy and Eneyev, eds., *M. V. Keldysh: izbrannyye trudi*, pp. 418–20.

- Research on a human conducting extended flight in orbit and landing
- Verifying the possibility of accomplishing manual orientation of the spacecraft and evaluating the possibility of return with the use of manual control
- Research on the working capabilities of a human in conditions of extended stay in a state of weightlessness
- Performing direct communications with ground points by the *Zarya* radio-telephone line
- The use of a film camera aboard the spacecraft by the pilot
- Observations via the porthole with the aid of simple optical instruments[146]

Various emergency modes of landing were also described in the document.

The timing of the mission was the source of some unusual dynamics. In mid-July, Khrushchev had invited Korolev and a number of other prominent chief designers to meet with him during a vacation in Crimea. Korolev told the Soviet leader that a second Vostok mission was under preparation. At the end of the meeting, Khrushchev casually added that Titov's launch should occur no later than August 10.[147] Korolev assured him that this would be so, although at the time he clearly had no understanding of why Khrushchev would make such an unusual request. Later, in mid-August, the reason was absolutely clear: the building of the Berlin Wall began on August 13, and Khrushchev had wanted to give the socialist world something of a moral boost at a time of great crisis.[148] While it was not the first case in which Khrushchev had suggested a particular time for a specific launch, it was clearly the first occasion in which the launch of a mission was timed to play a major role in the implementation of Soviet foreign policy.

There was some concern about the launch date because of heavy solar activity in mid-July, but these storms abated soon after, and the flight was set to start on August 6. In much the same way as for the earlier flight, the cosmonauts arrived at Tyura-Tam a few days prior and were present at various State Commission meetings to review the course of launch preparations. There was only a minor hitch during prelaunch operations when there was a leak in the core stage of the booster—a problem that was swiftly handled by Korolev's Deputy Voskresenskiy. On the morning of August 6, Titov and Nikolayev were taken by bus to the pad at site 1. Again, formalities and farewell speeches were kept to a minimum. With an exclamatory "She's off and running!," the twenty-five-year-old Major German S. Titov lifted off at 0900 hours Moscow Time on top of a thundering 8K72K booster and headed straight for orbit from the steppes of Kazakhstan. Orbital insertion occurred without problem. Unlike Gagarin's flight, booster performance was nominal, and the spacecraft, renamed Vostok 2, reached its slated 178- by 257-kilometer orbit inclined at 64.93 degrees. Immediately after entering orbit, Titov began to feel disoriented. As he later described, he felt as he was flying upside down, as if he was turning in a somersault with his legs up. He recalled that he was in a "strange fog," unable to identify Earth from the sky or to read his instrument panel.[149] Titov apparently tried

146. The cosmonaut would have the opportunity to make an independent decision to land by using the orientation system manually on the fourth, fifth, and seventeenth orbits. The spacecraft could be automatically returned on the third or sixth orbit. If landing at the beginning of the eighteenth orbit failed, then the pilot would have the opportunity to land by manual orientation on each of the nineteenth to twenty-second orbits.

147. Khrushchev, *Nikita Khrushchev: tom* 2, pp. 124–25.

148. Korolev's First Deputy Mishin later also confirmed that the Vostok 2 mission was timed to coincide with the construction of the Berlin Wall. See G. Salakhutdinov, "Once More About Space" (English title), *Ogonek* 34 (August 18–25, 1990): 4–5.

149. Golovanov, *Korolev*, pp. 672–73; Shelton, *Soviet Space Exploration*, p. 117; Riabchikov, *Russians in Space*, p. 163; Smolders, *Soviets in Space*, pp. 117–18.

The State Commission for the Vostok 2 mission is shown here before the launch of cosmonaut German Titov. In the front row from the left are Academy of Sciences President Mstislav Keldysh, State Commission Chairman Leonid Smirnov, Chief Designer Sergey Korolev, and Chief Designer Vladimir Barmin. (copyright Christian Lardier)

moving sharply in his seat to clear his head, but the upside-down feelings remained. The unpleasant sensations continued to grow, and by the second orbit, he even briefly contemplated asking permission to return to Earth. Aerospace medicine specialists had predicted such sensations for several years, based on research on the inner ear. Doctors believed that otoliths, minute bone concretions that press against the wall of the inner ear as a result of gravity and pass on information on posture, would not provide the same indications to the brain in microgravity, thus causing spatial disorientation.

Doctors on the ground were aware of the situation on the spacecraft from pneumographic, electrocardiographic, and kinetocardiographic sensors on Titov, and on the third orbit, they inquired about his general physical and psychological condition. Titov, resistant to alarm people on the ground, reported, "Everything is in order." As per his preflight instructions, he decided to take his first meal in space at the time of his sixth orbit, a three-course lunch in paste form delivered in tubes. Television pictures beamed to the ground showed Titov with his soup puree, liver pâté, and black currant jam in plastic dispensers. The cosmonaut, who was still reeling from feelings of nausea, elected not to eat much, and only squeezed some black currant juice into his mouth, which eventually made him vomit. Later, he also ate a small piece of bread and peas with added vitamins and drank some water. The meal was, however, extremely unappetizing to the still-suffering cosmonaut, and he took the opportunity to rest for a short while before conducting experiments, manually firing the attitude control jets on the spacecraft. It was the first such experiment on a Soviet space vehicle, and Titov encountered no problems during the two occasions he took over manual control, on the first and seventh orbits of his mission. He was scheduled to begin his sleep period at the end of the seventh orbit, but as he later reported, "I was having a difficult time maintaining a sense of balance."[150] Kamanin recalled in his diaries that the scope of Titov's discomfort was fairly serious and included "vertigo, nausea, aches in the head and eyes, disorders of the vestibular system, [and] loss of appetite."[151] At 1815 hours, he passed over Moscow and reported, "Now I'm going to lie down and sleep. You can think what you want, but I'm going to sleep."[152] Sleep rules necessitated that his helmet visor be closed at all times, but Titov was feeling incredibly stuffy inside his helmet, and feared that if he had to vomit, it might pose a hazard. He attached a piece of string to immediately jerk open the visor in case of an emergency while asleep.

Except for two minor incidents of waking up (on the tenth and eleventh orbits), Titov rested peacefully. He overslept by about thirty-five minutes, waking at 0237 hours on August 7 on his twelfth orbit. Contrary to most Western reports, the hapless cosmonaut felt just as worse after waking up; he still felt worn out and had a headache. He tried some cursory experiments, such as handwriting, opening and shutting his eyes, and testing coordination, and he was encouraged to observe that his reflexes were much better than during the first portion of the flight, although the "strange fog" was still with him. He also drank a little liquid chocolate, but immediately regurgitated what little food he had in his stomach. Having reached the nadir of his daylong excursion into space, for inexplicable reasons, at the end of his twelfth orbit, he suddenly began to feel better. With each passing minute, his outlook on the mission began to improve, and by the later orbits, he was completely functional and fully fit.[153]

Among the experiments that he *did* manage to conduct included the use of the special *Konvas* movie camera to take a ten-minute-long movie of Earth's horizon when both entering and exiting from Earth's shadow. Despite a malfunctioning exposure meter, the results of the experiment were fairly impressive, and they were later published in the Soviet media amid much fanfare. He also used a special optical sight named *Zritel*, which provided magnifications of three to five times over the naked eye. Internal TV cameras were improved from Gagarin's mission. Of the two cameras, one had a resolution of 400 lines over the 100 lines on the first Vostok. Both had a capacity of ten pictures per second. Another difference with the Gagarin capsule was the use of a new cabin atmosphere regeneration system. There were no major technical anomalies during the orbital phase of the mission, although at one point the temperature apparently dropped to ten degrees Centigrade. Engineers later found that both the primary and backup cooling fans had been inadvertently turned on at launch, thus causing the cool temperatures.[154]

The reentry was as traumatic as the first Vostok mission. After retrofire, Titov heard a loud crack, indicating that the two compartments of the spacecraft had separated. Soon after, however, he heard a light rapping sound and realized that the instrument section was still attached to the spherical descent apparatus by means of several straps. In a situation uncannily similar to Gagarin's return, the two wobbling modules reentered Earth's atmosphere, with the instrument section eventually burning up.[155] Titov ejected safely from his capsule and landed without further incident at 1018 hours near the village of Krasniy Kut in the Saratovskaya Oblast after a record flight of one day, one hour, and eleven minutes.

The young cosmonaut was in a fit of euphoria after landing, and on the flight back to Kuybyshev for the postflight briefing, he talked excitedly of his flight. To the alarm of accompanying doctors, he opened up a beer and downed it quickly in complete violation of postflight codes. At the briefing, Titov was candid about all the problems he had encountered, describ-

150. Shelton, *Soviet Space Exploration*, p. 121.
151. L. Kamanin, "Work in the First Two Years: Space Diary" (English title), *Pravda*, April 8, 1991, p. 2.
152. Riabchikov, *Russians in Space*, p. 168.
153. Golovanov, *Korolev*, pp. 673–74.
154. Kamanin, *Skrytiy kosmos*, p. 84.
155. Golovanov, *Korolev*, p. 674.

ing in great detail his experience with motion sickness. None of this was, of course, reported publicly at the time. In later summaries of the mission, Soviet journalists downplayed the extent to which Titov had suffered from discomfort during the flight. It was said that Korolev himself had been greatly perturbed by Titov's experience. At the time, there was little unanimity in the causes of his sickness. Some physicians were inclined to attribute the problems to the length of the mission, others to Titov's particular physiological makeup. Clearly, it raised the concerns of both engineers and physicians on proceeding with longer missions. Titov himself suffered no permanent effects of his tribulations, and like Gagarin before him, he was sent off on a requisite world trip, a traveling advertisement for the Soviet Union. By the end of 1961, Gagarin and Titov, escorted by Kamanin, had visited Afghanistan, Brazil, Canada, Ceylon, Cuba, Czechoslovakia, India, Finland, Hungary, Iceland, and the United Kingdom, with many more countries to come in 1962.

It seems that the trials of dealing with instant fame caught up with both these young men. They were both severely disciplined at a Communist Party meeting on November 14 for "acknowledged cases of excessive drinking, loose behavior towards women, and other offenses."[156] In what seems to have been a case of womanizing, in mid-October, Gagarin jumped out of a window of a young woman's room at a resort when his wife came knocking. He sustained a severe injury on his forehead, which left him in a hospital for a while. All photos of the cosmonaut past that point show a deep scar over his left eye. Gagarin later explained to the Soviet press that he had fallen down while playing with his daughter, adding "it will heal . . . before my next space flight."[157]

As the scars of the Soviet space program remained hidden, the public face was a massive propaganda juggernaut aimed at consolidating the image of the Communist Party. In 1961, the Soviets had reason to exult. They had launched two men into orbit, the second for a full day, opening the era of human spaceflight. On the other side, the United States had little reason to celebrate. The first American in space, thirty-eight-year-old Navy Lt. Commander Alan B. Shepard, Jr., was launched on May 5, 1961, in a Mercury spacecraft.[158] Whereas Gagarin had flown a complete orbit, twenty-three days later, all NASA could manage was a fifteen-minute, twenty-two-second suborbital hop into space. A second similar flight in July by Major Virgil I. Grissom II was meager consolation. The Soviets had consistently preempted the United States in every major endeavor in space, and Khrushchev continued to take personal credit for the accomplishments. Soon after Titov's flight, and a week after the building of the Berlin Wall, the official Communist Party newspaper *Pravda* reported:

> *[Khrushchev] participates in the discussion of all the most vital experiments, directs the development of the major directions of technical progress in the country, and the determination of the basic directions and establishment of generally planned growth of space science and technology. In his able proposals, there is evidence again and again of the great conviction in the triumph of Soviet rocket technology.*[159]

In contrast, at least in the eyes of the world, the U.S. space program had been lacking in strong leadership since the immediate aftermath of Sputnik.

156. Kamanin, *Skrytiy kosmos*, p. 66.

157. *Ibid.*

158. Linda Neumann Ezell, *NASA Historical Data Book: Volume II: Programs and Projects 1958–1968* (Washington, DC: NASA Special Publication (SP)-4012, 1988), p. 143.

159. Vladimir Orlov, *Pravda* (August 26, 1961), referenced in Nicholas Daniloff, *The Kremlin and the Cosmos* (New York: Alfred A. Knopf, 1972), p. 73.

Second cosmonaut German Titov (right) appears with NASA astronaut John Glenn and President John Kennedy at the White House in 1962. The twenty-five-year-old Titov was the youngest person to ever go into space—a record that still stands to this day. (files of Asif Siddiqi)

NASA, which was the most visible manifestation of the U.S. desire to explore space, had formulated a long-range plan by late 1959, which among other goals, called for "the manned exploration of the moon and the near-by planets."[160] A preliminary target date for the "First launching in a program leading to manned circumlunar flight and to [a] permanent near-earth station" was 1965–67, while actual "manned flight to the moon" was left to "Beyond 1970." President Eisenhower, while very much cognizant that a vigorous space race with the Soviet Union had emerged, was clearly unwilling to commit resources to win it at any cost. This impasse changed dramatically by the early spring of 1961 as a new Democratic President, John F. Kennedy, and a new NASA Administrator, James E. Webb, took up their responsibilities. Spurred and shocked once again by Gagarin's triumphant single-orbit mission, a flurry of activity ensued, prompted by a memorandum on April 20 in which Kennedy asked Vice President Lyndon B. Johnson for recommendations on activities in space that would provide "dramatic results" and a chance to beat the Soviets.[161] After intensive discussion among representatives of NASA, the U.S. Department of Defense, members of Congress, industry, and academia, Johnson's report was formally accepted by Kennedy during a meeting on May 10, five days after Shepard's launch. The report included a call for an unprecedented acceleration of U.S. efforts to explore space, specifically "to pursue projects aimed at enhancing national prestige."[162] Based on this report, Kennedy declared a national objective for the U.S. space program at an unusual second "State of the Union" address to a joint session of Congress on May 25, 1961. In perhaps the most important public policy statement in the history of U.S. space exploration, Kennedy told his audience of a new nationwide program that would restore U.S. prestige:

> *I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the Moon and returning him safely to Earth. No single space project in this period will be so difficult or expensive to achieve.*[163]

160. Office of Program Planning and Evaluation, "The Long Range Plan of the National Aeronautics and Space Administration," December 16, 1959, with excerpts published as Document III-2 in John M. Logsdon, gen. ed., with Linda J. Lear, Jannelle Warren-Findley, Ray A. Williamson, and Dwayne A. Day, *Exploring the Unknown: Selected Documents in the History of the U.S. Civil Space Program, Volume I: Organizing for Exploration* (Washington, DC: NASA SP-4407), pp. 403–07.

161. John F. Kennedy, Memorandum for Vice President, April 20, 1961, published as Document III-6 in *ibid.*, 1: 423–24.

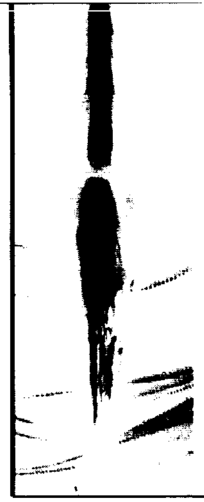
162. James E. Webb, NASA Administrator, and Robert S. McNamara, Secretary of Defense, to the Vice President, May 8, 1961, with attached: "Recommendations for Our National Space Program: Changes, Policies, Goals," published as Document III-1 in *ibid.*, 1: 439–52.

163. U. S. Congress, Senate Committee on Aeronautical and Space Sciences, *Documents on International Aspects of the Exploration and Uses of Outer Space, 1954–1962*, 88th Cong., 1st sess., S. Doc. 18 (Washington, DC: U.S. Government Printing Office, 1963), pp. 202–04.

Kennedy's speech on May 25, 1961, was a declaration of a national objective; there was no explicit indication in the language that the United States would have to get to the Moon *first*, only that an American should stand on the Moon before January 1, 1970. But implicit in his declaration was also a challenge—a challenge not only to "every scientist, every engineer, every serviceman, every technician, contractor, and civil servant" to harness capabilities in this great endeavor, but also a challenge to the Soviet Union itself.

From the Soviet perspective, this challenge was not perceived as such. From the beginning of the space era, the Soviets had been in the position to make the challenges, with the spectacular launches of a plethora of Sputniks, Lunas, and Vostoks. Given the rigorous secrecy that pervaded their space efforts, it would have been unusual for them to announce these projects in advance. Every challenge was manifested in hardware, in launches, and in accomplishments. The speeches came afterwards. The United States, of course, also responded with hardware, but all of them—Vanguard, Explorer, and Mercury—paled in the eyes of the public to Soviet accomplishments. Thus for the Soviet Union, on May 25, 1961, the dimensions of the space race changed little. Kennedy's speech was in fact not even widely reported in the Soviet media, and few in the space program took notice.[164] There were no major reassessments of Soviet goals and plans for space exploration. It was, after all, only a speech, and in the mind of the Soviet citizen, speeches were better left to celebrate victories, not plans for victories. What was a momentous occasion in U.S. space policy thus passed without a response in the Soviet Union. The Soviets never guessed that regardless of Kennedy's own commitment to space exploration, the wheels of a mammoth and well-oiled machine had been set into motion—one that would eventually humiliate the great Soviet space program of Sputnik and Vostok.

164. Interview, Georgiy Stepanovich Vetrov with the author, November 15, 1996.



Chapter Eight
Looking to the Future

There is a tendency in the Western discourse on the Soviet space program to make repeated allusions to "the Soviets." It was always the generic "Soviets" who decided on a particular goal or the "Soviets" who launched a satellite, while in the United States, one could comfortably write about NASA or the Department of Defense. In the face of pervasive secrecy, the inner workings of the program were as unknown as the secrets of the cosmos itself. It was as if there was a monolithic structure located in some far away place, an almost mythological quantity, which ran a program of gargantuan proportions. To a great degree, this myth has remained a fundamental characteristic of the Western writing on the history of the Soviet space program, some of it perhaps derived from the cultural divide in language, custom, and history that separated the Soviet Union from the rest of the world during the Cold War. What this myth did was to obscure a story of fallible people seeped in battles that were all too human. It was never "the Soviets" who made decisions or launched Sputniks, nor was it one single person either. Like any other scientific endeavor, there were different individuals and institutions with varying motivations and histories vying for the same resources. And having reached the absolute zenith of its trajectory in 1961, the Soviet space program was now to face a different kind of battle—one among institutions and individuals. This battle irrevocably altered the course of the Soviet space program.

Chelomey's Reach for Space

The official government decrees in June 1960 were the green light for Vladimir Chelomey's grand entrance into the space program. Khrushchev, perhaps dazzled by Chelomey's sophisticated ways, or simply favoring his son's employer, continued to maintain his unabated support for OKB-52, which grew at an unprecedented pace. This expansion was also abetted by the economic depression in the aviation sector, as numerous design bureaus had to postpone or terminate projects. In fact, with the singular exception of OKB-52, all aviation design entities were forced to curb their efforts. Taking advantage of such an unusual situation, Chelomey literally gobbled up organizations one after another.

The first to come under the Chelomey umbrella was Myasishchev's former OKB-23, which had been attached to OKB-52 in October 1960 as the latter's Branch No. 1. Production at its associated giant factory, the M. V. Khrunichev Machine Building Plant (ZIKh) located in the Fili suburb of Moscow, was now redirected toward manufacturing for Chelomey's various projects. A second factory, Plant No. 642 in Moscow, which briefly series-produced Chelomey's naval cruise missiles, was made the new Branch No. 2 in March 1963 under Deputy General Designer

Vladimir M. Baryshev.[1] The facility was used herein for designing ground equipment for various missiles and spacecraft operations.

Another acquisition was more notable: OKB-301 headed by General Designer Semyon A. Lavochkin, one of the most renowned aviation organizations in the Soviet Union. The beginning of the decade was not a good time for this design bureau. In February 1960, the Soviet government canceled work on the La-350 Burya intercontinental cruise missile. Four months later, Lavochkin was dead of a heart attack. Chelomey took advantage of this weak position. Within days of Lavochkin's death, he invited thirty of the senior-most engineers from OKB-301 —the so-called "brain" of the organization—to work for him in Reutov at his own design bureau. Among the relocated individuals was Naum S. Chernyakov, the lead designer for the Burya missile, and N. A. Kheyfits, a well-known pioneer of high-speed flight in the Soviet Union, who was no doubt an asset to Chelomey's burgeoning dreams of winged reusable space vehicles.[2]

The former Lavochkin design bureau's fortunes continued to decline. In 1962, the Soviet military finally terminated the remaining work on the Dal air defense network for the city of Leningrad. With nowhere to go, OKB-301 finally succumbed to Chelomey's growing power. The Chief of the Defense Industries Department, Ivan D. Serbin, a powerful Chelomey supporter in the Central Committee, agreed to Chelomey's request to take over the *entire* design bureau. By an executive order dated December 18, 1962, the old Lavochkin bureau at Khimki became the new OKB-52 Branch No. 3.[3]

These various absorptions allowed Chelomey to spread out all of his work from the central Reutov branch. With a larger number of engineers and more facilities, he was able to take on an incredibly wide range of military work that ran the gamut from naval cruise missiles to ICBMs to spacecraft. By the end of 1962, in terms of personnel, the OKB-52 empire was, in fact, far larger than Korolev's OKB-1, the founder of the Soviet space program.[4]

Chelomey's claims on the space program were to be effected in five different thematic directions. These were the development of:

1. Plant No. 642 was the location of KB-2 between 1946 and 1951 and GSNII-642 between 1951 and 1958. In 1958, GSNII-642 was closed down, and its plant was eventually tasked with producing Chelomey's P-25 naval cruise missile in 1961 and 1962. The new OKB-52 Branch No. 2 was established at Plant No. 642 on the basis of a department for ground equipment for missiles and spacecraft transferred from OKB-52's Branch No. 1. This department was transferred in March 1963. See M. Tarasenko, "35 Years for the OKB 'Vympel'" (English title), *Novosti kosmonavtiki* 8 (1998): 43–44; Aleksandr Shirokorad, "Rakety nad morem," *Tekhnika i vooruzheniye* no. 6 (November–December 1997): 1–80; Christian Lardier, "70 Years of Soviet Ramjets," presented at the 48th International Astronautical Federation, IAA-97-IAA.2.3.03, Turin, Italy, October 6–10, 1997.

2. Sergey Khrushchev, *Nikita Khrushchev: krizisy i rakety: uzglyad iznutri: tom 2* (Moscow: Novosti, 1994), pp. 42–44; Yaroslav Golovanov, "The 'Burya' Which Did Not Break Out" (English title), *Komsomolskaya pravda*, March 18, 1998, p. 3. Among the individuals transferred from OKB-301 were Acting General Designer N. S. Chernyakov, Fedorov, Kheyfits, and Yefimov. See also Mikhail Rudenko, "Designer Chelomey's Rocket Planes" (English title), *Vozdushniy transport* 47 (1995): 8–9. Note that in the last source, the transfer is incorrectly said to have taken place in May 1958.

3. Christian Lardier, *L'Astronautique Soviétique* (Paris: Armand Colin, 1992), p. 152. OKB-52 Deputy General Designer A. I. Eidis was appointed to head Branch No. 3 at the time. The branch was to aid in the development of the P-25 surface-launched anti-ship missile, the P-70 Ametist submarine-launched anti-ship missile, the "IS" anti-satellite, and the "US" ocean reconnaissance satellite programs. See S. M. Ganin and V. I. Ivanovskiy, "The Multi-channel 'Dal' Anti-Aircraft Missile System of Great Range" (English title), *Nevskiy bastion* no. 1 (1998): 7–15; Shirokorad, "Rakety nad morem."

4. There may have been a fourth addition to OKB-52 at the time. NII-2, headed by V. A. Dzhaparidze, was said to have been attached to Chelomey's design bureau sometime in the early 1960s. See Andrey Tarasov, "Space Science of the Future: Selection of Paths and Orbits" (English title), *Pravda*, May 17, 1990, p. 3. In addition, the design bureau also had production affiliates at Dubna and Saratov. See Gerbert Aleksandrovich Yefremov, "NPO Mashinostroyeniya is Moving Into the High-Technology Market" (English title), *Vooruzheniye, politika, konversiya* 3(10) (1995): 31–37.

- A series of new boosters to serve as ICBMs and space launch vehicles
- An automated anti-satellite system
- An automated ocean reconnaissance system
- Spaceplanes for the exploration of near-Earth space
- Spaceplanes for lunar and interplanetary space

The centerpiece of his expanding move into the space sector was the first "theme," specifically the UR-200 ICBM, which the Soviet space leadership approved for preliminary development in June 1960. The Central Committee and the Council of Ministers issued supplementary decrees on its development on March 16 and August 1, 1961.[5] In a move no doubt intended to ensure full support for the UR-200 project, Chelomey offered up the booster first as a new generation ICBM and then as a space launch vehicle. Chelomey, unlike Korolev, was also not resistant to using hypergolic storable propellants for the missile, thus pacifying powers in the Strategic Missile Forces who were initially alarmed by Chelomey's rapid encroachment into the missile business from the aviation sector.

As Chelomey's reach expanded, he also farmed out his own projects to the OKB-52 branches. While his leading deputies would maintain overall design supervision of particular vehicles, detailed design work would be undertaken by engineers at the branches. In the case of the UR-200, Chelomey gave the project to his new Branch No. 1 at Fili; with Myasishchev now gone, the engineers there resigned themselves to Chelomey's new projects and, in fact, went on to produce some of the most important Soviet space vehicles. The UR-200, formerly called the R-200, was a two-stage vehicle with a total launch mass of 138 tons. Payload capability to low-Earth orbit was limited to four tons, making it somewhat of a light launch vehicle, which is exactly what Chelomey had in mind. Overall length was thirty-five meters with a base diameter of three meters. In its ICBM version, the missile would carry a single warhead ranging from five to fifteen megatons over 10,000–12,000 kilometers.[6] Instead of Glushko's engines, which were standard for all long-range Soviet ballistic missiles, Chelomey contracted an aviation organization, OKB-154 headed by Chief Designer Semyon Kosberg, to design the new engines for the rocket. It was another step forward into the space business for Kosberg, whose first successful contribution to the Soviet space program was to design the upper stage engines for boosters that had launched the Lunas and Vostoks into orbit.[7] All the engines for the UR-200 used toxic components, specifically nitrogen tetroxide and unsymmetrical dimethyl hydrazine (UDMH).[8]

5. I. Afanasyev, "35 Years for the 'Proton' RN" (English title), *Novosti kosmonavtiki* 1–2 (1998): 45–48.

6. Mikhail Rudenko, "Designer Chelomey's Rocket Planes" (English title), *Vozdushniy transport* 48–49 (1995): 8–9; A. V. Karpenko, *Rossiyskiye raketnoye oryzhiye, 1943–1993gg* (St. Petersburg: PIKA, 1993), p. 12; Ye. B. Volkov, ed., *Mezhkontinentalnyye ballisticheskiye rakety SSSR (RF) i SShA* (Moscow: RVSN, 1996), p. 322.

7. The UR-200 was powered by the RD-0202 engine on the first stage and the RD-0205 engine on the second stage. The RD-0202 itself was composed of three RD-0203 engines and one RD-0204 engine, while the RD-0205 was composed of the RD-0206 sustainer and RD-0207 vernier. Total first-stage thrust was about 200 tons. The development of these engines began in March 1961. See Vladimir Rachuk, "Best Rocket Engines from Voronezh," *Aerospace Journal* no. 6 (November–December 1996): 30–33; "Engines for Combat Missiles," *Russian Space Bulletin* 4(3) (1997): 13–15; *KB KhimAvtomatiki: Stranitsy istorii: tom I* (Voronezh: KB KhimAvtomatiki, 1995), pp. 51–54.

8. Apart from use as a space launch vehicle and an ICBM, the UR-200 was also the focus of two other proposals. In July 1961, Chelomey offered up the missile as an orbital bombardment system that could drop nuclear warheads on enemy targets from orbit. In this variant, the missile would be called the Global Missile No. 1 (GR-1). Later in February 1962, a second proposal involved UR-200s equipped with guided ballistic warheads, which would reenter from orbit and guide themselves with aerodynamic surfaces to U.S. naval ships that were seen as a threat to the Soviet Navy. While work on both these proposals were undertaken to a preliminary stage, like many of Chelomey's projects, they were never finished. See Khrushchev, *Nikita Khrushchev: tom 2*, pp. 122, 155.

Chief Designer Semyon Kosberg designed numerous upper stage engines for Soviet space launch vehicles. He closely cooperated with Vladimir Chelomey in developing the UR-100, UR-200, and UR-500 ICBMs. (files of Peter Gorin)

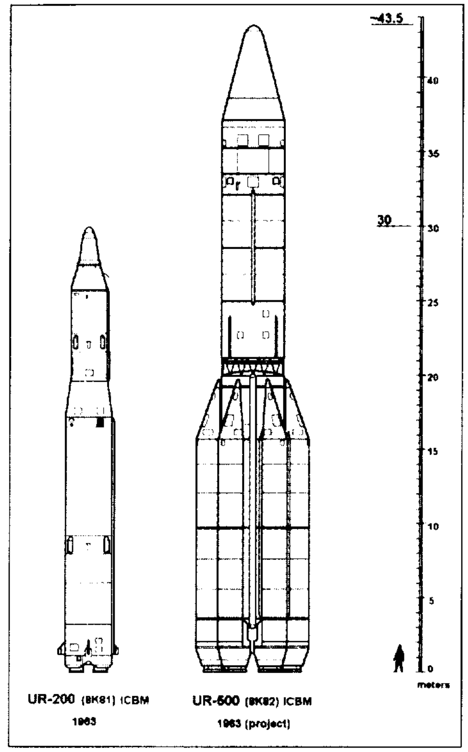
The UR-200 was only the first step in Chelomey's plans for a series of new ICBMs and space launch vehicles. Planning at his design bureau showed that to meet Chelomey's more grand plans for space exploration, he would need a second booster that could lift as much as twenty tons into orbit. Possible payloads would include piloted spaceplanes, space stations, and large military payloads. In late 1960, concurrent with the addition of Branch No. 1 to OKB-52, Chelomey's deputies began preliminary planning work on a new ICBM with a space booster that would have a capacity for launching heavy payloads into Earth's orbit. This vehicle would eventually emerge as one of the most important launch vehicles ever created in the Soviet space program, the Proton booster. Chelomey picked Pavel A. Ivensen, an old acquaintance of Korolev's from the late 1920s, to lead the project to develop the rocket. Ivensen, like Korolev, had been thrown into prison in the mid-1930s, and he was rehabilitated only in 1956. In the late 1950s, he initially worked on high-speed reconnaissance aircraft at the Tsybin design bureau, but the confusing series of changes in the aviation industry led him first to the Myasishchev organization and finally to work under Chelomey.[9]

In Ivensen's preliminary research on the possible designs for the booster, he made maximal use of technology from the smaller UR-200 as well as Myasishchev's own abandoned M-1 launch vehicle. The new rocket, designated UR-500 in design documentation, was planned from the very beginning as a two-stage ICBM and a three-stage space launch vehicle. At the time, Chelomey's engineers were closely watching the development of the American Titan I ICBM; in many ways, the UR-500 was posited as a parallel development with similar capabilities and equivalent possibilities for turning it into a heavy-lift launch vehicle. Ivensen's team studied a number of different possible designs for the first stage, including grouping together four two-stage UR-200 rockets together with a third stage, that itself would be a modified UR-200 second stage.[10] What emerged by 1963 was an unusual plan to cluster six long cylindrical propellant tanks around a central cylindrical tank. Unlike parallel-staged vehicles in which each strap-on was a self-contained unit, in the UR-500, the central cylinder would carry all the oxidizer while the tanks on the outside would carry the fuel. Thus, although it visually resembled a strap-on-type booster, the vehicle in fact had a standard tandem-type first stage with clustered tanks. There would be a single powerful engine at the base of each tank powered by

9. G. Amiryants, "Ivensen's 'Chayka'" (English title), *Aviatsiya i kosmonavtika* no. 4 (April 1990): 36–38; M. Yakovenko, "The Subterranean, Earthly, and Heavenly Creations of Ivensen" (English title), *Nauka i zhizn* no. 9 (September 1991): 20–27.

10. For descriptions of various early conceptions of the UR-500, see Afanasyev, "35 Years for the 'Proton' RN."

nitrogen tetroxide and UDMH, the same high-boiling propellants as the smaller UR-200.[11] The diameter of the central tank was limited to just above four meters; this was the maximum dimension that the Soviet railway system could accommodate for transportation from the manufacturing plant to the launch site. In its ICBM version, the UR-500 was designed to have a standard cylindrical second stage with four engines; a third stage would be added in the projected space launch vehicle version. Both these upper stages would have design antecedents in the smaller UR-200 ICBM.



This shows the original variants of the UR-200 and UR-500 ICBMs as conceived by Vladimir Chelomey in the early 1960s. (copyright Peter Gorin)

Chelomey's choice of storable propellants was clearly related to his plans to use the UR-500 as an ICBM. Such propellants, he believed, would also significantly simplify engine design because the components would be hypergolic—that is, self-igniting. Having decided on the basic design scheme and the choice of propellants, the next step was to choose a subcontractor. In late 1961, there was only one organization in the Soviet Union designing extremely high-thrust rocket engines for ICBMs: Glushko's OKB-456. At the time, Chelomey was fortuitously placed to take advantage of the increasing acrimony between Korolev and Glushko, which was beginning to incapacitate Korolev's grander plans of space exploration. As the bickering between the two reached a critical point, Chelomey stepped in. In November 1961, he sent a group of three senior engineers from Branch No. 1 on a visit to Glushko's enterprise to explore the possibility of cooperating on the UR-500.[12] Glushko took the chance, perhaps to prove to Korolev once again that he was not dependent on the latter for anything, and he signed an agreement to deliver to Chelomey the first-stage engines for the UR-500. In what may have been additional insult to Korolev, Glushko simply took the engines that he had offered for Korolev's giant N1 booster, modified them a little bit, and offered them to Chelomey. With six similar RD-253 engines firing at liftoff, the UR-500 missile would develop a total thrust of about 900 tons at launch, far in excess of any rocket in the world at the time.[13]

11. V. A. Vyrodov, M. K. Mishetyan, and V. M. Petrakov, "16 July—25 Years From the Time of the Start of Operations of the 'Proton' Rocket-Carrier" (English title), *Iz istorii aviatsii i kosmonavtiki* 64 (1993): 58–67; G. Maksimov, "Space Flight Support: The Proton Launch Vehicle" (English title), *Aviatsiya i kosmonavtika* no. 8 (August 1988): 40–41. In the early version of UR-500 missile, the first stage had four powerful Glushko engines on the core and one gimbaled low-thrust Kosberg engine on each of four strap-ons.

12. V. Petrakov and I. Afanasyev, "'Proton' Passion" (English title), *Aviatsiya i kosmonavtika* no. 4 (April 1993): 10–12; Vyrodov, Mishetyan, and Petrakov, "16 July—25 Years From the Time of the Start." The individuals who visited were D. A. Polukhin (Chief of the Complex for Engine Units), V. A. Vyrodov (Lead Designer of the project), and G. D. Dermychev (Chief of the Planning Department).

13. Petrakov and Afanasyev, "'Proton' Passion"

Glushko was taking a gamble in agreeing to produce these engines, the first "closed cycle" engines in the Soviet Union using storable propellants. Known in the West as "staged combustion cycle" engines, Glushko had had little luck with such motors since the failure of the RD-110 in the early 1950s. A technology demonstrator built at NII-1 in 1958–59 instilled growing confidence that the task could be accomplished. The relatively high-performance characteristics demanded by Chelomey's designers were principally because of the selection of the closed cycle scheme, which would allow extremely high chamber pressures to be derived without losses in specific impulse, thus adding significantly to performance. Glushko addressed this problem by installing the turbines for operating the fuel pumps inside the combustion chamber of the gas generator. During firing, the chamber would receive the full amount of oxidizer, but only a part of the fuel. This mixture would then burn in the preliminary combustion chamber at a relatively low temperature, thus driving the turbine. Later, the combustion gas would enter the main combustion chamber of the engine, where the remaining fuel would be added. The resulting reaction would be a total burning of the propellant components. With this layout, power used to drive the turbines could be reduced to nonexistent levels, while combustion pressure would be dramatically increased without losses of propellant. Finally, Glushko's feared combustion oscillations would be eliminated because of the extremely high temperatures of burning.[14] For Soviet engine design technology, this would be a new step forward; Chelomey, ever the ambitious scientist, took the idea and banked his future on it.

For the upper stages, Chelomey contracted Kosberg once again. The engines slated for the second and third stages of the UR-500 were, in fact, very similar to the ones earmarked for the first two stages of the smaller UR-200 booster.[15] In effect, the larger UR-500 was simply a new huge first stage with a thinner version of the UR-200 (albeit with modified engines) sitting on top of it. This sort of design decision, whereby "each of [their] launch vehicles was supposed to become part of a more powerful one," was a conscious design strategy of the Chelomey people, who held the belief that incremental testing of components separately was a more pragmatic idea in the face of technological and manufacturing limitations of the Soviet defense industry.[16] Thus, by extension, there were even preliminary plans at the time to use the UR-500 itself as the upper stages of an even bigger booster, one to launch hundreds of tons into Earth's orbit.

The development of the large UR-500 booster advanced very quickly along with work on the UR-200 and Chelomey's first automated satellite projects, the "IS" anti-satellite system and the "US" naval reconnaissance system. During a meeting with Khrushchev in February 1962 at the vacation resort of Pitsunda, Chelomey for the first time acquainted the Soviet leader with the UR-500 proposal. In a perfect example of how chief designers went about "selling" their space projects to the Soviet leadership, Chelomey introduced the UR-500 not as a space launch

14. Peter Stache, *Soviet Rockets*, Foreign Technology Division Translation, FTD-ID(RS)T-0619-88 (from unnamed source), Wright-Patterson Air Force Base, Dayton, Ohio, November 29, 1988, p. 405. This is a translation of Peter Stache, *Sowjetischer Raketen* (Berlin: Militarverlad der DDR, 1987).

15. In the initial variant of the UR-500, the second stage consisted of three RD-0208 engines and one RD-0209 engine. Each had a vacuum thrust of about sixty tons. When the three-stage variant of the UR-500 was introduced, new engines were used on the second stage: three RD-0210 engines and one RD-0211 engine. For the three-stage UR-500 (called UR-500K), the third stage would be equipped with a single RD-0212 engine, which consisted of the primary RD-0213 engine and the RD-0214 verniers. Total vacuum thrust would be sixty-two tons. See T. Varfolomeyev, "Readers' Letters: On Rocket Engines from the KB of S. A. Kosberg, and Carriers on Which They Were Installed" (English title), *Novosti kosmonavtiki* 26 (December 18–31, 1993): 46–48; *KB KhimAvtomatiki: tom I*, pp. 54–55.

16. The quote is from Dmitriy Khrapovitskiy, "Absolutely Unclassified: The Ground Waves of Space Politics" (English title), *Soyuz* 15 (April 1990): 15.

vehicle, but as a super-powerful ICBM named the GR-2, capable of launching warheads of thirty megatons at the enemy. The warhead would be launched into Earth orbit and eventually deorbited at the appropriate time to reach the target. Military-Industrial Commission Chairman Ustinov, who loathed Chelomey, was categorically against the idea. In the end, Khrushchev, perhaps dazzled by the booster's military applications and persuaded by aviation "minister" Dementyev's arguments, agreed to the proposal, asking both Ustinov and Dementyev to draw up the necessary documents for moving ahead with the project.[17] Less than three months later, on April 29, 1962, the Council of Ministers and the Central Committee issued a decree formally approving the UR-500 ICBM and space launch vehicle.[18] Within a month, Chelomey's engineers froze the final design scheme of the vehicle. The rocket, in its various models, would be ready in three years. While the principal design of the vehicle would be focused at Branch No. 1, manufacturing would be undertaken at the giant M. V. Khrunichev Machine Building Plant, which was essentially at Chelomey's disposal by this time.[19]

The UR-200 and UR-500 boosters were only the *means* by which Chelomey intended to undertake his assault into space. The actual payloads would consist of a variety of different sized spacecraft for a wide array of goals. From Chelomey's own perspective, perhaps the most important projects he worked on during the early 1960s were his spaceplanes, subsumed under two different thematic directions, the Kosmoplan and the Raketoplan. The research on the Raketoplan-Kosmoplan theme was evidently conducted in a remarkably haphazard manner. Sergey N. Khrushchev, the Soviet leader's son who was the deputy chief of a department at OKB-52, recalled later Chelomey's idiosyncratic behavior regarding the Kosmoplan-Raketoplan themes:

> *[He would say] "let's try to make the Kosmoplan using nuclear engines," and then in two weeks there would be another idea, some [more] drawings, some [more] calculations, and then he would say that, "No, this is crazy, it'll never work, forget about it . . . let's try plasma [engines] and this time we'll fly to Mars!*[20]

Irrespective of Chelomey's own whims, the project was real, and hardware was built. It would, in fact, not be an overstatement to say that of all Chelomey's space-related projects through his long career, the spaceplane work held the greatest emotional resonance for him. He would pursue this dream almost continuously unabated for close to a quarter of a century.

Funding for preliminary research on the Kosmoplan-Raketoplan theme was approved in the same June 1960 government decree that accelerated the Soviet space program on a wide range of thematic directions.[21] The degree of state commitment to these ambitious projects remains open to interpretation, but a few recollections suggest that it was significant. Georgiy N. Pashkov, a Deputy Chairman of the Military-Industrial Commission, recalled in 1989 that:

17. Khrushchev, *Nikita Khrushchev: tom 2*, pp. 157–58.

18. Vyrodov, Mishetyan, and Petrakov, "16 July—25 Years From the Time of the Start"; Petrakov and Afanasyev, "'Proton' Passion."

19. Previously named the State Aviation Plant No. 23, the plant was renamed the M. V. Khrunichev Machine Building Plant in July 1961 soon after the death of M. V. Khrunichev, the former Minister of Aviation Industry.

20. Telephone interview, Sergey Nikitich Khrushchev by the author, October 10, 1996.

21. Anatoliy Kirpil and Olga Okara, "Designer of Space Planes. Vladimir Chelomey Dreamed of Creating a Space Fleet of Rocket Planes" (English title), *Nezavisimaya gazeta*, July 5, 1994, p. 6. The authors state in the article, "In 1960 the government of the USSR decided to develop a rocket plane design at OKB-52."

> *. . . at the time [1960–61] a decision was taken that, in actuality, shifted the "firms" of S. P. Korolev and M. K. Yangel from primary to secondary roles. There appeared two projects which were given preference over all the others. According to the author of the idea [Chelomey], the first apparatus was planned for ensuring flight in near-Earth space [the Raketoplan], and the second, flight from planet to planet [the Kosmoplan]. Both apparatus were to be furnished with appropriately shaped wings, and each would have the capability to land at any assigned airport. I was astonished the author was undertaking to prepare the project in three years. Naturally, on the orders of Nikita Sergeyevich Khrushchev, he was immediately allocated the means, and large projects in which major work had already been started were stripped [of their support]. In short, starting in 1961 our rocket-space industry began to be subsumed by confusion, which left us dearly stalled.*[22]

Funding for the research was coming from the Ministry of Defense, in particular the Soviet Air Force, which had watched two of its most promising spaceplane projects, from Tsybin and Myasishchev, canceled one after another.[23] The Air Force was banking on the success of the effort, perhaps seeing in the program its means to counter the dominance of the Strategic Missile Forces. As with most military endeavors, dissension existed within the Air Force on the idea itself; some were more prone to ally themselves with Korolev's more traditional spacecraft designs, arguing that there was a greater chance of success, while others were reluctant to let go of winged conceptions and thus put their support with Chelomey.[24] At various points during the early 1960s, the Soviet Air Force issued "tactical-technical requirements," which were specifications for orbital vehicles to support Air Force objectives. For example, at a secret military conference in January 1962, the final recommendations included the development and creation of:

- An air-spaceplane with a flight altitude of sixty to 150 kilometers and an orbital spaceplane with an altitude of 1,000 to 3,000 kilometers
- A carrier-aircraft for launching "air-to-space" and "space-to-air" spacecraft and rockets[25]

Chelomey clearly catered his Raketoplan-Kosmoplan research to such proposals, although it is apparent that there was never a clear consensus on the issue at the time even within the Air Force. While winged reusable vehicles were preferable, senior military strategists also had to address the possibility that such vehicles would not be a reality in the near future.

There was an additional issue that factored into the military's intentions: the Soviet military closely followed the U.S. Air Force's X-20A Dyna-Soar spaceplane program. While some people considered Chelomey's Raketoplan research some sort of "raging fantasy," others in the General Staff could point out that the United States was conducting similar research. This is, in fact, what exactly happened on occasion. As the fate of the Dyna-Soar shifted up and down, the Ministry of Defense became less or more liberal with funding. According to some reports, funding for Chelomey's grand project periodically dwindled to zero as the wildly different news on U.S. hypersonic efforts filtered through to the General Staff in Moscow. One participant later

22. Nikolay Dombkovskiy, "October — April — The Universe" (English title), *Sovetskaya rossiya*, April 12, 1989, p. 3.

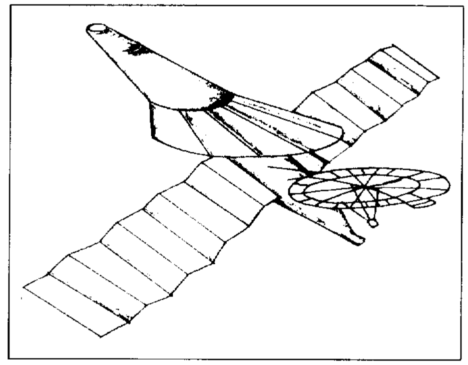
23. Igor Afanasyev, "Kosmoplan: Chelomey's Project" (English title), *Krasnaya zvezda*, August 26, 1995, p. 6.

24. See N. P. Kamanin, *Skrytiy kosmos: kniga pervaya, 1960–1963gg* (Moscow: Infortekst IF, 1995), p. 27, for a brief discussion over the Korolev versus Chelomey issue from the Air Force side.

25. *Ibid.*, p. 87.

observed that "it created the impression that our work was directed not from Frunze Street, but rather from the Pentagon."[26]

As indicated in the younger Khrushchev's observations about Chelomey, the goals of the Soviet program evolved and changed almost as fast as the designs of the vehicles themselves. By January–February 1961, the Kosmoplan theme encompassed automated and piloted missions to the Moon, Mars, and Venus, with the possibility of extended reconnaissance missions in low-Earth orbit. This last type of mission was probably its selling point to the Air Force. Through 1959–61, engineers had worked on numerous different designs of the Kosmoplan, but four of these offered the most promise:



This is one conception of Vladimir Chelomey's idea of a robotic Kosmoplan to visit Mars. The design dates from the early 1960s. (copyright Asif Siddiqi, based on a drawing by Igor Afanasyev)

- The automated AK-1-7 would be for flights to Mars or Venus. The spaceplane would be launched into orbit by a three-stage variant of Korolev's R-7 ICBM.
- The automated AK-1-300 would also be for flights to Mars or Venus. The A-300 booster, an early conception of a launcher developed at OKB-52, would launch this spaceplane.
- The automated AK-3-300 would be for both flights to the planets and missions in low-Earth orbit. Launch would be by the A-300 rocket.
- The piloted AK-4 spaceplane, studied in 1961, would be designed for carrying a single pilot into Earth orbit on the A-300 booster. The spaceplane would return from orbit in a special container, which would be discarded after atmospheric reentry at an altitude of twenty kilometers. The AK-4 would then glide 200 kilometers to a landing on an airstrip.[27]

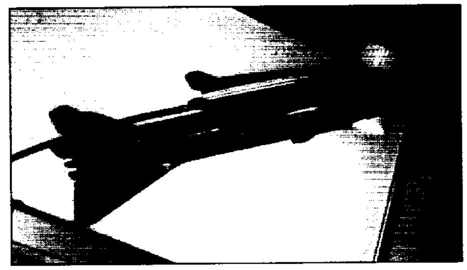
Despite heavy research on the ambitious program, by 1961, Chelomey's engineers were running into some major problems. Clearly, one of these obstacles was OKB-52's lack of experience in operating any space vehicles, let alone piloted ones. A step to creating a winged spaceplane for a flight to Mars proved to be a little too ambitious, given OKB-52's sole experience in developing a number of short-range naval cruise missiles. There were also purely technical issues, such as ensuring the reliability of the main spacecraft systems for such long-duration missions in conditions of vacuum, radiation, weightlessness, and so forth. One of the major problems was developing a nuclear power source, its proximity to the rest of the vehicle, and ensuring its return back to Earth.

Through 1961, OKB-52 prepared a predraft plan for the Kosmoplan project, which may have been examined by an *ad hoc* commission to assess its realistic prospects. Chelomey, apparently faced with the great technical and logistical difficulties of the effort, decided in 1961 to redirect the resources expended on the effort to more realistic proposals. These included the development of the "US" ocean reconnaissance satellite system, which would also use a nuclear power reactor during its missions in Earth's orbit. At the same time, Chelomey did not

26. Sergey Khrushchev, *Nikita Khrushchev: krizisy i rakety: vzglyad iznutri: tom 1* (Moscow: Novosti, 1994), p. 481.

27. E-mail correspondence, Igor Afanasyev to the author, November 28, 1997; Rudenko, "Designer Chelomey's Rocket Planes," 48–49. Note that in the latter source, the AK-4 is referred to as the A-4.

completely abandon the Kosmoplan idea. Despite a significant reduction in work on this theme, engineers used the extensive research data base on the project, all on paper at that point, to explore various further options for piloted spacecraft to explore the Moon and Mars.[28]



This is a model of Chelomey's air-launched piloted Raketoplan for suborbital and orbital missions for the Soviet Air Force. The model was displayed at an exhibition in the 1990s. (copyright Steven Zaloga)

Like the Kosmoplan theme, work on the Raketoplan project also advanced swiftly in 1959–61. The program was originally conceived as a suborbital system for piloted missions, including anti-satellite missions, photo-reconnaissance, the identification of foreign satellites, and even bombing runs over the United States.[29] All the various models of the Raketoplan conceptualized by the end of 1961 had common features in design, and they were given the name "SR" (for Suborbital Rocket-Glider). There were only variations in specific design components, such as the presence or absence of jet engines for the returning first stage, the possibility of having folding wings for the second stage, or using a "flying wing" or canard-type configuration for both stages. Each particular design choice was closely tied to the stage arrangement of the Raketoplan—that is, either tandem or parallel—and thus affected the overall takeoff mass of the various conceptions. For example, one variant, the SR with a tandem arrangement of stages, had an engine unit for the first stage that allowed it to return back to the launch area.

In general, the Raketoplans had a launch mass of about 45 percent higher than the R-7 launch mass, the most powerful Soviet booster of the period. Based on early research, OKB-52 studied two major models of the Raketoplan, one for 8,000 kilometers range and the other for 40,000 kilometers. In dimensions and appearance, both models were relatively similar. The pilot sat in the central portion of the vehicle. The long-range version had three propellant tanks: a conical one with oxidizer at the forward end, a cylindrical one with fuel in the center, and another cylindrical one with oxidizer in the aft part of the fuselage. The short-range model had only two tanks: the conical one with oxidizer in the forward end of the spacecraft and a short cylinder with fuel in the aft end. Instead of the omitted third tank, the short-range spaceplane had a small passenger cabin for four to six seats. Engineers proposed that half-scale models of the Raketoplan could be launched on test flights to a range of 5,000 kilometers by Chief Designer Yangel's R-14 intermediate-range ballistic missile or to a range of 18,000 kilometers by Chelomey's own yet-to-be-developed UR-200 ICBM. Actual full-scale models of the spaceplane second stage could use two-stage variants of the R-7 for flights to 40,000 kilometers. These models would have folded wings for the initial ascent.

Given its ambitious nature, it is not surprising that Chelomey ran into serious problems with the Raketoplan program, too. Because the system combined elements of two different vehicles—an airplane and a rocket—it also inherited the weaknesses of both. The system as a whole was extremely complex and was very large, requiring the development of high-performance liquid-propellant rocket engines, new construction materials, and miniaturized electronics—technologies that posed great challenges for Soviet industry at the time. Like the Kosmoplan, the Raketoplan project also suffered from the limitations of OKB-52's experience in the field of developing missile-space systems.

28. Afanasyev correspondence, November 28, 1997.
29. Afanasyev, "Kosmoplan: Chelomey's Project"; Khrushchev, *Nikita Khrushchev: tom I*, pp. 480–81.

An official decree of the Central Committee and the Council of Ministers, dated May 13, 1961, and titled "On the Revision of Plans for Space Objects Towards Accomplishment of Goals of a Defense Nature," had a direct effect on both the Raketoplan and Kosmoplan projects.[30] As a result of this governmental decision, preliminary work on both themes was terminated. The news was not all bad. Apparently, people in the government and Communist Party believed that the research carried out on the Raketoplan theme had great prospects for future work. The decree authorized OKB-52 to use the accumulated research work to proceed on a new piloted variant of the Raketoplan for military missions in Earth's orbit and deep space.[31] For Chelomey's fortunes in general, this particular decree was perhaps one of the more important ones in his career. A leading designer from Korolev's OKB-1 later recalled:

> *In May 1961, just ten [sic] days prior to President Kennedy's speech on the U.S. commitment to go to the Moon, the Soviet government issued another decree on space matters. It actually reversed the previous decree of June 1960. Funds were taken from OKB-1 and transferred to the Chelomey design bureau. The same thing happened to subcontractors of OKB-1; they were ordered to shift their efforts to support Chelomey.*[32]

A significant amount of funding that had originally been allocated to Korolev was now shifted to Chelomey. The decree thus effectively killed the overtly far-reaching space program that Korolev proposed in the major June 1960 decree. Two factors played a role in this astonishing turnaround. The first was clearly Chelomey's continuing rise in prominence in the defense industry and his unmatched clout with Khrushchev. Second, there were the needs of the defense sector. While Korolev was pursuing projects that were predominantly for exploration, Chelomey's programs, especially the Raketoplan, catered to a Ministry of Defense increasingly uneasy about the possibility of war expanding to space.

In this climate, Chelomey continued to pursue work on the Kosmoplan project, despite an official order suspending such efforts. The amount of work on both the Kosmoplan and Raketoplan in 1960–64 was, in fact, unprecedented and compared very favorably with space-related work at the Korolev design bureau. OKB-52 engineers built mini-dimension ballistic models of their spaceplanes for aerodynamic testing in the wind tunnels at the Central Aerohydrodynamics Institute at Zhukovskiy, and they performed work on spacesuits for cosmonauts and catapults for rescuing cosmonauts during various phases of the mission. Other enterprises involved in the work included NII-1, NII-88, KB-1, NII-2, the M. M. Gromov Flight-Research Institute, the Institute of Aviation and Space Medicine, and the Central Institute of Aviation Motor Building.[33] The pace of work was breathtaking. An engineer involved in the program later recalled, perhaps a little immodestly:

> *The most amazing thing was how we tore ahead, skipping even the initial drafts, immediately going on to the working plans stage, and even with such a speed how we nevertheless created heat shielding for the vehicle which even today has no analog in the world with respect to reliability and practical feasibility.*[34]

30. The decree is mentioned in Yu. P. Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya "Energiya" imeni S. P. Koroleva* (Korolev: RKK Energiya, named after S. P. Korolev, 1996), p. 248.

31. Afanasyev correspondence, November 28, 1997.

32. Boris Arkadyevich Dorofeyev, "History of the Development of the N1-L3 Moon Program" (English title), presented at the 10th International Symposium on the History of Astronautics and Aeronautics, Moscow State University, Moscow, Russia, June 20–27, 1995.

33. Rudenko, "Designer Chelomey's Rocket Planes," 48–49.

34. Mikhail Rudenko, "'Star Wars'—History of the 'Death' of a Unique Spaceplane" (English title), *Trud*, August 26, 1993, p. 6.

All of this, of course, produced some tangible results. The work in late 1960 and early 1961 culminated in the creation of the first automated test bed called the MP-1 (the "MP" standing a little prematurely for "Maneuvering, Piloted"). Although engineers never finished a formal draft plan for the vehicle, the spacecraft was manufactured and ready for flight by late 1961.

The MP-1, developed primarily by the group of engineers transferred from the Lavochkin design bureau, was a small two-meter-length winged spacecraft with a mass of 1,750 kilograms. The vehicle had adjustable braking panels in the form of an umbrella mounted at the rear to ensure proper braking during reentry into the atmosphere. Engineers also installed graphite rudders on the vehicle for guidance, similar to those on outdated ballistic missiles. The test program for the vehicle included a single suborbital flight with ballistic maneuvering during descent. Maximum altitude would be 405 kilometers. The spacecraft would lift off and fly downrange 1,760 kilometers before entering the atmosphere at a velocity of 3,760 meters per second. After the maneuvering phase, the vehicle would land 1,880 kilometers downrange from the launch site. Recovery would be effected by a three-level system of drawing, braking, and primary parachutes working at altitudes of eight to four kilometers, thus reducing vertical downward velocity to about ten meters per second.[35] Because Chelomey did not have any boosters ready for launch at the time, he signed an agreement with Yangel to obtain an R-12 medium-range ballistic missile for the MP-1 test flight.

The day before the launch, set for December 27, 1961, the younger Khrushchev received his graduate degree, and there was a private dinner party given by Chelomey at a Moscow restaurant. Khrushchev recalls that everyone was quite a bit drunk by the time they got on the plane that night and headed out to the launch range to direct the flight.[36] Unlike all previous space-related launches, this one was to take place at the Air Defense Forces Test Range at Vladimirovka, just a few kilometers southeast of the Kapustin Yar site. Preparations proceeded without trouble the next morning amid heavy snowfall. The MP-1 was mounted on top of the R-12, and it was clearly visible as a spaceplane from a distance. The rocket lifted off successfully from the pad at site 1, and about forty minutes later, controllers received news that the vehicle had passed through the atmosphere and landed successfully by parachute.[37] The launch was kept secret for more than thirty years, but it was a landmark in the history of space exploration. It was the world's first hypersonic flight of a lifting body during which aerodynamic forces were used to control the atmospheric phase of reentry. When engineers inspected the spacecraft the following day, they were elated to discover that the heat shielding was almost completely undamaged; unexpected burning had been primarily limited to connection points between the ailerons and the wings.[38]

The relative success of the MP-1 flight no doubt added to the engineers' confidence that they were on the right track in their work. By 1963, engineers at OKB-52 had completed the draft plan for the Raketoplan project, which contained the details of four variants of such a vehicle:

- A single-seat orbital anti-satellite spaceplane
- A single-seat orbital bomber of ground targets
- A seven-seat passenger ballistic spacecraft for intercontinental ranges
- A two-seat scientific spacecraft for circumlunar flight[39]

35. Kirpil and Okara, "Designer of Space Planes"; Mikhail Rudenko, "Designer Chelomey's Space Planes" (English title), *Vozdushniy transport* 51 (1995): 8–9; Khrushchev interview.

36. Khrushchev interview.

37. Rudenko, "'Star Wars'—History of the 'Death' of a Unique Spaceplane."

38. Khrushchev interview.

39. E-mail correspondence, Igor Afanasyev with the author, November 23, 1997.

The first, second, and fourth vehicles would be launched by the UR-500 rocket, while the third would be launched by the UR-200. One of the more interesting elements of this modified Raketoplan theme was the piloted circumlunar mission. A number of Russian sources have suggested over the years that there was a firm state-level commitment to a piloted circumlunar project from as early as 1961.[40] Other reliable sources are vehement that there was no such commitment.[41] It is more than likely, given the generally nonspecific nature of the entire Raketoplan-Kosmoplan effort, that the idea elicited only cursory interest from higher authorities, much like several of Korolev's piloted lunar plans of the period. Overwhelming evidence suggests that in the immediate years following Kennedy's speech, there were a litany of proposals from various chief and general designers to develop spacecraft to carry out piloted circumlunar flight, but that none of these prompted any serious consideration from Khrushchev, Kozlov, Ustinov, or Smirnov. Perhaps Chelomey grasped on the idea of circumlunar flight after hearing of similar proposals from the Korolev design bureau during the 1962–63 period. Little is known about Chelomey's 1963 vintage circumlunar spacecraft. It was one of the "scientific" versions of the Raketoplan and had a low lift-to-drag ratio. The vehicle was apparently a wingless spacecraft, capable of carrying one to two cosmonauts, that would carry out a ballistic reentry into Earth's atmosphere after flight around the Moon.[42] Chelomey also continued work on the Kosmoplan theme at a low level from 1961 through 1964. Although the scope of the research remains unclear, it probably included work on a vehicle called "K" for automated flight to the Moon, Mars, and Venus, followed by a return to a regular airport on Earth.

Despite continuing problems, Chelomey's engineers obtained further data applicable to the Raketoplan-Kosmoplan theme from another active experiment in the early 1960s. In the framework of OKB-52's research on "aircraft warheads," the engineers developed a second hypersonic vehicle, the M-12, to test the technology for guided reentry into the atmosphere. Although the spacecraft was built specifically for the military warhead program, it served a dual purpose by continuing the research program begun by the first MP-1 spaceplane launched in 1961. The "conceptual design" of this vehicle was completed in October 1962, and the ensuing months were spent building a flight-test article at the design bureau's plant.[43] The M-12 was similar in design to the MP-1, although the engineers finally dispensed with the umbrella-shaped braking panels and introduced new aerodynamic graphite rudders. The new vehicle was also equipped with on-board control systems far more complex than its predecessor.

The only launch of the M-12 model took place on March 21, 1963, from the same pad at site 1 at Vladimirovka where the MP-1 had lifted off. The launch on another of Yangel's R-12 missiles was successful at 1440 hours Moscow Time, and the engineers had to wait fifty minutes before they received news that the spacecraft had been destroyed upon reentry into the

40. See, for example, S. Golotyuk, "First People on the Moon (A Quarter of a Century Later)" (English title), *Novosti kosmonavtiki* 15 (July 16–29, 1994): 32–40; M. Chernyshov, "Why Were Soviet Cosmonauts Not on the Moon?" (English title), *Leninskoye znamya*, August 1, 1990, p. 3; V. P. Mishin, "Why Didn't We Fly to the Moon?" (English title), *Znaniye: tekhnike: seriya kosmonavtika, astronomiya* no. 12 (December 1990): 3–43. In the last source, Mishin writes that in "1961 V. N. Chelomey's firm was assigned to work on a rocket-space system intended for circumlunar flight." One source hints that the circumlunar decision was a part of the major June 1960 space policy statement by the Soviet Communist Party and government. See Rudenko, "Designer Chelomey's Rocket Planes," 48–49.

41. Interview, Georgiy Stepanovich Vetrov by the author, January 9, 1997.

42. Interview, Gerbert Aleksandrovich Yefremov by the author, March 3, 1997. Note that one OKB-52 engineer, A. Petrov, recalled in 1995 that his diploma project in 1962 had been on a winged spacecraft for flight around the Moon and return to Earth. The lift-to-drag ratio was 1.0–3.0 "with suppression of overloads during reentry in the atmosphere up to 1.0." See Rudenko, "Designer Chelomey's Rocket Planes."

43. Yefremov interview.

atmosphere. The failure no doubt demoralized the design team, but they apparently received useful data via telemetry, which allowed them to make certain refinements to the spaceplane research and development process. The engineers later ascertained that the heat shield had not been sturdy enough to protect the vehicle because of a technical defect.[44]

It seems that the Soviet Air Force, the chief sponsor of Chelomey's Raketoplan project, began to cool off on the effort by this time. This change of heart may have had much to do with the fate of the X-20A Dyna-Soar program in the United States. Prompted by a variety of reasons, principally Secretary of Defense Robert S. McNamara's belief that the spaceplane had no effective military use, the Johnson administration announced the termination of the project on December 10, 1963.[45] The Soviets themselves may have also seen the potential political and public relations cost of pursuing a space-based system, one of whose goals was nuclear weapons delivery. There were other Soviet Air Force concerns, primarily the long lead-time expected for the operational capability of such a system. In January 1963, the Air Force sent a number of high-ranking representatives to visit OKB-52 to discuss the Raketoplan project. Commenting on reports on the project's progress, Lt. General Kamanin wrote:

> *[F]or the present it's not even on paper, although we've been assured that the Draft Plan [will be ready] by February. Chelomey has already had a long two years to work on this theme, and in January 1961 when we were there with the Commander-in-Chief—then he made many promises—but nothing that was promised has been carried out. The real space ships in the future 3–5 years will be Korolev's ships, and only his—all the rest are unlikely to advance outside the bounds of experimentation.*[46]

Ironically, two of Chelomey's automated space projects may have contributed to the lack of interest from the military. Both the "IS" anti-satellite and the "US" ocean reconnaissance programs were geared toward many of the same objectives slated for the Raketoplan. Undoubtedly, automated systems were much cheaper. The question of whether one was more optimal than the other was one that would not be adequately answered for many years, but given the strong inclination of senior military personnel to support robotic versus piloted military systems, the fortunes of the Raketoplan did not look too bright. Through the overwhelming obstacles, both technical and political, Chelomey continued to doggedly pursue his pet project, fielding even more advanced versions of single-seat military fighters in space.

Despite the setbacks, Chelomey was still at his peak at the time. If the June 1960 decree was meant to seal Korolev's preeminence as the leading space designer, the May 1961 decree effectively reversed that trend. In search of "revisions" to the original decree, the Soviet Communist Party and government stepped back from the original grandiose plans of a massive Soviet space program heading outwards into the solar system. The changed tenor of goals was now explicitly redirected to "goals of a defensive" nature—that is, anti-satellite weapons, reconnaissance satellites, and orbital bombers. And who better to pick to lead these programs than someone who had not only been doing work on these topics for some time, but a designer whose rising star was abetted and protected by the Soviet leader himself? Oddly enough, the revised decree was issued almost exactly a month after Gagarin's flight, a point in time one would suspect was the peak of power for Korolev. There were, however, simply too many forces

44. Rudenko, "Designer Chelomey's Space Planes"; Yefremov interview; Kamanin, *Skrytiy kosmos*, p. 239; Afanasyev correspondence, November 23, 1997.

45. Roy F. Houchin II, "Why the Dyna-Soar X-20 Program Was Cancelled," *Quest* 3 (Winter 1994): 35–37.

46. Kamanin, *Skrytiy kosmos*, p. 211.

This rare photo dating from the early 1970s shows Vladimir Chelomey with some of the leading scientists from the USSR Academy of Sciences. In the foreground, left to right, are TsNIIMash Deputy Director Vsevolod Avduevskiy, political scientist Piotr Fedoseev, General Designer Chelomey, and Academy President Anatoly Aleksandrov. In the immediate background, the two men facing each other are Korolev's successor Vasiliy Mishin and nuclear weapons scientist Yevgeniy Velikhov. (files of Peter Gorin)

working against Korolev and too few dramatic victories such as the Gagarin flight to compensate.

In 1963, the breadth of the projects at Chelomey's OKB-52 was staggering. The projects included three new ICBMs (UR-200, UR-500, and UR-100), two orbital bombardment systems (GR-1 and GR-2), two space launch vehicles (UR-200 and UR-500), a nationwide strategic defense system (Taran), an Earth-orbital spaceplane (Raketoplan), a lunar and interplanetary spaceplane (Kosmoplan), plans for an automated anti-satellite project (IS), and an automated naval reconnaissance program (US). This was in addition to his old work on as many as ten different naval cruise missiles.[47] All this was from an organization whose sole contribution to the defense industry by 1959 was a single short-range cruise missile. On April 29, 1962, he was elected a full Academician, joining the select ranks of Keldysh, Korolev, and Glushko. His influence in seemingly casual matters was also said to be without precedent. In a perhaps apocryphal story, a Soviet defector recalled years later that in the early 1960s, Chelomey wanted to build a dacha (a cottage) for his family in an area near Moscow where no buildings were allowed. He first appealed to the chairman of the Moscow Party Council to have the standard regulations waived in his case, but the chairman refused. Chelomey took the matter personally to Khrushchev. After hearing his story, the Soviet leader telephoned the chairman and told him, "I understand you have turned down comrade Chelomey's request. Aren't you forgetting you are an elected official?" Soon after, Chelomey was given his dacha.[48]

47. The naval cruise missiles included the early P-5 and P-5D models, the P-6 and P-35 (both approved on August 17, 1956), the P-70 Ametist (approved on April 1, 1959), the P-7 (approved on June 19, 1959), the P-35 Redut (approved on August 16, 1960), the P-25 (approved on August 26 1960), and the P-120 Malakhit and P-500 Bazalt (both approved on February 28, 1963). All were anti-ship missiles, either launched from submarines or surface ships. See Shirokorad, "Rakety nad morem."

48. Andrew Cockburn, *The Threat: Inside the Soviet Military Machine* (New York: Vintage Books, 1984), p. 136.

It is easy and far too simplistic to attribute this immense growth of the Chelomey empire to the personal whims of Khrushchev. The Soviet leader was not deeply involved in much of the decision-making in the space program, weighing in only for the most important projects or for macro-level policy statements. He may not even have been partial to Chelomey simply because his son worked for the general designer. It is clear, however, that those *under* Khrushchev who were responsible for important decisions, well aware of the younger Khrushchev's location in the space industry, would only be too happy to favor Chelomey. Thus, it was probably never a case of direct gratuitous support as many historians have claimed. It was more likely a case of the upper ranks in the space program, such as Serbin, Ustinov, Smirnov, and Dementyev, making decisions that they believed would put them on the Soviet leader's good side.

In the two years since 1961, the entire climate of the Soviet space program had changed immensely as Kennedy's challenge began to finally infiltrate the stratum of the secret Soviet space program. The problem was no longer reaching the Moon, but reaching the Moon first. Having been mired for two years in various spaceplane projects, Chelomey, now certainly the most dominant designer in the Soviet space program, was not about lose out on this race. It was a race not only with the Americans, but, in a far more deleterious way, with his primary competitor and nemesis, Korolev.

Rocket Engines on the Frontier

The central goal of the comprehensive space plan issued by the government in June 1960 was the development of a series of heavy-lift launch vehicles—specifically the N1 and N2—to support a variety of future space projects. They were also to be OKB-1's means to maintain its preeminent position as the dominant Soviet space organization. The post-Sputnik euphoric climate—when OKB-1 Chief Designer Korolev was the toast of Party, military, and government leaders—was in its last breath. Despite the glowing successes of the Luna spacecraft and the flights of Gagarin and Titov, there was trouble on the horizon for Korolev's design bureau. The pressure was coming from all sides. Khrushchev had found in Yangel and Chelomey better alternatives to the strong-headed Korolev. Both Yangel and Chelomey were more interested in gearing their products toward military needs than some abstract youthful dream. Chelomey had ascended literally from nowhere, threatening to run over any in his path. The military continued to have problems with Korolev over his pathological insistence on using cryogenic propellants over storable ones. Finally, Korolev had broken ranks with his closest collaborator, Glushko, over a variety of technical issues related to engine design.

As astonishing as it seems, mid-1961, right after Gagarin's flight, was a time of great uncertainty for Korolev. In a revealing episode from the period, Korolev clearly let the stress show through. In late July 1961, Korolev met secretly with another beleaguered Chief Designer, Grigoriy V. Kisunko of the KB-1 design bureau, which was responsible for designing the Soviet Union's first anti-ballistic missile system, to discuss the "attack' from Chelomey. Kisunko later recalled Korolev's words vividly: "This is the second time they have tried to cross me out of life."[49] The two designers discussed writing a letter to other individuals in the Central Committee about Khrushchev's favoritism, but they decided to abandon the idea, perhaps so as not to risk their own careers. In this climate, the N1 and N2 boosters were not simply the "next" of Korolev's projects, but his lifeline to maintaining singular domination of the space program. Most of his grand plans from the June 1960 decree—the development of large piloted space stations, piloted lunar space vehicles, and interplanetary ships—all rested on the fate

49. Mikhail Rebrov, "Project 'Taran'" (English title), *Krasnaya zvezda*, June 18, 1994, p. 6.

of these boosters. They assumed an increasingly symbolic and mythological proportion in his life, becoming literally "the last love of his life" as some of his biographers have claimed.

The June 1960 decree specified that the draft plan for the first vehicle, the N1, would be completed by the end of 1962. With this date in mind, OKB-1 issued a formal "technical assignment" on October 1, 1960, to four rocket engine design bureaus for the development of very high-performance engines. All the engines would be closed cycle with high-pressure combustion chambers, high specific impulses, and relatively small mass. The subcontracting organizations were Glushko's OKB-456 at Khimki, Isayev's OKB-2 at Kaliningrad, Kosberg's OKB-154 at Voronezh, and Kuznetsov's OKB-276 at Kuybyshev.[50]

While Glushko, Isayev, and Kosberg had been involved in rocket engine design for ballistic missiles, it would be a relatively new field of work for Kuznetsov. He had become involved in the missile business in the late 1950s during the open conflict between Korolev and Glushko over the R-9 ICBM. When Kuznetsov's engines were eventually rejected for a variant of the R-9, under pressure from OKB-1 First Deputy Chief Designer Mishin, Korolev invited him to work on the N series boosters. The invitation was clearly related to Kuznetsov's preference for working with Korolev and Mishin's favored cryogenic combinations as opposed to Glushko's storables. Kuznetsov's OKB-276 was also located very close to OKB-1's subsidiary manufacturing plant, the Progress Machine Building Plant in Kuybyshev. Despite Korolev's somewhat desperate act of inviting Kuznetsov to participate, Glushko was clearly far ahead of the game; he was already in the midst of developing a powerful series of new engines for Yangel's ICBMs with storable propellants. Kuznetsov, on the other hand, would have to start from scratch.[51]

At some point soon after, it seems that Kosberg's OKB-154 dropped out from the running because of commitments to Chelomey's projects, to be replaced by another aviation engine design organization, OKB-165.[52] Headed by fifty-two-year-old General Designer Arkhip M. Lyulka, the design bureau, established in March 1946, had primarily designed turbojet engines for a variety of Soviet military and civilian aircraft, remaining outside the mainstream of the missile and space programs.[53] Thus the four remaining designers—two from the aviation industry (Kuznetsov and Lyulka) and two from the armaments industry (Glushko and Isayev)—signed an amended technical assignment document on March 1, 1961.[54] Somewhat comparable to the Western concept of a request for proposals, the technical assignment included specific recommendations for particular areas for each designer on which to focus in creating the N1 and N2 boosters. Glushko and Kuznetsov were assigned to develop engines for the first three stages, while Lyulka and Isayev would focus on high-energy upper stages, as follows:

50. Igor Afanasyev, "N1: Absolutely Secret" (English title), *Krylya rodiny* no. 9 (September 1993): 13–16.

51. B. Ye. Chertok, *Rakety i lyudi: Fili Podlipki Tyuratam* (Moscow: Mashinostroyeniye, 1996), pp. 345–46.

52. Note that although Kosberg did not sign the adjusted technical assignment document, his design bureau did produce a powerful 150-ton-thrust engine, the 8D415K, in support of the N1 program. The propellants were liquid oxygen and kerosene. See Varfolomeyev, "Readers' Letters: On Rocket Engines."

53. Lt.-Col. S. Vachayev, "From the Origins of the Reactive Era" (English title), *Aviatsiya i kosmonavtika* no. 3 (March 1988): 31–32; S. P. Kuvshinnikov, "23 March—75 Years From the Birth of A. M. Lyulka (1908)" (English title), *Iz istorii aviatsii i kosmonavtiki* 48 (1984): 87–95. Lyulka did, however, cooperate with Kuznetsov during the development of the NK-9 rocket engine for the abandoned R-9M missile in 1958–59.

54. G. Vetrov, "The Difficult Fate of the N1: Part II" (English title), *Nauka i zhizn* no. 5 (May 1994): 20-28; Afanasyev, "N1: Absolutely Secret."

Designer	Propellant Combination	Thrust	Stage on the N1
Glushko	LOX-UDMH	150 tons	Stage I
Glushko	N_2O_4-UDMH	150 tons	Stage I
Glushko	LOX-UDMH	180 tons	Stage II
Glushko	N_2O_4-UDMH	150 tons	Stage II
Glushko	Fluorine, etc.	20–25 tons	Stage III
Kuznetsov	LOX-kerosene	150 tons	Stage I
Kuznetsov	LOX-kerosene	45 tons	Stage II
Kuznetsov	LOX-kerosene	45 tons	Stage III
Lyulka	LOX-LH_2	40 tons	Stage II
Lyulka	LOX-LH_2	40 tons	Stage III
Isayev	LOX-kerosene	Not available	Stage II
Isayev	LOX-LH_2	7.5 tons	Stage III[55]

Key: LOX = liquid oxygen; UDMH = unsymmetrical dimethyl hydrazine; N_2O_4 = nitrogen tetroxide; and LH_2 = liquid hydrogen.

The rationale behind Glushko's selection was obvious: his propellants were all geared toward dual use on military ICBMs as well as space launch vehicles, a strategy that makes perfect sense given the economic exigencies of the day. Of the four first- and second-stage engines, the favored ones for the N boosters would be the two nitrogen tetroxide (N_2O_4)–UDMH engines, known as the RD-253 and RD-254, respectively. These were the first closed-cycle rocket engines developed by Glushko.[56] By the early 1960s, Glushko had all but abandoned liquid oxygen (LOX) because of problems associated with high-frequency oscillations, and the two proposals for LOX-based engines for the N1/N2 program seems to have been his last stab at LOX before focusing fully on storable propellants. The fluorine-based engine was more of a curiosity than anything else. Theoretically, fluorine-type rocket engines would offer high specific impulses, but this remained to be proved in test conditions.

The origins of Kuznetsov's engines were far more interesting. OKB-276's first foray into the development of high-thrust liquid-propellant rocket engines had been developing the NK-9 engine for the first stage of an abandoned variant of Korolev's R-9 ICBM, named the R-9M. The organization's extensive experience in designing aircraft engines was little use in this project, and to hasten development, there was significant cooperation with the rocket engine department at OKB-1. Foreseeing a possibly difficult time in engine development, Korolev allowed Kuznetsov's engineers to have full access to propulsion research data on one of OKB-1's new upper stage engines.[57] The R-9M missile was eventually never built because of severe pressure from Glushko, and Kuznetsov simply decided to use the same engine as a basis

55. *Ibid.*; Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p. 262.

56. The less well-known RD-254 is mentioned by journalist A. Bolotin in M. Rudenko, "The Moon Slips Away" (English title), *Ekonomika i zhizn* 48 (November 1991): 19.

57. Korolev's engine was the S1.5400, and it served as the fourth-stage engine for the 8K78 (or Molniya) booster used to launch the early Mars and Venus interplanetary spacecraft. See Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p. 123.

to design ones for the N1 and N2. The forty-ton single-chamber NK-9 would serve as the foundation for different directions of development. First, Kuznetsov's engineers would scale up its performance characteristics to produce an engine with a 150-ton thrust; second, they would produce high-altitude variants of the engine for use on the N1's second and third stages. To shorten development periods, all three engines would retain basic design elements of Korolev's upper stage engine.

High-energy engines for the upper stages—in particular those using liquid hydrogen (LH_2) and LOX—were assigned for development to Lyulka and Isayev. In 1961, manufacturing of LH_2 for rocketry purposes in the Soviet Union was almost nonexistent. Neither the technology nor the resources were available. It was well-known among most space enthusiasts, as far back as Tsiolkovskiy, that of all the chemical sources of propellants, the LH_2-LOX combination was the most efficient; specific impulses were significantly higher with LH_2 than with either Glushko's storable components or the R-7's LOX-kerosene pairing. Unfortunately, LH_2 was also extremely difficult to manufacture, maintain, and use as propellant. The boiling temperature of LH_2 is −252.6 degrees Centigrade, necessitating refrigeration techniques well beyond the means of Soviet industry at the time. Despite these difficulties, the same belief in its performance led the Advanced Research Projects Agency in the U.S. Department of Defense to issue a contract for the development of a LH_2-LOX engine in late 1958. This engine, which became part of the Centaur upper stage, was flown as early as May 1962.[58]

Korolev was without doubt the primary instigator for a similar effort in the Soviet Union. One would have expected Glushko to support these efforts, but his historic dislike of cryogenic propellants veered him away from committing to the design of a high-energy LH_2 stage. Glushko's opponents in fact like to quote one of his more infamous exhortations, authored in 1935, when as a twenty-seven-year-old engineer he had written: "liquid oxygen is far from the best oxidizing agent, while liquid hydrogen will never be of any practical use in rocket equipment."[59] Korolev, with a much more solid faith in the capabilities of LH_2, fired off a letter to the government on April 8, 1960, in which he argued:

> *OKB-1 considers it extremely necessary to develop on a wide front of work the creation of an industrial base for the creation of liquid hydrogen, for work on methods of its storage and transportation and also the study of its characteristics and the operational characteristics of hydrogen, and preparation of recommendations for the design of special aggregates and fixtures for working with hydrogen.*[60]

A draft plan on the use of LH_2, "On the Possible Characteristics of Space Rockets Using Hydrogen," dated September 9, 1960, was also addressed to Keldysh, Glushko, Lyulka, and Academician Anatoliy P. Aleksandrov, the erstwhile Director of the Academy's Institute of Atomic Energy.[61] Resistance from Glushko may have played a significant part in downplaying the need for such work. Although preliminary work on LH_2 engines began at the Isayev and Lyulka design bureaus in 1960, these efforts had very little funding. In addition, the military, for

58. Linda Neuman Ezell, *NASA Historical Data Book, Volume II: Programs and Projects 1958–1968* (Washington, DC: NASA Special Publication (SP)-4012, 1988), p. 44. The May 1962 launch was a failure. The second launch in November 1963 was successful.

59. A. Tarasov, "Missions in Dreams and Reality" (English title), *Pravda*, October 20, 1989, p. 4. The quote is from Glushko's monograph *Khimicheskiye istochniki energii* (*Chemical Sources of Energy*), which was published in 1935 while he was working at the RNII.

60. G. Vetrov, "The Difficult Fate of the N1: Part I" (English title), *Nauka i zhizn* no. 4 (April 1994): 78–80.

61. *Ibid.*; Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p. 248.

obvious reasons, had little interest in them. It was a strategic mistake that cost the Soviet space program much in terms of capability and efficiency, but Korolev alone did not have the force to single-handedly create a new industry in the Soviet Union. Initial versions of the N1 and N2 rockets would have to rely on less efficient combinations.

Another area of advanced research was nuclear engines, a pipe-dream of sorts that had been bandied about by different designers through the postwar years. Nuclear energy, of course, could theoretically provide even higher specific impulses than LH_2. While the best LH_2-LOX rocket engines could be expected to have specific impulses in the range of 400 to 450 seconds, nuclear engines could potentially have values as high as 800 to 1,000 seconds (with solid fuel) or even 2,000 to 5,000 seconds (with uranium compound plasmas).[62] Even prior to the launch of the first Sputnik, in 1955 and 1956, the advanced projects NII-1 research institute, headed by the ubiquitous Keldysh, had initiated preliminary plans for nuclear propulsion development. Government intervention on the matter occurred on June 30, 1958, with the issuing of a top-level decree requesting a draft plan on a nuclear engine.[63] Such a preliminary document was prepared and approved by Korolev on December 30, 1959. By 1960, at least six design bureaus and four scientific-research institutes were involved in the effort.[64] As with numerous other advanced technology programs, the United States and the Soviet Union engaged in research almost simultaneously. After discussions dating back to the mid-1940s, the U.S. Department of Defense and the Atomic Energy Commission began such research efforts as Kiwi and NERVA at the same time.[65]

Applications for the use of nuclear engines were also studied vigorously at the time. In 1959 and 1960, the OKB-1 proposed three new rockets—two space launch vehicles and an ICBM—that would use nuclear engines in some capacity. Engines would be provided by Glushko's OKB-456 and another design bureau, the OKB-670 headed by Chief Designer Mark M. Bondaryuk, a specialist in the development of ramjet engines. Bondaryuk had previously developed the engines for the abandoned Burya and Buran intercontinental cruise missiles in the 1950s. One of the space launch vehicles proposed, the YaKhR-2, had an unusual configuration: it looked just like the standard R-7 except it had *six* instead of four strap-ons. The core itself would be equipped with the nuclear engine. The other launcher tabled was a "super-rocket" with a lifting capacity of 150 tons to Earth orbit and a launch mass of 2,000 tons. The second stage would use a powerful nuclear engine.[66] None of these proposals were pursued with any seriousness after late 1960 as a result of intensive research, which proved that for immediate purposes, chemical sources of propulsion would be more fruitful. Many of the design bureaus in the nuclear program also lost interest. It would be the mid-1960s before both nuclear and LH_2 engines received sufficient support to commence dedicated projects to develop such engines.

62. Joseph R. Wetch, Alexey Ya. Goldin, Anatoly A. Koroteev, Alexander D. Konopatov, Vladimir A. Pavshook, Nikolai N. Ponomarev-Stepnoy, Vitaly F. Semyonov, and Ivan Fedik, "Development of Nuclear Rocket Engines in the USSR," AIAA/NASA/OAI Conference on Advanced SEI Technologies, AIAA 91-3648, September 4–6, 1991; A. Koroteyev, "From the History of Space Science: The Scientific-Research Institute of Jet Propulsion" (English title), *Aviatsiya i kosmonavtika* no. 6 (November–December 1993): 39–41.

63. The title of the decree was "On the Creation of Missiles with Engines on the Basis of Using Nuclear Energy." See Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p. 248; Leonid Kvasnikov, Anatoliy Kostylev, and Vladimir Maksimovskiy, "Nuclear Rocket Engines" (English title), *Vestnik vozdushniy flota* no. 6 (June 1996): 53–55. A high-level meeting in February 1959 purportedly about nuclear propulsion research is described in Aleksandr Romanov, *Korolev* (Moscow: Molodaya gvardiya, 1996), pp. 323–26.

64. The design bureaus were OKB-1 (S. P. Korolev), OKB-165 (A. M. Lyulka), OKB-301 (S. A. Lavochkin), OKB-23 (V. M. Myasishchev), OKB-670 (M. M. Bondaryuk), and OKB-456 (V. P. Glushko). The institutes were NII-1 (M. V. Keldysh), the P. I. Baranov Central Institute of Aviation Motor Building or TsIAM, the I. V. Kurchatov Institute of Atomic Energy (A. P. Aleksandrov), and VNII NM. See Kvasnikov, Kostylev, and Maksimovskiy, "Nuclear Rocket Engines."

65. Ezell, *NASA Historical Data Book, Volume II*, pp. 482–83.

66. Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p. 248.

Korolev Versus Glushko: No Compromise

In January 1961, a large meeting of chief designers, senior military officers, and defense industry representatives took place at Tyura-Tam, ostensibly to discuss the future of heavy-lift boosters in the Soviet Union. Glushko, as one of the leading chief designers in the space program, served as the *ad hoc* chairman of this meeting. The proceedings for the most part went remarkably smooth, with agreement on the principal design of the N1 and N2, both of which would dispense with the old "cluster" design of the R-7 and instead use the structurally simpler "tandem" design.[67]

Progress on the N series of boosters was dramatically affected by the May 1961 government decree that effectively gave Chelomey a dominant role in the space program. As recalled by a senior OKB-1 engineer, "government authorization of the N1 development was downsized to further paper studies."[68] A number of subcontractors for the N1, including Kosberg's design bureau, were ordered to redirect their efforts toward Chelomey's projects. Whereas in the earlier government order from 1960 the dates for completion of the project were 1960–63 (for the N1) and 1963–67 (for the N2), the new decree pushed the timetable back further to 1962–65 (for the N1) and 1963–70 (for the N2).[69]

The delays and uncertainties in the program no doubt negatively affected the Korolev-Glushko relationship over the issue of propellants. In July 1961, two weeks before Titov's day-long Vostok 2 mission, Korolev paid a personal visit to Glushko's design bureau at Khimki, intent on trying to convince the engine designer to consider the possibility of using cryogenic propellants. The conversation began calmly but quickly escalated into an accusative tone. Glushko, standing his ground with toxic storable propellants, called Korolev's ideas about designing the N1 akin to "dilettantism."[70] He reminded Korolev of the infamous failure of the 120-ton cryogenic engine for the R-3 program in the early 1950s, which had delayed the entire Soviet rocketry program. The problems with high-frequency oscillations in that LOX-kerosene engine had been simply too much to overcome. For his part, Korolev reminded Glushko of the 1960 disaster involving the R-16 ICBM, a rocket that used toxic self-igniting propellants. The meeting ended without resolution, as rational arguments began to be increasingly couched in terms of personal attacks. It was symptomatic of many more meetings to come.[71]

The propellant issue came to a head in December 1961, when Glushko decided to take action. In an official letter to Korolev, he demanded that the N1 be redesigned to be equipped with storable propellants, with N_2O_4 instead of LOX. As one Soviet space historian recalled, it

67. Georgiy Stepanovich Vetrov, "Development of Heavy Launch Vehicles in the USSR," presented at the 10th International Symposium on the History of Astronautics and Aeronautics. A serious conflict occurred only when Glushko abruptly informed Korolev that contrary to their earlier agreed-on technical assignment, he would develop engines of 100 tons thrust instead of 150 tons. Calling this a violation of their earlier agreement, Korolev argued that this was unacceptable because lower thrust engines would require a higher number of engines. The matter was eventually left unresolved, as was the final choice of propellants for the boosters, which was a far more thorny issue between the two designers.

68. Dorofeyev, "History of the Development of the N1-L3 Moon Program."

69. Mishin, "Why Didn't We Fly to the Moon?"; Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p. 248.

70. Romanov, *Korolev*, pp. 425–27.

71. As early as 1960, Korolev had begun to attack what he considered Glushko's monopoly in the creation of high-thrust liquid-propellant rocket engines in the Soviet Union. In a letter dated July 4, 1960, written to Commander-in-Chief of the Strategic Missile Forces Marshal M. I. Nedelin, Korolev wrote that "OKB-1 has reason to believe that there is a lag arising . . . there are too few OKBs at the present time which are engaged in work on rocket engines." See Vetrov, "The Difficult Fate of the N1: Part I," p. 80.

was "a sort of ultimatum."[72] Glushko claimed that he had "special authority" to make such a demand, apparently at the behest of Khrushchev himself. In retrospect, the timing of the letter goes a long way to explain Glushko's apparent "ultimatum." In November 1961, a month before this letter, he had more or less committed to building the 150-ton storable propellant engines for Chelomey's new UR-500 booster. If he agreed to Korolev's demands on the N1 engines, he would now have to design yet another similar 150-ton engine, only with LOX-kerosene—an effort that he reasonably considered a duplication and a waste of time. Combined with his earlier problems with LOX and the military's fondness for storable propellants, from Glushko's point of view, there was simply no other rational choice: he would stick with his RD-253 and RD-254 engines and propose them for the N1 and N2 boosters. Glushko's letter served to bring the debate to a standstill. Within days, the Soviet government established a commission, headed by Academy of Sciences President Keldysh, to specifically look into the matter and make a formal recommendation on the propellant issue. The commission meetings started out as acrimoniously as one would expect. Perhaps sensing that Keldysh would side with Korolev, Glushko, for the first time, openly quarreled with Keldysh. Glushko had reason to be defensive: by January 1962, after a visit to the Kuznetsov engine design bureau in Kuybyshev, it was becoming clear that the commission was indeed favoring Korolev.

There are almost no photos of Korolev and Glushko together. This is an extremely rare shot of the two giants of the Soviet space program dating from around 1959 and taken at Tyura-Tam. (files of Peter Gorin)

The matter was finally taken to the "ministry" level with a series of intensive meetings between February 10 and 21, 1962, at the premises of the State Committee for Defense Technology in the Kremlin. Presiding was the State Committee Chairman Smirnov, who having been appointed to the position only nine months earlier was having to face a battle of gargantuan proportions. Apart from purely technical issues, it was clear that both Korolev and Glushko needed each other to move ahead on the N series boosters. If anything, Korolev needed Glushko far more than the reverse. It would be a significant risk for Korolev to build the centerpiece of the future Soviet space program without the help of the most successful engine builder in the Soviet Union. On the other hand, Glushko could possibly do without Korolev's N1; he had, after all, sided with Chelomey on his new UR-500 booster, and given Chelomey's continuing rise to power, he could continue to ride on his coattails. The meetings at Smirnov's proved to be the breaking point for the conflict. On one particular occasion, the discussions degenerated into a shouting match of insults and personal attacks between the two. Korolev was insistent that storable propellants were far too toxic and explosive. When Korolev began talking about "powder kegs," Glushko shot back, "Oh, I understand, you'd ideally like a steam engine! . . . So you want to fly in space but remain Mr. Clean?!"[73] Glushko began to invoke "state interests"—that is, the military's preference for storables—but Korolev would not hear

72. Vetrov, "Development of Heavy Launch Vehicles in the USSR."
73. Yaroslav Golovanov, *Korolev: fakty i mify* (Moscow: Nauka, 1994), p. 712.

it. Yelling by this time, Korolev cut him off: "Listen, if you don't want to, then don't do it! We'll get by without you!"[74] Dead silence followed as even Smirnov refrained from saying anything. The deputies of both Korolev and Glushko quietly left the room, letting the two old men deal with each other's demons.

The Propellant Commission, after these meetings, recommended the following pairs of propellant for the N boosters, in order of their preference: LOX-kerosene, LOX-UDMH, and nitric acid-UDMH. For obvious reasons, Glushko was not happy with the decision, and as the intransigence of both designers came to the fore, "a number of high-ranking officials" found themselves trying to mediate the discord.[75] Buoyed by the commission's decision and unwilling to compromise with Glushko, Korolev immediately began resorting to his contingency plans—that is, put his lot with the inexperienced Kuznetsov design bureau. Of the four engine designers contracted in the initial technical assignment, only Kuznetsov and Glushko had agreed to design the first- and second-stage engines. With Glushko out, there was simply no other choice. Despite the commission's decision, the future of his boosters was not guaranteed. Korolev had a number of major opponents in powerful positions to overcome before the N booster project was allowed to continue. His new R-9 ICBM had been performing poorly since test flights began in April 1961; this had deleterious effect on OKB-1's relationship with important individuals in both the Communist Party and the military. The ascendance of Frol R. Kozlov as the Party leader of the space program was also a big stumbling block to Korolev's plans; Kozlov had consistently sided against Korolev at important junctures and may have been responsible for the May 1961 decree favoring Chelomey. Given that Kozlov was the most important decision-maker in the Soviet space program, the N program's fate depended to a great extent on Kozlov's assessment of the situation.

In early 1962, immediately after the commission's recommendations, there was a major design change in the conception of the N1 and N2 boosters. Korolev's engineers scrapped the original N1 proposal (forty to fifty tons to low-Earth orbit) and renamed the more powerful N2 proposal (fifty to eighty tons to low-Earth orbit) the "new" N1 launch vehicle. The nominal payload capability was set at seventy-five tons, sufficient to allow the accomplishment of a variety of long-term goals, including military missions and a piloted mission to Mars (the latter being one of the more favored future plans at OKB-1 at the time).[76] It was clear to Korolev that a direct jump from the modest Vostok booster (about six tons) directly to the N1 (seventy-five tons) would be a tremendous leap and a significant risk. Before receiving further funding and support to continue the project, he would not only have to justify the effort in terms of the needs of the defense industry, but he would also have to provide some kind of guarantees to the various reviewing scientific-technical councils that a leap from six tons to seventy-five tons would be feasible given the current state of Soviet rocket technology. Any argument in support of Korolev's position would no doubt also suffer from the fact that Glushko was no longer a willing participant in the endeavor.

To ease the jump in payload capabilities, Korolev hatched a brilliant strategy. In 1961, when discussions on orbital weapons systems had first been discussed at high-level government meetings, OKB-1 had also begun studying a similar project. Designated the Global Missile No. 1 (GR-1), the rocket would launch a 2.2-megaton warhead into a 150-kilometer orbit around

74. *Ibid.*

75. Vetrov, "The Difficult Fate of the N1: Part II."

76. See Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p. 249, where it states, "Computations proved the majority of goals of military and space nature could be solved by a [rocket-carrier] with a payload mass of 70–100 tons put into a circular orbit around the Earth at an altitude of 300 km." This mass analysis may have been undertaken in cooperation with the military, in particular the research and development institute of the Strategic Missile Forces, NII-4.

Earth. In case of hostilities, the warhead container would deorbit, reenter, and hit the "designated target."[77] In one sense, Korolev's GR-1 proposal was meant to appease an increasingly restless military, who were disappointed with the erratic performance of the trouble-prone R-9. On the other hand, the missile would also serve as a perfect test bed for N1 engine technology. The engine for the first stage of the GR-1, the NK-9, was the same one used for the abandoned R-9M ICBM. The GR-1's second stage would simply use a variant of the NK-9, named the NK-9V, whose only difference was that it was modified for altitude use. Both these engines were prototypes for engines for the first three stages of the giant N1. Finally, the third stage of GR-1 would be equipped with the 8D726 engine, yet another prototype for an upper stage engine for the N1.[78] All the stages would use Korolev's favored LOX-kerosene combination. As a proposal, it was perfect in all respects. The GR-1 would fly dozens of test missions proving out important aspects of N1 architecture; by the time that the N1 would come on line in the mid-1960s, all of its primary propulsion components would be tested and ready. The only hurdle was the approval to undertake both projects.[79]

In early February 1962, Korolev received an invitation from Khrushchev to attend a meeting of the top-secret Council of Defense at the holiday resort of Pitsunda. The entire high command of the Soviet defense industry, Communist Party, armed forces, and design bureaus were to attend.[80] It would not be an overstatement to suggest that it was perhaps the single most important policy meeting in the early Soviet space program, as the three main space designers—Korolev, Chelomey, and Yangel—vied for a slice of the cosmos. To Korolev, it was clear that this would perhaps be his last opportunity to save the N1 project. An endorsement from Khrushchev himself would remove a number of problematic obstacles, in particular the less-than-enthusiastic Kozlov. Each of the three designers arrived at Pitsunda in late February armed with beautifully illustrated posters of their respective proposals and projects, intent on coercing the minds of the most powerful in the Soviet state. The first day of the meeting, February 22, was dedicated to briefings by several naval commanders, ending with a presentation by Chelomey. His performance was flawless. By the end, he had earned the green light to proceed with a new version of the UR-200 ICBM, as well as a completely new all-purpose ICBM/space launch vehicle/orbital bombardment system, the famous UR-500. Because of time limitations, Korolev's speech was delayed to the second day.

77. *Ibid.*, pp. 128–30.

78. *Ibid.*, pp. 129, 252; Peter A. Gorin, "The Dark Side of the Moon Race," presented at the annual meeting of the American Association for the Advancement of Slavic Studies, Boston, MA, November 14–17, 1996.

79. Korolev had already apprised the Soviet leadership of the GR-1 proposal. In September 1961, he sent a letter on the issue to the government, and in November, one to Khrushchev himself. The latter was signed by S. P. Korolev, N. D. Kuznetsov, N. A. Pilyugin, M. S. Ryazanskiy, and V. P. Mishin, implying that at least three of the "big six" chief designers—Korolev, Pilyugin, and Ryazanskiy—were supportive of the idea.

80. Among those known to have been present at the meeting were N. S. Khrushchev (First Secretary of the Central Committee), F. R. Kozlov (Secretary of the Central Committee for Defense Industries and Space), I. D. Serbin (Chief of the Defense Industries Department of the Central Committee), A. N. Kosygin (First Deputy Chairman of the Council of Ministers), A. I. Mikoyan (First Deputy Chairman of the Council of Ministers), R. Ya. Malinovskiy (Minister of Defense), A. A. Grechko (First Deputy Minister of Defense), M. V. Zakharov (Chief of the General Staff of the Ministry of Defense), S. S. Biryuzov (Commander-in-Chief of Air Defense Forces), S. G. Gorshkov (Commander-in-Chief of the Navy), K. S. Moskalenko (Commander-in-Chief of the Strategic Missile Forces), S. P. Ivanov (Secretary of the Council of Defense), D. F. Ustinov (Chairman of the Military-Industrial Commission), L. V. Smirnov (Chairman of the State Committee for Defense Technology), P. V. Dementyev (Chairman of the State Committee for Aviation Technology), B. Ye. Butoma (Chairman of the State Committee for Ship Building), Ye. P. Slavskiy (Minister of Medium Machine Building), M. V. Keldysh (President of the Academy of Sciences), S. P. Korolev (OKB-1 Chief Designer), V. P. Glushko (OKB-456 Chief Designer), V. N. Chelomey (OKB-52 General Designer), M. K. Yangel (OKB-586 Chief Designer), V. P. Makeyev (SKB-385 Chief Designer), N. A. Pilyugin (NII-885 Chief Designer), V. I. Kuznetsov (NII-944 Chief Designer), and S. N. Khrushchev (OKB-52 Deputy Department Chief).

In contrast to the smooth and sophisticated Chelomey, Korolev spoke in concise, choppy phrases. He showed his posters of the N1 to the assemblage, briefly reviewing the work done since the June 1960 decree. Emphasizing the delays and problems with funding, he casually brought up the need to raise the payload capability of the vehicle from its current forty tons to seventy-five tons. Calculations had showed that forty tons would be simply insufficient for missions to the Moon and the other planets. Two variants were conceptualized at that point: one with twenty-four 150-ton-thrust engines and one with a smaller number of 600-ton engines. All the engines would use LOX and kerosene, with the upper stages using LH_2. Korolev apparently startled Khrushchev by saying that all these engines would be designed not by Glushko but by a new entrant to the space program, Kuznetsov. When asked why Glushko was not participating, Korolev was forthright, saying Glushko had refused to work on the engines and that he was also burdened by orders from Yangel and Chelomey. Amazingly, Glushko and Korolev began to argue vociferously in front of the distinguished assemblage, threatening to derail any notion of rationality. Khrushchev, silent all this time, cut them off, and instructed Ustinov to carefully assess Korolev's modified proposals and prepare recommendations.[81] Korolev's proposal on the GR-1 was brushed away, mainly at the behest of Central Committee Secretary Kozlov, who had been opposed to the idea all along. The continuing problems with Korolev's R-9 ICBM had put a wedge in the relationship between his design bureau and the Central Committee.

Yangel spoke after Korolev and put a new twist on the entire situation. Yangel had always been somewhat of an "odd man out" in the Soviet space program. Although he had made quick progress in converting his old medium-range ballistic missiles, such as the R-12 and the R-14, into space launch vehicles, he had not expressed any explicit interest in the *piloted* space program. His primary domain was the development of Soviet ICBMs, and he seemed relatively content to limit his activities in the space arena to modest automated satellites for military purposes. Unlike Korolev's flashy Zenit reconnaissance satellites, Yangel's smaller spacecraft were for research on Earth's ionosphere, meteoroid concentration in Earth orbit, cosmic rays, and Earth's magnetic field—areas that had indirect application to military goals.[82] At the meeting in Pitsunda, Yangel proposed a massive new ICBM (the R-36), yet another orbital bombardment system (the R-36-O), and a heavy-lift space launch vehicle (the R-56). The latter would have a launch mass of 1,400 tons and a lifting capability of forty tons to a 200-kilometer orbit, specifications remarkably similar to Korolev's original N1 plan.[83] Dazzled by the performance of Yangel's design bureau in the rapid development of new high-performance military systems, the

81. Khrushchev, *Nikita Khrushchev: tom 2*, pp. 149–62. In another one of those curious contradictions of the study of Soviet space history, an account of this very important meeting at Pitsunda has been published that differs completely from the one given in the above source. See Golovanov, *Korolev*, pp. 717–19. In the latter source, the author suggests that it was Khrushchev himself who proposed the change in N1 payload mass from forty tons to seventy-five tons, invoking the need to develop a huge battle station that could not only keep a watch on the U.S. mainland but also serve as a station point for nuclear warheads. Khrushchev was concerned about the differences in times for a nuclear attack. U.S. missiles could reach the Soviet mainland in eight to ten minutes, while Soviet missiles would take twenty to thirty minutes. By Khrushchev's reasoning, such a battle station, to be launched on the N1, would go a long way in redressing this imbalance.

82. For a detailed summary of the early Yangel satellite launches, see V. Agapov, "Marking the First ISZ of the 'DS' Series" (English title), *Novosti kosmonavtiki* 6 (March 10–23, 1997): 54–64.

83. Khrushchev, *Nikita Khrushchev: tom 2*, pp. 162–66, 169–70; S. N. Konyukhov and V. A. Pashchenko, "History of Space Launch Vehicles Development," presented at the 46th Congress of the International Astronautical Federation, IAA-95-IAA.2.2.09, Oslo, Norway, October 2–6, 1995. A fourth proposal, the R-46 ICBM, was also apparently tabled at this time. This rocket was an ICBM capable of carrying a fifty-megaton warhead. The military, evidently, had no interest in this proposal. See also Mikhail Rudenko, "Space Bulletin: 25 Years From the Landing of American Astronauts on the Moon" (English title), *Vozdushniy transport* 29 (1994): 8–9, for descriptions of the Pitsunda meeting.

Soviet leadership, especially those in the Communist Party, were very receptive to the new proposals. All three of them were approved for further development.

If Korolev had gone into the meeting with some hope of salvaging his beloved N1, those hopes must have sank to heretofore unseen depths with the issuance of a formal decree of the Central Committee of the Communist Party and the USSR Council of Ministers on April 16, 1962, titled "On Important Work on Intercontinental Ballistic and Global Missiles and Rocket-Carriers for Space Objects." The decree specified that all work on the N1 in 1962 should be limited to work on the draft plan with "necessary economic substantiation of the cost of its creation."[84] The slowdown in the project was clearly related to the conflict between Glushko and Korolev. The decree specified that each of the different versions proposed—that is, the one with Glushko's engines versus the one with Kuznetsov's engines—be appraised in financial terms to come to a decision. While Korolev's lot was sinking, both Yangel and Chelomey gained significantly. The decree approved all three of Yangel's proposals, thus positing the latter's R-56 as a direct competitor to the N1, threatening to completely sink the entire N1 project.[85] A second decree in late April granted Chelomey the approval to move ahead with *his* Pitsunda proposals. With two parallel orbital bombardment systems, Yangel's R-36-O and Chelomey's UR-500, there was little need for a third one from Korolev. The OKB-1 chief designer had effectively left Pitsunda empty-handed.

The Keldysh Commission

Since the issuance of the June 1960 decree on approving preliminary work on N series boosters, OKB-1 had been engaged in intensive study oriented to selecting a single design configuration for the vehicle. During the period 1960–62, a department at the design bureau studied at least sixty different versions of the booster, from multiple-component configurations to monocoque designs, in both tandem and parallel configurations. Feasibility studies and analyses of each variant's advantages and disadvantages were considered during this phase. Early research had already resulted in the rejection of the parallel or strap-on configuration used on the R-7. Although there were advantages of that design in terms of manufacturing processes, transport, and assembly, the less than optimal mass characteristics as well as the existence of far too many pneumatic, hydraulic, and electrical connections would negate any of the favorable factors. The configuration eventually selected was a three-stage tandem or successive-staged scheme with a semi-monocoque design. In a full monocoque design, the mainframe of the rocket also served as the propellant tanks, thus allowing a number of significant mass savings.

Perhaps the most unusual design characteristic of the chosen N1 design was the use of giant spherical propellant tanks. These would be suspended within the main load-bearing outer frame of the rocket, held in place by the forces on them. Engineers theorized that at liftoff, air from the surrounding atmosphere would be ejected by the exhaust streams of the rocket engines into the internal space beneath the lower spherical tank. These exhaust gases would, in theory, form a huge jet engine, which would include the entire lower part of the first stage. Even without the standard expectation of "afterburning" of the rocket engine exhaust, the engineers believed that this phenomenon would provide a significant augmentation of rated thrust. The connections between the first and second as well as the second and third stages would be made up of huge networks of lattice structures, allowing gases to exit at the moment of "hot launch" of the next stage. In the interest of simplicity, the engineers completely dispensed with

84. Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p. 248.

85. V. Pappo-Korystin, V. Platonov, and V. Pashchenko, *Dneprovskiy raketno-kosmicheskiy tsentr* (Dnepropetrovsk: PO YuMZ/KBYu, 1994), pp. 68–69. Note that another source says that Yangel's plan was approved on May 12, 1962. See Khrushchev, *Nikita Khrushchev: tom 2*, p. 165.

the idea of using gimbaled rocket engines on the rocket for yaw and pitch, and instead they opted to incorporate a system whereby opposing rocket engines on the stages would develop mismatched thrusts. Roll maneuvers would be carried out by small thrusters fed by gases diverted from the turbopump assemblies.

In formulating a comprehensive economical and technical analysis of the final version, the engineers also addressed the issues of construction, transportation, and assembly of the rocket. One of the major obstacles encountered was moving the vehicle from the manufacturing plant to the launch site at Tyura-Tam. Because the individual stages were expected to be huge, rail transportation was out of the question. Preliminary options included designing the outer shell of the vehicle in such a way that it could be disassembled; similarly, the propellant tanks would be made of petal-shaped strips that would be assembled at Tyura-Tam. Clearly, there was a paramount need for a massive new assembly building at the launch site specifically built for the N1 program—an associated cost that was factored into the preliminary projections.[86]

Of the elements of the N1 studied during this stage, perhaps the most important were the determination of the number of engines required for the first stage of the giant launch vehicle and their thrust. After extensive analysis of the possible options, OKB-1 settled on using a large number of medium-thrust engines instead of a small number of high-thrust engines, as NASA would do in the case of the Saturn V. OKB-1's reasoning was justified by four factors:

- The development and manufacture of engines with thrust levels of 150 tons could be carried out with the current existing technical base without extensive remodeling or construction as would be required for larger engines of 600 to 900 tons thrust.
- Engines with thrusts of 150 tons used on the first stage could also be used on the second stage without significant modification, thus saving an entire level of development as would be required for more powerful engines.
- Because the reliability and capacities of the engines would depend on the quantity of ground tests, greater reliability could be achieved with an equal expenditure for engines of smaller thrust over engines of larger thrust.
- With the use of a large number of engines, a failure of one or two engines would not pose a catastrophic risk to a mission, because the remaining engines could compensate for the failures.[87]

To address the last point, the engineers conceptualized a system known as the Engine Operation Control (KORD) system, which would have the capability to quickly switch off malfunctioning engines as well as units diametrically opposite to the suspect engine. In practice, this system turned out to be much more difficult to operate than was anticipated at the time.

Korolev's engineers addressed the propellant issue in the final stages of the preliminary analysis. Perhaps to give this process a note of impartiality, this analysis was carried out not only at OKB-1, but also at other research institutions, such as NII-4. It seems that cost-benefit and technical analyses were conducted of two complete variants of the N1: one with Korolev's favored LOX-kerosene combination and one with Glushko's N_2O_4-UDMH combination. The analyses clearly proved that the latter was far inferior to the former in terms of operational characteristics. The storable propellant variant would decrease the potential payload mass (while keeping the launch mass constant), lower specific impulse, increase propellant mass (because of higher elasticity of the components), and significantly increase the costs associated with the development of a large industrial base for storable components.[88] All the

86. Igor Afanasyev, "N1: Absolutely Secret: Part II" (English title), *Krylya rodiny* no. 10 (October 1993): 1–4.
87. Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p. 249.
88. *Ibid.*, p. 250.

This famous picture is of the so-called "Three K's" of the Soviet military-industrial complex. From far left are Sergey Korolev from the missile program, Igor Kurchatov from the atomic bomb program, and Mstislav Keldysh from the Academy of Sciences. On the extreme right is Korolev's First Deputy Vasiliy Mishin. The photograph dates from July 1959, when Korolev, Keldysh, and Mishin visited Kurchatov's institute. (files of Peter Gorin)

engines on the cryogenic variant were designed to be of the closed cycle type, allowing higher combustion pressure and better performance. Engineers chose such a scheme no doubt because both OKB-1 and Kuznetsov's OKB-276 had experience with closed cycle units. In contrast, all of Glushko's aborted efforts at designing cryogenic engines in the 1950s and early 1960s had been of the open cycle type, better known in the West as "gas generator cycle" engines.

The research and development effort leading to the preparation of the N1 draft plan was not only carried out at OKB-1. At Korolev's insistence, a large number of other design bureaus and scientific-research institutes were involved in the process "for reducing the number of critics we would run up against in subsequent work. That way, the component manufacturers would know that their ideas had been taken into consideration from the very beginning of the design process."[89] At OKB-1 itself, the complete effort was directly overseen by Korolev and his immediate deputy, Vasiliy P. Mishin, both perhaps seeing the future of their design bureau in the project. For someone who was primarily a manager rather than an engineer at this point in his life, Korolev's personal contribution to the design of the N1 was remarkably significant. For example, a set of notes to a deputy chief designer authored by Korolev on February 5, 1962, detailed recommendations and comments on a variety of issues, including launch mass, engines, payloads, manufacturing, assembly, welding of parts, propellants, storage facilities, and ground testing. In addition, he had detailed suggestions for how drawings of various N1 systems should be prepared, as well as standard managerial assignments on the project.[90]

89. R. Dolgopyatov, B. Dorofeyev, and S. Kryukov, "At the Readers' Request: The N1 Project" (English title), *Aviatsiya i kosmonavtika* no. 9 (September 1992): 34–37.

90. A. Yu. Ishlinskiy, ed., *Akademik S. P. Korolev: ucheniy, inzhener, chelovek* (Moscow: Nauka, 1986), pp. 195–97. Note that the N1 is not actually mentioned anywhere in the source, because the existence of the rocket was still classified information at the time. The deputy chief designer in question was S. S. Kryukov, one of the primary designers of the N1 rocket. A declassified version of these same notes has been published as S. P. Korolev, "Notes on the N1" (English title), in B. V. Raushenbakh, ed., *S. P. Korolev i ego delo: svet i teni v istorii kosmonavtiki: izbrannyye trudy i dokumenty* (Moscow: Nauka, 1998), pp. 355–57.

The forty-five-year-old Mishin, officially OKB-1's First Deputy Chief Designer for Planning-Design Work, was one of the most aggressive individuals in the design bureau's "high command." An outspoken and assertive engineer, he had served as Korolev's right-hand man since the establishment of OKB-1 as an entity in 1946. His particular engineering specialties were ballistics, dynamics, aero-gas dynamics, and stress, but he oversaw almost every single program at the design bureau. By his own account, he was "groomed" by Korolev to be his successor. In fact, at every point in the history of the design bureau, Mishin was promoted or given awards together with Korolev. In 1961, after Gagarin's flight, Korolev had nominated Mishin for an unprecedented second Hero of Socialist Labor award, reserved only for chief designers; the proposal was ultimately rejected "at the highest level," and instead Mishin was conferred the less prestigious Order of Lenin.[91]

Mishin's own relationship with Korolev was dictated to a great extent by the idiosyncrasies of both personalities. Mishin later recalled, "It should not be thought that just because I was Korolev's first deputy, this meant that I was both a very close friend and counselor . . . we would not speak for weeks because of some disagreement."[92] Both apparently agreed that they "would only sort out [their] differences in private with no witnesses in attendance."[93] While he was certainly one of the most creative engineers at the design bureau, he was endowed with less than stellar diplomatic talents, putting him into confrontations on many occasions with various people. More passionate about the use of LOX on missiles and rockets than even Korolev, Mishin had continuously and vigorously argued the oxidizer's use on the R-9 and the N1 at every step of the way. Mishin's relationship with Glushko was even worse than Korolev's, perhaps resulting from an incident in 1960 when Glushko had insulted Mishin to his face in front of a group of leading designers amid a discussion on the merits of closed cycle versus open cycle LOX engines.[94] If Korolev had any inclination to compromise with Glushko on the propellant issue, he was most likely swayed by Mishin, who was adamantly against capitulating to the powerful engine designer.

Apart from Korolev and Mishin, the importance of the N1 project in the framework of OKB-1's long-range plans was demonstrated by the inclusion of no less than eight other deputy chief designers at the design bureau. They were to oversee various aspects of the design work: Konstantin D. Bushuyev and Sergey S. Kryukov (planning and computational-theoretical work), Sergey O. Okhapkin (design and strength), Boris Ye. Chertok (guidance systems), Mikhail V. Melnikov (rocket engines), Leonid A. Voskresenskiy and later Yakov I. Tregub (testing systems), Anatoliy P. Abramov (ground complexes), and the famous Mikhail K. Tikhonravov (general thematic research, continuing his pioneering work in the evolution of the Soviet space program).[95]

Korolev signed the initial fifteen-volume draft plan for the N1 on May 16, 1962.[96] The draft plan for the related GR-1 missile had already been completed and signed a month earlier. The N1 draft plan, as prepared at the time, included a detailed step-by-step plan for the program, encompassing different variants of the basic N1 vehicle. In its basic configuration, the vehicle would be a three-stage (each known as Blok A, Blok B, and Blok V) rocket augmented by two upper stages (Blok G and Blok D). Perhaps responding to criticism on moving from the modest Vostok launcher to the giant N1, the May 1962 draft plan included proposals for three progressively powerful launch vehicles—the N1, N11, and N111—all sharing common elements. A fourth rocket, the GR-1, would test the remaining components of the N1.

91. Yu. A. Mozzhorin, *et al.*, eds., *Dorogi v kosmos: I* (Moscow: MAI, 1992), pp. 119–20.
92. Tarasov, "Missions in Dreams and Reality," p. 4.
93. Vasiliy Mishin, "We Would Make You Work to the Best of Your Ability," *Aerospace Journal* no. 1 (January–February 1997): 76–78.
94. Chertok, *Rakety i lyudi: Fili Podlipki Tyuratam*, p. 343.
95. Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p. 250.
96. Golovanov, *Korolev*, p. 711.

The N1 I would use the second, third, and fourth stages of the N1, omitting the giant first stage. The N1 1 1 would use only the third and fourth stages of the base N1 and a third stage transferred from the second stage of the R-9A ICBM. There were two significant advantages to this plan. First, it would make the design and flight testing of the basic N1 booster much more efficient by testing vital stages and instrumentation on smaller sized test articles. Second, it would introduce three new classes of launchers for satisfying very different mission requirements. The GR-1 orbital bombardment system would be almost the same as the proposed N111; the only difference would be the use of the N1's critical fifth stage (Blok D) as the GR-1's third stage. This particular stage, designed for use in vacuum conditions, was required to carry out multiple firings on the same mission; vigorous testing on the GR-1 would qualify the engine for nominal operation on the base N1. In effect, with such a progressive booster program, by the time the N1 flew its first mission, all the stages, save the first stage, would have already been tested and qualified in flight conditions. The payload capabilities and launch masses of the three N series boosters would be:

Booster Variant	Stage Designations	Launch Mass	Payload Capability to Earth Orbit
N1 (or "11A52")	Blok A (Stage 1) Blok B (Stage 2) Blok V (Stage 3) Blok G (Stage 4) Blok D (Stage 5)	2,160 tons	75 tons
N11 ("11A53")	Blok B (Stage 1) Blok V (Stage 2) Blok G (Stage 3)	700 tons	20 tons
N111 ("11A54")	Blok V (Stage 1) Blok G (Stage 2) R-9A Blok B (Stage 3)	200 tons	5 tons[97]

The proposed requested amount for the manufacture of the first ten rockets of the series was 457 million rubles.[98]

A special "expert commission" affiliated to the USSR Academy of Science examined the complete project materials on the N1 project, spanning twenty-nine volumes and eight appendices, during an intensive series of meetings held between July 2 and 16, 1962. Members of the commission included the leading chief designers, industrial representatives, military officers, scientists, and Party apparatchiks involved in the Soviet space program. Academician Mstislav V. Keldysh, the President of the Academy of Sciences, served as chairman. As one would expect, the primary issue of contention was the selection of propellants—a conflict that threatened to bring the project to a complete standstill. Both Glushko and Korolev were allowed to make cases for their respective variants—the former with the N_2O_4-UDMH combination and the latter with the LOX-kerosene combination. Glushko supported his position with several argumentative points. He believed that:

97. Dolgopyatov, Dorofeyev, and Kryukov, "At the Readers' Request: The N1 Project"; Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p. 250.

98. S. Kryukov, "The Brilliance and Eclipse of the Lunar Program" (English title), *Nauka i zhizn* no. 4 (April 1994): 81–85.

- The creation of very powerful LOX-based engines would be the source of paramount problems because of such factors as intermittent combustion and the need to protect the combustion chamber and nozzle walls from overheating. His design bureau had faced these problems in the development of several single-chamber LOX-kerosene engines (in particular the RD-110 and RD-111) during the 1950s and 1960s.
- The creation of very powerful LOX-based engines would be plagued by high-frequency oscillations, which had served as significant obstacles in the development of the RD-110 and RD-111.
- The use of storable propellants, which produce steady combustion in the engine chamber at temperatures 280 to 580 degrees Centigrade lower than those with LOX, would allow for a quicker development phase.
- The use of hypergolic or self-igniting propellants would allow for a simpler engine design.
- The development of storable propellant engines for the N1 would not necessitate significant additional resources on his part—that is, take less time and money—because his design bureau was already developing similar engines for Chelomey's boosters (in particular the RD-253).

Korolev countered each point based on the analysis conducted at his design bureau as well as in other organizations. His belief was that:

- Glushko's concerns about the problems associated with the development of the LOX-kerosene engine were invalidated to a great degree because OKB-1 was advocating the use of a closed cycle scheme for the design of the engines—a design that circumvented most, if not all, of the problems enumerated by Glushko. OKB-1 and OKB-276 already had significant experience in the design of closed cycle rocket engines (with the S1.5400 and NK-9 engines). In his report, Korolev stressed that:

  All arguments about the difficulty of developing oxygen-kerosene engines were based only on the experience of the OKB of Glushko of developing [liquid-propellant rocket engines] with an open scheme, in which the oxidizer (oxygen or nitrogen tetroxide) is delivered to the chamber in a liquid and cold state. It should be emphasized that the difficulties to which the OKB of Glushko refer to have nothing to do with the engines having been adopted for the N1 with a "closed" scheme, in which the oxidizing agent (oxygen) is delivered to the chamber in a hot and gaseous state. . . .[99]

- The use of storable propellants would significantly decrease the specific impulse of the engines, thus lowering payload mass.
- The use of storable propellants would significantly increase the mass of the propellant tanks.
- The use of cryogenic propellants would be significantly less expensive than storable propellants. In the case of the one-time capital expense for the development of the engines, the former would be two times less expensive; in the case of the components themselves, the cost of the former would be seven times less expensive.
- The use of storable propellants would dramatically increase the danger in working with the rocket not only because of the high toxicity of the propellants, but also because of their hypergolic characteristics. On this point, Korolev cautioned:

99. Vetrov, "The Difficult Fate of the N1: Part II," p. 20.

These components are self-igniting and toxic, which increases the potential of pressurizing the components. Especially great is the danger to the service personnel at times of abnormal functioning of the aggregates and the systems.[100]

The arguments went back and forth for days without much compromise, sometimes fracturing the modicum of unity among the other chief designers. Eventually, the commission arrived at a consensus: it voted to recommend Korolev's LOX-kerosene variant, adding in its official report that the N1 draft plan fulfilled "high scientific-technical standards" that had been originally demanded in the initial proposals.[101] Glushko was aghast. Despite the decision, he insisted on a total revision of the N1 plan, allowing for the use of N_2O_4-UDMH; he simply refused to make the LOX engines necessary for the project. Several other prominent chief designers, including Barmin and Ryazanskiy as well as Strategic Missile Forces Lt. General Mrykin, apparently made great efforts to mediate the issue by having Glushko participate in the project, but the two designers refused to work together. By default, the job to develop the N1 engines ended up in the lap of Nikolay D. Kuznetsov of Kuybyshev.

The July 1962 decision by the Keldysh Commission effectively fractured the space program into the Korolev and Glushko camps, destroying any semblance of unity that may have existed during the Sputnik days. Although the break between the two was over purely technical issues, the repercussions were far-reaching: the two giants of the Soviet space program would not live to cooperate on another project. Korolev had turned his back on the most powerful and successful rocket engine designer in the country, resorting to someone who had almost no experience in the field, while Glushko lost his role in what was to be the most expansive and greatest project in the history of the Soviet space program. In a sense, it was the end of the beginning of the dramatic road from Sputnik. Western observers did not even suspect the break between the two until more than a quarter of a century later during the *glasnost* era. Over that twenty-five-year period, there was only one single hint of the discord, and it came from the pen of Nikita Khrushchev himself. In his smuggled-out memoirs, published in 1974, he had written:

The principal designer of the [R-7] booster was Korolev's friend and collaborator, whose name I forget. The best booster rocket in the world won't make a broomstick fly. So while Korolev designed the rocket, his colleague designed the engine. They made an excellent team. Unfortunately, they split up later. I was very upset and did everything to patch up their friendship, but all my efforts were in vain.[102]

The troubled N1 was conceived during an unexpected window of opportunity in 1960. Its path to birth was marred not only by the Korolev-Glushko battle, but also marked indifference from the Soviet leadership. At the Pitsunda meeting in February 1962, Khrushchev had been remarkably ambivalent about the N1, instead forcing through a number of alternative proposals from Yangel and Chelomey. There had been some cursory orders to continue "paper studies," which eventually resulted in the Keldysh Commission's positive appraisal of the effort in July. Despite the acrimony over the propellant issue, the commission's recommendations

100. The summary of the arguments are taken from *ibid.*; Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, pp. 249–51; Afanasyev, "N1: Absolutely Secret: Part II"; Kryukov, "The Brilliance and Eclipse of the Lunar Program." OKB-1's complete defense of the N1 draft plan has been published as S. P. Korolev, "Report on the Powerful N-1 Carrier-Rocket at the Meeting of the Expert Commission" (English title), in Raushenbakh, ed., *S. P. Korolev i ego delo*, pp. 363–82.

101. Kryukov, "The Brilliance and Eclipse of the Lunar Program."

102. Nikita Khrushchev, *Khrushchev Remembers: The Last Testament* (Boston: Little, Brown & Co., 1974), pp. 46–47.

clearly pushed the project into overdrive; within two months, the Soviet leadership was finally ready to give the go-ahead. On September 24, 1962, the USSR Council of Ministers and the Central Committee of the Communist Party issued a joint decree (no. 1021-436), which approved full-scale work on the development of the N1 booster, its component N11 and N111 launch vehicles, and the GR-1 orbital bombardment system. Beginning with the bold challenge to achieve "the goal of ensuring the leading position of the Soviet Union in the exploration of space," the decree called for work on the creation of the 2,200-ton booster with a lifting capability of seventy-five tons to low-Earth orbit.[103] In versions with upper stages using LH_2, the booster would have lifting capacity of about ninety to 100 tons. The September 1962 decree enumerated a fairly ambitious program leading to the first launch of the N1 in 1965.[104] Although it would be the most powerful space launch vehicle ever built in the Soviet Union, it would still fall short of the baseline capability of the early version of the equally giant Saturn C-5, which was formally approved by NASA Headquarters on January 25, 1962.[105]

Literally hundreds of organizations were invited to participate in the N1 program, notable only by the absence of Glushko's OKB-456. Korolev's OKB-1 would serve as the primary contractor responsible for overall design. Its affiliate Branch No. 3, located at Kuybyshev and headed by Deputy Chief Designer Dmitriy I. Kozlov, was assigned to oversee manufacture and production at its adjacent Progress Plant. As in the postwar days of building modified A-4 missiles, the inertial guidance and radio control systems would be developed by NII-885 under Chief Designers Pilyugin and Ryazanskiy, respectively. GSKB SpetsMash under Chief Designer Barmin would design and build a new large launch complex at Tyura-Tam specifically for N1 operations. The development of the main rocket engines of the base N1 variant were, of course, tasked to OKB-276 at Kuybyshev. Other major subcontractors included NII-4 (for ground telemetry complexes); OKB-12 (for propellant loading systems); NII-88, the Central Aerohydrodynamics Institute, and NII-1 (for aerodynamics research); the B. Ye. Paton Institute of Welding and NITI-40 (for manufacturing processes); and NII-229 at Zagorsk (for ground testing of all components).[106]

The Keldysh Commission and the subsequent governmental decree also addressed the problematic issue of transportation and assembly of the N1. Because the entire rocket would not be transportable in one piece, the commission recommended further research on means to transport the rocket via air, sea, or land. OKB-1's initial proposal was to manufacture the components of the rocket at the Progress Plant at Kuybyshev, assemble and test the entire rocket at the same location, disassemble the vehicle, and then transport the parts to Tyura-Tam. At the launch site, the parts would then be assembled and tested once again, which would be carried out horizontally in a massive assembly building near the pad area. There was apparently much

103. Vetrov, "The Difficult Fate of the N1: Part II."

104. The decree stated that (1) autonomous firing work on the engines of the third, second, and first stages would be finished in 1964, 1965, and 1965, respectively; (2) cluster firing work on engines on the stages and units would be carried out from 1964 to the first quarter of 1965; (3) the manufacture of two complexes of ground equipment at Tyura-Tam would be in 1964; (4) preparation in 1964 of launch and technical sites would ensure the first launch of the rocket; (5) work on ground complexes together with the rocket would be in 1965; and (6) completion of construction of the launch position and converting to operational activities would be in 1965. See Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p. 251.

105. Roger E. Bilstein, *Stages to Saturn: A Technological History of the Apollo/Saturn Launch Vehicles* (Washington, DC: NASA SP-4206, 1996), pp. 58–59. The low-Earth orbit capability of the Saturn C-5 was projected as 113 tons at the time.

106. Dolgopyatov, Dorofeyev, and Kryukov, "At the Readers' Request: The N1 Project"; Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, pp. 248–49; Dorofeyev, "History of the Development of the N1-L3 Moon Program."

resistance to this idea because it involved the design and construction of a massive new building at Tyura-Tam dedicated exclusively for the N1. Studies in 1962–63 explored several alternatives, which included using a single dirigible with a lifting capacity of 250 tons or using two *Katamaran*-type connected dirigibles. Land transportation in the form of a major highway was also considered but dismissed by the Ministry of Defense because of the costs involved in building a 1,300-kilometer road from Kuybyshev and Tyura-Tam. Eventually, by mid-1963, the military conceded their position and agreed on the original OKB-1 proposal to transport the rocket part by part to the launch site and assemble it in a giant building. The giant spherical propellant tanks themselves would be manufactured in the form of flower petals, which could be assembled and disassembled as needed.[107]

When the N1 rocket was originally conceived in 1960, the issue of suitable payloads for the booster was left sufficiently vague so as to include a variety of missions. In fact, unlike NASA's Saturn C-5 launch vehicle, the N1 was never proposed as a rocket for a dedicated single mission such as a lunar landing project. Conceptualized as "a universal launch vehicle," the series of decrees in 1960–62 was remarkably ambiguous as to its ultimate use, merely alluding to unspecified military, scientific, and interplanetary missions of the future Soviet space program. Korolev, clearly cognizant that the Ministry of Defense would be the primary funding conduit for the project, continually targeted the rocket for use on vague military projects. It was a "Trojan horse" strategy that had worked well for the R-7 ICBM, and like the R-7 effort, he delicately phrased his requests so as not to alarm military officials into believing that funding the N1 would siphon off resources from the huge strategic arms buildup in the 1960s. This tradeoff between the scientific and military needs of the country, while symptomatic of the nuances of civilian-military relations in many other countries, was accentuated in the Soviet Union to a great extent by the inherent outgrowth of the space program from the ballistic missile effort.

The original June 1960 decree had tasked the Ministry of Defense, in cooperation with the defense industry, to formulate a set of missions for the use of new spacecraft for exclusively military purposes. But space as a component of strategic military policy had clearly not emerged at such an early period; space simply did not "fit into then-existing notions of defense" in the Soviet Union. The Ministry of Defense tactical-technical requirement document for the N1 had not been issued by 1961, prompting Korolev to action. In a letter dated January 15, 1961, to Commander-in-Chief of the Strategic Missile Forces Marshal Moskalenko, Korolev reminded Moskalenko that no such document had been received by OKB-1. In a second letter signed the same day, he addressed then-Chairman of the State Committee of Defense Technology Konstantin N. Rudnev:

> *The in-depth study of the project plan and the discussions that were carried out with the leading chief designer-workers and a number of specialists and scholars leads to the conclusion that all the enumerated space objects have military importance. [There are a number of ways] to reach new standards in the sphere of rocket technology . . . necessary for the successful solution of the problems the defense industry faces nowadays. . . . The creation of the heavy carrier N1 occupies a special place among these.*[108]

Korolev added that the heavy booster could play important roles in the orbiting of heavy space stations, which could provide ideal conditions for conducting space-based

107. Vetrov, "The Difficult Fate of the N1: Part II"; Dorofeyev, "History of the Development of the N1-L3 Moon Program"; Kryukov, "The Brilliance and Eclipse of the Lunar Program"; Afanasyev, "N1: Absolutely Secret: Part II."

108. *Ibid.*

reconnaissance, carrying out early warning missions for detecting launches of foreign strategic missiles and nuclear explosions, and determining levels of solar radiation. The military remained unusually uninterested in the N1 through 1962, perhaps dazzled by concurrent proposals of Chelomey and Yangel, such as the UR-500 and the R-56. Perhaps the military simply believed that the more modest payload capabilities of these latter two boosters would be sufficient to meet any possible demands of the Ministry of Defense.

The July 1962 decision in favor of the N1 by the Academy of Sciences did not help either. According to Korolev's First Deputy Mishin, the "decision of the Academy of Sciences was supposed to define the objectives and produce a proposal for the development of space vehicles to be inserted into space by [the N1]."[109] The academy refrained from doing so, leaving the project in somewhat of a lurch. The final governmental decree in September of the same year also did not address the question of specific payloads for the booster, merely referring to the catch-all "universal launcher" terminology. The dearth of suggestions from either the Ministry of Defense or the academy did not prevent a plethora of internal OKB-1 studies on possible N1 payloads. Much of these in the early 1960s were clearly focused on military applications and remain classified amid the still-secret archives of the design bureau. It is known, however, that thematically speaking, these military spacecraft were geared toward exotic goals, such as anti-satellite and anti-ballistic missile defense, something of a precursor to the U.S. "Star Wars" program of twenty years later. According to one of the "fathers" of the N1, OKB-1 Deputy Chief Designer Kryukov, the N1 was to launch into orbit multiple spacecraft as well as giant spacecraft "for accomplishing inspection, control and . . . means of destruction."[110] While the details still remain obscure, it is clear that none of these studies of a military "Orbital Belt" were considered anything more than proposals; they remained consigned to paper, proposed only to ensure the survival of the N1 project as an insurance policy to the primary financiers of the program.

To Mars

Beginning with Tsiolkovskiy in the early part of the century, Soviet space scientists had consistently targeted the planet Mars as the singular most important objective in plans to explore space. Piloted flight to Mars had figured prominently in the famous June 1960 decree on the Soviet space program; Korolev's draft of the decree includes mention of an Object KMV for sending cosmonauts around Mars and back to Earth again. Proposals for such missions remained on the forefront of the Soviet space program's agenda after Sputnik and Vostok, seemingly unaffected by President Kennedy's 1961 pronouncement on the challenge to reach the Moon prior to the end of the decade. To a great extent, it was Korolev's personal interest in Mars, perhaps motivated by the dreams of his idealistic youth spent poring over the works of Tsiolkovskiy. It had been a long thirty years since the late Fridrikh A. Tsander's "Onward to Mars!" exclamation, and now Korolev was in a position to make that call for arms a reality. Initial exploratory work on this issue began as early as 1959, when a group under Gleb Yu. Maksimov at OKB-1 began toying with designs for a large interplanetary spaceship capable of flight to the other planets. Maksimov, a veteran of Tikhonravov's studies on artificial satellites in the early 1950s, was at the same time heading OKB-1's work on automated lunar and interplanetary stations. It was the research under Maksimov from 1959 to 1960 that may have been the primary reason for freezing the N1 payload mass at seventy-five tons, which was sufficient for a piloted interplanetary spacecraft.

109. Mishin, "Why Didn't We Fly to the Moon?"
110. Kryukov, "The Brilliance and Eclipse of the Lunar Program," p. 84.

The research on an interplanetary spacecraft culminated in a proposal for a Heavy Interplanetary Ship (TMK), which was aimed at "rapid realization of the program with the resources at hand."[111] Maksimov's plan called for the N1 to launch a seventy-five-ton payload into Earth orbit, composed of a transplanetary boost stage and a fifteen-ton spacecraft with a three-person crew. Because there was still much uncertainty concerning the reliability of the N1 at the time, a second backup option involved the launch of an uncrewed TMK and its booster stage into Earth orbit by the N1, followed by delivery of the crew in a Vostok-type spaceship to the TMK. Following systems checkout in Earth orbit, the TMK would be sent on a trajectory toward Mars using a conventional LOX-kerosene acceleration stage, conduct a flyby of the planet, and then, using Martian gravitational pull, fly back to near-Earth space. At that point, a detachable return apparatus with the crew would separate and land on Soviet territory by means of parachute.

This is a model of the Heavy Interplanetary Ship (TMK) proposed in the early 1960s to carry humans around Mars on a multiyear-long trip. A proposed Earth-orbital station dating from the same period also used the same design as this interplanetary spacecraft. Note the docking nodes in the middle of the cylinder for visiting spacecraft. Several "floors" are visible on the lower half of the model. (copyright Mark Wade)

On paper, the cylindrical TMK had a length of about twenty meters and a maximum diameter of four meters. The spacecraft had three main compartments: one for biological research, one for instrumentation, and a pressurized section for the crew. Their volumes were seventy, twenty-five, and twenty-five cubic meters, respectively. The instrumentation compartment would contain a specially shielded radiation shelter for the crew during peak periods of solar activity as well as a "chlorella reactor" for generating the crew's food needs. The spacecraft would be rotated around its axis through most of the two- to three-year-long mission to generate artificial gravity. Large solar panels would ensure a constant power supply during the mission. The initial technical design for this conception of the TMK, known as the TMK-1, was completed on October 12, 1961.[112]

Maksimov's group, up to then involved only in the design of automated spacecraft, was an unusual choice to design such a complex spacecraft, and this seems to have raised the specter of competition *within* OKB-1. The group of designers led by Feoktistov, who had served as the chief architects of the Vostok spacecraft and were afraid of being left behind by the Maksimov group, took it upon themselves to join the fray and began work "in an underground manner" with a plan to surprise Korolev with their diligence. Curiously, both men reported to

111. I. B. Afanasyev, "Unknown Spacecraft (From the History of the Soviet Space Program)" (English title), *Znaniye: novoye v zhizni, nauke, tekhnike: seriya kosmonavtika*, astronomiya (December 1991): 1–64.

112. Raushenbakh, ed., *S. P. Korolev i ego delo*, p. 623; Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p. 279; Afanasyev, "Unknown Spacecraft"; Mikhail Rebrov, "Saga from the Archives of Document No. 23891 and an Unknown Space Project" (English title), *Krasnaya zvezda*, May 13, 1995, p. 6; Ishlinskiy, ed., *Akademik S. P. Korolev*, pp. 99–100.

Tikhonravov, who as Department No. 9 chief oversaw both the Maksimov and Feoktistov groups. On the evening of April 30, 1960, after a presentation by Maksimov on his TMK plans, Feoktistov unfurled the results of his own preliminary research. Korolev was apparently ecstatic that there was such interest in Mars.[113] Feoktistov got the green light to move ahead on his proposal, which in all ways was far more ambitious than Maksimov's plan because it involved the landing of humans on the surface of Mars.

The Feoktistov variant, also called the TMK, would be assembled in orbit via two N1 launches with seventy-five-ton payloads, making a grand total of 150 tons in Earth orbit. The linked-up spacecraft resembled a daisy flower with a compact seven-kilowatt nuclear reactor in the center and radiator-emitters serving as petals. The crew cabin was located at one end of the cylindrical stem. Primary propulsion would be performed by a set of low-thrust (seven and a half kilograms) electrical rocket engines working off a nuclear energy source. These engines were to fire slowly over a period of months as the TMK gathered enough speed to boost itself out of Earth orbit toward Mars. At the Red Planet, the entire spacecraft would enter orbit, followed by separation of the landing vehicle, which would alight on the surface. The landing vehicle itself was composed of five "platforms": one for the crew cabin and drilling equipment, one for a glider for conducting reconnaissance over the Martian surface, two rockets for returning the crew back into Martian orbit, and one for nuclear power sources. Over the course of one year, the mobile vehicle would move across the Martian surface carrying out scientific research while transmitting information back to the orbiting vehicle. A portion of the lander would then take off, dock with the orbiter, and then head back to circumterrestrial space with the aid of the same electrical rocket engines. The total mission for a ten-person crew would last three years.[114]

OKB-1 expended a significant amount of effort on both these projects in the early 1960s, diverting resources especially to the development of electrical rocket engines working on nuclear energy, as well as the development of closed-loop life support systems. Electric rocket engines, which unlike regular liquid-propellant engines allow the working fluid to be accelerated to discharge velocities, had been a focus of intensive research since Glushko's pioneering work in the early 1930s. Post-Sputnik research work on such propulsion systems began anew at OKB-1 in 1958 and were coordinated to a great extent on the plans for the TMK project. The design bureau, working hand-in-hand with the Physical-Power Institute at Obninsk, preferred using a nuclear power source for the engines; the research was thus carried out in parallel with research on nuclear rocket engines. The preliminary studies conclusively proved that electrical rocket engines would significantly increase the performance characteristics of the TMK with regard to multiyear-long missions. The June 1960 decree on the Soviet space program approved a proposal by OKB-1 to commence full-scale work on the electric engines, and by 1962–63, many institutes and design bureaus were involved in the project.[115]

113. Ishlinskiy, ed., *Akademik S. P. Korolev*, pp. 99–100.

114. *Ibid.*; Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p. 280; Afanasyev, "Unknown Spacecraft"; Igor Afanasyev, "Piloted Flight to Mars . . . A Quarter Century Ago" (English title), *Vestnik vozdushniy flota* no. 7–8 (1996): 103–05. There were different conceptions of the TMK lander proposal. For example, one predraft plan finished in May 1966 consisted of a six-section TMK spacecraft. These included (1) an expedition ship to carry the crew during the mission, (2) an orbital complex with living and working compartments, (3) a descent apparatus for descending to the Martian surface, (4) a return apparatus for carrying the crew from the surface back to the expedition ship, (5) a return rocket for sending the return apparatus from the surface of Mars either into Martian orbit or on a trajectory back to Earth, and (6) a planetary station for piloted research on the Martian surface. At least four different mission profiles were considered for this ambitious proposal, all using the N1. Raushenbakh, ed., *S. P. Korolev i ego delo*, pp. 633–34.

115. Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p. 409; G. V. Petrovich, ed., *The Soviet Encyclopedia of Space Flight* (Moscow: Mir Publishers, 1969), 120. Among the other institutions involved in the research on electric rocket engines were NII-1, NII-88, OKB-670, TsAGI, TsIAM, IAE, VNIIEM, MAI, OKB-456, OKB-586, and OKB Zarya.

The research on electrical engines was a serious component of the TMK studies and, as one of Korolev's leading ballistics experts, Mikhail S. Florianskiy, recalled, critical in affecting the design of the spaceship itself:

> *The interplanetary ship was of the form resembling a rifle bullet with a hatch "at the head." I took part in the computations and showed Sergey Pavlovich [Korolev] that by using electric rocket engines of low thrust for movement to Mars, the launch mass to orbit could be possibly reduced to 125 tons. Then for approximately two years, the interplanetary ship would fly around Mars with its crew of three people. . . .*[116]

By April 1963, OKB-1 Deputy Chief Designer Bushuyev was ready to present a report to the Council of Chief Designers titled "On the TMK for the N1," which summarized all the possible options for the interplanetary spaceship. The two most serious options considered at that point involved a massive 680-ton spaceship using chemical propellant engines assembled in Earth orbit from ten N1 launches and a seventy-five-ton spaceship launched on a single N1 launch equipped with electric rocket engines.[117]

The question of developing life support systems that could function autonomously for two to three years was the subject of serious attention. In 1962, Korolev created a special department at OKB-1 under Ilya V. Lavrov to specifically design and develop a closed-cycle life support system designated the Scientific-Experimental Complex (NEK). For obvious reasons, existing life support systems based on nonrenewable resources of water, food, and air were not considered for the project. Lavrov opted not to use chemical sources for regenerating resources, turning instead to biological systems, which could replicate the closed ecological system of Earth on a micro level. To simplify the process of early research, only water and oxygen were considered essential for recycling. Some of the required water would be produced from moisture breathed into the internal atmosphere of the ship and purified by ion-exchange resins. Bodily wastes would provide the remaining portion using physio-chemical and biological processes. Oxygen would be regenerated from carbon dioxide exhaled by the cosmonauts by using chlorella-type algae, the latter also being used to treat human waste. Food for the multiyear-long trip would be stored in freeze-dried form selected on the basis of calorific value and specific mass. Vegetables grown in special hydroponic greenhouses would augment the primary food rations, allowing the crew to economize in terms of food mass by 20 to 50 percent. Large external solar reflectors, instead of internally generated light, would deliver sunlight to the greenhouses.[118]

Given the limited resources and funding available, Maksimov's Mars flyby design was considered a more realistic proposition than Feoktistov's landing expedition. Initial plans in the early 1960s forecast a circum-Martian flight as early as 1968–70. The landing project, on the other hand, was considered a distant prospect, ready for realization perhaps in the early 1970s. Feoktistov himself recalled that although Korolev was well aware that the landing was not a realistic prospect of the near future, the thought of developing such a spacecraft "excited him terribly."[119] By all accounts, he considered these seemingly fantastic proposals more engineering problems than unrealistic dreams, continually keeping close watch on the work of

116. Golovanov, *Korolev*, p. 768.

117. This was evidently part of a larger report presented by Bushuyev on April 22, 1963, to the Scientific-Technical Council of OKB-1, which was titled "Proposals on the Development of Space Objects on the Basis of the N1 Carrier." One early conception of a Mars landing mission envisioned the use of twenty to twenty-five launches, allowing for the assembly of a huge 1,630-ton spaceship in Earth orbit. A nominal Mars landing mission of this Martian Piloted Complex (MPK) would take two and a half years. After a landing mission, the crew would return to Earth in fifteen-ton reentry module. See Afanasyev, "Piloted Flight to Mars."

118. Afanasyev, "Unknown Spacecraft"; Golovanov, *Korolev*, p. 768.

119. Golovanov, *Korolev*, p. 768.

both Maksimov and Feoktistov. This is underlined to a great extent by a set of priceless notes in Korolev's own handwriting, which were declassified nearly twenty years after he had jotted them down in September 1962. He goes into detail on a variety of factors in the development of the TMK, including artificial gravity, life support systems, biological investigations, and so on. He also mentions a Heavy Orbital Station (TOS), which would have many design commonalties with the TMK. As Korolev wrote, "maybe the Heavy Interplanetary Station will be the Heavy Orbital Station during the first phase, thus contributing to the reliable debugging of all systems in the vicinity of the Earth, e.g. during one year."[120] Very preliminary work on a unique variant of the TOS, specifically for military goals, had also begun at OKB-1 by 1960. These objectives included reconnaissance, anti-satellite missions, the targeting of ground assets, and communications. An initial predraft plan for this station was completed as early as May 3, 1961. This concept may have eventually evolved into a huge four-story space station named *Zvezda* ("Star"), which was reportedly the focus of some research in the mid-1960s.[121]

Until much of the work at OKB-1 was declassified in the late 1980s and early 1990s, the work on the TMK and the TOS, like many other projects, was consigned to the black hole of Soviet space history. But the program was very real, and it tied up a modicum of resources within OKB-1. Although the N1 was developed as "a universal launcher" in the early 1960s, barring unspecific military satellites, the primary payload of the giant booster was a piloted Martian spaceship. In many ways, in that time period, the ambitions of the Soviet space program were much more far-reaching than NASA's seemingly dramatic road to the Moon. For the Soviets, and in particular Korolev, the Moon was certainly a worthy goal, but it was not the end-all of everything; it was merely an important step in the ultimate goal of sending cosmonauts to the surface of Mars. Thus, while President Kennedy's speech awoke a sleeping giant into action in the United States, the Soviets continued to persevere slowly but deliberately on their own road to Mars, first with Earth-orbital stations serving as bases and finally with interplanetary ships. It was a step-by-step plan that was remarkably faithful to half-century-old ideas of Tsiolkovskiy. If Korolev had his way, by the end of the 1960s, there would be a proliferating Soviet space program spreading through the solar system from giant stations in Earth orbit. These plans, of course, never came to fruition. The architects of the Soviet space program finally began to take notice of an awakened giant, and its gaze was not at Mars, but directed toward the Moon.

Designing for a New Generation

Plans for a new spacecraft to succeed the Vostok ship existed well before Gagarin's historic launch. In 1958 and 1959, engineers at OKB-1 considered various mission objectives of such a vehicle before settling on two primary goals that dominated the thinking on piloted spacecraft for the ensuing half decade: circumlunar flight to the Moon and the mastering of rendezvous and docking that would eventually lead to the establishment of space stations in Earth orbit. The Moon itself figured prominently in OKB-1's plans for automatic research, but in the context of piloted exploration, it remained essentially a component of the design bureau's ultimate plans to reach Mars. While the salient details on exactly why a circumlunar project was targeted remain

120. S. P. Korolev, "Notes on Heavy Interplanetary Ships and Heavy Orbital Stations (1962)" (English title), in M. V. Keldysh, ed., *Tvorcheskoye naslediye Akademika Sergeya Pavlovicha Koroleva: izbrannyye trudy i dokumenty* (Moscow: Nauka, 1980), pp. 450–56.

121. Golovanov, *Korolev*, p. 768. On several occasions, Korolev proposed the use of the TOS for military applications. In a letter to the then-Chairman of the State Committee for Defense Technology K. N. Rudnev dated January 15, 1961, Korolev proposed launching the TOS into orbit to carry out military missions. A fifteen-part treatise on the TOS was prepared by OKB-1 at the time. See S. P. Korolev, "Letter to K. N. Rudnev on Planning Work at OKB-1 in 1961–62" (English title), in Raushenbakh, ed., *S. P. Korolev i ego delo*, pp. 316–19, 621–23.

undisclosed, it is highly likely that the relative simplicity of such an effort was what attracted Korolev to begin work on this issue. In addition, cosmonauts successfully flying around the Moon would not only provide the space designers with valuable experience in a variety of technical areas, but would also be a tremendously exciting public relations extravaganza prior to more substantial missions to Mars. Rendezvous and docking on the other hand were considered logical extensions of Soviet plans to gain a permanent foothold in space. All of Tsiolkovskiy's early plans clearly hint at orbital assembly in Earth orbit as a starting point to move further into the cosmos. There was another more earthly reason for mastering rendezvous and docking: the lack of powerful enough launch vehicles to accomplish the ambitious goals of OKB-1. By 1961, the most powerful booster in the Soviet canon, the 8K78, could manage to send only a modest one and a half tons toward the Moon, while the 8K72K, which had launched Gagarin, could launch about just over four and a half tons into Earth orbit. With the larger N1 still years away from flight, orbital assembly was the only avenue for piloted lunar exploration.

These two considerations—circumlunar missions and orbital assembly—dominated the design of the first post-Vostok spacecraft. The choices and decisions engineers made from 1959 to 1963 based on these requirements had a profound impact on the shape and look of the Soyuz spacecraft as it eventually emerged in the late 1960s. Initially, the engineers studied at least two different spacecraft, both of which were geared to Earth orbit. Work on the first, the *Sever* ("North"), began in April 1959. Initial plans envisioned a large spacious vehicle with room for three cosmonauts dressed in spacesuits. A second proposal emerged from Pavel V. Tsybin, the man who had worked on the unfulfilled PKA spaceplane project. Tsybin's new idea encompassed a spacecraft capable of carrying seven cosmonauts, certainly a large leap from the modest Vostok.[122] His proposal was apparently rejected very early in the design process, and by 1959 and 1960, engineers were harnessing their energies in the development of the Sever spacecraft, which became the focus of the second-generation Earth-orbital spacecraft. It was slated to fly its first mission by the second half of 1962.[123] A piloted spacecraft capable of lunar flight designated the "1L" was also studied concurrently, sharing numerous design characteristics with the Sever.

It was originally the famous Department No. 9 at OKB-1, with such luminaries as Tikhonravov and Feoktistov, that began studying the next generation of Soviet spacecraft. By 1960, it had issued a "scientific-technical prospectus," proving that rendezvous and docking in orbit were realistic goals achievable in the near future. Based on this premise, in 1960 and 1961, the department studied a number different variants of the Sever and 1L ships, proposing that a circumlunar flight could be achieved by linking up several booster stages in Earth orbit to reach escape velocity in the direction of the Moon. By this time, the effort to a design new spaceship essentially took on a competitive character within OKB-1 itself. Departments No. 9 and 11, headed by Tikhonravov and Vladimir F. Roshchin, respectively, proposed parallel design concepts of the new vehicle, while the development of lunar spacecraft as a whole was subordinated to Department No. 3 under Yakov P. Kolyako. This peculiar sort of competition in such a centralized command system was clearly contrary to all Western conceptions of the Soviet defense industry at the time. Most outside analysis attributed a simpler monolithic scientific infrastructure, which had no allowance for this almost Western notion of competitive ideas. The overall research was overseen by Deputy Chief Designers Bushuyev and Kryukov.

The two most important areas of research during the design of the Sever and 1L spacecraft were the identification of an optimal reentry profile and the selection of the shape of the

122. Golovanov, *Korolev*, p. 720; S. S. Kostin, "Some Aspects of Planning the 'Vostok' Space Ship" (English title), *Iz istorii aviatsii i kosmonavtiki* 42 (1980): 62–66.

123. Kamanin, *Skrytiy kosmos*, p. 56. By May 1961, Korolev was planning the first Sever launch in the third quarter of 1962.

spacecraft—factors that were clearly interdependent. In terms of the reentry and landing on Earth's surface, engineers considered two broad approaches: an aviation perspective using aerodynamic surfaces and a missile perspective using a ballistic reentry with landing by parachutes. Beginning in 1960, the engineers under Bushuyev's supervision at the various departments studied three specific variants of the reentry capsule of the new spacecraft:

- One with large wings such as an aircraft from Department No. 9 (called the "canard" scheme)
- One for a simple ballistic reentry such as the Vostok spacecraft
- A hybrid version with a blunt nosecone, such as NASA's Mercury capsule, but with wings (called the "tail-less" configuration)

Comparative analysis on the three different variants included studying their aerodynamic characteristics, types of trajectories, thermal protection, mass characteristics in relation to their chosen methods of landing, and the layout of instrumentation. By 1961, winged designs were abandoned, because of the attendant problems with mass and heat protection, in favor of guided or what the Soviets termed "glancing" reentries, which would allow significant reductions in stress as compared to direct ballistic profiles.

Having narrowed the possibilities down, Roshchin's department carried out more detailed analysis on reentry profiles with special regard to reentry at high speeds following a flight around the Moon. Because the spacecraft would return from the Moon, the engineers dispensed with a special orbital braking rocket such as the one used on Vostok, saving valuable mass on the ship. Instead, they settled on a profile that called for a "double-dip" into the atmosphere to reduce both velocity and gravitational loads on the crew. In the first stage, the return capsule would graze off the upper atmosphere before entering again, by which time, the g-loads would have decreased significantly. The requirements showed that the spacecraft would have to have sufficient lift characteristics to allow the "double-dip" profile as well as permit a landing on Soviet soil following a travel down a 3,000- to 7,000-kilometer-long corridor from the south to the north of the planet. Gravitational loads would be limited to three to four g's, while landing could be achieved with a plus/minus fifty-kilometer error.

For obvious reasons, the concerns over reentry profiles significantly affected the decisions over the shape of the reentry capsule. Apart from engineers within OKB-1, scientists at other institutions, including NII-1, the Central Aerohydrodynamics Institute, and NII-88, were involved in this stage of research. They examined three different configurations:

- A so-called "segmented sphere"
- A "sphere with a needle"
- A "sliced sphere"

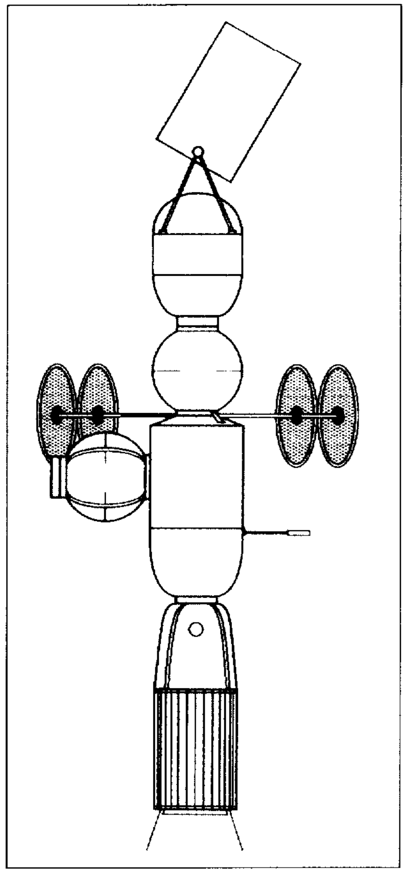
Once again, the investigations focused on a comparative analysis of aerodynamic characteristics, determinations of optimal return trajectories, the selection of the structure itself, and requirements for thermal protection. The results of the research proved that from a technical perspective, the most rational choice from the criteria of mass and volume was Department No. 11's segmented sphere with a displaced center of gravity in the transverse direction. By 1962, Roshchin's group had modified this idea into an asymmetrical segmented sphere, similar in shape to an automobile headlight, in which the length of the capsule was equal to the base diameter. Computations showed that such a design would increase lift during reentry, thus avoiding the pitfalls of direct ballistic return into the atmosphere. The Scientific-Technical Council of the OKB-1 rejected a competitive variant from Department No. 9 of a semi-spherical capsule, and after approval by Korolev and Bushuyev, the "headlight" idea was adopted formally for the Sever spacecraft by 1962.

Yet another important issue was the means of landing on Soviet soil. Water landings were apparently not considered at all, and all research focused on hard landings on Soviet soil. A plethora of proposals crowded the research on this issue, so much so that even after a final decision on the landing was made in 1963, research on alternative versions continued up until 1966, a full five years after this work had begun. Korolev himself was apparently reluctant to continue using parachutes and instead tried to explore much more unusual approaches, as evidenced by his interest in helicopter-type landings for the Vostok spacecraft. Numerous organizations were involved in this stage of the research, including OKB-329 (on a subsonic rotor system), the Mozhayskiy Academy (hypersonic rotors), OKB-300 (fanjet engines), OKB-2 (liquid-propellant rocket engines), Plant No. 81 (solid-propellant rocket engines), NIEI PDS (controlled parachutes), Plant No. 918 (an ejection system as a reserve method), and NII RP (external inflatable shock-absorbing balloons). OKB-1 itself studied the use of turbojet engines. The proposals from all these organizations, to a great degree, affected the design of the spacecraft itself, and it was not until 1963 that Korolev approved the recommendation of Department No. 11 to use a combination parachute-reactive system with solid-propellant engines. The return capsule would deploy a series of parachutes during descent, followed by the firing of powerful solid-propellant rocket engines a few seconds prior to contact with the ground to lessen the shock of impact.

The issue of rendezvous and docking in space, critical to any mission goals foreseen for the near future, was the subject of intensive research at Department No. 27 headed by Boris V. Raushenbakh, designer of the first Soviet space orientation systems. The overall work was supervised by Deputy Chief Designer Boris Ye. Chertok, one of the most senior veterans at OKB-1. The research, conducted between 1960 and 1963, divided the rendezvous phase of two Earth-orbiting spacecraft into two components: the long-range and the close-range portions. The former would depend to a great extent on putting the spacecraft into an optimal trajectory at orbit insertion, based on composite ground measurements and computational models. Ground stations would compensate for errors by sending appropriate commands to the orbiting ship to perform the required orbital changes to bring the active spacecraft to its target. Theoretical calculations by engineers showed that with the existing systems, the two spacecraft could be brought within a twenty five- by fifteen- by fifteen-kilometer volume in space with a relative velocity of plus or minus forty meters per second.

For Raushenbakh's group, the more problematic portion of the rendezvous maneuver was the close-range approach. The "free trajectory" from launch was clearly not sufficient to allow two spacecraft to dock. In addition, ground measurements would not distinguish two vehicles at such high altitudes to ensure the required precision. Shipboard measurements were also ruled out because of the need for the presence of powerful and compact computing machines aboard the spacecraft, which were simply beyond the limits of Soviet miniaturization technology for the time. Raushenbakh's team developed a combination system using the so-called "parallel approach," in which a line of sight extending from the active to the passive spacecraft would be established for movement. A special on-board radar would then take over control of the spacecraft to bring the two spacecraft to docking. Four different institutions offered competitive proposals to design and build the radars. The two finalists were the Experimental Design Bureau of the Moscow Power Institute and NII-648. After detailed analysis, the former's *Kontakt* ("Contact") was rejected in favor of the latter's *Igla* ("Needle") in 1963. Raushenbakh's group at OKB-1 developed the algorithms for the logic command instruments for the entire rendezvous and docking procedure.[124]

124. Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, pp. 162–65. The other two competitors in radar design were TsNII-108, whose design was too heavy, and TsKB Geofizika, which proposed a laser-optical system. See B. Ye. Chertok, *Rakety i lyudi: goryachiye dni kholodnoy voyny* (Moscow: Mashinostroyeniye, 1997), pp. 395–96.



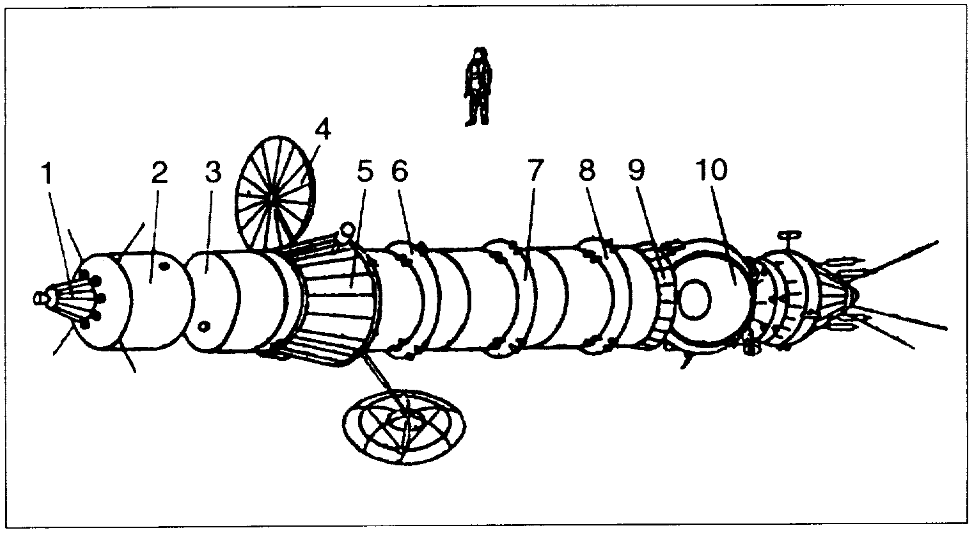
This is one conception of an early Earth-orbital station dating from 1962. A visiting spacecraft called the Sever is shown docked to the station at the bottom of the drawing. The design of the Sever eventually evolved into the future Soyuz spacecraft. (copyright R. F. Gibbons, based on a drawing by Igor Afanasyev)

Korolev's engineers finalized the configurations for both the Sever and 1L spacecraft by early 1962. The Sever, slated only for Earth-orbital operations, was much larger than the Vostok spacecraft, although it, like the Vostok, was divided into two main sections: a cylindrical instrument module and a headlight-shaped return capsule attached at the forward end of the spacecraft.[125] The former would carry all the guidance and control systems, propulsion units, power sources, and propellant tanks. The latter would carry the crew and be equipped with life support systems and controls for the crew to guide the spacecraft. The 1L spacecraft, meant for lunar missions, had a more complicated configuration, prompted by the concerns of engineers who wanted to ensure comfortable conditions for a crew during a potentially weeklong circumlunar mission. As early as 1960, Department No. 11 had proposed the addition of adding a *third* pressurized module to the spacecraft, called the orbital module, which would allow cosmonauts more volume than the cramped quarters of the return capsule. A competitive proposal from Department No. 9 retained the old two-module configuration, with the crew remaining in the return capsule for the duration of the mission. Like many of the latter department's proposals, this conservative arrangement was rejected in favor of Department No. 11's idea to use a third module.

The placement of the new module as part of the 1L spacecraft was the subject of much debate. Initial conceptions showed the return capsule at the top of the spacecraft, followed by the new orbital module below it between the other two compartments. The crew would be able to open a hatch in the heat shield at the base of the return capsule to move into the orbital module. The instrument module would remain at the base of the spacecraft and would not be accessible to the crew. Tests at the time proved that having a hatch in the heat shield was not an optimal arrangement and raised all sorts of potential dangers for burn-through during reentry. The engineers eventually adopted a novel arrangement, with the orbital module at the very forward end of the spacecraft. A hatch at the apex of the return capsule would allow the crew to move *forward* into the cylindrical orbital module.[126]

125. The Sever has not been described in any detail in any Russian sources. The above description is based on a drawing published in Afanasyev, "Unknown Spacecraft."

126. There has been some speculation that the three-module design adopted for the 1L spacecraft was appropriated by OKB-1 engineers from a publicly available study by U.S. defense contractor General Electric. During 1960, NASA, in planning for a post-Mercury spacecraft, had asked for proposals from several major aerospace companies. The concept submitted by General Electric on October 9, 1960, had a similar configuration to the 1L, in particular with relation to the placement of the reentry module between the "mission module" and the "propulsion module." See P. S. Clark and R. F. Gibbons, "The Evolution of the Soyuz Programme," *The Journal of the British Interplanetary Society* 36 (1983): 434–52.



This is the design of the Vostok-7/1L complex for a piloted circumlunar spacecraft. The legend is: (1) forward section of the 1L spacecraft; (2) 1L living compartment; (3) 1L descent apparatus; (4) solar panel; (5) 1L instrument compartment; (6, 7, and 8) three "rocket block" propulsion modules; (9) jettisonable section of the final rocket stage; and (10) Vostok-7 spacecraft. (copyright Igor Afanasyev)

The 1L design was also distinguished from the Sever spacecraft in terms of several other aspects. The instrument module was shaped like a cylindrical skirt, with two disk-shaped solar panels attached at the end of two booms to provide power—a first for a Soviet piloted spacecraft. This instrument module was also equipped not only with a propulsion system, but also a docking system at the *aft* of the spacecraft. The return capsule itself harked back to early conceptions of segmented spheres and was shaped more like a cylinder than the later "automobile headlight" design adopted for the Sever. By 1962, when engineers finalized the design of the 1L spacecraft design, it had four separate sections from aft to fore:

- A cylindrical skirt-shaped instrument-aggregate compartment
- A segmented spherical descent apparatus
- A cylindrical living compartment
- A conical nose propulsion system[127]

The nose propulsion system was simply a small compartment at the forward end of the spacecraft for carrying out attitude control during rendezvous and docking in Earth orbit.

Elements of both the Sever and the 1L spacecraft would eventually serve as the basis for the development of the famous Soyuz spacecraft, certainly the most important piloted spacecraft of the Soviet space program. The final variants of both the 1L and the Sever, as well as of the still-flying Vostok spacecraft, were part of an idea proposed by Korolev on January 26, 1962, for a four-module fifteen- to twenty-five-ton "space train" ensuring circumlunar flight.[128] The first results of the research on this theme were summarized in a "scientific-technical prospectus" titled "Complex for the Assembly of Space Vehicles in Artificial Earth Satellite

127. Afanasyev, "Unknown Spacecraft."
128. Lardier, *L'Astronautique Soviétique*, p. 155.

Orbit," which was signed by Korolev on March 10, 1962.[129] The project as a whole was designated Soyuz, the Russian word for "union." There were three different goals of the complex:

- The creation of an orbital piloted station for military missions
- The creation of piloted spaceships capable of circumlunar missions
- The creation of a global communications satellite system

A nominal circumlunar mission would be achieved by assembling a series of rocket stages in Earth orbit into a multistage rocket that would boost the payload toward the Moon. The four major components of the complex were:

- A modified Vostok spacecraft designated the Vostok-7
- A "rocket block," three of which would be launched
- A jettisonable toroidal compartment attached to the base of each rocket block containing rendezvous and docking instrumentation
- The primary payload, a 1L spacecraft

The Vostok-7 was a modified Vostok-3A spacecraft that had launched Gagarin. In contrast to Gagarin's spacecraft, the "new" vehicle would include rendezvous and docking gear, a multi-use primary propulsion system capable of orbital changes, and attitude control engines.[130] While these changes would increase mass by 1,100 to 1,300 kilograms, in all other respects, the spacecraft was similar in design configuration to the old Vostok-3A vehicle. The rocket blocks, 4,800 kilograms each, were simply short cylindrical modules capable of independent flight and equipped with engines for work in vacuum.[131] The Vostok-7 spacecraft, the rocket blocks, the 1L vehicle, and the Sever spaceship would all be launched into orbit by means of improved versions of the old 8K72K booster equipped with a more powerful third stage.[132]

A mission to perfect rendezvous and docking techniques would start with the launch of a Vostok-7 spacecraft with a single cosmonaut, designated a "pilot-assembler." At a designated

129. Afanasyev, "Unknown Spacecraft." This document, in a censored version and with a different title, has been published as S. P. Korolev, "Proposal for the Creation of Means for Orbital Assembly" (English title), in Keldysh, ed., *Tvorcheskoye naslediye Akademika*, pp. 445–49. Note that Korolev sent a letter to the Military-Industrial Commission, dated March 5, 1962, requesting permission to develop this complex; he enumerated several military goals for the system, including reconnaissance and anti-satellite operations. An abridged version of this letter has been reproduced as S. P. Korolev, "Proposal for Complex for the Assembly of Space Apparatus in an Earth Satellite Orbit (Theme 'Soyuz')" (English title), in Raushenbakh, ed., *S. P. Korolev i ego delo*, pp. 359–60.

130. The Vostok-7 would include the following systems in addition to the ones already existing on the Vostok-3A: (1) apparatus for controlling rendezvous as part of the orientation and control system; (2) apparatus for search and targeting; (3) on-board radio systems; (4) the coordination engine system with eight engines and a reserve of propellant; (5) optical systems for observing rendezvous and docking; (6) a docking node with mechanical locks and electrical connections; (7) apparatus to control mechanical and electrical connections; (8) and additional power sources. The following systems would be modified from those on the original Vostok-3A: (1) orientation and control systems; (2) the cosmonaut's control panel; (3) the TV system; (4) the Zarya communications system; and (5) the retrorocket engine. See Korolev, "Proposal for the Creation of Means for Orbital Assembly."

131. Each rocket block would have the following systems: (1) engines; (2) armature for firing, controlling, and shutting down the engines; (3) propellant tanks; (4) systems for ensuring proper propellant flow; (5) guidance systems; and (6) mechanical systems for connecting with other spacecraft. The jettisonable portion of each rocket block would include: (1) systems for coordinating the engines; (2) orientation systems; (3) systems for measuring orbital parameters; (4) communications systems; (5) systems for search and targeting; (6) communications systems for work with other space ships; (7) TV cameras; (8) lights for optical signals to other ships; (9) the Signal telemetry system; (10) docking nodes; (11) apparatus for controlling mechanical and electrical connections between the ships; (12) thermo-regulation systems for the propellants; and (13) power sources.

132. This booster was the 8K711.

time when the spacecraft would pass over the launch site, the first rocket block would be launched into a similar orbit. The pilot would then switch on the automatic system of approach, which would bring the Vostok-7 spacecraft to a distance of about five to ten kilometers from the rocket block. The second stage of rendezvous with the aid of radars would decrease the distance to 100 to 200 meters. After docking by manual control, the pilot would establish electrical and mechanical connections between the two vehicles, now with a total mass of eleven to twelve tons. The jettisonable torroidal section of the rocket block would then separate and be discarded, revealing a docking node on the opposite end of the cylinder-shaped block. The mission would continue with further launches of at least two more rocket blocks which would connect to the complex, creating a four-vehicle "space station." After performing some military experiments, the Vostok-7 spacecraft would separate from the first rocket block of the complex and return to Earth.

In the case of a circumlunar mission, a fifth vehicle, the 1L, would be launched with a crew of one to three cosmonauts and perform a docking at the end of the final rocket block by literally backing into the complex. At this point, the Vostok-7 spacecraft, its job done, would undock from the complex and return to Earth. The remaining rocket stages would fire one by one, gaining sufficient velocity to boost the 1L spacecraft and its crew on a simple circumlunar mission.

The prospectus also described the launch of large 1,100- to 1,200-kilogram communications satellites into geostationary orbit by means of the three similar rocket stages and the Vostok-7 spacecraft. In such a mission profile, the satellite would replace the 1L as the primary payload of the complex. Another mission mode proposed in the same document was the creation of a small piloted orbital station crewed by three cosmonauts. The station itself would consist of two units: a "living section" and a science-package unit. Four large disk-shaped solar panels on two booms would provide on-board power. The crew would travel to and from the station by means of the Sever spacecraft, equipped with the headlight-shaped guided reentry vehicle. The primary objective of such a station was apparently Earth observation, presumably for military purposes. A final mission for the complex would be in conjunction with the 5KM piloted military "space fighter."[133]

Among the multitude of goals planned for the Vostok-7 complex, possibly the most important for Korolev was the piloted circumlunar mission, which had become somewhat of a priority among Soviet space organizations at the time. General Designer Chelomey's OKB-52 was also exploring such missions with its own resources during the same period. Furthermore, in 1962, Academician Keldysh's "brain center," at the Department of Applied Mathematics of the V. A. Steklov Mathematics Institute of the Academy of Sciences, had just completed a detailed mathematical study on the technical aspects of a piloted circumlunar mission with a particular focus on having the return capsule land on Soviet territory.[134] In documents dating back to January 1962, Korolev was already requesting the manufacture of eight Vostok-7 spacecraft specifically for the circumlunar mission, most likely set for the 1963–64 timeframe.[135]

The high priority on the accomplishment of a circumlunar mission as early as possible resulted in many of the odd design elements of the Vostok-7/1L plan. Because there would be no heavy booster to carry out a single mission profile, Korolev opted instead to carry out a multitude of dockings in Earth orbit. The use of the Vostok spacecraft for such an ambitious

133. Afanasyev, "Unknown Spacecraft"; Korolev, "Proposal for the Creation of Means for Orbital Assembly."

134. This report has been published as M. V. Keldysh, M. L. Lidov, A. M. Mikish, and G. I. Taratynov, "Flight Around the Moon With a Return to Earth and Landing on the Territory of the Soviet Union" (English title), in V. S. Avduyevskiy and T. M. Eneyev, eds., *M. V. Keldysh: izbrannyye trudy: raketnaya tekhnika i kosmonavtika* (Moscow: Nauka, 1988), pp. 422–57.

135. Kamanin, *Skrytiy kosmos*, p. 88.

mission, despite research on a next generation of spacecraft, was clear indication that the plan was somewhat of a hasty idea. Korolev, in fact, at one point even explored the possibility of using solid-propellant rocket engines, five of them, as propulsion for the rocket stages, but he was talked out of this idea by the combined persuasive efforts of Kryukov, the nominal head of the design project, and design engineer Feoktistov.[136]

Regardless of the merits of the plan, a month after the Vostok-7/1L technical prospectus was issued, on April 16, 1962, the Soviet Communist Party and the government signed a decree on Korolev's Soyuz theme, apparently prompted by its military applications.[137] Quite possibly, the circumlunar nature of the project was an added bonus for the leadership. The timing of the decree was clearly an anomaly; it was issued during a period when Chelomey was the dominant figure in the space program, and Korolev's star had dropped to its literal nadir. Judging by the subsequent events, it seems that the decree had little effect. Like much of Korolev's efforts during this period, the Party and government failed to back up a commitment with actual action. Despite the ambivalent repercussions of the decree, there *was* a marked shift in Korolev's strategy of piloted space exploration around the early summer of 1962. The complicated Vostok-7/1L plan was put back on drawing boards for major changes in its weak points, especially the use of the Vostok spacecraft as part of a circumlunar mission. In addition, perhaps to focus limited resources on the circumlunar plan, the center of Korolev's Earth-orbital plans, the innovative Sever spacecraft, was completely abandoned. The experience in designing both the Sever and the 1L did, however, have a lasting influence on the shape of a famous Soviet spacecraft of the future.

The Soyuz

The redirection of OKB-1 plans in mid-1962 resulted in at least one positive outcome: the development of a more optimal second-generation spacecraft, much more advanced than the Vostok-7. By taking elements from the 1L and the Sever spaceships, by late 1962, engineers at the design bureau emerged with a new spacecraft, simply called the Soyuz or "the product 7K," which would become the basis of Soviet piloted space exploration for the next thirty years. The engineers retained the three-module configuration of the 1L, but they adopted the headlight-shaped return capsule and the cylindrical instrument module from the Sever. A significant alteration from both the 1L and the Sever was the marked decrease in the size of the return capsule. Originally, Department No. 11 had adopted a capsule with a diameter of 2.2 meters (2.3 meters, including the thermal protection), but to decrease the overall mass of the spacecraft, Feoktistov proposed reducing the dimension down to two meters, thus creating very cramped conditions within the module. Upon being told of this proposal at a meeting, the unconvinced Korolev marked off an area in his office the size of the capsule and ordered one of the authors of the idea to spend the remaining time of the meeting in the area. Despite the discomfort, the engineer continued to pursue the idea. Korolev finally caved in, and by late 1962, the size of the return capsule on the 7K/Soyuz was reduced to two meters. In retrospect, this decision proved to be "irrational" when, by 1968, an extra 200 kilograms had been shaved off the mass of the spacecraft, thus no longer requiring the smaller dimension. But by that time, it was too late. The cosmonauts would have to endure the launch in relatively cramped conditions.[138]

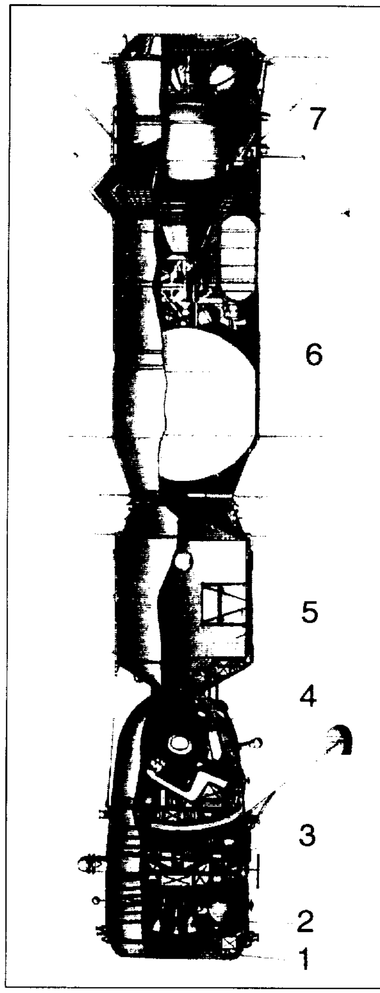
136. Golovanov, *Korolev*, pp. 720–21.

137. Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p. 635. Note that this source says that the title of the decree was "On the Development of the 'Soyuz' Complex for Piloted Flight Around the Moon." This is probably an error. See also Raushenbakh, ed., *S. P. Korolev i ego delo*, p. 685.

138. Ishlinskiy, ed., *Akademik S. P. Korolev*, p. 96; Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p. 170.

The use of multiple rendezvous and docking as part of a circumlunar mission was not abandoned, despite reservations from key engineers at OKB-1. One particularly insistent opponent of the plan was Deputy Chief Designer Leonid A. Voskresenskiy, one of Korolev's most trusted aides who had worked with him since World War II. Although he did not have any formal higher education, Voskresenskiy had earned his reputation by a seat-of-the-pants decision-making and a remarkable intuitive capability, which had allowed him to earn the respect of OKB-1 engineers. The deputy was simply against the idea of conducting four dockings in Earth orbit, rightly seeing in the profile immense possibilities for failure. The design bureau had begun the development of a complex docking system only in the summer of 1962, but the two engineers leading the project, Viktor P. Legostayev and Vladimir S. Syromyatnikov, ran into significant obstacles. As Syromyatnikov recalled:

> *The Chief Designer was not satisfied either with the organization of the work, nor with its results. The designs turned out to be cumbersome, complex to control, and contained many separate mechanisms. Significant simplification and greater compactness was required. Only by the spring of 1963 did the* outline *of the future design for the docking assembly become clear: a moving pintle on an active spacecraft and an acceptor cone on the passive one.*[139]



The 7K-9K-11K piloted circumlunar complex emerged in 1963 as a successor to the Vostok-7/1L conception. The image here shows the 7K spacecraft docked to the 9K translunar injection stage, which has been loaded with propellant by means of several 11K orbital tankers. The legend is: (1) and (7) jettisonable compartments; (2) 7K aggregate compartment; (3) 7K instrument compartment; (4) 7K descent apparatus; (5) 7K living compartment; and (6) 9K rocket block. Note the close resemblance of the 7K to the future Soyuz spacecraft. (reproduced from M. V. Keldysh, ed., Tvorcheskoye naslediye Akademika Sergeya Pavlovicha Koroleva: izbrannyye trudy i dokumenty *(Moscow: Nauka, 1980))*

The delays in the development of a docking system, as well as the attendant obstacles of designing rendezvous systems, did not deter Korolev from adopting yet another multiple docking plan for his coveted circumlunar mission. A "new" plan involving the two-person 7K/Soyuz spacecraft, the 9K translunar injection rocket stage, and the 11K propellant tanker was finalized in a preliminary draft plan signed by Korolev on December 24, 1962, only months after the abandonment of the earlier Vostok-7/1L multiple docking scheme.[140] Over opposition from some of his deputies, the final technical draft plan for the 7K/Soyuz spacecraft itself was signed by Korolev on March 7, 1963, thus committing OKB-1 to forge ahead with the development of the ship as the center of its immediate goals of human spaceflight.

139. Ishlinskiy, ed., *Akademik S. P. Korolev*, p. 231. Author's emphasis. The author of the "pin-needle" docking mechanism was OKB-1 engineer L. B. Vilnitskiy.

140. Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p. 163.

These internal design bureau deliberations in favor of the multiple docking circumlunar plan were aided to a large degree by external shows of support. The Interdepartmental Scientific-Technical Council on Space Research, the interagency forum composed of the most important chief designers, academicians, and military officers of the space program, for the first time addressed Korolev's 7K/Soyuz spacecraft proposal at a meeting in early December 1962. Under the direction of Academician Keldysh, the council recommended the creation of an "expert commission" to examine the salient details of the program.[141] This commission, with four subsections representing interests other than OKB-1, was able to suggest amendments to the technical design of the space complex during the ensuing few weeks.[142] A second meeting of the council was held on March 20, 1963, once again presided by Keldysh to decide on the project, based on the expert commission's recommendations. Among those in attendance were Chelomey and Glushko, both erstwhile opponents of Korolev's own plans for space exploration.[143] In his speech at this meeting, Korolev expounded on the primary goals of the Soyuz project, mentioning both rendezvous and docking as well as piloted circumlunar missions. Keldysh, Chelomey, and Glushko spoke after Korolev and made approving comments on the proposal; not surprisingly, Chelomey and Glushko had some additional comments on the potential "of great difficulties in its realization." Despite their words of caution, Korolev had sufficient support to obtain the full-fledged approval of the project, optimistically projecting the first test flight of the 7K/Soyuz spacecraft by the summer of 1964.

The council's unanimous decision in favor of Soyuz was, of course, not binding because neither the Communist Party nor the government had issued a document in support of the new proposal. The recommendation did, however, have the effect of shoring up Korolev's relatively weak position in the space industry at the time. With continuing troubles with the N1, Korolev pinned his hopes at regaining a flash of his glory days on the Soyuz project. Less than two months after the council's meeting, on May 10, 1963, OKB-1 issued a new "technical prospectus" titled "Assembly of Space Vehicles in Earth Satellite Orbit," which described in detail the 7K-9K-11K, or the Soyuz complex, which was to take the first Soviet cosmonauts around the Moon.[144]

The center of these plans was the 7K or Soyuz spacecraft, a 7.7-meter-long three-module vehicle designed by meshing together the 1L and the Sever ships. The three primary components from aft to fore were:

- The cylindrical instrument-aggregate compartment
- The headlight-shaped descent apparatus
- The cylindrical living compartment

141. Kamanin, *Skrytiy kosmos*, pp. 191–92. Among those present at the meeting on December 6, 1962, were S. P. Korolev (OKB-1), V. N. Chelomey (OKB-52), M. K. Yangel (OKB-586), A. F. Bogomolov (OKB MEI), V. I. Kuznetsov (NII-944), M. V. Keldysh (AN SSSR), A. Yu. Ishlinskiy (NII-944), N. M. Sisakyan (AN SSSR), A. A. Blagonravov (AN SSSR), A. I. Sokolov (RVSN), K. A. Kerimov (RVSN), N. P. Kamanin (VVS), and N. N. Alekseyev (MO NTK).

142. One of the subsections was from the Air Force, which recommended three changes to the Soyuz spacecraft: the use of spacesuits at all times for cosmonauts; the use of wings to provide aerodynamic lift; and the use of catapults for launch escape. None of them were accepted by OKB-1. See *ibid.*, p. 211.

143. *Ibid.*, pp. 239–40. Among those present were M. V. Keldysh (AN SSSR), S. P. Korolev (OKB-1), V. N. Chelomey (OKB-52), A. Yu. Ishlinskiy (NII-944), V. P. Glushko (OKB-456), A. A. Kobzarev (GKAT), G. I. Voronin (OKB-124), N. S. Stroyev (LII), N. P. Kamanin (VVS), M. P. Odintsov (TsPK), V. I. Yazdovskiy (GNII AiKM), Ye. A. Karpov (TsKP), Yu. A. Gagarin (TsPK), G. S. Titov (TsPK), A. I. Sokolov (NII-4), and N. N. Yuryshev (RVSN).

144. Afanasyev, "Unknown Spacecraft." The document has been reproduced with censored designations as S. P. Korolev, "The 'Soyuz' Orbital Rocket Complex" (English title), in Keldysh, ed., *Tvorcheskoye naslediye Akademika*, pp. 489–500.

The instrument-aggregate compartment had four components analogous to successive "slices" down the cylinder, none of which would permit access by crewmembers. These sub-compartments were from aft to fore:

- The jettisonable orbital compartment in the form of a torus at the base of the spacecraft, which contained rendezvous instrumentation, radio systems to control its orbit, apparatus for transmitting guidance commands, thermo-regulation systems, automatic guidance systems, and tracking systems
- The aggregate compartment, which carried the primary "approach-correction" engines of the 7K vehicle, as well as attached solar batteries to serve as power sources
- The instrument compartment, the largest section of the cylinder, which contained the essential instrumentation of the vehicle to ensure extended flight in space, including long-range radio apparatus, orientation and attitude control systems, radio-telemetric systems, primary thermo-regulation systems, power sources for the ship, programmable timer devices, on-board switching systems for controlling the automatic guidance systems, and sensors and "switchboard-relay apparatus" for tracking
- The transfer compartment, which contained the attitude control engines on the exterior and their propellant tanks in the interior

The descent apparatus was merely a smaller version of the headlight on the Sever, with life support systems, thermo-regulation systems, optical and TV systems for observation and guidance, control panels for the crew, radio communications systems, systems to guide the capsule in the atmosphere, and a parachute system for landing on Earth. Thermal protection at the base of the capsule would provide sufficient defense during high-speed reentry from lunar distances. The living compartment was the additional cylindrical module, with approximately the same diameter as the instrument-aggregate compartment, a little more than two meters. This section would contain life support systems, elements of the thermo-regulation system, microphones and "dynamic" systems of communications, scientific instruments, and movie cameras. The cosmonauts could also use the compartment as an airlock for extravehicular activity. In addition, the apex of the living compartment, and thus the whole spaceship, would have a large docking system for linking up with other spacecraft. The total mass of the 7K/Soyuz ship was 5,500 to 5,800 kilograms.

The single rocket stage, designated the 9K, was designed to accelerate the 7K/Soyuz vehicle on a translunar trajectory. The 7.8-meter-long spaceship was shaped like a simple cylinder divided into two primary sections, the large 9KM rocket block and the smaller 9KN jettisonable compartment. The latter contained an orbit correction engine, control systems, and rendezvous instrumentation, as well as a docking node on one side, which would allow the transfer of propellants from the tankers. The former carried the main translunar rocket engine with a thrust of four and a half tons, as well as more instrumentation and a second docking node on the opposite end of the spacecraft. Launch mass was 5,700 kilograms.

The final element of the complex was the 4.2-meter-long cylindrical tanker named the 11K. It had two major compartments, the 11KA for the oxidizer and the 11KB for the fuel. The remaining portion of the spacecraft consisted of attitude control engines, electronic instrumentation for guidance, and a docking node. The total fueled mass was 6,100 kilograms. All the three components, the 7K, the 9K, and the 11K, would be launched by new three-stage versions of the R-7, designated the 11A55 and 11A56.

The primary mission of the Soyuz complex, a piloted circumlunar mission, would begin with the launch of the 9K rocket stage. The automated spacecraft would carry out the necessary changes to its orbit by means of its small orbit correction engine until it had reached the desired orbital parameters. When the 9K passed over Tyura-Tam, the first 11K tanker would be launched into orbit carrying 4,155 kilograms of extra propellant. The initial orbital trajectory would posit the tanker within twenty kilometers of the 9K rocket block. If because of errors in orbital insertion the 11K module did not approach its parry to within a twenty-kilometer range, then the 9K block would carry out the necessary orbital adjustments to bring the two spacecraft within twenty kilometers. Automatic radars on both spacecraft would then complete the final approach, and the 9K (active vehicle) would dock with the 11K (passive vehicle). The docking would be carried out on the aft end of the 9K (with the jettisonable compartment). After the transfer of propellants through linked lines across the docking node, the 11K tanker would separate and be discarded.

At least three more tankers would be launched until the 9K was fully loaded with twenty-five tons of propellant. At this point, the 7K/Soyuz piloted ship would launch into orbit with its crew of two to three cosmonauts. The crew could either try manual or automatic docking; unlike the tankers, the 7K/Soyuz would dock on the 9K rocket stage's forward end. The jettisonable compartment on the 9K would continue to carry out necessary orbital maneuvers following docking. This compartment would then be discarded, finally revealing the powerful main engine of the 9K rocket block, which would then fire to boost the 7K/Soyuz, rear end first, toward the Moon. The 7K/Soyuz propulsion system itself would be used for trajectory corrections during flight to and from the Moon. After return to the vicinity of Earth, the 7K/Soyuz spacecraft would separate into its three component modules, with the descent apparatus making a controlled descent into the atmosphere, landing by parachute on Soviet territory.[145]

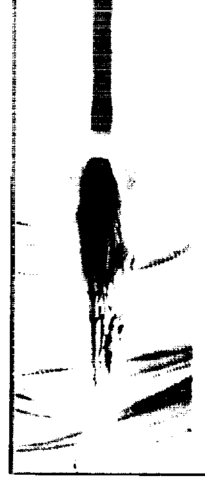
Mastering rendezvous and docking operations in Earth orbit may have been one of the primary objectives of the Soyuz complex, but the incorporation of five consecutive dockings in Earth orbit to carry out a circumlunar mission was purely because of a lack of rocket-lifting power in the Soviet space program. The May 1963 document on the Soyuz complex thus emerged less as a technical exercise than from an inclination to promote a space project before the advent of the N1. It was a risky gamble—and one that evidently had the support of most of the major players in the space program, as evidenced by the Interdepartmental Council's unanimous approval two months earlier. Contracts for the Soyuz complex were also handed out in 1963. In a move motivated by limited resources at OKB-1, Korolev signed agreements with two relatively new organizations that until then had zero involvement in the piloted space business. Both of them were led by protégés of Korolev: SKB-385 at Miass under Chief Designer Viktor P. Makeyev to produce the important 9K acceleration block and OKB-10 at Krasnoyarsk-26 under Chief Designer Mikhail F. Reshetnev to build the 11K tanker.[146] Both Makeyev and Reshetnev had been key engineers at OKB-1 in the 1950s, rising to senior positions in management before being sent by Korolev to head independent organizations focusing on naval missiles and automated spacecraft, respectively.

The agreements of Korolev with Makeyev and Reshetnev were symptomatic of the remarkable decentralization of the Soviet space industry that had taken place between 1960 and 1963. At that point, no longer only competing with the Americans, Soviet space designers found themselves in battles among themselves, with institutions rising and falling with the tides of political favoritism. Chelomey's dramatic entrance and support from Khrushchev had clearly put him in a much more powerful position than Korolev, but there was still one important factor on which Korolev could count within the confines of the Soviet defense industry, and that

145. Korolev, "The 'Soyuz' Orbital Rocket Complex"; Afanasyev, "Unknown Spacecraft."

146. Golovanov, *Korolev*, pp. 721–22. Other sources claim that both the 9K and 11K modules were to be manufactured at the Progress Plant in Kuybyshev.

was prestige. It was, after all, he who had launched Sputnik and then Gagarin. The Soyuz complex was partly an attempt to maintain that prestige in the near future, while the N1 would take care of it in distant years. For the present time, in 1962 and 1963, Korolev's ace in the hole was still Vostok, and it was with the Vostok spacecraft that the Soviet space program continued to accrue its accolades from a vast and unsuspecting public all over the world.



Chapter Nine
Space Politics

The Soviet space program was neither a high priority nor a central tool of Soviet state policy. The spectacular achievements of the late 1950s and early 1960s were pushed by the chief designers, grudgingly approved by the Communist Party and government, and then used as propaganda vehicles by Soviet leaders for selling the virtues of the socialist system. Thus, while Communist Party functionaries eagerly extracted maximum political mileage from the Sputnik, Luna, and Vostok missions *post facto*, the political utility of these launches did not figure significantly into the original formulation of the flights. On the odd occasions when political considerations did enter into the equation, they were also instigated not by higher-ups in the decision chain, but rather the middle men involved in the space program. In the post-Gagarin period, many chief designers in fact offered up a variety of proposals to the leadership, all couched in terms of advancing the Soviet image across the world. One immediate example of such behavior was the launch of the first woman into space in 1963. Another was competing with the United States in the "race to the Moon." Both had little to do with a rational program of space exploration—and even less to do with scientific research. But both were symptomatic of the chaotic nature of the Soviet piloted space program during the 1960s.

Twins in Space

Because the Vostok program did not have any formal long-range program of missions, Soviet space officials planned flights based purely on the number of such vehicles that were rolling off OKB-1's production plant in Kaliningrad. Immediately after Gagarin's flight, in May 1961, there were orders for eighteen Vostok-type spacecraft, half of which were for piloted flight and the remainder being the reconnaissance satellite version.[1] To a great degree, future plans for piloted missions depended on Korolev's unwritten rule that each mission be a significant advance over the previous one. Thus, the two identical suborbital flights of astronauts Shepard and Grissom in 1961 would have been unthinkable in Soviet mission planning. Based on this somewhat unsound premise, in September 1961, one month after Titov's flight, Korolev proposed a *triple*-spacecraft joint flight in November: three Vostok spacecraft, each with a single cosmonaut, would be launched on three successive days. The first pilot would conduct a three-day mission, while the two others would be in space for two to three days. There would be one day during the joint mission when all three spacecraft would simultaneously be in space.[2]

1. N. P. Kamanin, *Skrytiy kosmos: kniga pervaya, 1960–1963gg* (Moscow: Infortekst IF, 1995), p. 56.
2. *Ibid.*, p. 60; Nikolay Kamanin, "Work in the First Two Years: Space Diary" (English title), *Pravda*, April 8, 1991, p. 2.

Both Air Force representatives and the physicians in charge of biomedical preparations strongly opposed the plan. The latter were particularly concerned about unduly extending the duration of future missions after Titov's startlingly poor experience in August. By late October, after opposition from highly placed Air Force leaders, including Commander-in-Chief Vershinin, Korolev limited the plan to *two* simultaneous launches of Vostok spacecraft. This more modest proposal was motivated by the limitations of the Soviet tracking and rescue networks, which would have been put under significant strain for a triple-flight plan. On the matter of mission length, Korolev was less interested in compromise, and the issue remained unresolved with a month left to launch. The schedule was seriously interrupted in late October when the Soviet Party and government abruptly adopted a decision to focus all resources on the Zenit-2 reconnaissance satellite program instead of Vostok, clear evidence that the piloted space program was not only not a priority for decision makers, but in many ways was hindered by work on the reconnaissance effort. The crewed Vostok mission was delayed until January 1962 at the earliest.

The cosmonauts themselves were put on continuous training regimes, ready to be able to undertake a mission within one month of the final order. In October, six cosmonauts—Bykovskiy, Komarov, Nelyubov, Nikolayev, Popovich, and Shonin—were assigned to train for the dual mission. All of them conducted three-day training sessions in the new TDK-2 simulator delivered to the Cosmonaut Training Center at the time. The selection and training of cosmonauts took an interesting turn at the end of 1961—one that was primarily driven by political considerations. In the summer of 1961, Lt. General Nikolay Kamanin, the Air Force General Staff representative overseeing the cosmonaut group, somewhat abruptly emerged with the idea to send a woman into space on one of the following Vostok missions. He apparently attempted to get highly placed leaders, such as Korolev, Keldysh, and even USSR Minister of Defense Rodion Ya. Malinovskiy, interested in his idea, but they all were unanimously opposed to the proposal.[3] On why the Soviet Union needed to send a woman into space, Kamanin wrote in his journal:

1. *Women will definitely fly into space—thus it is better to begin training them for this kind of mission as soon as possible.*
2. *Under no circumstances should an American become the first woman in space—this would be an insult to the patriotic feelings of Soviet women.*
3. *The first Soviet cosmonaut will be as big an active advocate for communism as Gagarin and Titov turned out to be.*[4]

Despite the high degree of opposition he faced, Kamanin did not drop the idea; he claimed that he took the matter directly to Khrushchev, who approved the plan. Whether indeed he did do so continues to be a matter of debate, but clearly his lobbying produced results. On December 30, 1961, the Central Committee approved a plan to select sixty new cosmonauts for the Soviet space program, including five women.[5] Although it seems that the plan to select the *men* was postponed indefinitely, physicians from the Air Force's Institute of Aviation and Space Medicine contacted aviation clubs from all over the country to prepare a master list of

3. Yaroslav Golovanov, *Korolev: fakty i mify* (Moscow: Nauka, 1994), p. 689; Christian Lardier, *L'Astronautique Soviétique* (Paris: Armand Colin, 1992), p. 132; E-mail correspondence, Sergey Voevodin to the author, January 30, 1997.

4. Kamanin, *Skrytiy kosmos: 1960–1963*, p. 62; Debra D. Facktor and Valentina Ponomareva, "Women in the Early Soviet Spaceflight Program," presented at a meeting of the American Association for the Advancement of Slavic Studies, Boston, MA, November 14–17, 1996; Bart Hendrickx, "The Kamanin Diaries 1960–1963," *Journal of the British Interplanetary Society* 50 (January 1997): 33–40.

5. Kamanin, *Skrytiy kosmos: 1960–1963*, pp. 238–39.

400 women candidates. Women with significant aviation or parachuting experience were given preference over others, the latter qualification being especially important for ejecting from the Vostok capsule after reentry. Having cut the list down to fifty-eight candidates by January 1962, the women were subjected to an intensive battery of medical testing, including runs on centrifuges, pressure chambers, and vibration stands. A special Mandate Commission, which included Gagarin himself, narrowed the list down to three women at a meeting on March 3; the formal orders inducting them into the cosmonaut team were signed nine days later. Orders for an additional two women were signed on April 3. The five were:

- Tatyana D. Kuznetsova (twenty years old)
- Valentina L. Ponomareva (twenty-eight)
- Irina B. Solovyeva (twenty-four)
- Valentina V. Tereshkova (twenty-four)
- Zhanna D. Yerkina (twenty-two)[6]

While they were not Air Force pilots, each had well-suited assets for competing to be the first Soviet woman in space. Solovyeva, an alumni of Ural University, had 900 parachute jumps to her credit, followed by Tereshkova with seventy-eight and Ponomareva with ten. Ponomareva was clearly the most accomplished pilot, with 320 hours to her credit accrued on PO-2 and Yak-18 aircraft at her local sports club. She also had the distinction of having graduated from the prestigious Moscow Aviation Institute and having served as a scientist at the Department of Applied Mathematics of the USSR Academy of Sciences. Unwittingly, however, Ponomareva became the center of a controversy when Gagarin opposed her inclusion into the team because she was the only candidate who was a mother. Social stigma in the Soviet Union to mothers risking their lives in dangerous endeavors was significant enough for some vacillation on the issue. In the end, Academy of Sciences President Keldysh, who had encouraged her application in the first place, weighed in behind her, and her name was included in the final selection. One candidate, Tereshkova, did not have the academic honors to compete with the others, but had some other prized assets—for example, she had been an active member of the local Young Communist League near her home in the Yaroslav Region on the upper Volga.[7] As plans stood in early 1962, the women were to compete for a single seat on a Vostok mission during the latter part of the year.

The women cosmonauts arrived at the Cosmonaut Training Center at Zelenyy near Moscow at a time of great uncertainty about the next Vostok mission. Many of the systems and resources used for the Vostok program were common to the military Zenit-2 project, and having declared the latter an immediate priority, dates for the former were continuously delayed. The first Zenit-2 was launched on December 11, 1961, but it failed to reach orbit because of a failure in the third stage of 8K72K booster, the same launch vehicle used for the Vostok missions.[8] A second launch attempt in January 1962 had to be aborted at the last moment. Forced to conduct an examination of the booster problems, Korolev postponed the dual-Vostok launch again. There were also problems with both the parachutes and life support systems on the Vostok spacecraft, which had emerged during ground testing in early 1962, instilling doubt in the ability of the spacecraft to carry out missions safely. The somewhat lackadaisical attitude

6. V. Semenov, I. Marinin, and S. Shamsutdinov, *Iz istorii kosmonavtiki: vypusk I: nabory v otryady kosmonavtov i astronavtov* (Moscow: AO Videokosmos, 1995), pp. 8, 12; S. Yegupov and I. Karpenko, "At the Request of Readers: Detachment of Air Forces' Cosmonauts" (English title) *Aviatsiya i kosmonavtika* no. 5 (May 1990): 46–47.

7. Golovanov, *Korolev*, p. 691; Facktor and Ponomareva, "Women in the Early Soviet Spaceflight Program."

8. V. Agapov, "Pages From History: Launches of the 'Zenit-2' Space Apparatus" (English title), *Novosti kosmonavtiki* 10 (May 6–19, 1996): 65–77.

from the government on piloted space exploration was given a sudden jolt by news from the United States. Since January 23, NASA had been attempting to launch Major John H. Glenn, Jr., on the first U.S. piloted orbital spaceflight. Although the launch was delayed several times over the following weeks, all the preparations were carried out amid a torrent of media attention, contrasting sharply with the extreme secrecy of the Soviet program.

The publicity surrounding Glenn's Mercury launch had a dramatic effect. With curious abruptness, Military-Industrial Commission Chairman Ustinov called Korolev on February 17, just three days before the NASA launch, and ordered the Vostok launch in mid-March, no doubt to take some of the steam out of the Mercury flight. Glenn's spectacular mission on February 20 began the ball rolling in the Soviet Union. The day after, Lt. General Kamanin short-listed a group of seven cosmonauts to begin intensive training for the dual-Vostok flight, with two flying and two serving as backups. Kamanin himself captured the haphazardness of the decision-making in his diary:

> *I was unofficially notified (by Ustinov) that the next flight should take place around March 10–12. Apparently, after Glenn's flight, Khrushchev demanded that our next piloted flight be brought forward. In order to fly around the 10–12th, we'll have to fly to the launch site on March 2–3. This is the style of our leadership. They've been doing nothing for almost half-a-year and now they ask us to prepare an extremely complex mission in just ten days time, the program of which has not even been agreed upon.*[9]

The seven cosmonauts—Bykovskiy, Komarov, Nelyubov, Nikolayev, Popovich, Shonin, and Volynov—began mission-specific training at the time, but the resources were simply unavailable to mount a mission within thirty days. Month by month, the launch was again delayed as resources were tied up in the Zenit-2 program. At least two launches of the reconnaissance satellite were planned before Korolev could focus on the Vostok mission. The first of these finally occurred on April 26 with the successful orbital insertion of the first Soviet reconnaissance satellite. The second, using a slightly different model of the launch vehicle, was delayed several weeks and did not take place until June 1, 1962, from the launch pad at site 1, the same pad planned for use on the Vostok flights. In this case, the rocket landed 300 meters from the launch site, while one of the strap-ons remained at the pad, seriously damaging the structure as a result of a fire.[10] The response to Glenn's flight was hopelessly delayed as engineers estimated a month of repair work to bring the pad back to operational status.

As with Titov's flight, the issue of the length of the two ensuing Vostok missions was the source of arguments that lasted months. Korolev was absolutely insistent that the first mission last three days and the second two days. This was in the face of the opinions from all the Air Force physicians, the cosmonauts, Kamanin, Academy President Keldysh, Chairman of the State Committee for Defense Technology Smirnov, and top Air Force leaders, all of whom favored a more conservative one-day mission for each, prolonged to two days if everything went well. Korolev, in typical fashion, bulldozed his opinions over a period of weeks and, by the end of June, had persuaded almost all of the key leaders directing the Vostok program, including the leading biomedicine specialist Vladimir I. Yazdovskiy. The latter capitulated despite a formal document signed by the leading physicians on September 23, 1961, stating: "At the present time there is no basis to plan the next space flight for more than one day. If during a day long flight the cosmonaut is in good physical health, then the flight can be prolonged, but not to

9. Kamanin, *Skrytiy kosmos: 1960–1963*, p. 94; Hendrickx, "The Kamanin Diaries 1960–1963."
10. Agapov, "Pages From History"; Kamanin, *Skrytiy kosmos: 1960–1963*, pp. 118–19.

more than two days."[11] Kamanin refused to give in, but as the weeks wore on, he found himself in a minority.

At the first meeting of the *ad hoc* State Commission for Vostok on 16 July, the members set the dual Vostok launches for August 5–10, 1962. The second spacecraft would be launched into orbit the day after the first. One of the primary goals of the mission was to launch the spacecraft in such a way that the two vehicles would pass by each other in close proximity. Although a rendezvous was beyond the means of the modest Vostok spacecraft, such a mission profile had an important application to long-range plans at OKB-1. One of the key elements of the 7K-9K-11K Soyuz circumlunar project was rendezvous in Earth orbit. The first part of the rendezvous, an approach to within twenty kilometers, would be achieved simply by the trajectory imparted to the spacecraft by the launch booster. This meant that the second spacecraft would have to be launched at a specific time, to a specific inclination, and the cutoff velocity had to be perfectly timed to enter the designated orbit and orbital plane. The whole procedure was complicated by Earth's rotation; the "rendezvous" had to be based on computations of the velocity at which Earth rotated the launch pad underneath the first overflying Vostok spaceship. According to the plan, the two spacecraft would pass by each other at a relatively far distance, continue their own missions, and then land simultaneously, the first Vostok after three days and the second after two days. On July 26, in a meeting at OKB-1, leading participants, including OKB-1 Deputy Chief Designer Bushuyev, Department Chief Raushenbakh, Gagarin, and Cosmonaut Training Center Director Karpov, discussed the possibility of having the cosmonauts observe each other's spacecraft in orbit. Because of propellant limitations in the attitude control systems, they limited observations to two options for the first cosmonaut: viewing the upper stage of the 8K72K launcher after orbital insertion and detecting the launch of the second Vostok while flying over Tyura-Tam.[12] Observations of each other's spacecraft were not ruled out, but this was not a primary mission goal.

One safety concern that officials addressed in the weeks leading up to the launch of the Vostoks was nuclear radiation. On July 9, 1962, the United States detonated a nuclear warhead in space with the aid of a Thor missile over the Johnston Atoll in the Pacific Ocean. This generated high amounts of radiation that scientists believed was trapped in Earth's magnetic fields. Alarmed by the possibility that such radiation might harm the cosmonauts, the State Commission depended on the investigations of two small automated satellites, Kosmos-3 and Kosmos-5, which had been launched earlier in the year. The latter, in particular, was used to assess the degree of potential danger to humans flying over the Pacific. Noted nuclear physicist Sergey N. Vernov reported at a commission meeting on July 16 that as long as the launch was three to five days after a U.S. explosion, there would be no real danger to the cosmonauts.[13]

After a final meeting of the State Commission presided over by Chairman Smirnov on July 30, the first participants, including the five cosmonauts training for the joint mission—

11. Kamanin, *Skrytiy kosmos: 1960–1963*, pp. 125–26. A description of a meeting on the issue of mission length in March 1962, attended by S. P. Korolev, K. D. Bushuyev, M. K. Tikhonravov, O. G. Gazenko, N. P Kamanin, and Ye. A. Karpov, is described in Aleksandr Romanov, *Korolev* (Moscow: Molodaya gvardiya, 1996), pp. 445–49.

12. Kamanin, *Skrytiy kosmos: 1960–1963*, pp. 128–29; William Shelton, *Soviet Space Exploration: The First Decade* (New York: Washington Square Press, 1968), p. 139.

13. V. Pappo-Korystin, V. Platonov, and V. Pashchenko, *Dneprovskiy raketno-kosmicheskiy tsentr* (Dnepropetrovsk: PO YuMZ/KBYu, 1994), p. 69; Kamanin, *Skrytiy kosmos: 1960–1963*, p. 125. The summary report on the effects of Project Starfish has been published as M. V. Keldysh, "On Radiation as a Result of High-Altitude Nuclear Explosions" (English title), in V. S. Avduyevskiy and T. M. Eneyev, eds., *M. V. Keldysh: izbrannyye trudy: raketnaya tekhnika i kosmonavtika* (Moscow: Nauka, 1988), pp. 459–60. Another source suggests that Kosmos-7 was also used for the same task. See V. P. Glushko, ed., *Kosmonavtika entsiklopediya* (Moscow: Sovetskaya entsiklopediya, 1985), p. 201. Kosmos-3 and Kosmos-5 were "2MS" class satellites launched on April 24 and May 28, 1962, respectively (nos. 1 and 2). Kosmos-7 was a Zenit-2 reconnaissance satellite (no. 4) launched on July 28, 1962.

Bykovskiy, Komarov, Nikolayev, Popovich, and Volynov—began flying into Tyura-Tam on August 2. By the time Korolev and the other major chief designers arrived the following day, cosmonaut overseer Lt. General Kamanin was leaning toward Nikolayev and Popovich as the likely candidates for the two missions. One of the few bachelors in the cosmonaut team, the thirty-two-year-old Nikolayev began his career as a lumberjack before later joining the Soviet Air Force and receiving his pilot's wings in 1954. Possessed of a remarkably calm disposition, his completely unflappable manner in potentially life-threatening situations as both a pilot and a cosmonaut-trainee had guaranteed a place for him on such an early Vostok mission. The ebullient Popovich, also thirty-two, was Nikolayev's polar opposite in temperament. He had had a distinguished career in the Soviet Air Force before receiving the Order of the Red Star for an assignment in the Arctic. His wife Marina was one of the most accomplished women test pilots in the USSR.[14]

Training for Nikolayev, Popovich, and their three backup cosmonauts continued almost to the day of their scheduled launch, which was set for August 10–11. On August 4, the cosmonauts received instructions on how to orient their spacecraft for observations as well as for maintaining a smooth roll motion throughout the mission for equitable heating from the Sun's rays across the entire spacecraft. Veteran cosmonauts Gagarin and Titov were intensively involved in all premission operations, having jumped from being mere cosmonauts to being important members of the State Commission participating in all the key decisions regarding the flights. Gagarin arrived at Tyura-Tam on August 6, along with State Commission Chairman Smirnov, who presided over a prelaunch technical review meeting the same night. The formal "go-ahead" session of the commission was held on the night of August 7. It was at that point that Kamanin formally nominated Nikolayev and Popovich to fly the missions. Cosmonauts Bykovskiy and Komarov were named their backups, while Volynov was named "reserve."[15] Among the speakers at the meeting was First Deputy Commander-in-Chief of the Soviet Air Force Marshal Sergey I. Rudenko, who in his two-minute speech twice referred to cosmonaut Popovich as "Popov." The *faux pas*, recorded on film at the time, was later excised no doubt to save both Popovich and Rudenko from embarrassment. Remarkably, Rudenko repeated his error at a subsequent commission meeting the following day.

There were no major anomalies during the remaining days leading up to the first launch. On the morning of the liftoff, August 11, all the leading chief designers—Korolev, Alekseyev (ejection seat), Barmin (launch complex), Bogomolov (telemetry systems), Gusev (radio communications), Isayev (Vostok engine), Kosberg (upper stage engine), Kuznetsov (gyroscopes), Pilyugin (guidance systems for the booster), Tkachev (parachutes), and Voronin (life support systems)—met and declared their respective systems ready for flight.[16]

At 1130 hours Moscow Time, exactly as scheduled, the 8K72K booster lifted off with Captain Andrian G. Nikolayev aboard; his first words were "Full speed ahead!"[17] Perhaps aware of the recent booster failures, Korolev was unusually nervous throughout the ascent phase of the flight as he held on tight to the red telephone with which he would give the vocal order to abort the mission in case of a booster failure. At T+687 seconds, ground controllers breathed a sigh of relief as the spacecraft, renamed Vostok 3, was successfully inserted into orbit. Initial orbital parameters were nominal: 180.7 by 234.6 kilometers at 64.98 degrees inclination to the equator. Approximately two hours into the mission, at the end of Nikolayev's first orbit, news

14. Shelton, *Soviet Space Exploration*, pp. 134–35, 142.

15. Kamanin, *Skrytiy kosmos: 1960–1963*, pp. 133, 136–37.

16. The chief designers were heads of the following organizations: S. M. Alekseyev (Plant No. 918), V. P. Barmin (GSKB SpetsMash), A. F. Bogomolov (OKB MEI), L. I. Gusev (NII-695), A. M. Isayev (OKB-2), S. A. Kosberg (OKB-154), V. I. Kuznetsov (NII-944), N. A. Pilyugin (NII-885), F. D. Tkachev (NIEI PDS), and G. I. Voronin (OKB-124).

17. Evgeny Riabchikov, *Russians in Space* (Moscow: Novosti Press Publishing House, 1971), p. 186.

of the launch was reported to Khrushchev, Kozlov, and Ustinov back at the Kremlin. Kozlov called into launch control at Tyura-Tam, mistakenly promoting Nikolayev to lieutenant colonel instead of major before correcting himself. Throughout the mission, physicians on the ground kept a close watch on the cosmonaut's health to detect signs of the malaise that had afflicted Titov. A battery of sensors and instruments were attached to the cosmonaut's body, bringing in continuous telemetry; these included measurements for electrocardiograms, pneumograms, electroencephalograms, skin-galvanic reactions, and electro-oculograms. To measure movements of the eyes, doctors had attached tiny silver electrodes at the outer corners of Nikolayev's eyes to record the biocurrents of the muscles of the eyeballs. Electrodes placed on the front and lower third of the cosmonaut's right shin detected skin-galvanic responses. As was standard, the spacecraft also carried samples of *drosophila*, dry seeds, lysogenic bacteria, and microspores.[18] The telemetric information was augmented by a continuous stream of oral reports on appetite, adaptability to noise, vibration, overstrain, and the ability to work and sleep.

Nikolayev reported none of the problems that Titov had experienced. For the first time on a Vostok mission, a cosmonaut was allowed to unstrap himself from his seat to float freely in the zero gravity inside the cabin. Air Force physician Yazdovskiy had warned Nikolayev that he may experience nausea and drowsiness on his sixth and seventh orbits.[19] Nikolayev felt none and completed the "floating" experiment without any problems, bolstering Korolev's idea to have the mission last three days. During the mission, Nikolayev also had specially prepared meals, which, for the first time, were not packed in tubes.

Soviet leader Khrushchev spoke to Nikolayev from the ground control station of Simferepol about four hours into the mission, visibly excited as Nikolayev smiled on TV from outer space. In a surprise move, on the spacecraft's seventh orbit, a little more than six hours after liftoff, Soviet TV broadcast the first live pictures of Nikolayev. Viewers were able to see the cosmonaut move his arms and head via the two cameras mounted in the cabin. In a politically motivated move, the U.S. embassy was handed a document during the early part of the mission stating: "The United States must refrain from carrying out any measures which could in any degree hinder the exploration of outer space for peaceful purposes or endanger the cosmonaut's life."[20] It was an implicit reference to Project Starfish a month earlier, which had raised the possibility of delaying the Vostok 3 mission. U.S. officials assured the Soviet government that there were no plans for such upper atmospheric explosions in the near future, wishing Nikolayev "a safe flight and a happy landing."

Except for minor communications problems with the ground, Nikolayev's first day in space ended without incident; he went to sleep at 2200 hours. After a seven-hour nap, he awoke refreshed, awaiting the dramatic events of the new day. Activity at Tyura-Tam had continued at a feverish pitch following Nikolayev's launch. The pad at site 1 was cleaned out, and a new 8K72K booster with a Vostok spacecraft was wheeled in for launch. Major Pavel R. Popovich was launched successfully at 1102 hours, 33 seconds Moscow Time on August 12 into a 179.8- by 236.7-kilometer orbit inclined at 64.95 degrees to the equator. His spacecraft was named Vostok 4 upon orbital insertion. It was the first time in the history of spaceflight that more than one piloted spacecraft, or indeed more than one human, had been in orbit. Vostok 3's ground track had passed directly over Tyura-Tam at the time, and ten minutes prior to Vostok 4's launch, Nikolayev had manually oriented his ship so as to observe the launch plumes on the ground. He

18. George Wukelic, ed., *Handbook of Soviet Space-Science Research* (New York: Gordon and Breach Science Publishers, 1968), pp. 54–55; Kenneth Gatland, *Manned Spacecraft* (New York: Macmillan, 1976), pp. 118–19; Kamanin, *Skrytiy kosmos: 1960–1963*, p. 147.

19. Riabchikov, *Russians in Space*, p. 187.

20. Shelton, *Soviet Space Exploration*, p. 138.

was, however, unable to see anything. The surprise of the second launch was without precedent. The press in the West was literally agog with the possibility that the two craft might link up in space. Western "experts" on the Soviet space program, such as the British astronomer Sir Bernard Lovell, helped dramatize the situation by pronouncements claiming that the flights of Vostok 3 and Vostok 4 were "the most remarkable development man has ever seen."[21]

Cosmonaut Pavel Popovich is shown in a still picture during his Vostok 4 mission in August 1962. (files of Asif Siddiqi)

The two spacecraft were in very similar orbits and reportedly passed each other as close as five kilometers on Vostok 4's first orbit. During a postflight conference, Popovich claimed that he actually managed to see the other ship in orbit as "something like a very small moon."[22] It seems, however, that neither cosmonaut ever spotted the other's spacecraft in orbit. Gradually, the distance between the two ships increased over the day to approximately 850 kilometers. The experiment was clearly a boon to Korolev's plans to use the 7K-9K-11K Soyuz complex for a circumlunar flight to the Moon because the latter mission required a precision of about twenty kilometers upon orbital insertion. Popovich and Nikolayev followed precisely synchronized schedules, dining and sleeping at the same time. In contrast to the reticent Nikolayev, Popovich was far more animated and jocular during his TV transmissions, showing viewers floating pencils and logbooks inside his cabin.

During the remainder of the missions, both cosmonauts performed modest physical exercises as well as sessions manually changing the attitude of their respective ships. The men also regularly communicated with each other, although there was some amount of static and noise that hindered fruitful exchanges during the early part of the missions. The cosmonauts ate four meals a day consisting of meat cutlets, roast veal, fillet of chicken, pastries, special sweets, miniature loaves, sausages, dragees, and chocolate. They also conducted extensive visual and photographic observations. Based on Titov's early experiments with movie-camera photography, both Nikolayev and Popovich used similar instruments. Nikolayev focused on imaging Earth's surface, while Popovich photographed Earth's horizon and terminator during several runs.[23]

Originally, the State Commission had approved Korolev's proposal that the Vostok 3 mission last three days while the Vostok 4 flight last two days. By the late hours of August 13, the night before their scheduled landing, most State Commission members were of the opinion that Nikolayev's flight could be prolonged to *four* days. Kamanin was once again the only major participant who resisted the proposal, raising some fairly serious issues. The temperature aboard the Vostok 3 ship had abruptly dropped from 27 to 13 degrees Centigrade on Nikolayev's twenty-ninth orbit. Although the temperature had remained static since then, Kamanin believed that the mission should be kept to its original three-day length to preclude negative effects on the cosmonaut's health. Because 13 degrees was still above the limit considered for aborting a mission, and given that all other systems aboard the ship were performing nominally, all the chief

21. *Ibid.*, p. 140; Kamanin, *Skrytiy kosmos: 1960–1963*, p. 149.

22. *Soviet Space Programs, 1962–65: Goals and Purposes, Achievements, Plans, and International Implications*, prepared for the Committee on Aeronautical and Space Sciences, U.S. Senate, 89th Cong., 2d sess. (Washington, DC: U.S. Government Printing Office, December 1966), pp. 536–39. Reports differ as to the closest approach, varying from five to six and a half kilometers.

23. Yu. P. Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya "Energiya" imeni S. P. Koroleva* (Korolev: RKK Energiya, named after S. P. Korolev, 1996), p. 116; Gatland, *Manned Spacecraft*, p. 120.

designers, including Korolev, Bogomolov, Kuznetsov, Alekseyev, and Pilyugin, voted to prolong the mission. In the end, Commission Chairman Smirnov had Gagarin personally ask Nikolayev's opinion on prolonging the mission. Although the brief communications session did not permit an informed decision on Nikolayev's part, he gladly agreed to the extension, saying that he felt "excellent."[24]

The State Commission finally decided to prolong the Vostok 3 mission to four days and the Vostok 4 flight to three days on the early morning of August 14, just hours prior to the originally scheduled return of both cosmonauts. Thus, if all went well, both men would land in the late morning of the following day within minutes of each other. During their last scheduled day in orbit, Nikolayev and Popovich conducted some more Earth observation sessions. Popovich carried out an experiment with a pressurized flask two-thirds full with water. If the flask was left undisturbed, he reported that all the air coalesced in the middle of the flask. Upon shaking the container, Popovich discovered that the air would scatter in hundreds of small bubbles, which eventually came together into a single large air bubble in the middle.[25] In an experiment to reproduce Titov's strange sensations, Nikolayev, on his fourth day in space, sharply turned his head from side to side repeatedly but felt no apparent discomfort. Popovich, on the other hand, experienced "some abnormalities," although it was nothing on the level of Titov's sickness.

On the night of August 14, Khrushchev and Kozlov telephoned Commission Chairman Smirnov and unexpectedly raised the issue of prolonging Popovich's flight another day to four days in the interest of not "offending" the cosmonaut. An unplanned meeting of the inner members of the State Commission—Smirnov, Korolev, Keldysh, Rudenko, Pilyugin, and Kamanin—was convened immediately to discuss the issue. Most of the members were in favor of extending Popovich's mission. Korolev himself was diplomatic:

> *The goals having been completely fulfilled, we have already extended Nikolayev's flight to four days, raising some risk. There's no reason to end Popovich's mission due to technical or medical reasons, but I do not see any great gains in prolonging his flight, although I will not vote against such a decision.*[26]

This time, not only Kamanin but also Gagarin, Bushuyev, Feoktistov and others opposed the proposal based on concerns about shifting landing zones as well as, incredibly, dropping temperatures in Vostok 4, which were down to eleven to twelve degrees Centigrade. This was just above the limit for safe conditions in the vehicle. Clearly under pressure to carry out the directives of Khrushchev and Kozlov, Smirnov did not want to give in and asked Korolev to put the question to Popovich. As one would expect, Popovich replied that he was ready to fly for four days. Smirnov, perhaps relieved, telephoned Khrushchev on the State Commission's decision to prolong the flight, adding that Kamanin, Gagarin, and others had opposed the recommendation.

All these plans fell to the wayside the following morning, August 15. During a regular meeting of the State Commission, controllers reported that the temperature on Vostok 4 was down to 10 degrees Centigrade, below safe levels, and the humidity had decreased to 35 percent. Popovich reported that he was feeling well when he woke up, but he added, "The temperature and humidity are continuing to drop, and I've tried all necessary measures but the decline is continuing."[27] It was clear to most ground controllers that by Vostok 4's forty-eighth orbit, the safety of life support was threatened. At that point, Kamanin, Keldysh, and Rudenko demanded

24. Kamanin, *Skrytiy kosmos: 1960–1963*, pp. 144–45.
25. Gatland, *Manned Spacecraft*, p. 120.
26. Kamanin, *Skrytiy kosmos: 1960–1963*, p. 152.
27. *Ibid.*, p. 153.

that Popovich be brought back on the next pass over Soviet territory, which as it turned out was the very next orbit, the originally planned time for landing. Smirnov continued to insist that the flight be continued. These arguments became somewhat academic when Popovich reported that he was "observing a thunderstorm." Before the flight, Popovich had agreed to use a series of coded phrases to communicate any abnormalities during the flight. "Observing a thunderstorm" meant that he was suffering severe motion sickness. Not surprisingly, Popovich's report caused great alarm on the ground, and controllers tried to confirm the report by asking how he was feeling. Popovich, realizing his error in terminology, replied, "I'm feeling excellent. I observed a *meteorological* thunderstorm and lightning."[28] Both Kamanin and Gagarin were skeptical of Popovich's second report, believing that the cosmonaut had overcompensated for his first call of distress, perhaps because of embarrassment. Controllers later discovered that Popovich had in fact been observing a real thunderstorm over the Gulf of Mexico and that he was feeling perfectly fine.

The "thunderstorm" issue sealed the matter of Popovich's landing on the forty-eighth orbit. Thus, both Vostok 3 and Vostok 4 fired their retrorockets within six minutes of each other in the late morning of August 15. Nikolayev landed by parachute after a three-day, twenty-two-hour, twenty-two-minute flight, during which he had circled Earth sixty-four times. Popovich landed 200 kilometers away from his comrade after a two-day, twenty-two-hour, fifty-seven-minute flight and forty-eight orbits.[29] It was a triumphant end to two missions that were, by all standards, spectacular achievements for the Soviet space program. Not only had ground services displayed the capability to rapidly launch piloted spacecraft in succession from the very same launch pad, but the entire ground tracking network had given an exemplary performance of its capabilities. Nikolayev, with his four-day mission, had also broken the previous world endurance record set by Titov a year before. By comparison, the longest U.S. piloted space mission at the time was a modest five hours. The cosmonauts themselves were recovered in good health, although cardiovascular responses did not return to normal until seven to ten days after landing. Both men's good physical state was a significant reassuring factor after Titov's performance had thrown doubt into the possibility of long-duration missions.

Nikolayev and Popovich, after their formal report to the State Commission on the evening of August 16, flew into Moscow two days later for a tumultuous reception at the Red Square hosted by Khrushchev, Kozlov, and others. In typical fashion, Soviet officials maximized the stunning effect of the dual-Vostok mission. At a press conference for the Moscow press on August 21 attended by both Nikolayev and Popovich, Academy of Sciences President Keldysh announced quite melodramatically:

> *The flights of Andrian Nikolayev and Pavel Popovich in the* Vostoks 3 *and* 4 *mark a new, notable stage on this road which brings us closer to the realization of interplanetary flights. The group flight of the spaceships is of great significance for the development of interplanetary stations, for the creation of spaceships and for the conquest of interplanetary routes.*[30]

28. *Ibid.*; Golovanov, *Korolev*, p. 686.

29. These times are for the landing of the cosmonaut. In the case of the descent apparatus of the two Vostok spacecraft, the times were three days, twenty-two hours, nine minutes, fifty-nine seconds for Vostok 3 and two days, twenty-two hours, forty-four minutes for Vostok 4. See Glushko, ed., *Kosmonavtika entsiklopediya*, p. 66.

30. *Soviet Space Programs, 1962–65*, p. 537. During the press conference, Popovich inadvertently stated in answer to a question that "Like Titov and Gagarin, I landed beside the ship," implying that Gagarin had parachuted out of the Vostok descent apparatus prior to landing. This was clearly contrary to the official position that Gagarin landed inside his ship. It is not clear whether Popovich was penalized for this "slip" from the official Party line.

Such statements, backed up by the lack of detailed information on the Vostok missions, helped foster a climate of awe about the Soviet space program; many Westerners believed that the Soviets could have docked the two spacecraft with each other. Korolev's First Deputy Chief Designer Mishin commented many years later on the building of myths:

> *The group flight . . . well, a day after launch, the first craft was over Baykonur. If the second craft were launched now with great precision, then they would turn out to be next to each other in space. And that's what was done. . . . The craft turned out to be 5 kilometers from each other! Well, since, with all the secrecy, we didn't tell the whole truth, the Western experts, who hadn't figured it out, thought that our Vostok was already equipped with orbital approach equipment. As they say, a sleight of hand isn't any kind of fraud. It was more like our competitors deceived themselves all by their lonesome. Of course, we didn't shatter their illusions.*[31]

Woman in Space

The program of flights in the Vostok program remained indistinct throughout the life of the project. Proposals would be floated—many of them rejected, some considered for months—and then they were eventually laid to the wayside. A major reason for such disarray was partly because of the military's cool attitude toward the missions, partly because of the fact that science played very little role in mission planning, but mostly because the Soviet leadership was not very interested in establishing a coordinated plan. One additional factor may have been Korolev's health. For years, he had been in poor shape, plagued by a variety of physical ailments exacerbated to a great degree by his overstretched schedule. Working eighteen hours a day straight for several weeks on end was not anathema to him; he was an incurable workaholic with the need to have his hand in the most trivial of matters in his giant organization. Soon after the Vostok 3/4 mission, he had been beset by intestinal bleeding, resulting in unbearable pain that had landed him in a hospital. After a long stay in the hospital, he was released on September 15 and was ordered to take a short vacation at the seaside resort of Sochi. True to his nature, he took his work there and spent hours on the phone or with visitors such as Kamanin and Yazdovskiy planning future Vostok missions.[32]

After the Nikolayev and Popovich missions, it was clear that the next Vostok mission would include a woman, but the clutter of proposals from various factions made pursuing a particular course of action impossible. Days after the successful Vostok 3/4 mission, Chairman of the State Committee for Defense Technology Leonid V. Smirnov, the "ministerial" head of the space program, was foreseeing a lone flight of a woman as early as late October 1962. Kamanin, on the other hand, believed that it would be more prudent to carry out the flight in March–April 1963 as part of a joint flight with men on one or two other spacecraft. The men would perform seven- to eight-day missions, while the woman would be in space for two to three days.[33] Given the delays associated with previous missions, the March–April 1963 date proved to be much more realistic, although, by November, it was still not clear whether the female mission would be a solo or a group flight.

The women themselves engaged in intensive training throughout 1962. The program included time in centrifuges being subjected to loads as high as ten g's, weightlessness training in Tu-104 aircraft, regular physical exercises, flight training in MiG-15UTI trainers, water

31. G. Salakhutdinov, "Once More About Space" (English title), *Ogonek* 34 (August 18–25, 1990): 4–5.
32. Riabchikov, *Russians in Space*, pp. 198–99; Golovanov, *Korolev*, p. 772.
33. Kamanin, *Skrytiy kosmos: 1960–1963*, p. 158.

survival techniques, and theoretical studies on astronomy, astronautics, and the Vostok spacecraft itself. They also performed between seventy to eighty parachute jumps from Il-14 aircraft to master the landing phase of a Vostok mission. To a great extent, the women's training was marked by different motivations than the earlier training of the men. While the men could count on later missions if passed over at first, no such luxury was afforded the women. Only one woman out of the five would make it into space, the rest most likely being consigned to a footnote in history. This singular fact was not lost upon the women themselves, and it characterized their interpersonal relationships with an unusual sense of competitiveness rather than any sense of unity.[34]

At the end of the training program, the youngest of the lot, twenty-one-year-old Kuznetsova, dropped out of the running, having performed poorly in the pressure chamber and the centrifuge. Ponomareva, the only scientist in the group, was a clear favorite based on her excellent health and theoretical performance. However, given the peculiar combination of sexism and political standards that was propagated by Kamanin, she was deemed to have "unsteady" morals. She was very independent, self-assured, and probably much more accomplished than some of the men—that is, completely unacceptable in Kamanin's mind. The other contender for first place, Tereshkova, on the other hand, was reticent, modest, and "a model of good breeding."[35]

In late November 1962, four of the five women took their final exams; Kuznetsova was absent at the time because of poor health. The remaining four all received excellent grades and were awarded the military rank of junior lieutenant and were formally inducted as Air Force cosmonauts. Kamanin summarized their strengths and weaknesses in his journal on November 29:

> *Ponomareva has the most thorough theoretical preparation and is more talented than the others—she exceeds all the rest in flight—but she needs a lot of reform. She is arrogant, self-centered, exaggerates her abilities and does not stay away from drinking, smoking and taking walks (although she has a husband and four-year old son). Solovyeva is the most objective of all, more physically and morally sturdy, but she is a little closed off and is insufficiently active in social work. Tereshkova—she is active in society, is especially well in appearance, makes use of her great authority among everyone who she knows. Yerkina has prepared less than well in technical and physical qualities, but she is persistently improving and undoubtedly she will be a rather good cosmonaut. We must first send Tereshkova into space flight, and her double will be Solovyeva. . . . Tereshkova, she is a Gagarin in a skirt.*[36]

Although the four women were ready for their flight, there was still much uncertainty about the mission. There was still no clear consensus on whether it would be a joint mission with a second Vostok, and if so, whether the second spacecraft would carry a man or a woman. There were also purely technical issues: Plant No. 918 had run into serious problems in designing a pressure suit specifically for women. As with many other flights, the Soviet Party and government proved unable or perhaps uninterested in setting a specific timetable by which all its subordinate organizations could work. The two spacecraft for the proposed women's missions had already been manufactured and almost ready for flight by mid-1962, but the lack of action from the Military-Industrial Commission and the Central Committee kept them on the ground for another year.

34. Golovanov, *Korolev*, p. 691; Facktor and Ponomareva, "Women in the Early Soviet Spaceflight Program."
35. Kamanin, *Skrytiy kosmos: 1960–1963*, p. 182.
36. *Ibid.*, pp. 187–88.

The options available for the women's flights were discussed at a meeting at OKB-1 in mid-January 1963. Three options were given serious consideration for the flight, then set for April–May:

- A single flight of a woman on a Vostok ship lasting one to three days
- A group flight of two ships with women, one launched a day after the other, and both landing on the same day
- A group flight with one ship carrying a man for five to seven days and one ship carrying a woman for three days

The Air Force seemed to be leaning toward a group flight of two women, but these plans were thrown into flux by opposing institutional viewpoints. For example, at one point in late January, State Committee for Defense Technology Chairman Smirnov had expressed the opinion that only one spacecraft (3KA no. 7) be used for the women's flight, while the second one (3KA no. 8) be consigned as a museum piece. The implication was clearly that the female flight would be limited to a single ship and not a joint mission.[37]

Apart from OKB-1, the primary motivator in supporting the Vostok program was the Air Force. Having been completely kept out of the entire missile business by the armaments people in the Strategic Missile Forces, the Air Force, as the overseer of the cosmonauts, was taking steps to vigorously support piloted space activities. While it may have been purely an interservice rivalry issue, the lobbying did produce results. Top Air Force leaders, including Commander-in-Chief Vershinin, were able to convince Ustinov and Smirnov of not sending a perfectly good spacecraft sent to a museum. On March 18, several leading Air Force generals along with Korolev met with Secretary of the Central Committee for Defense and Space Frol R. Kozlov. On the question of the female mission, Kozlov asked many questions, some pointed (Why is this necessary?) and some simply ignorant (Who among you is deciding to prepare the women?). It seems that the combined effort did produce results. On March 21, the Central Committee formally decided to move ahead with a group flight with one woman and one man, thus quashing any plans for a double-woman mission. The flight was tentatively set for "no earlier than" August 1963. OKB-1 also received formal approval to manufacture four additional Vostok spacecraft by the end of 1963.[38] Thus, a whole seven months following the Nikolayev-Popovich flight, the Soviet leadership finally committed itself to the next Soviet piloted space mission.

There was some adjustment to this plan when Korolev's engineers discovered that the design lifetime of both the slated spacecraft was to expire in May–June 1963, well before the August deadline. Korolev had asked his men to explore the possibility of extending "the shelf life" of the vehicles, but he was informed that this would not be possible. Thus, OKB-1 was put in a bind: either launch the two spacecraft by June 15 or throw them out. The revised plan was passed up to the Military-Industrial Commission and the Central Committee. The latter, on April 29, formally approved carrying out the group flight earlier, in May–June of 1963. The first spaceship would carry a man into orbit for a full eight days, while the second would carry the first woman into space for two to three days.

Cosmonauts Bykovskiy, Khrunov, Leonov, and Volynov were the four candidates for the male seat. Of the four, Bykovskiy and Volynov had been sporadically training for the possibility of such a mission since September 1962, but dedicated preparation for the joint flight did not begin until mid-April 1963, just two months before the planned launch. Such an unusually short preparation period, impossible in the case of NASA astronauts, was possible in the

37. *Ibid.*, pp. 208, 216–17, 223–24.
38. *Ibid.*, pp. 238–39, 240.

Soviet Union because cosmonauts in training groups were in a continuous state of preparation for months prior to being assigned a particular flight. Through the month of May, the four went through an accelerated and compressed training program involving more parachute jumps, three- to four-daylong ground simulations, and tests on the centrifuge. Air Force officials expected that Bykovskiy and Volynov, the best trained of the four, would be ready for launch by May 30, while Khrunov and Leonov would be ready by June 15, just in time to make the mission.[39] In a very telling comment in his journal, Kamanin wrote:

> *Because of the squabbling between various departments, we make very poor use of our technical capabilities, hastily preparing flight programs, and doing a lot of other stupid things. A space mission, or to be more exact, its preparation should begin with giving the crew a flight program, but we are doing exactly the opposite: we first prepare the ships and their equipment and then tailor the crew's flight program to the ship's configuration and equipment.*[40]

The flight program of the ensuing two missions was very similar to the Vostok 3/4 flight a year before. The length of seven to eight days for the first mission necessitated some changes in timing: the only requirement was that the two spacecraft fly in space at the same time for at least one to two days. None of the earlier Vostok missions had included any serious scientific experiments, and it seems the scientific community had taken steps to include some observational research on the new mission. On May 17, 1963, Academy of Sciences President Keldysh submitted a formal document to the Council of Ministers suggesting experiments on the next Vostok missions. These dealt with the study of the brightness of Earth's atmosphere system, especially the horizon, the structure of the clouds, the light regime, and the transparency of the atmosphere by means of black-and-white and color photography with subsequent photometric observations. A program of research that included these experiments was apparently prepared for the next dual-Vostok flight, although it is not clear whether all the instrumentation was actually carried into orbit.[41]

The first meeting of the State Commission for Vostok took place on May 10. Presiding was a new commission chairman, forty-eight-year-old Artillery Lt. General Georgiy A. Tyulin, at the time the First Deputy Chairman of the State Committee for Defense Technology. His career with the missile had begun in 1944 when, as a young lieutenant colonel, he had been tasked to study captured portions of the German A-4 missile. A close friend of Korolev's, Tyulin had petitioned several times to be transferred to OKB-1 as an engineer, but these requests had been denied because his expertise was needed elsewhere. After the year in Germany in 1945–46, he had ended up at the military research and development NII-4 organization directing the development of ground tracking stations for the R-7 ICBM and later sea-based tracking for space satellites. In August 1959, Tyulin was tapped to become director of the famous NII-88, the former "overseer" institute of Korolev's OKB-1. Within two years, both Ustinov and Korolev strongly supported Tyulin's nomination to enter the State Committee for Defense Technology, the "ministry" responsible for the space program. Tyulin, more committed to scientific and engineering research, was reluctant to leave his job at NII-88, but he agreed in June 1961 to

39. *Ibid.*, p. 258. Cosmonaut Komarov was also briefly considered for the mission from early February to May 9, when he was dropped because of health problems.

40. *Ibid.*, p. 261; Hendrickx, "The Kamanin Diaries 1960–1963."

41. The Academy of Sciences document has been published as M. V. Keldysh, "On A Program of Observation in the Launches of the '*Vostok*' Spaceship" (English title), in Avduyevskiy and Eneyev, eds., *M. V. Keldysh: izbrannyye trudy*, p. 477. An instrument for the study of luminescence in the upper atmosphere was also proposed for the mission, although Keldysh states in his letter that there would be some difficulty in placing the instrument in the Vostok capsule.

become the committee's First Deputy Chairman. Tyulin stayed with his new job, clearly gaining a foothold in the top levels of the space industry.[42] One of the most overlooked characters in the tapestry of the Soviet space program, he was also one of the most ubiquitous.

Traditionally, the position of chairman of the *ad hoc* State Commission for Vostok was held by an individual with a "ministerial" rank; the appointment of Tyulin, who had a rank of first deputy "minister," was unexpected. Clearly, the Communist Party no longer viewed the project as sufficiently important as before. Under Tyulin's supervision, the State Commission met on May 10 to discuss preparations for the flight. In attendance were all the principal participants preparing the woman flight, including both Korolev and Glushko. This was at the zenith of their fight over the N1 propellants, and it is surprising that the two of them actually managed to sit in the same room and discuss a neutral project. Also present were several Strategic Missile Forces and Air Force officers, chief designers, scientists from the Academy of Sciences, veteran cosmonauts, and Air Force physicians.[43] The relevant chief designers reported that both spacecraft slated for the flight had been tested and all defective instruments replaced. Korolev in particular complained of the poor quality of the workmanship of a particular plant, which had produced twenty-eight defective parts.

After the formal meeting, a smaller group provisionally agreed to set the two launches for June 3–5. The preliminary choice for the first mission was Bykovskiy, more than likely because he was the lightest of the men competing for the position; the Vostok spacecraft was already pushing the limit of the launch vehicle's capabilities with a variety of modifications. The decision on the woman was a little more difficult. A year before, when the five women had come to Tyura-Tam to see the launches of Vostok 3 and Vostok 4, Korolev had clearly been pleased with Tereshkova and had even confided this to then-Director of the Cosmonaut Training Center Col. Yevgeniy A. Karpov. Before the weeks leading to launch, however, two clear factions had emerged in picking a single woman. On one side, Korolev, Karpov, Kamanin, and parachute training instructor Nikolay K. Nikitin strongly supported Tereshkova's candidacy. There were, however, powerful forces behind the clearly well-qualified Ponomareva: Institute of Aviation and Space Medicine Director Lt. General Yuvenaliy M. Volynkin; leading space medicine specialist Vladimir I. Yazdovskiy, of the same institute; Academician Aleksandr Yu. Ishlinskiy, one of the most influential scientists in the space program; and, most important of all, Academy of Sciences President Keldysh. Gagarin, a powerful member of the State Commission, at first did not have an opinion on the issue, but on being pressured insistently by Keldysh, he "rebelled" against Keldysh and sided against Ponomareva. At the meeting on May 10, the vote on Tereshkova versus Ponomareva was split again, but the tide began to turn against Ponomareva soon. During a visit to the Cosmonaut Training Center on May 21 by Keldysh, Korolev, Mrykin, Rudenko, and others, Bykovskiy and Tereshkova were named the primary crewmembers of the two missions. According to former Cosmonaut Training Center Director Karpov, if Keldysh and physician Yazdovskiy had not been lobbying so intensely for Ponomareva, she would have been the first woman in space. At one point during his visit to the center, Korolev asked Ponomareva why she looked so sad. She simply answered, "I am not sad, I'm simply serious, as always."[44]

42. Col. M. Rebrov, "Where the Cranes Fly" (English title), *Krasnaya zvezda*, September 19, 1987, pp. 3–4; Yu. A. Mozzhorin, "The Central Scientific-Research Institute of Machine Building—The Main Center in the Soviet Rocket-Space Industry" (English title), *Iz istorii aviatsii i kosmonavtiki* 60 (1990): 20–40; Yu. A. Mozzhorin, *et al.*, eds., *Dorogi v kosmos: I* (Moscow: MAI, 1992), p. 168.

43. Among those present were G. A. Tyulin (GKOT), G. N. Pashkov (VPK), S. P. Korolev (OKB-1), V. P. Glushko (OKB-456), V. P. Barmin (GSKB SpetsMash), A. Yu. Ishlinskiy (NII-944), G. A. Skuridin (AN SSSR), A. G. Mrykin (GURVO), K. A. Kerimov (GURVO), S. M. Alekseyev (Plant No. 918), G. I. Voronin (OKB-124), N. P. Kamanin (VVS), A. I. Kutasin (VVS), Yu. M. Volynkin (IAKM), L. I. Goreglyad (VVS), M. I. Odintsov (TsPK), V. I. Yazdovskiy (IAKM), Ye. A. Karpov (TsPK), Yu. A. Gagarin (TsPK), and V. A. Smirnov (VVS).

44. Kamanin, *Skrytiy kosmos: 1960–1963*, pp. 261, 266; Golovanov, *Korolev*, p. 691; Facktor and Ponomareva, "Women in the Early Soviet Spaceflight Program."

On May 27, the members of the State Commission flew into Tyura-Tam to oversee the launch preparations for the two 8K72K boosters and their respective payloads. Various chief designers identified a number of significant failures during a meeting on May 31, including problems with communications and TV systems, which prompted some heated exchanges. Tyulin delayed the launches to June 7–10 to eliminate all the anomalies. The cosmonauts, primary members Bykovskiy and Tereshkova, as well as backups Volynov, Solovyeva, and Ponomareva, arrived from Moscow the following day with about thirty other prominent space program leaders. The complete State Commission for Vostok assembled on the morning of June 4 to discuss and finalize preparations for the historic missions. All systems were declared ready for launch, although the possibility of launching on June 7 was put in doubt by the chance of high winds at the launch site. A "ceremonial" version of the State Commission meeting was later held for the benefit of a small group of Soviet journalists who were flown into Tyura-Tam. Kamanin officially nominated Bykovskiy for the eight-day flight of the first spacecraft, Vostok 5. His backup would be Volynov. Cosmonaut Tereshkova was nominated for the second mission, which would last between one and three days, based on the state of the cosmonaut and her spacecraft, Vostok 6. Solovyeva and Ponomareva would serve as backups for Tereshkova.[45]

Once again, so as to fool the Western tracking stations that would monitor voice communications, the State Commission drew up a short list of coded messages the cosmonauts could send to the ground. "Feeling excellent, the ship's equipment is working excellently" would imply that there were no problems and that flight should continue. In place of "Feeling excellent," "Feeling well" would indicate that the cosmonaut had doubts about being able to fulfill the flight; "Feeling satisfactory" would mean that the flight had to be terminated immediately. The launch, set for June 8, had to be delayed by three to four days when a major problem with the remote radio command system arose. This and other malfunctions in the guidance and communications systems were the subject of a long State Commission meeting on June 7, during which the institute chief responsible for the offending radio system, Chief Designer Armen S. Mnatsakanyan of NII-648, explained that the failure in the system had occurred because of a single failed triode, a product of poor workmanship at the production plant.[46] The first launch with Bykovskiy was rescheduled for June 11. Tereshkova would follow into orbit two days later. An alternate variant was for Tereshkova to launch into space five days after Bykovskiy. Thus, the two could return to Earth together after Bykovskiy's eight days in space.

The delay proved to be only the first of many. On the night of June 10, Academy of Sciences President Keldysh, back in Moscow, sent a message to the State Commission in Tyura-Tam that solar activity had sharply increased, significantly raising radiation levels in the upper atmosphere. The commission decided to postpone the launch again. On the night of June 11, the solar activity issue was discussed in depth: a solar storm had evidently broken out on June 8 and was expected to last between five and perhaps up to eight days. Astronomers predicted a possible peak the very next day. The launch was postponed again to June 14–15 at the earliest.

Continually delaying the flight contributed to increased tensions at the launch site. Korolev had been seriously ill in recent weeks. He had a fever for several days and was diagnosed with inflamed lungs. He looked "pale and wane" to everyone, his voice hoarse from talking.[47] The stress on not only Korolev but also the other chief designers reached a breaking point on June 14, the day of the launch. At a last-minute, early-morning meeting of the State Commission, the members recommended a launch at 0900 hours Moscow Time, based on reduced solar activity. Trouble began soon after Bykovskiy arrived at the pad and was helped

45. Kamanin, *Skrytiy kosmos: 1960–1963*, pp. 268, 274, 276–78.

46. *Ibid.*, p. 282.

47. Pavel Popovich and Alexander Nemov, "Galactic Secrets," in V. Mitroshenkov, ed., *Pioneers of Space* (Moscow: Progress Publishers, 1989), p. 206.

Chief Designer Viktor Kuznetsov was responsible for the design of the gyroscope instrumentation for Soviet missiles, launch vehicles, and spacecraft. He was one of the six original members of the Council of Chief Designers. By the 1960s, his organization, NII-944, had become the Scientific-Research Institute of Applied Mechanics. (files of Peter Gorin)

into the ship. Controllers reported that both of the ultra-shortwave transmitters on the Vostok ship were not functional. After a brief meeting, they decided to continue with the countdown and rely only on the short-wave transmitters for the mission. A little later, a pin stuck in the ejection hatch forced a thirty-minute delay. Finally, at T–5 minutes, the indicator light on the control panel for the Blok Ye third stage of the booster refused to light up. The problem was traced to a failure in the gyroscope-instrumentation unit on the stage. Korolev's first response was to yell, "Where the hell's Kuznetsov?!"[48]

Chief Designer Viktor I. Kuznetsov of NII-944, one of the original members of the Council of Chief Designers, was ultimately responsible for all gyroscopes on Soviet space launch vehicles. Perhaps the least well-known member of the council, he was originally a naval engineer. In the late 1930s, he had designed fire control stabilizers for the famous *Kirov* and *Maksim Gorky* cruisers in the late 1930s. In October 1940, Kuznetsov had been assigned to Germany during the brief period of the Stalin-Hitler pact. Once the Nazis attacked the Soviet Union, Kuznetsov suffered through a dramatic trip out of Germany into Turkey and finally back to the Soviet Union. After the war, he reluctantly joined the inspection teams into Germany, where he met Korolev, Glushko, and other soon-to-be chief designers. Kuznetsov told his associates, "Somewhere, they are producing new ships, while I must mess around with the fascist [V-2]."[49] In 1946, Special Committee No. 2 appointed him chief designer of NII-10, with the responsibility to create all gyroscope systems for Soviet long-range ballistic missiles. The tall, lanky chief designer was one of several men who had been spared a gory death during the R-16 disaster in October 1960 because of their need to smoke last-minute cigarettes. After the accident, he had headed the technical commission investigating the disaster when he came into conflict with the "total incompetence" of Soviet leaders. Kuznetsov remembers:

> *Brezhnev did not delve into the situation. He sat in his hotel room in his pajamas and constantly reminded [Kuznetsov]: "Moscow is waiting for the report. Don't dawdle over the details, just a few general conclusions—that is all. . . ."*[50]

Unlike the other members of the council, Kuznetsov was unusually reticent and quiet. Dressed perpetually in his leather jacket, he would always sit to one side of the room, rarely ever taking part in discussions during meetings of the State Commission.[51] At the time of the Vostok 5 launch, Kuznetsov was fifty years old.

With tempers flaring, Korolev and Kuznetsov began heatedly arguing in front of their colleagues about the failure, which had potentially devastating consequences. If Kuznetsov's

48. Golovanov, *Korolev*, p. 694; Yu. A. Skopinskiy, "State Acceptance of the Space Program: Thirty Years of Work: From the History of Science" (English title), *Zemlya i vselennaya* no. 5 (September–October 1988): 73–79; Kamanin, *Skrytiy kosmos: 1960–1963*, pp. 286, 288-289.

49. Col. M. Rebrov, "The Seven Faces of Fate: Pages From the Life of the Chief Designer of Rocket-Space Command Instruments" (English title), *Krasnaya zvezda*, January 7, 1989, p. 4.

50. *Ibid.*

51. Golovanov, *Korolev*, pp. 698–99.

engineers did not fix the failure within six hours, then the launch would have to be postponed for another day because of poor weather conditions during the landing opportunities for later launch windows. And if the launch was postponed, the 8K72K booster would have to be unfueled, taken back to the Assembly-Testing Building, and disassembled. In that case, the launch would have to be delayed to August. By August, the lifetime of the two Vostok spacecraft would have expired. Korolev and Kuznetsov thus had hours to make a decision that could potentially derail the piloted space program for another year. One of Kuznetsov's deputies finally reported that his engineers could replace the offending unit with a new one within two to three hours. Kuznetsov, in consultation with Pilyugin and Ryazanskiy, decided to go with the plan. State Commission Chairman Tyulin opted to keep Bykovskiy in his capsule through this period as the repairs dragged on to a full six hours.[52]

As the final minutes clocked down to liftoff, the hopes for a successful launch seemed to be abruptly thwarted by indications in the ground bunker that the booster had not disengaged the cable connecting itself to the external power sources that fed the rocket during the entire countdown. With the seconds ticking away to launch, Korolev, Voskresenskiy, and Strategic Missile Forces launch operations chief Kirillov looked at each other in a moment of panic. In the handful of seconds remaining, they unanimously decided to launch. Although the launcher was still plugged into the ground supply, power had evidently switched to on-board systems. At ignition, the cable simply tore off its sockets and fell to the wayside.[53]

Unaware of the drama, twenty-eight-year-old Major Valeriy F. Bykovskiy lifted off in his Vostok 5 spacecraft at 1458 hours, 58 seconds Moscow Time. His initial orbital parameters were 174.7 by 222.1 kilometers at 64.96 degrees inclination to the equator. The orbit achieved was slightly lower than anticipated, evidently because of the less-than-nominal performance by the third stage of the launch vehicle. Instead of the standard ten-day lifetime predicted for the other Vostok missions, Bykovskiy was given about eight days in space prior to natural decay. To maintain adequate safety margins, it was clear that Bykovskiy would not be able to stay in orbit for the seven to eight days originally planned. To the joy of ground controllers, the ultra–short-wave transmitters came back on line soon after orbital insertion. Bykovskiy was also able to observe the upper stage of the 8K72K booster moving away from him after orbital insertion. Soviet leader Khrushchev spoke to Bykovskiy, on a then-standard exchange of messages, on the fourth orbit. During his first two days, Bykovskiy carried out the usual flight program perfected over the previous Vostok missions, including checking and reporting on spacecraft parameters and his own health and conducting Earth observations. During one orbit, he tested the manual orientation system, finding that the pressure in the nitrogen bottles had reduced to ten atmospheres pressure. Because at least five atmospheres was required in case of manual orienting for reentry, Bykovskiy put the spacecraft in a thermal roll mode at one revolution per eight minutes. Later on his eighteenth orbit, he removed himself from his restraining straps and floated about in the relatively spacious capsule. TV transmissions continued to send down an endless stream of video of Bykovskiy's antics.[54]

Through the first two days he spent alone in orbit, as part of his Earth observations program, Bykovskiy used a special movie camera to take black-and-white pictures of the horizon, the Moon, and Earth. Unfortunately, one of the film cartridges remained stuck in his camera; he found another cassette to be empty of film! One of the few scientific experiments included noting the growth of peas and observing the behavior of liquids in microgravity. The rest of his

52. Skopinskiy, "State Acceptance of the Space Program"; Kamanin, *Skrytiy kosmos: 1960–1963*, p. 289; Lt. Gen. Georgy Aleksandrovich Tyulin, "Task For the Future: Notes of the State Commission Chairman" (English title), *Krasnaya zvezda*, April 3, 1988, p. 4.

53. Golovanov, *Korolev*, p. 699.

54. Riabchikov, *Russians in Space*, pp. 200–01; Kamanin, *Skrytiy kosmos: 1960–1963*, p. 298.

Here are three women cosmonauts at Tyura-Tam prior to the launch of Vostok 6. Left to right are Valentina Ponomareva, backup Irina Solovyeva, and prime crewmember Valentina Tereshkova. Behind the women are State Commission Chairman Georgiy Tyulin (left) and Strategic Missile Forces Commander-in-Chief Sergey Biryuzov. (files of Asif Siddiqi)

time was divided between physiological research or more Earth observation. The former program included modest calisthenics and noting the change of his vision in orbit with special binoculars (which he found difficult to use). As part of the latter program, Bykovskiy used optical instruments with special light filters to observe Earth and Sun's corona (which he was unable to see). As with the previous Vostok missions, a large complement of biological specimens accompanied Bykovskiy; these included cancer cells, amnion and fibroblast cells, frog ova and sperm, *drosophila* insects, plants, air dried seeds, chlorella algae, and bacteria.[55]

As Bykovskiy finished up his second day in space, back on the ground, Tereshkova was preparing for her moment of fame. Late on June 15, a final meeting of the technical group of the State Commission had taken place; Tereshkova's launch was set for 1230 hours Moscow Time the following day. Earlier, Commission Chairman Tyulin had received a message from Moscow announcing that in Tereshkova's launch communiqué, TASS would announce that she was a civilian and not a military officer. By this time, only Tereshkova and Solovyeva were involved in actually preparing for the mission; third trainee Ponomareva was consigned to ground support functions. On the day of the launch, Tereshkova arrived at the pad in the late morning and was greeted by Korolev, Tyulin, and other members of the State Commission. This time, the prelaunch preparations were far more uneventful. Jr. Lieutenant Valentina V. Tereshkova, twenty-six, lifted off at 1229 hours, 52 seconds Moscow Time on June 16 in her Vostok 6 spacecraft. Within minutes, she had successfully entered orbit, thus becoming the first woman in space. Her initial orbital parameters were 180.9 by 231.1 kilometers at a 64.95-degree inclination to the equator. The orbit of Vostok 6 was in an orbital plane about thirty degrees apart from that of Vostok 5, in contrast to the Vostok 3/4 combination when the second vehicle had been launched as the first was directly over Tyura-Tam. Because of the slightly different mission profile, the two new vehicles only approached each other twice for a few minutes every orbit.[56]

Throughout the world, Soviet news services poured forth a plethora of rhetoric linking the flight to the inevitable progress of socialism. While there were some Westerners who correctly identified the flight as an exercise in pure propaganda, most were further cowed by the breadth and ambition of the Soviet space program. As Kamanin had predicted two years before, the flight was a brilliant political success all over the world.

Vostok 5 and Vostok 6 flew closest to each other immediately after launch, when they passed each other at a range of about five kilometers. Bykovskiy later reported that he had not

55. Wukelic, ed., *Handbook of Soviet Space-Science Research*, pp. 346–48; Kamanin, *Skrytiy kosmos: 1960–1963*, pp. 298–99.

56. Phillip J. Klass, "Vostok 5 May Have Separated Too Early," *Aviation Week & Space Technology*, June 24, 1963, pp. 34–35.

spotted Vostok 6, while Tereshkova thought she might have glimpsed Vostok 5. Like Bykovskiy, she did, however, view the third stage of the booster rocket. The two cosmonauts established communications contact with each other by 1300 hours, and within three hours, Moscow TV was showing live shots of Tereshkova in her capsule. It seems that Tereshkova may have briefly suffered from the same affliction that marred Titov's flight two years before. The Soviets later reported that she:

> *was not feeling so well on the first few orbits. The commission was even discussing the possibility of ending the flight of Vostok-6 ahead of schedule. [Tyulin] talked it over with Tereshkova by radio. She asked that the flight not be interrupted, said that she already felt better (that was later verified with the telemetry data), and assured the State Commission that she would carry out "everything that the program called for" and would do "everything as we were taught."*[57]

On the morning of June 17, the technical group of the State Commission decided to curtail Bykovskiy's mission down to five to six days because of his lower-than-nominal orbit. Unless there was an emergency, Tereshkova's flight would last the complete three days. Both cosmonauts reported feeling excellent through the day; communications between the two vehicles were maintained only in the first part of the day, apparently the last communications the two had during the remainder of the mission. On the morning of June 18, the State Commission finally decided on landing times for both cosmonauts: Bykovskiy would return on his eighty-second orbit at the end of his fifth day, with Tereshkova coming back on her forty-ninth orbit at the end of her third day. The former would set an absolute world endurance record, far surpassing the longest U.S. piloted space mission of the time.[58] Tereshkova continued to report that she felt excellent, but TV transmissions on June 18 showed her tired and looking a little weak. Ground controllers were very disappointed when Tereshkova failed to perform one of the major goals of her mission: manual orientation of her spacecraft. For reasons that are unclear, it seems that she had attempted to use the attitude control system but was unable to do so. This caused much anxiety on the ground because if the automatic system failed during reentry, Tereshkova would have to orient the ship manually.

Kamanin ordered Gagarin, Titov, Nikolayev, and OKB-1 Department Chief Raushenbakh to send up instructions to Tereshkova on manual orientation. On the morning of June 19, on her forty-fifth orbit, Tereshkova successfully carried out a twenty-minute experiment in manual orientation, keeping her vehicle in the correct attitude for reentry for a full fifteen minutes. Korolev and the other members of the State Commission were somewhat reassured by her performance, mitigating concern that she might not be able to orient the craft manually if needed for reentry.[59] Bykovskiy raised somewhat of a scare a day earlier when he transmitted a message to the Khabarovsk ground station on short wave that "At 9 hours 5 minutes there was the first space knock."[60] This report was immediately passed on to Korolev and Tyulin, and there was lively

57. Skopinskiy, "State Acceptance of the Space Program," p. 76.

58. This was L. Gordon Cooper's Mercury Atlas 9 mission in May 1963, which had lasted one day, ten hours, and twenty minutes.

59. There is still some confusion about Tereshkova's manual orientation exercises in orbit. Some otherwise reliable sources suggest that she never completed any of these tests. See Golovanov, *Korolev*, pp. 700–01; B. Ye. Chertok, *Rakety i lyudi: goryachiye dni kholodnoy voyny* (Moscow: Mashinostroyeniye, 1997), pp. 235–38. On the other hand, N. P. Kamanin, in his personal diaries from the time of the mission, suggests otherwise. See Kamanin, *Skrytiy kosmos: 1960–1963*, p. 295.

60. Chertok, *Rakety i lyudi*, p. 236; Kamanin, *Skrytiy kosmos: 1960–1963*, p. 295; Gatland, *Manned Spacecraft*, pp. 122–23.

speculation on everything from meteor strikes to extraterrestrials. Soon, when ground control directly asked Bykovskiy about the incident, he replied that what he had said was that "there had been the first space stool," the Russian word for "stool" (*stul*) being mistaken for the word for "knock"" (*stuk*). Either way, it was a historic moment because it was the first time a human had had a bowel movement in space, another dubious first for the Soviet space program.

The postflight reports by both cosmonauts were illuminating. Bykovskiy commented that he excitedly looked forward to the scheduled periods when he would float unstrapped inside his ship (which he did on the eighteenth, thirty-fourth, fiftieth, and sixty-sixth orbits). On one occasion, he floated for an entire orbit, although he found it difficult to orient himself when his eyes were closed. He also had some comments about instrument placement inside the Vostok cabin, suggesting that although the switches were accessible, the indicators were hard to read. In addition, the food rations were placed in a difficult position to access, and the medicine cabinet was simply too far to reach without unfastening himself. His helmet also apparently weighed him down. Problems with the waste management system also cropped up during the last portion of his time in space. Despite these minor inconveniences, he claimed that he felt excellent throughout the mission.

Tereshkova was more candid in *her* postflight report:

> *I took movie films of cities, clouds, and the Moon . . . removing the film [from the camera] was very difficult. I didn't conduct any biological experiments—I was not able to reach the objects. The dosimeter remained at zero. The sanitary napkins moistened very poorly and were too small. It's necessary to have something to clean teeth. I carried out observations with light-filters. The horizon was luminous over the poles. Over South America I observed a storm. At night the cities were defined very sharply. The Moon illuminated the Earth and the clouds very beautifully. It was difficult to determine the constellations. I didn't observe the solar corona.*[61]

She was very forthright about the conditions in the vehicle and the difficulties she had faced:

> *On the first day I didn't feel the spacesuit. On the second day there was a nagging pain on my right knee and by the third day it had begun to worry me. The helmet bothered me pressing against my shoulder . . . [it also] pressed against my left ear. The sensor belt [around my head] did not disturb me. [However] the sensors themselves gave me itches and headaches.*[62]

These experiences were more than likely a comment about the poor level of comfort afforded by the Vostok spacesuit than any bad experiences on Tereshkova's part. Throughout her reports from orbit and in her postflight report, she emphasized that she had felt well during her mission:

> *Weightlessness did not arouse any unpleasant sensations. . . . The bread was dry and so I didn't eat it. The juice and the cutlet were pleasing. I threw up once but this was due to the food, and not to any vestibular disorder.*[63]

61. Kamanin, *Skrytiy kosmos: 1960–1963*, p. 300.
62. *Ibid.*, pp. 300–01.
63. *Ibid.*, p. 301.

The order for firing the reentry engine on Vostok 6 was sent at 0939 hours, 40 seconds Moscow Time on June 19. Tension was high at the control center at NII-4 near Moscow because Tereshkova had not reported on the proper work of the solar orientation system. In fact, for some inexplicable reason, she remained silent throughout the reentry, not reporting on the retrofiring or the separation of her spacecraft modules. She safely ejected from her capsule at six and a half kilometers altitude, but while she was parachuting down, in violation of the training procedures, she had looked up to the side of the parachute canopy at the upper line of the pressure suit's helmet, when a piece of metal hit her straight on the nose.[64] She touched down without further incident after a two-day, twenty-two-hour, fifty-minute mission about 620 kilometers northeast of the town of Karaganda in Kazakhstan. Bykovskiy's reentry was more eventful. As with Gagarin and Titov, his instrument compartment failed to separate on time from the spherical descent apparatus prior to reentry into the atmosphere. He recalled later that the separation was "disorderly," but the problem seems not have perturbed him too much. He landed after a record-breaking four-day, twenty-three-hour, six-minute mission about three hours after Tereshkova and 800 kilometers away.[65]

Tereshkova's health during her mission has been the subject of much speculation for many years, with the more sensationalist stories suggesting she was completely sick when she landed.[66] There were clearly two factors that played against her: she was unable to test the attitude control system when required and did not conduct any medical experiments. After touchdown, she had also apparently given all the remaining food in her capsule to the villagers who greeted her, completely contrary to mission rules. This made it difficult for doctors to verify her assertion that she had eaten 60 percent of the food aboard the Vostok 6 spaceship during her three days in space. As physicians led by Yazdovskiy jumped to attribute a pitiful performance on her part, Tereshkova became defensive, claiming that she had felt well during the flight, although she had suffered from fatigue and lack of sleep. Yazdovskiy eventually wrote up a hypercritical report on Tereshkova's mental and physical state during the mission, stating that she had felt poorly on the thirty-second and forty-second orbits, had vomited, had a poor appetite, and had "weak cardiac activity." All of this eventually reached Korolev's ears, and he invited the young cosmonaut on July 11 to speak one-on-one about her flight. What they spoke about is not known, but Korolev was clearly displeased with her performance. Kamanin wrote later: "I remember well all our troubles during the Tereshkova flight. There were many disruptions, and when Tereshkova finally landed, Korolev said: 'If I ever get involved with broads again...'."[67] Korolev's First Deputy Mishin was even more extreme: "Tereshkova turned out to be at the edge of psychological stability. It would seem that her flight . . . should have discredited Khrushchev."[68]

Part of this hostility toward Tereshkova was clearly because she was a woman. The standards by which all the engineers, physicians, and military officers judged her performance were completely different than for the men. Titov, who had suffered severe motion sickness and was unable to do many of the tasks assigned to him during his mission, was never considered a pariah after his flight. Unlike Tereshkova, he was recycled into other space projects, and neither

64. Tyulin, "Task For the Future"; Riabchikov, *Russians in Space*, pp. 204–05.

65. The times given are for the landing of the cosmonaut in his or her parachute. The mission durations for the descent apparatus of the two vehicles were: four days, twenty-two hours, fifty-six minutes, and forty-one seconds (for Vostok 5) and two days, twenty-two hours, forty minutes, and forty-eight seconds (for Vostok 6). See Glushko, *Kosmonavtika entsiklopediya*, p. 66.

66. See, for example, Leonid Vladimirov, *The Russian Space Bluff* (New York: The Dial Press, 1973), pp. 114–15.

67. L. N. Kamanin, "In the Future His Name Will Probably Be . . ." (English title), *Ogonek* 7 (February 9–16, 1991): 28–31; Kamanin, *Skrytiy kosmos: 1960–1963*, pp. 308, 315.

68. Salakhutdinov, "Once More About Space," p. 5.

Kamanin nor Korolev believed that he had failed their trust in him. Thus, while Tereshkova's flight was not an outright success, it was also by no means the complete failure as that seen by Kamanin and Korolev. At the time, of course, all this was talked about behind the curtain of the Soviet space propaganda machine. One of the most publicized aspects of Tereshkova's mission was that she had flown in space longer than *all* the six Mercury flights combined, certainly a fantastic achievement considering the political dimension of the "space race." Bykovskiy, for his part, had also claimed a new victory for the Soviet space program. Traveling a total distance of 3,325,957 kilometers during his flight, he had set an absolute world duration record. For a single-crew spaceship, it is a record that still stands today, thirty-five years after his mission.

At the time that Bykovskiy and Tereshkova completed their flights, there were no approved plans for subsequent missions in the Vostok series. Korolev was probably keen to discontinue the program and instead concentrate resources on flying the more advanced 7K-9K-11K Soyuz complex and the N1 booster projects. The flights in June 1963 were thus effectively the last in perhaps the most historically important Soviet piloted space project. Between 1961 and 1963, despite growing political bickering, the Soviets had managed to launch the first human into space, conduct the first daylong flight, carry out the first "group flight," conduct the longest space mission to date, and launch the world's first woman into orbit. It was a stunning show of form for a nation whose technological capacity had been dismissed by many.

Cosmonauts Under the Public Eye

The publicity afforded to Tereshkova's historic mission was capped off by an even more sensational public relations extravaganza: Tereshkova's wedding to the "most eligible Russian bachelor," Vostok 3 pilot Nikolayev. A few Russian historians have cynically suggested that their union was a public relations exercise, perhaps engineered by Cosmonaut Training Center Director Karpov or his boss Kamanin. This may have indeed been true. Although Nikolayev and Tereshkova were good friends, most accounts from the time suggest that the two were hardly close enough to be husband and wife.[69] Regardless of their own feelings on the matter, the plans for marriage began to take a life of their own. In the first state-hosted wedding in Soviet history, Nikolayev and Tereshkova were married to each other on November 3, 1963, just four months following the latter's spaceflight. Attendees included all the top leaders of the space program: Khrushchev, Malinovskiy, Biryuzov, Smirnov, Keldysh, Rudenko, Serbin, and others. In what must be considered the rarest of opportunities, both Korolev and Glushko were allowed to attend this most public of ceremonies at the Government Reception House. The names of neither were, of course, announced, nor were they allowed to sit close to Khrushchev or Tereshkova. Western correspondents who were also invited evidently discovered through informal conversation that the "chief designers" of the Soviet space program were in attendance. Within a week, a *New York Times* correspondent was able to file the following report:

> *Reports circulating in Moscow's Western community last week have mentioned two rocket pioneers as likely key figures in the Soviet space program. Although the identities of the top scientists in these jobs remain an official secret, a number of unofficial reports have been pointing to two academicians, Valentin P. Glushko, a combustion engineer, and Sergei P. Korolyov, a mechanical engineer. These reports cannot be confirmed from official sources. The leading figures in the Soviet space effort have been cloaked behind*

69. Golovanov, *Korolev*, pp. 703–04.

such designations as Chief Designer and Chief Theoretician, which always appear in the Soviet press with capitalized initials.[70]

With the identification of Korolev and Glushko, one might have believed that the machinations of the enigmatic Soviet space program would become clearer to Western observers. But even U.S. intelligence services seemed to be having a difficult time in determining exactly who ran the Soviet space program—a question that no doubt often boggled those *within* the program itself. As late as April 1961, the Central Intelligence Agency was claiming that the Soviet space effort was directed by the "Interagency Commission for Interplanetary Communications under the Astronomy Council of the Academy of Sciences," a body that had been publicized by the Soviet media in the mid-1950s ostensibly to serve as a public forum for their participation in the International Geophysical Year.[71]

In the early 1960s, the six cosmonauts who had flown in space were the most visible ambassadors of the Soviet space effort, and they were packed off to scores of countries. They were portrayed as flawless representatives of the socialist system at levels often approaching hero worship. Behind the veils of secrecy, they were, of course, as fallible as any other men and women. Trainee Major Rafikov was dismissed from the cosmonaut team on March 24, 1962, because of a variety of offenses, including womanizing and "gallivanting" in Moscow restaurants, and so forth.[72] Although Rafikov had requested that he be reinstated into the team after a few years, he never returned to cosmonaut training.

A much more serious loss to the team occurred a year later on March 27, 1963, when three unflown cosmonauts—Nelyubov, Anikeyev, and Filatev—were returning to the training center at Zelenyy after dinner in Moscow. They had apparently been drinking and became involved in an altercation with a military patrol on a railway platform. Nelyubov threatened to go over the head of the offended officers if they filed a formal report against the three of them. Top officials at the Cosmonaut Training Center requested that the duty officer not file a report against the three, and the latter reluctantly agreed, provided that Nelyubov apologize for his behavior. Although Anikeyev and Filatev agreed to make amends, Nelyubov categorically refused. The offended duty officer filed a report against the three of them, and within a week, the top Air Force leaders decided to dismiss all three from the cosmonaut team. Their official dismissal orders were signed on April 17. Losing Nelyubov, one of the most qualified and brightest cosmonauts, was particularly hard to accept for the other pilots. He had served as Gagarin's second backup during the first Vostok mission, and he certainly would have gone on to fly one of the early Vostok flights had it not been for Kamanin's disapproval of his "individualistic" ways. There was some discussion among Kamanin and the cosmonauts in later months on bringing Nelyubov back into cosmonaut training, based on Nelyubov's performance at his new assignment in an Air Force unit in the Soviet far east. This never happened. It seems that Nelyubov suffered from a psychological crisis through the following years, as cosmonaut members junior to him started flying *their* space missions. By 1966, he was despondent. The final Air Force report in his name merely stated: "On Feb. 18, 1966, while in a state of drunkenness, he was killed by a passing train on a railroad bridge at Ippolitovka station on the Far Eastern Railroad."[73]

70. Theodore Shabad, "Soviet Space Planners' Identity Believed Known," *New York Times*, November 12, 1963, p. 2; Nicholas Daniloff, *The Kremlin and the Cosmos* (New York: Alfred A. Knopf, 1972), pp. 67–70. A Soviet defector named G. A. Tokaty-Tokayev had claimed that Korolev and Glushko were key figures in the Soviet space program in a lecture to the British Interplanetary Society as early as September 1961. See G. A. Tokaty, "Soviet Space Technology," *Spaceflight* 5 (March 1963): 58–64.

71. U.S. Central Intelligence Agency, "National Intelligence Estimate 11-5-61: Soviet Technical Capabilities in Guided Missiles and Space Vehicles," Washington, DC, April 25, 1961, p. 50.

72. Kamanin, *Skrytiy kosmos: 1960–1963*, pp. 99–100.

73. Yaroslav Golovanov, "Cosmonaut No. 1: Selection" (English title), *Izvestiya*, April 5, 1986, p. 3.

He was thirty-one years old at the time. The other two—Filatev and Anikeyev—also did not resume cosmonaut training. Filatev returned to the Air Defense Forces before eventually becoming a teacher. He passed away on September 15, 1990, at the age of sixty. Anikeyev died two years later on August 8, 1992, at the age of fifty-seven.

Of the cosmonauts who had flown, the most prominent was clearly Gagarin, but his time-consuming unofficial job as ambassador-at-large for the Soviet Union did not seem to be a role he particularly relished. In part because of his importance as a national monument, Air Force officials were incredibly reluctant to allow him to resume training for space missions. To keep him on the ground in a high-visibility position, in July 1963, Kamanin seriously considered offering Gagarin the job of director of the Cosmonaut Training Center. As one would suspect, Gagarin was not at all enthusiastic for a desk job and declined several times, despite pressure from the general. Later in the year, he finally buckled under continuing pressure that he become a *deputy* director at the center. Having been promoted from an Air Force major to a colonel in the space of two years, Gagarin was appointed Deputy Director for Flight and Space Preparations at the Cosmonaut Training Center on December 21, 1963.[74] For the moment, his chances of making it back into space were nil.

When Gagarin assumed his new job at the Cosmonaut Training Center, while he may not have been in flight training, there were plenty of others from which to choose. A brand new group of cosmonaut-trainees had in fact arrived at Zelenyy in 1963 to complete a yearlong training program before assignment to future Vostok and Soyuz missions. While the first batch of twenty cosmonauts were young Air Force pilots with little higher education, the new group of fifteen military officers all had higher degrees from a military academy or a civilian university. The selection was limited not only to pilots, but also to military engineers and navigators, adding significant expertise to the cosmonaut team from a wide variety of backgrounds. Of the group, eight were from the Air Force, four from the Strategic Missile Forces, two from the Air Defense Forces, and one from the Navy. The age limit on this second group, raised to forty, meant that the new trainees were almost all older than the Gagarin group. Air Force Commander-in-Chief Vershinin signed orders formally inducting the fifteen men into the cosmonaut corps on January 11, 1963.[75] The most qualified member of the group, thirty-five-year-old Air Force Major Vladimir A. Shatalov, was appointed the informal leader of the group, as they conducted their preliminary training programs through the next twelve months.

During the period 1960–63, the Cosmonaut Training Center itself grew at a rapid pace on the promise of a vast and expansive piloted space program of the future. While originally the cosmonauts conducted training sessions at simulators on the premises of the Air Force's Institute of Aviation and Space Medicine or at specific design bureaus, by the mid-1960s they no longer needed to leave the center. Buildings around the original complex were annexed as at least seven new devices were added: a Treadmill Facility and an Ontokinetic Drum in 1960, the *Rotor* three-stage rotating cab and a Rocking Platform in 1961, a Shielded Room and a Hot Room in 1962, and an Anechoic Chamber in 1963. A specially equipped Tu-104L flying laboratory was consigned to the center in 1961 for flying parabolic trajectories to simulate short periods of weightlessness. Although most of the original cosmonaut-trainees were Air Force pilots, they had refrained from dedicated air training until 1963, when a top Air Force test pilot,

74. Lardier, *L'Astronautique Soviétique*, pp. 137–38. Gagarin's immediate superior was Maj. General N. F. Kuznetsov, the new director of the Cosmonaut Training Center, who had been appointed to his post on November 20, 1963. He replaced Maj. General M. P. Odintsov, who had clashed repeatedly with the cosmonauts during his short eleven-month stint in the position.

75. Yegupov and Karpenko, "At the Request of Readers"; Semenov, Marinin, and Shamsutdinov, *Iz istorii kosmonavtiki: vypusk I*, p. 8; Rex Hall, "Soviet Air Force Cosmonauts," in Michael Cassutt, ed., *Who's Who in Space: The International Space Year Edition* (New York: Macmillan, 1992), p. 211.

Vladimir S. Seregin, was tapped to head an air squadron specifically for the cosmonauts. Money was also apportioned for an athletic stadium, a large swimming pool, a huge housing complex, and even a restricted-access train station for employees and cosmonauts commuting from Moscow.[76] The center employed 600 people by 1963.

Until 1963, the Institute of Aviation and Space Medicine provided all the ground and flight medical support to the piloted space program. Officially, the Cosmonaut Training Center was subordinate to this institute. By 1962, however, the center had clearly outgrown its original mandate as a temporary training ground for cosmonauts, evolving into the Soviet Air Force's primary means to maintain some control over the Soviet space program. On April 10, 1962, the center became a separate and official entity, no longer subordinate to the Institute of Aviation and Space Medicine.[77] In addition, underlying the growing importance of space exploration to a newly interested Air Force, the service introduced the new post of First Deputy Chief for Space of the General Staff. As the first holder of this ranking, Lt. General Kamanin would continue to be the primary overseer of all activities related to cosmonaut training and the planning of piloted space activities on behalf of the Air Force.

These changes had the one negative effect of limiting the influence of the Institute of Aviation and Space Medicine. Its diminished authority was tempered by its critical say over every single aspect of space biomedicine in the Soviet space program, but even this function began to slip out of its hands by late 1963. The Ministry of Health, yet another party of the Soviet government eager to covet for itself a place in the Soviet space program, heavily lobbied through the year to bring all space biomedicine research under its wings, thereby leaving the Air Force institute without a mandate. The Air Force could only helplessly watch as the ministry's request was parlayed through the right political corridors during the summer of 1963. On October 26, 1963, a new entity, the Institute for Biomedical Problems (IMBP), was established in the Third Chief Directorate of the Ministry of Health.[78] The idea to establish a dedicated space biomedicine entity was not new; as early as May 1959, Korolev and Keldysh had written to the government on the need for such an institution. In many ways, the formation of the new institute was a delayed, but nonetheless concrete response to that important letter. The new institute itself was established by joining together several subdivisions from the Air Force's old Institute of Aviation and Space Medicine, thus neutralizing much of the agenda of the latter. As many military physicians migrated to the new institute, the Air Force entity lost its all-important place in the pantheon of Soviet space exploration. Having been involved in space biomedical research since 1949, after 1963, it faded into the background.

The new IMBP became the first civilian institution in the Soviet Union dedicated to the study of the physiological effects of space exploration. It eventually became responsible for all Soviet medical and biological support for human spaceflight, including providing ground support to piloted missions, planning and carrying out space biology experiments in space, selecting and training cosmonauts, and developing various generations of life support systems. Andrey V. Lebedinskiy, sixty-two, a student of the famous Soviet scientist Pavlov, was appointed to head the new institution. Among its eventual employees were all the progenitors of the space biomedicine field in the Soviet Union—Oleg G. Gazenko, Abram M. Genin, Nikolay N. Gurovskiy, and Vasiliy V. Parin—all of whom served as visible ambassadors to the Soviet space program at conferences throughout the world in the 1960s. It continued to play the same role for the *Mir* space station into the late 1990s.

76. Col. V. Gorkov, "History of the Soviet Space Program" (English title), *Aviatsiya i kosmonavtika* no. 2 (February 1990): 42–43.

77. Kamanin, *Skrytiy kosmos: 1960–1963*, p. 102.

78. Lardier, *L'Astronautique Soviétique*, p. 147. The negotiations on the establishment of the new institute had begun as early as April 1963.

Fighting in the Military

Supervision over biological research in the space program was only one facet of the control that the Air Force relinquished during this period. As the space program gained strength in the early 1960s, there was a vigorous battle within different armed services within the Ministry of Defense to gain operational control over the space program. The so-called "artillerymen" had inherited the role of primary clients of the ballistic missile program in 1946, consolidating their position through the 1950s with the strong arm of the late Marshal Nedelin. Their position was entrenched in 1959 with the formation of the Strategic Missile Forces, which through its Chief Directorate of Reactive Armaments served as the primary financiers of all missile weapons. With the emergence of the space program, the Strategic Missile Forces widened their agenda to the new area, forming new departments within the Chief Directorate dedicated to space. Key Strategic Missile Forces personnel were also sprinkled throughout the space industry at various levels, influencing every aspect of the space program, including such key programs as the N1 and Soyuz.

The early 1960s proved a difficult time for the Soviet military as a whole. As the famous Soviet physicist Andrey D. Sakharov later wrote, "Khrushchev appeared anxious to limit the resources invested in military technology and [wanted to] concentrate on the most effective programs."[79] These attempts to "curb military expenditures and to demilitarize the economy . . . provoked resistance in the armed forces." The one service that benefited from the restructuring was the Strategic Missile Forces, which threw all their resources into the development of new ICBMs. Space as a component of military policy was only barely emerging at the time, and the Strategic Missile Forces were remarkably uninterested in the piloted space program, seeing the Vostok, Soyuz, and N1 projects as a colossal waste of money. These programs were funded and supported only grudgingly by the two Strategic Missile Forces Commanders-in-Chief during the 1960–63 period: Marshals Kirill S. Moskalenko and Sergey S. Biryuzov. Their opinions were bolstered significantly by USSR Minister of Defense Rodion Ya. Malinovskiy and his Deputy Andrey A. Grechko, both of whom on more than one occasion took the opportunity to rail at the "uselessness" of the piloted space program.

The Air Force stepped in and tried to take advantage of this vacuum. Through the early 1960s, it vigorously attempted to establish for itself what it saw as its rightful position as the leader of Soviet piloted cosmonautics. All its proposals were aimed at the use of cosmonauts for military purposes—ideas that were discussed at a number of conferences dedicated solely to the military applications of piloted spaceflight. Although Air Force leaders such as Commander-in-Chief Marshal Vershinin supported Chelomey's Kosmoplan-Raketoplan approach, they were also of the opinion that immediate goals could be achieved by modifying the Vostok spacecraft. Korolev was in a difficult position over this conflict. Until 1960, OKB-1 had almost no contact with the Air Force. Through the development of various ballistic missiles in the 1940s and 1950s, it had been the artillerymen who had worked closely with Korolev's engineers. They had developed close relationships, and among Korolev's engineers at least, there was a definite allegiance with the Strategic Missile Forces stemming from these long friendships. But it was the Air Force pushing piloted human spaceflight, while the Strategic Missile Forces were remarkably uninterested in spaceflight in general. Korolev clearly had to negotiate the matter delicately because he did not want to alienate either side. On several occasions in 1962–63, he promised the Air Force that he would convince Malinovskiy and even Khrushchev on the need to have the Air Force fully take over the Vostok program. At the same time, he continued to promise the Strategic Missile Forces that he could produce better ICBMs for them.[80]

79. Andrey Sakharov, *Memoirs* (New York: Alfred A. Knopf, 1990), pp. 210–11.
80. Chertok, *Rakety i lyudi*, pp. 229–30; Kamanin, *Skrytiy kosmos: 1960–1963*, p. 166.

The core of Air Force proposals, beginning in late 1961, addressed the issue of ordering the construction of ten Vostok spacecraft specifically to fly military missions. In September 1962, cosmonauts Nikolayev and Popovich, fresh off their joint flight during the summer, were asked to report to the scientific-technical council of the Ministry of Defense's General Staff on the possible uses of the Vostok spacecraft for military purposes. Issues such as reconnaissance, interception, and attack—that is, those things analogous to maneuvers of a fighter aircraft—were on the agenda. The cosmonauts suggested that while the Vostok spacecraft could be used for piloted reconnaissance, newer vehicles would be needed for interception and attack. But Air Force leaders such as Vershinin had to ultimately clear their proposals with Malinovskiy, Grechko, and General Staff Chief Marshal Matvey V. Zakharov, and none seemed to have any inkling to pursue the idea. Lt. General Kamanin recalled:

> *After an hour . . . I was once again convinced of the utter callousness of our military leadership. Grechko, and then Malinovskiy twice refused to order the* "Vostoks." *The General Staff's [Scientific-Technical Committee] and Zakharov, altered our document, asking the Minister to order 4 "Vostoks." Malinovskiy refused, declaring literally the following: "The* 'Vostok' *ship does not have any military importance, and we will not accept it into armaments or order it. . . ."*[81]

Somewhat dramatically, Kamanin added:

> *History repeats itself: exactly 50 years ago, the Tsar generals evaluated the military applications of aircraft in the same exemplary fashion. Malinovskiy, Grechko, and Zakharov let pass the possibility for the creation of the first military space power. . . .*[82]

As was customary in the Soviet space program, this was not the final word on the issue. It seems that Marshal Zakharov had a change of heart, and on November 9, 1962, the Air Force finally issued a proposal on new Vostok missions in support of the Air Force. These were to include:

- Ordering ten new Vostok spacecraft
- Equipping the Vostok for military applications, such as reconnaissance, interception, and attack
- Carrying out two military missions in 1963, one with a man in orbit for eleven to twelve days and another with a dog for thirty days
- Launching ships with dogs to extremely high orbits
- Carrying out special experiments, including landing by manual orientation, landing within the ship, depressurization of the ship in space, and so on[83]

The persistent lobbying by highly placed Air Force representatives eventually produced a compromise result. On February 8, 1963, the Military-Industrial Commission issued a formal decree (no. 24), signed by its Chairman Ustinov, calling for future Vostok missions for biomedical research. As part of this plan, four Vostok spacecraft, down from the ten requested by the Air Force, would be constructed by OKB-1 within the first half of 1963. Ustinov also called for a formal report in two weeks' time on the possibility of augmenting the fairly rudimentary capabilities of the Vostok spacecraft. In a month's time, all the major players in the space pro-

81. Kamanin, *Skrytiy kosmos: 1960–1963*, p. 174.
82. *Ibid.*, pp. 174–75.
83. *Ibid.*, p. 178.

gram—the State Committee for Defense Technology, the Ministry of Defense, and the Academy of Sciences—were to submit to the Military-Industrial Commission a report on "a program of work on the mastery of cosmic space with the aid of piloted space objects in the next two years, which would ensure the absolute primacy of the USSR in this direction."[84] A Central Committee decree the following day, February 9, gave the decision a forceful measure.[85] Fighting over limited resources, the Chelomey camp, in the person of State Committee for Aviation Technology Chairman Dementyev, immediately protested the decision, invoking "other important goals"—those presumably worked on by Chelomey—but it seems the Air Force had invested sufficient support into the decree to neutralize the opposition.

The approval of the plan to build four new Vostok spacecraft, supported by both OKB-1 and the Air Force, accelerated the planning for post-woman-flight missions during the 1963–64 period. As Air Force plans stood in February 1963, three of the new vehicles would be used for flights of single cosmonauts on flights lasting up to six to ten days. The fourth would carry a dog on a thirty-day mission. All four, Vostoks 7, 8, 9, and 10, would be equipped with experiments supplied by the Air Force. Korolev addressed the salient points of this plan in a report to the Central Committee on March 21 as part of a larger discussion on the future of the Soviet piloted space program. Knowing full well that he would find no allies within the Strategic Missile Forces, Korolev tried to rush headlong into an alliance with the Air Force by suggesting that all functions related to the preparation and accomplishment of Vostok flights be transferred to the Air Force.

The Air Force's insistence on assuming a lead role in the piloted space program came at a time when the Soviet space program finally began to assume an independent character. While the Strategic Missile Forces may not have been particularly interested in financing human space projects, they were not exactly amenable to giving up control over space program operations inherited by default in the late 1950s. The question of who controls space program operations—that is, launches, command, control, communications, military space forces, and most importantly finances—was an issue that pit the Air Force and the Strategic Missile Forces in a vicious interservice battle within the Ministry of Defense during 1963–64. At risk lay the future of Korolev's grand vision of Soviet human exploration: the Strategic Missile Forces would half-heartedly support it and in most cases oppose it, while the Air Force could be counted on to give its full support.

On March 28, 1963, Marshal Biryuzov, the new chief of the USSR Ministry of Defense General Staff, signed a decree (no. 216888) calling for the formation of a commission to discuss the military future of the 3KA variant of the Vostok spacecraft, implicitly addressing the issue of control between the Strategic Missile Forces and the Air Force. The odds were heavily stacked against the Air Force: of the eight members, only one person was from the Air Force (Marshal Vershinin), while the rest were from the Strategic Missile Forces. Vershinin immediately proposed Air Force control over "orders, adoption, launch, and control," and just as quickly, the Strategic Missile Forces rejected it. Through the following months, the two services continued to fight the matter out. Korolev visibly threw his full support behind the Air Force and may have tried to influence high military officers. At one point in late 1963, Biryuzov and new Strategic Missile Forces Commander-in-Chief Marshal Nikolay I. Krylov seemed to have considered handing control over to the Air Force. This brief interlude was temporary. In December 1963, the Ministry of Defense General Staff tabled a final proposal for the formation of a "directorate" within the Ministry of Defense that would unite the various agencies in the military engaged in space activities, with the exception of cosmonaut training and the search

84. *Ibid.*, pp. 222–23.

85. A second decree from the Central Committee and the USSR Council of Ministry on the construction of the four Vostoks was issued on April 13, 1963. See *ibid.*, p. 253.

and recovery services for space capsules, which would remain with the Air Force.[86] It seems that the Air Force resisted the idea, but in vain. In October 1964, the Ministry of Defense established the Central Directorate of Space Assets (TsUKOS), whose agenda was "modernization of existing [space complexes] and the creation new space complexes, and the carrying out of the constantly expanding activities of multi-goal space systems."[87]

TsUKOS was established on the basis of an existing department within the Strategic Missile Forces's Chief Directorate of Reactive Armaments (GURVO), which, since September 1960, had been overseeing space operations for the military. The effect of the 1964 reorganization was to separate TsUKOS from GURVO and subordinate it directly to the commander-in-chief of the Strategic Missile Forces. Henceforth, TsUKOS served as the primary "client" entity for almost all assets created for the Soviet space program—that is, specifications for all space projects had to be approved by TsUKOS. Subordinated to it were two control centers: one created in March 1963, called the Center for Leading the Development and Production of Space Armament Assets, and the other, the Center of the Command-Measurement Complex, which oversaw the nationwide tracking, communications, and flight control stations of the space program.[88] The first commander of TsUKOS was Maj. General Kerim A. Kerimov, a forty-six-year-old artillery officer who was one of the many who had gone to Germany to capture A-4 remains after World War II.[89] Kerimov was a natural choice for the position, having served as the head of the smaller Strategic Missile Forces department on space issues. He was also a prominent member of the State Commission for Vostok, representing Strategic Missile Forces interests within the piloted space program. Although Kerimov was well liked and respected by Korolev, the formation of TsUKOS was a setback to the chief designer's long-range plan for human space exploration. With the Air Force effectively shut out of financing the space program, all the major leaders of the military—Malinovskiy, Grechko, Biryuzov, and Krylov—were decidedly "anti-space" in their actions, and reluctant to fund Korolev's "idle dreams." The artillerymen had won again. And Korolev would suffer the consequences.

The Genesis of Voskhod

The Soviet Air Force had lost much of its clout during the deliberations that led to the creation of TsUKOS in 1964. But the battles left behind one important legacy: the approved order from the Communist Party and the government in the spring of 1963 allocating funds to build four Vostok spacecraft in support of piloted missions during 1963–64. These four vehicles formed the basis for all immediate planning for piloted spaceflight in the near future. For the more distant future, OKB-1 envisioned the use of the 7K-9K-11K Soyuz complex, whose pri-

86. *Ibid.*, pp. 245–46, 398.

87. Yu. P. Maksimov, ed., *Raketnyye voyska strategicheskogo naznacheniya* (Moscow: RVSN, 1992), p. 49; I. D. Sergeyev, ed., *Khronika osnovnykh sobytiy istorii raketnykh voysk strategicheskogo naznacheniya* (Moscow: TsIPK, 1994), p. 17. N. P. Kamanin in his diaries suggests that Marshall S. S. Biryuzov and A. A. Grechko were strong supporters of putting TsUKOS under the control of the Air Force. Apparently, a commission created by Biryuzov in 1964 had come to this conclusion. Kamanin implies that after Biryuzov's death in October 1964 in an air crash, pro-Strategic Missile Forces officers used the opportunity to put TsUKOS under the Strategic Missile Forces. See N. P. Kamanin, *Skrytiy kosmos: kniga vtoraya, 1964–1966gg* (Moscow: Infortekst IF, 1997), pp. 113, 247.

88. V. V. Favorskiy and I. V. Meshcheryakov, eds., *Voyenno-kosmicheskiye sily (voyenno-istoricheskiy trud): kniga I: kosmonavtika i vooruzhennyye sily* (Moscow: Sankt-Peterburgskoy tipografii no. 1 VO Nauka, 1997), pp. 101, 112.

89. *Ibid.*, p. 112; Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p., 603. Kerimov's first deputy was V. I. Shcheulov. His two other deputies were A. A. Maksimov (also chief of the Center for Leading the Development and Production of Space Armament Assets) and A. G. Karas (also chief of the Center of the Command-Measurement Complex).

mary goals were rendezvous and docking in orbit, leading to circumlunar flight. Korolev's plans for the Soyuz complex were characteristically far too optimistic. In August 1962, he set the first automated Soyuz mission for May 1963. The work burden at OKB-1 was, however, far too heavy to maintain such an ambitious schedule. Apart from intensive work on Vostok, engineers at the design bureau were also engaged in the development of the Zenit-2 reconnaissance satellite; the Molniya-1 communications satellite; the Elektron scientific satellite; automated lunar, Venusian, and Martian probes; and new launch vehicles such as the N1. Work also included modifications to the Vostok booster. Certainly the most important work at OKB-1 in the early 1960s was not space but the development of long-range ballistic missiles for the Strategic Missile Forces. These included the R-9 ICBM and its modifications, the RT-1 and RT-2 solid-propellant ballistic missiles, and the GR-1 orbital bombardment system. While Korolev's heart may have been in space exploration, it is a gross miscalculation on the part of Western analysts to suggest that OKB-1 was overburdened with space-related projects. By far, the largest portion of its resources continued to be siphoned off for missile-related programs.

The general direction of the Soviet space program was the subject at hand during a meeting of the Interdepartmental Scientific-Technical Council for Space Research on December 6, 1962. In attendance were all the major chief designers as well as representatives from the Academy of Sciences, the Strategic Missile Forces, and the Air Force. The council proposed a summary list of goals in the 1963–64 period for approval by the Military-Industrial Commission. Besides the numerous automated programs suggested, the council recommended the launch of ten to twelve Vostoks and four to six Soyuz spacecraft as part of the Soviet human space program.[90] These issues were discussed at the Central Committee level in March 1963, but as a result of the battle between the Air Force and the Missile Forces, the orders for the Vostok were curtailed; the Soyuz program was simply delayed by technical problems as well as poor resource management. After the historic Bykovskiy-Tereshkova mission in June 1963, Korolev was adamant about moving full-speed ahead with the Soyuz program, leaving Vostok to the Air Force. But delays in the former were significant enough to revise that approach. Instead, Korolev looked to the Air Force to use its four Vostok vehicles as a stopgap effort to continue piloted exploration in Earth orbit until the Soyuz came on line.

Taking a cue from original Air Force conceptions, Korolev produced a plan in early July 1963 for near-term Vostok missions. He proposed four missions. The first would be a ten- to eleven-day flight of a dog in Earth orbit at an altitude of 600 to 1,000 kilometers in February–March 1964. The goals of the mission would be twofold: to study the physiology of the dog in an extended period of weightlessness and to investigate the effects of radiation at high altitudes on a living organism. Based on the results of the dog flight, the remaining three Vostoks would carry single cosmonauts on flights in orbit up to ten days each. The spacecraft themselves would be modified from the original 3KA variant to accommodate a wide range of scientific and military experiments. The new missions were discussed at another huge gathering of space program leaders on July 26, 1963, dedicated to the future use of the Vostok spacecraft—a vehicle that was rapidly nearing obsolescence, almost five years after its original conception. OKB-1 Deputy Chief Designers Konstantin D. Bushuyev and Pavel V. Tsybin presented reports that there remained a wide variety of tasks that the Vostok could carry out, including flight to altitudes of 1,000 to 1,200 kilometers for up to ten days with a single cosmonaut. Most of the other speakers—from the military, the defense industry, and various design bureaus—supported this conclusion. It is not clear why all these individuals, clearly cognizant of the limited capabilities of the Vostok, continued to support the "old" Vostok. A rational course of action would have been to

90. Kamanin, *Skrytiy kosmos: 1960–1963*, pp. 191–92.

completely abandon the by-then primitive spacecraft and focus all resources on the Soyuz spacecraft—a vehicle that was a significant qualitative leap in space operations. One of the factors may have been the delays in the Soyuz project itself and the need to maintain a significant piloted presence in space during the interim. Korolev, in his report at the meeting, concluded that:

> *The* "Soyuz" *ship will fly no earlier than 1965, therefore in 1964 we should fly the* "Vostok." *We have already built four* "Vostoks," *and it's necessary to build 6–8 more. A program of flight to altitudes of 1,200 kilometers with extended flight to 10 days with significantly broadened scientific and military research is fully acceptable and can be carried out. It will be necessary to install a reserve breaking engine, work on the accomplishment of soft-landing, have improved long-range communications and television [systems], as well as to [increase] the volume and capacity of scientific research.*[91]

The serious intent of OKB-1 in modifying the original 3KA Vostok variant was emphasized by a study completed at the design bureau at the time that resulted in the issuance of a document titled "On the Possibility of Using the '*Vostok*' Ship for Experimental Research on the Prospective Problems of Cosmonautics."[92] The eight primary objectives of the series of missions were:

- Extended piloted flights up to ten days
- Flights in orbits with apogees up to 1,000–1,200 kilometers
- The training of cosmonauts in realistic conditions of spaceflight
- Earth and astronomical observations as well as communications experiments
- Scientific studies of Earth's upper atmosphere
- Biomedical investigations
- Manual landing of the descent apparatus, with the goal of achieving a more comfortable return
- The "exit" of a test animal from the ship into open space

To achieve these goals, engineers would modify the original 3KA Vostok spacecraft in the following ways:

- Install a parachute-reactive system for landing on Earth
- Expand biomedical instrumentation
- Install equipment for the *Vykhod* ("Exit") experiment, which would include a depressurizable special container for an animal
- Add new scientific experiment instrumentation
- Add improved guidance and control systems, communications systems, and optical sensors[93]

The Air Force drew up a final manifest for Vostok missions in December 1963, which included four missions:

91. *Ibid.*, p. 325.

92. This document, a scientific-technical "certificate," has been reproduced in full in as S. P. Korolev, "On the Possibility of Using the '*Vostok*' Ship for Experimental Research on the Prospective Problems of Cosmonautics" (English title), in M. V. Keldysh, ed., *Tvorcheskoye naslediye akademika Sergeya Pavlovicha Koroleva: Izbrannyye trudy i dokumenty* (Moscow: Nauka, 1980), pp. 457–60.

93. *Ibid.* Details of the goals and modifications can be found in Asif A. Siddiqi, "Cancelled Missions in the Voskhod Program," *Journal of the British Interplanetary Society* 50 (January 1997): 25–32.

- Vostok 7: a flight of an animal for thirty days into an orbit of 600 kilometers
- Vostok 8: a flight of a cosmonaut up to eight days
- Vostok 9/Vostok 10: a group flight of two cosmonauts up to ten days[94]

To support these missions, the Cosmonaut Training Center formed a group of eight cosmonauts on September 17, 1963, consisting of all the remaining members of the original Gagarin group who had still not flown in space.[95]

These piloted missions were timed to conclude the Vostok project at a time when the first Soyuz spacecraft would begin flying in early 1965. Progress on the 7K-9K-11K Soyuz projects had been remarkably slow since the Interdepartmental Scientific-Technical Council on Space Research had approved the basic goals and technical aspects of the program in May 1963. Originally, Korolev had planned the first automated 7K missions by mid-1964, but because of a combination of technical and financial difficulties, he continually revised this timetable through the months. Money was clearly a significant factor, exacerbated by the lack of a government decision in favor of the project. By early November 1963, Korolev was publicly complaining that he "had no money" to continue to work on Soyuz. By the end of 1963, OKB-1 had plans to build the first four Soyuz spacecraft in 1964, which would consume 80 million rubles; at the time, the Military-Industrial Commission had only committed to 30 million.[96]

The Communist Party and the USSR Council of Ministers issued a joint decree on December 3, 1963, finally committing to the 7K-9K-11K Soyuz project with an ultimate goal of piloted circumlunar flight.[97] The primary client of the new generation of Soviet space spacecraft would be the Strategic Missile Forces. The Air Force and the Air Defense Forces would only "take part" in the development of tactical-technical requirements for the Soyuz and its test flights. As specified in the decree, the first flight-ready model would be available by August 1964, with the second and third by September. This decision effectively put OKB-1 in the position of having to work simultaneously on the manufacture of two completely different piloted spacecraft, the Vostok and the Soyuz, for the following year. The situation raised management problems in assigning priority of one over the other. Korolev was insistent that the Soyuz fly by the end of 1964, a mantra he had repeated through the preceding year endlessly to all those who would hear. There was clearly a reason for the insistence, and it had less to do with maintaining previously set timetables than to respond to actions thousands of kilometers away.

NASA had carried out the last Mercury mission successfully in May 1963, thus verifying the technology necessary to maintain a human in Earth orbit for a short period of time. Well before that last flight, plans for a second-generation spacecraft were already on the drawing boards. As early as December 7, 1961, NASA Associate Administrator Robert C. Seamans formally approved a "Mercury Mark II" vehicle proposed by the former Space Task Group, which had been renamed the Manned Spacecraft Center.[98] This new spacecraft would be capable of conducting extensive rendezvous and docking operations in Earth orbit, allowing astronauts to acquire experience in advanced operations required in the Apollo lunar landing program. By January 1962, the project had been renamed Gemini, and in March 1963, NASA established guidelines for conducting extravehicular activity (EVA) operations in orbit by the pilots of successive crews. The Gemini project was clearly a qualitative leap in abilities over either the

94. Kamanin, *Skrytiy kosmos: 1960–1963*, p. 391. In an OKB-1 report prepared in December 1963, Korolev proposed four preliminary biological missions with dogs (instead of one), plus three human flights.

95. The eight cosmonauts were P. I. Belyayev, V. V. Gorbatko, Ye. V. Khrunov, V. M. Komarov, A. A. Leonov, G. S. Shonin, B. V. Volynov, and D. A. Zaykin. See *ibid.*, p. 382.

96. *Ibid.*, p. 388.

97. Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p. 163.

98. Linda Neuman Ezell, *NASA Historical Data Book, Volume II: Programs and Projects 1958–1968* (Washington, DC: NASA Special Publication (SP)-4012, 1988), p. 155.

Mercury or Vostok; it would be capable of changing orbits, it would carry two astronauts, and it would allow flights lasting as long as two weeks. The only competitor it had was the Soyuz spacecraft, but by early 1964, it was clear to Korolev that Soyuz would not be ready by late 1964 or early 1965. By that time, Gemini would already be flying.

With Gemini looming over the horizon, Soviet space officials were in a difficult situation. Their options were slim; none of the four projected Vostok missions in 1964 would compare to a Gemini flight. The Soviet flights were all with a single cosmonaut, none of them included EVA, and none of them would have the capability to change orbits. In this climate, a most unlikely idea emerged—one whose origins remain obfuscated to this day amid clouded memories. Most accounts from this period suggest that Soviet leader Khrushchev contacted Korolev and ordered him to convert the Vostok spacecraft into a vehicle capable of carrying not two but *three* cosmonauts. Such a mission, if successfully accomplished, would be guaranteed to retain the Soviet lead in space, at least in the public eye. Korolev's First Deputy Mishin recalled in 1990 that "Khrushchev phoned Korolev and ordered the launch of three cosmonauts right away."[99] Air Force Lt. General Kamanin's personal diaries seem to confirm that the idea did not originate from Korolev, but he does not mention Khrushchev specifically. On February 5, 1964, Kamanin wrote:

> *Just yesterday Korolev received an order: no longer work on the "Vostoks," and use the 4 available "Vostoks" to prepare and accomplish a flight of a three-person crew in 1964. This high-level decision took place for two reasons:*
> *1. The Soyuz will not fly in 1964.*
> *2. The Americans, preparing to launch the "Gemini" and "Apollo" ships into space, may already overtake us in 1964.*[100]

According to Kamanin, Korolev was not pleased with the order:

> *It was the first time that I had seen Korolev in complete bewilderment. He was very distressed at the refusal to continue construction of the* "Vostok" *and could not see a clear path on how to re-equip the ship for three in such a short time. Several times he repeated: "I don't understand how one can refuse to continue the building of the* 'Vostoks.' *. . . It will be impossible to turn a single-seater ship into a three-seater in a few months. . . ."*[101]

A respected Russian space historian, Georgiy S. Vetrov, later revealed that Korolev agreed to Khrushchev's order to build a three-person version of the Vostok only if Khrushchev would make a more firm commitment to a piloted lunar program. Vetrov added, "This agreement was never spelled out openly, nor was the staff of OKB-1 ever told that 'Khrushchev personally ordered us to do this or that.' That was not the practice at the time."[102] Not surprisingly, Khrushchev's son begs to differ. In an interview in 1996, he confided that:

> *The three people [in a spacecraft concept] . . . it was Korolev's idea. It was Korolev's idea . . . Korolev, he wanted to be first as long as possible. And he used everything. And*

99. Salakhutdinov, "Once More About Space." One engineer at OKB-1 claims to have actually been present during this phone call. A. S. Kasho, the "lead designer" of three-stage variants of the R-7 booster, told OKB-1 Deputy Chief Designer B. Ye. Chertok that he was in Korolev's office when Khrushchev made this phone call. See Chertok, *Rakety i lyudi*, pp. 181–82.

100. "The Space Diaries of N. P. Kamanin" (English title), *Novosti kosmonavtiki* 1 (January 1–12, 1997): 76.

101. *Ibid.*

102. James Harford, *Korolev: How One Man Masterminded the Soviet Drive to Beat America to the Moon* (New York: John Wiley & Sons, 1997), pp. 180–81.

he knew about the American [plans] . . . Khrushchev had never heard about this American program. And he didn't care too much about these things. It was very important for Korolev, but it was not so important for Khrushchev. And especially such a stupid thing [as] "If you'll do this, I'll give you permission to go to the Moon!"[103]

Other reliable sources also strongly suggest that it was Korolev and not Khrushchev who had originally proposed the idea to modify the Vostok ship.[104] The record is more muddied by evidence that suggests that Korolev was thinking of a three-seated Vostok as early as February 1963.[105]

This particular issue of who ordered the three-person Vostok effort has a crucial importance from a historical perspective. This is not only because this new diversionary project essentially derailed the Soviet piloted space effort for two years, but also because it serves as supporting or contradictory evidence for one of the central tenets of historical inquiry into the Soviet space program for the past thirty years: that Khrushchev was personally involved in distorting the "normal" evolution of the Soviet space program to extract short-term political gain. While it seems more than likely that someone in the Communist Party or government ordered Korolev to convert the single-seated Vostok into a three-seated ship to beat Gemini, the evidence that it was Khrushchev does not completely hold up to in-depth study. Perhaps it was Leonid I. Brezhnev, the Secretary of the Central Committee for Defense Industries and Space, or perhaps it was someone lower on the ladder of power. Ultimately, we may never probably know until the minutes of Central Committee or Presidium meetings are declassified.[106]

From Kamanin's diaries, it is clear that Korolev was not too happy with the idea, at least in the initial days after the decision. But it is easy to forget that Korolev himself had an almost pathological desire to be first—to beat the Americans at all cost. It would not have been contradictory to his personality to pursue the three-cosmonaut-in-a-Vostok plan simply to upstage the early Gemini missions. He was, after all, strongly committed to flying an additional four Vostok spaceships in 1964, all of which would tenuously extend to the limit the capabilities of a vehicle that was fast becoming obsolete. The three-cosmonaut-in-a-Vostok idea may have been a challenging technical problem, but in terms of vision and planning, it was not so much different from some of the technological changes on his four "extended Vostok" missions planned for 1964. Ultimately, the proposal to usurp Gemini proved to be one of the most deleterious decisions in the early Soviet piloted space program. It completely ignored the natural progression of space vehicles and inserted a diversionary program that would ultimately result in little qualitative gain for Korolev's grand vision of an expansive space program. For the Soviets, the "space race" had degenerated into a little more than a circus act of one-upmanship.

With the order to move ahead with the interim program, Korolev dropped his earlier plans to fly four "extended Vostok" missions in 1964. Instead, OKB-1 would use the same four vehicles for the new politically motivated effort. The Soyuz program was put on the backburner. To present the image that the Soviet Union was engaging in a new and qualitative leap in space exploration, Soviet officials named the new project *Voskhod* ("Sunrise"). If the publicity machine in the USSR worked as well as it had in previous years, no one would guess that the Voskhod spacecraft was simply a modified Vostok packed with three cosmonauts. Officials

103. Telephone interview, Sergey Nikitich Khrushchev with the author, October 10, 1996.

104. See, for example, Golovanov, *Korolev*, p. 731. Interestingly enough, Military-Industrial Commission Chairman L.V. Smirnov had rejected Korolev's plan for the series of "extended Vostok" missions on February 1, 1964, just three days before the order to build a three-man ship. Quite likely, the two events were connected.

105. See, for example, Romanov, *Korolev*, pp. 454–57.

106. Kamanin suggests in his diary entry for March 21, 1964, that the "initiators" of the three-seated Vostok were D. F. Ustinov, L. V. Smirnov, S. P. Korolev, and M. V. Keldysh. See Kamanin, *Skrytyy kosmos: 1964–1966*, p. 30.

discussed the proposal at a meeting of the Military-Industrial Commission on March 13, 1964, and Chairman Smirnov signed a decree (no. 59) the same day, which called for the creation of four three-seated spaceships based on the Vostok. The commission set the first piloted launch for the first half of August 1964, which was less than five months' time.[107]

In the weeks after the Military-Industrial Commission decree, Korolev added or was forced to add a second diversionary mission before moving on to Soyuz: a flight to carry out an EVA. The decision was again evidently motivated by impulses to prevent the U.S. space program from racing ahead of the Soviets. As early as March 1963, NASA had established guidelines for performing spacewalks during the Gemini program. Through the remaining part of the year, the Manned Spacecraft Center in Houston evaluated various proposals for an EVA life support package. By January 1964, officials at the Houston center had completed the final details of the plan. Gemini IV, then scheduled for February 1965, would have the crew pilot open the hatch and stand up for a short period.[108] Once again, the Vostok spacecraft presented the most realistic vehicle for performing a Soviet EVA mission, in a modified variant known as *Vykhod* ("Exit"). The design would be based in part on the preliminary studies on EVA by animals in the original "extended Vostok" mission plans.

On April 13, 1964, the Central Committee of the Communist Party and the USSR Council of Ministers issued a decree fully approving both the Voskhod and Vykhod missions. The decree provided the green light to build two "new" classes of spacecraft in support of the Voskhod program, both derived from the old 3KA Vostok spacecraft that had carried all six Soviet cosmonauts into orbit from 1961 to 1963. The "new" ships were: the 3KV spacecraft for a crew of three cosmonauts (Voskhod) and the 3KD spacecraft for a crew of two cosmonauts (Vykhod), which would allow EVA in Earth orbit.[109] Specifically, the Central Committee and the Council of Ministers sanctioned funding for the manufacture and launch of five of the new vehicles, three for Voskhod and two for Vykhod. The program itself would be carried out in two stages: the launch of a dog into Earth orbit to test out each model, followed by a second flight with an actual crew. Presumably, the fifth vehicle would remain as a spare. With the decree on April 13, 1964, Vostok was irrevocably over, and Voskhod had begun.

Moving to a Standstill

On January 25, 1962, NASA formally approved the development of a three-stage booster, designated the Saturn C-5, for use in the Apollo lunar landing missions.[110] By August, all the primary contracts had been awarded for the giant vehicle. The Saturn V (as it was renamed in February 1963) would have a total length of 111 meters and a liftoff thrust of 3,404 tons. Unlike the baseline version of the N1, engineers at the Marshall Space Flight Center opted to use high-energy cryogenic propellants in the upper stages of the Saturn V, taking advantage of the valuable experience gained from the development of the Centaur high-energy upper stage. The Saturn V would have an eventual capability to orbit a 130-ton payload to a 195-kilometer Earth orbit, far in excess of the N1. The effort was supported by a vast infrastructure spread across the

107. I. Marinin, "The First Civilian Cosmonauts" (English title), *Novosti kosmonavtiki* 12–13 (June 3–30, 1996): 81–87; Kamanin, *Skrytyy kosmos: 1964–1966*, p. 32. According to the VPK decree, the first ship would be ready at the launch site by June 15, 1964, the second by June 1964, and the third and fourth by July 1964. The contents of this decree were based on an OKB-1 document dated February 8, 1964, titled "On Preparations for a Three-Seater Satellite-Ship." In the document, Korolev noted that such a mission would "maintain the preeminence of the Soviet Union in the development of space and rocket technology."

108. David Baker, *The History of Manned Spaceflight* (New York: Crown Publishers, 1985), p. 184.

109. Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, pp. 116, 636. Another source says that the Voskhod decree was issued on June 14, 1964. See Chertok, *Rakety i lyudi*, p. 242.

110. Ezell, *NASA Historical Data Book, Volume II*, p. 61.

United States, with hundreds of subcontractors and a management philosophy that was unparalleled in producing results. With a budget of which Soviet engineers could only dream, technology that was beyond the reach of Soviet industry, and management techniques that fostered creativity and responsibility, the Saturn V program was the living antithesis of the N1 program.

The Soviet counterpart program was bestowed official sanction by the Soviet Party and government in September 1962, after several years of preliminary research on heavy-lift boosters. That decision allowed OKB-1 engineers to put together the design documentation for the N1 in preparation for its manufacture. A good portion of the work at the time was focused on developing the engines for the first three stages of the N1. The effort, earlier beset by personal battles, was plagued by technical obstacles. With Glushko ejected from the program, the onus of designing the engines fell on the shoulders of General Designer Nikolay D. Kuznetsov, the head of OKB-276 based at Kuybyshev. By the end of 1962, Korolev and Kuznetsov had finalized the layout of engines for the stages of the N1, as follows:

Stage	**Engine Type**	**Number**		**Thrust (sea level of vacuum)**
Stage I	NK-15	24	x	153.4 tons thrust (sea level)
Stage II	NK-15V	8	x	178.6 tons thrust (vacuum)
Stage III	NK-21	4	x	41.0 tons thrust (vacuum)

Korolev had sent clarifications for the original technical assignment for designing the NK-15V and NK-21 engines to Kuznetsov earlier in July 1962.[111] Although Kuznetsov had little experience with developing liquid-propellant rocket engines, there was a fairly substantial database of research into which his engineers tapped. The design schemes of all three of the N1 engines had antecedents in the two engines developed for Korolev's GR-1 orbital bombardment system, as shown here:

Original Engine	**Use on GR-1**	**Thrust**	**Changes to:**	**Engine**	**New Use on N1**	**Thrust**
NK-9	Stage I	c. 40 tons	Scaled-up version	NK-15	Stage I	c. 150 tons (sea level)
			Altitude version of scaled-up version	NK-15V	Stage II	c. 180 tons (vacuum)
NK-9V	Stage II	c. 40 tons	Similar	NK-21	Stage III	c. 40 tons (vacuum)
			Similar	NK-19	Stage IV	c. 40 tons (vacuum)[112]

111. Igor Afanasyev, "N1: Absolutely Secret: Part II" (English title), *Krylya rodiny* no. 10 (October 1993): 1–4; V. P. Mishin, "Why Didn't We Fly to the Moon?" (English title), *Znaniye: tekhnike: seriya kosmonavtika, astronomiya* no. 12 (December 1990): 3–43; V. S. Anisimov, T. C. Lacefield, and J. Andrews, "Evolution of the NK-33 and NK-43 Reusable LOX/Kerosene Engines," presented at the 33rd AIAA/ASME/SAE/ASEE Joint Propulsion Conference & Exhibit, Seattle, WA, July 6–9, 1997; Mikhail Rudenko, "Space Bulletin: 25 Years From the Landing of American Astronauts on the Moon" (English title), *Vozdushniy transport* 29 (1994): 8–9.

112. Anisimov, Lacefield, and Andrews, "Evolution of the NK-33 and NK-43."

The original NK-9 and NK-9V engines themselves were distinguished by the fact that the latter was merely a high-altitude version of the former. The NK-9 had also been offered as the first-stage engine for an alternative version of Korolev's R-9 ICBM, but it was rejected in favor of a Glushko engine.

Technical problems plagued the program throughout the early years. During the first eleven months of 1962, there were fifty-seven ground firings of the NK-9 engine with a new gas generator. Of these, twenty-six were outright failures, twenty-three displayed high-frequency oscillations, and only eight were completely successful. The results of these tests no doubt had an influence on the improved NK-15 engine, although participants later claimed the engineers of Kuznetsov and Korolev were remarkably resourceful in overcoming obstacles:

> *At the stage of design-related research on the development of sustainer engines in 1962 and 1963, despite the lack of any experience and despite its being far removed from the test stands, N. Kuznetsov's OKB solved problems associated with the fundamental functioning of the engines and their assemblies.*[113]

Throughout 1963, during a period of intense "optimization" toward the N1 booster design, engineers from Kuznetsov's organization remained permanently stationed at OKB-1 to ensure that the changes in booster design were taken into account in the design of the NK-15 engines. Intriguingly enough, there seems to have been a collaboration of sorts between the design bureaus of Kuznetsov and Glushko, certainly rival organizations at the time. Glushko, based at Khimki, was then developing the RD-253 for Chelomey's UR-500 missile—an engine that he had originally offered to Korolev for the N1. Given that the RD-253 shared a number of design characteristics with the NK-15, engineers under Kuznetsov "were familiar with all the basic documentation on the Khimki engines and often traveled to Glushko's firm to exchange information."[114] By April 1964, Kuznetsov's engineers were able to build and display a full-size, nonfunctional mock-up of the NK-15 in their assembly shop.[115]

The baseline design of the N1 used only liquid oxygen (LOX)-kerosene engines. Later models were to use LOX-liquid hydrogen and perhaps even nuclear engines to significantly increase payload capability from the modest seventy-five tons in the first N1 model. As per the original tactical-technical assignment signed by engine designers in 1961, Isayev's OKB-2 and Lyulka's OKB-165 were to develop high-performance LOX-liquid hydrogen engines for the upper stages of the N1. Korolev also commenced planning for the use of such engines on other more modest launch vehicles, such as the GR-1 and the 8K78; in short, OKB-1 believed that the use of such propellants would have to be an integral part of any future Soviet space program. By April 1964, Korolev had also invited Kuznetsov at Kuybyshev to begin developing a series of LOX-liquid hydrogen engines based on the NK-9, despite the severe load of having to design all the more traditional N1 engines.[116]

All this enthusiasm on Korolev's part could not save the overall effort from near oblivion. Two factors played deleterious roles: the lack of a liquid hydrogen production industry in the Soviet Union and the absence of testing grounds and facilities for the static firing of these engines. Korolev's almost-desperate letters from the early 1960s to the military and government

113. R. Dolgopyatov, B. Dorofeyev, and S. Kryukov, "At the Reader's Request: The N1 Project" (English title), *Aviatsiya i kosmonavtika* no. 9 (September 1992): 34–37.

114. Igor Afanasyev, "N1: Absolutely Secret: Part III" (in Russian), *Krylya rodiny* no. 11 (November 1993): 4–5.

115. Afanasyev, "N1: Absolutely Secret: Part II"; Rudenko, "Space Bulletin: 25 Years From the Landing." The building of the model had apparently begun in March 1963.

116. These OKB-276 engines would be developed in three stages, with progressively powerful engines of forty-five, sixty, and eighty tons.

remained more or less ignored as both OKB-2 and OKB-165 were still drawing up designs by the time that NASA's Centaur was actually flying on top of the Atlas booster. Work on building static testing stands for LOX-liquid hydrogen engines did not even begin until 1965, when construction began at the vast NII-229 test facility in Zagorsk.[117]

Nuclear, electrical, and electrical-nuclear engines for the N1 were also the focus of much effort at OKB-1. In March and April 1963, the Central Committee and the Military-Industrial Commission hosted discussions on such engines—consultations that led to the establishment of an interdepartmental commission to oversee work on electric and nuclear engines.[118] By this time, under the leadership of Deputy Chief Designer Mikhail V. Melnikov, OKB-1, together with researchers from the Physical-Power Institute at Obninsk (which was under the Academy of Sciences) and Keldysh's NII-1, had examined several different approaches of converting the heat energy from a nuclear reactor into electrical energy. What they chose eventually was a so-called thermo-emission converter (often called thermionic) reactor, which scientists believed had significant advantages over other schemes, such as steam turbines or gas turbines. In 1962, Melnikov completed his initial studies with the issuance of a document on applications of nuclear engines for a heavy interplanetary spacecraft.[119] As with the liquid hydrogen program, the nuclear engine effort never received the funding required for intensive development. It was only in August 1965 that Korolev signed the draft plan for a low-thrust nuclear electric-rocket engine, the YaERD-2200, designed specifically for use on piloted interplanetary spaceships. The 8.3-kilogram thrust engine had a dual block scheme, with each block generating 2,200 kilowatts. Unfortunately, given the limited support and funding, few plants were willing to take on the work to develop such engines. One of those that did was Chief Designer Kosberg's Design Bureau of Chemical Automation at Voronezh, which began work in 1965 on a more powerful nuclear engine with a thrust of forty tons.[120] With the generally slow pace of the research, neither engine was expected to come on line before the end of the decade.

The funding problem, compounded by institutional and technical obstacles, cut across almost every aspect of the N1 program and its GR-1 testbed precursor. By the end of 1962, OKB-1 planned to fly the first GR-1 missile from Tyura-Tam by the third quarter of 1963. Within weeks, this completely unrealistic deadline was pushed back as a variety of factors all resulted in delays. The military, lukewarm early on to the use of the GR-1, was even more indifferent to it by 1963. Despite pressure from OKB-1, the Strategic Missile Forces—more specifically its Chief Directorate of Reactive Armaments—refused to agree to a common tactical-technical assignment for the missile, naturally delaying its design. One of the most challenging problems was the development by OKB-1 of a third-stage engine that would be capable of operating in vacuum. A similar engine was also projected for use on the N1, but if its early development record was any indication, there was little to be optimistic about: there was failure after failure during ground tests in 1963.

117. NII-229 was the primary static testing facility for liquid-propellant engines in the Soviet Union. All high-thrust engines beginning with the RD-100 for the R-1 in the late 1940s had been tested at this location. It was originally subordinate to NII-88, but it separated in August 1956 at the same time as OKB-1.

118. The commission, whose chairman was Yu. I. Danilov, included representatives from OKB-1, NII-1, NII-88, OKB-670, TsAGI, TsIAM, OKB-456, IAE, VNII EM, MAI, and OKB-586.

119. Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p. 409; S. P. Umanskiy, "Manned Flight to Mars" (English title), *Zemlya i uselennaya* no. 6 (November–December 1994): 22–32. The document was entitled "Materials for a YaERD for Heavy Interplanetary Ships." "YaERD" is the Russian abbreviation for "nuclear-electric rocket engine."

120. The August 1965 draft plan, drawn up in coordination with the Physical-Power Institute at Obninsk, also included a design for a forty-ton thrust nuclear electric-rocket engine. It was probably the same engine proposed by the Design Bureau of Chemical Automation. See also Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, pp. 408–09.

Progress with the GR-1 was critical to maintaining the original N1 schedule, but the problems with the N1 were even more severe. The primary bottleneck was money—a factor compounded by economic depression in the region where the most intense activity on the booster was carried out: Kuybyshev, the location of Kuznetsov's OKB-276, and the nearby Progress Plant, the primary manufacturing site for the N1. Partly because of general economic mismanagement and partly because of the downturn in the aviation industry stemming from Khrushchev's abrupt about-turn in favor of missiles, plants and subcontractors in the region were unable to cope with Korolev's orders. Korolev personally appealed to several high-level Communist Party administrators at Kuybyshev to offer all the assistance they could.[121] As a result of their actions, as many as twenty-eight different industrial firms located in and around Kuybyshev were brought into the N1 program. Most of these institutes, plants, or design bureaus had earlier been involved in producing parts for aircraft but had lost all their orders and thus means of existence in recent years.[122] OKB-276 had extremely poor engine testing facilities, with certainly nothing to allow it to test-fire 150-ton-thrust engines—a factor that was no doubt an issue of concern when Glushko, with his much better resources, pulled out of the program. An OKB-1 engineer later remembered:

> *Kuznetsov did not have the necessary facilities or test stands. This would result in great losses of time. Korolev wrote "stern" letters to Kuznetsov and simultaneously appealed to the then-secretary of the oblast committee V. I. Vorotnikov, to help Nikolay Dmitriyevich [Kuznetsov]. A third letter immediately went to V. E. Dymshits of the Council of Ministers: "The people in Kuybyshev are having a hard time. Help them!" That's how Sergey Pavlovich strove to "press all the buttons."*[123]

The N1 program literally became the provider for the entire Kuybyshev region, although it still remained a state secret. In fact, an individual employee at a particular plant would quite possibly have been unaware of exactly where his or her particular part was ultimately destined.

The management of the N1 program—certainly the most ambitious "civilian" Soviet space project of its time—was mired in the gridlock symptomatic of the poor performance of the Soviet civilian economy. Thus, it never mattered whether a particular production order was supposed to be carried out; the job might never get done were it not for some personal favor or "unconventional" input. Deadlines often depended on a personal visit, a letter, or a telephone call from a well-placed individual, not on a signed and sealed document. This type of management naturally resulted in a chaotic system in which parts were often delivered months later or in some cases not at all. There was no "single plan of action" to coordinate the hundreds of plants and research institutions. Because the military was not particularly interested in the project, by default, many of the subcontractors were from the "civilian" economy. OKB-1 First Deputy Chief Designer Mishin, one of the leading architects of the entire program, recalled later that:

121. Among those to whom Korolev appealed was V. Ya. Litvinov, the then-chairman of the Kuybyshev Council of National Economy (Kuybyshev Sovnarkhoz), the local economic administration entity. Until 1962, Litvinov had served as the director of the Progress Plant, and thus he was well acquainted with the rocketry and space industry. The Progress Plant (also known as Plant No. 1) had been manufacturing R-7–based boosters since 1959. Others at Kuybyshev who were instrumental in offering help to Korolev were V. Orlov and V. I. Vorotnikov, both secretaries of the Communist Party's Regional Committee. See Sergey Leskov, "How We Didn't Get to the Moon" (English title), *Izvestiya*, August 18, 1989, p. 3; Mishin, "Why Didn't We Fly to the Moon?"

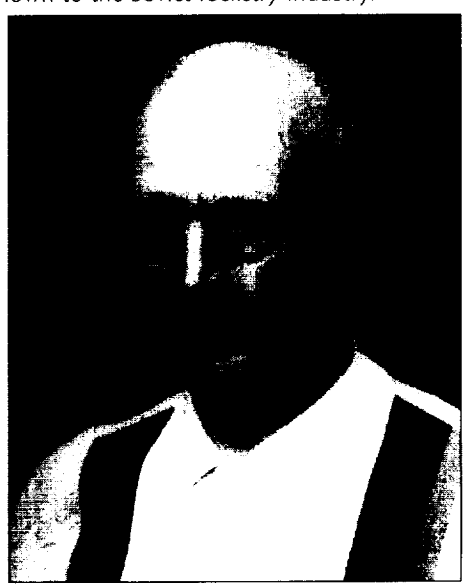
122. These "firms" included the Institute of Aviation, Plant Nos. 24, 207, 276, 305, 525, and 454, OKB-1 Branch No. 3, the Progress Plant, and OKB-276.

123. Col. M. Rebrov, "But Things Were Like That—Top Secret: The Painful Fortune of the N1 Project" (English title), *Krasnaya zvezda*, January 13, 1990, p. 4.

The N1 was being made by 500 organizations in 26 departments. Of these, only nine fell within the jurisdiction of the Military-Industrial Commission. The rest had to be begged for. Resolutions from the Council of Ministers did not help at all: the tasks were just outside their competence and delivery schedules were not met . . . we failed to agree with minister after minister as they made the rounds, and often it ended in checkmate.[124]

The enormous problems related to management and finances did not hinder a remarkably productive period of design through 1963 and up to the first quarter of 1964, when the primary design documentation was prepared under Deputy Chief Designer Sergey O. Okhapkin. His engineers addressed and resolved significant problems related to the manufacture of large-scale welded propellant containers, thermal protection for tanks maintained at cryogenic temperatures, the use of new metallic and nonmetallic materials, the welding of large and thick materials, the assembly of large-scale compartments, and the development of means for assembling and disassembling large sections of the tail and payload compartments. Specific groups were established within the design bureau to complete studies addressing flight ballistics, the computation of load variances during flight, the issue of stability of movement, the pneumo-hydraulic and thermal process associated with ascent to orbit, and the design of electrical and pneumo-hydraulic connections between the stages. One of the most challenging areas was the development of armature—that is, pipelines, umbilicals, valves, and so on—which necessitated a very high degree of precision until then unknown to the Soviet rocketry industry.[125]

The luckless job of overseeing the design of the N1 fell on the shoulders of OKB-1 Deputy Chief Designer Sergey S. Kryukov, who was fifty-five years old in 1963. A tall, bespectacled, and quiet man who was outwardly unemotional, Kryukov had graduated from the Moscow Higher Technical School after World War II before being sent to Germany as part of the A-4 recovery teams. His technical and managerial expertise made a good impression on Korolev through the years as he contributed to all ballistic missile projects at OKB-1, in particular the famous R-7. In 1961, Korolev appointed him a deputy chief designer, putting him in league with the so-called "high guard" of the design bureau—that is, those at the top levels of decision-making. Along with Korolev, Mishin, Bushuyev, Okhapkin, and Chertok, he was one of the most powerful men in the organization, as evidenced by his leading role not only in the N1 program, but also in the Soyuz project, the R-9 ICBM effort, and a variety of classified military programs. His very existence, not to



OKB-1 Deputy Chief Designer Sergey Kryukov was perhaps the leading architect of the N1 Moon rocket. He oversaw the initial design layout of the giant booster during the early 1960s. (files of Peter Gorin)

124. A. Tarasov, "Missions in Dreams and Reality" (English title), *Pravda*, October 20, 1989, p. 4.

125. S. Kryukov, "The Brilliance and Eclipse of the Lunar Program" (English title), *Nauka i zhizn* no. 4 (April 1994): 81–85; Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p. 251. The work on new precision criteria with consideration to the specific loads on the rocket was headed by Deputy Chief Designer S. O. Okhapkin. The work on the armature was carried out under A. N. Voltsifer at Department No. 41. The ballistics work was led by S. S. Lavrov, and the computations of load variances was led by V. F. Gladkiy.

mention his significant contribution to the overall direction of the Soviet human space program, was a state secret until the early 1990s.[126] Kryukov's official duties were to oversee "design and computational-theoretical" work on the N1, but he effectively led the team that designed the rocket in its initial stages.

Kryukov, along with Korolev and Mishin, participated in one of the most fatal decisions of the N1 program. As early as March 1963, they were considering the elimination of ground testing of the complete first stage with its full complement of twenty-four engines. This particular issue has been clouded in recent years by conflicting information; some argue that the decision to omit first-stage static testing was imposed by space program leaders, while others maintain it was a purely internal decision at OKB-1. Both sides agreed that it was taken primarily because of a lack of funds. Large amounts of money would be required to build giant static test stands for the completed first stage, and no such facility then existed in the Soviet Union. A second factor was time. Even if never overtly stated as such, the N1 booster came to be a direct competitor to the Saturn V. Having a payload capability of seventy-five tons (compared to the Saturn V's 130 tons) was embarrassing enough, but introducing the booster much later than the Saturn V was simply unacceptable to Korolev. Vladimir V. Vakhnichenko, a senior engineer working on the N1, recalled almost three decades later:

> *In discussing the fate of the N1, it is impossible to be silent about the fact that, in the creation of the launcher, the unwritten law of rocket building was violated: that the bugs in the burn of the rocket stages must be worked out on the test stand. In order to save time and money, it was decided not to construct a stand for the first stage, which meant that the crucial final tests would be shifted to the flight-test stage. The underestimation of the scale factor—the immense size of the launch vehicle, each launch of which was an event in the life of the country—played a fatal role in the erroneousness of this decision. Earlier when smaller launch vehicles and military missiles were being developed, many ground-test "flaws" would be eliminated during flight-testing. And it was no big deal that for some rockets it was necessary to carry out 40–50 launchings before they "learned" to fly. But that approach was unsuitable for the N1.*[127]

Korolev was even unwilling to launch an N1 with simply a live first stage and dummy upper stages, preferring "all-up" testing, with flight-ready versions of *all* the stages. This was a recipe for disaster because the first stage with its complement of twenty-four engines would not be tested a single time before flight. "If the rocket takes off with dummies instead of the second and third stages, how I can I show my face when I get out of the bunker?," he evidently used to tell his associates.[128] In one sense, the decision to move ahead with "all-up" testing for the N1 was not as risky a decision as might seem in retrospect. In 1963, Korolev had one big ace up his sleeve: the GR-1. By the time that a fully stacked N1 was on the pad, OKB-1 expected to have finished testing the orbital bombardment system, thus reducing the risk of failure on the upper stages of the N1. That, of course, still left the most critical and weakest link of all, the first stage, open to possible catastrophe.

In the hope of compensating for the decision to dispense with first-stage ground testing in concurrence with "all-up" testing, OKB-1 adopted two measures. One of them was the use

126. Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p. 252; Golovanov, *Korolev*, pp. 474–75; Mozzhorin, *et al.*, eds., *Dorogi v kosmos: I*, pp. 101–09. Note that Kryukov himself claims that he was appointed a deputy chief designer "in 1959–1960"; Golovanov states that it was in 1961.

127. Rebrov, "But Things Were Like That—Top Secret."

128. Leskov, "How We Didn't Get to the Moon."

of the KORD system, which was designed to shut off particular engines in the circle of twenty-four if the slightest malfunction was detected. The control system was highly complex, difficult to design, and pushed the limits of Soviet computer technology, but OKB-1, in cooperation with Korolev's old friend Chief Designer Pilyugin, doggedly pursued the idea. That the system was reactive rather then predictive does not seem to have given pause to either Korolev or Pilyugin, although there was criticism from many other quarters. The second compensatory measure was to "extrapolate" results from the static firings of the eight-engine second stage to the similar but larger first stage. There was a weak link even in these "extrapolations." In a decision taken sometime later, OKB-1 and OKB-276 agreed not to test each and every NK-15 engine on the ground; instead, a statistical program was devised in which a group of six engines would be selected randomly from a batch of manufactured units. Of the six, two would be selected randomly and tested thoroughly at a static stand; if they passed the tests, the *remaining* four would be cleared for flight.[129] Such was the price of the lack of time and money.

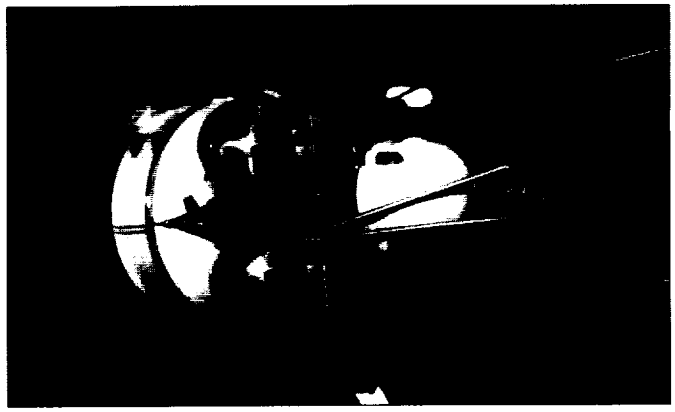
Delays also plagued the design of the launch complex for the N1. In December 1962, OKB-1 and the GSKB SpetsMash signed "The Initial Data and Primary Technical Requirements for Designing the Launch Complex for the N1 Rocket" with the State Committee for Defense Technology. Progress on this issue was bogged down, however, in an intense conflict between Korolev and Chief Designer Barmin over launch complex design. It took a year to resolve the matter; it was only on November 13, 1963, that the Supreme Council of the National Economy formally approved the "interdepartmental" schedule for work on the design documentation for construction of the complex, enumerating in detail the technical and material needs for the job. A governmental resolution a month later, on December 24, was a promise to ensure that this goal was indeed achieved on time. However, as was typical, the Ministry of Defense, the "owners" of the Tyura-Tam range, refused to follow up on the governmental decree; GSKB SpetsMash, the primary launch complex design organization, was left with little money to do anything. By this time, engineers and architects had marked out a vast area at the range, comprising sites 110, 112, and 113, for all N1 operations. Two launch complexes would be built at site 110, the giant assembly building and fueling area at site 112, and the residential zone and welding facilities at site 113. Actual construction at the sites began in 1964 under the direction of Chief Designer Barmin, but it was at a snail's pace. The Ministry of Defense allocation for launch complex construction for the year 1965 was one-third of what was requested.[130]

Funding for the space program had always fallen short of what was requested by the leading chief designers, but one factor in the severe crunch may have been Chelomey's rising dominance within the missile and space programs. Although his organization, OKB-52, had little to show in terms of actual accomplishments by 1963 or 1964, the scope of work at the Reutov-based organization was breathtaking. With its several branches spread out across the Moscow area, it was engaged in the development of ICBMs, orbital bombardment systems, space launch vehicles, radar ocean reconnaissance satellites, anti-satellites, various models of piloted and automated spaceplanes, naval anti-ship cruise missiles, and a nationwide ballistic missile defense system.

Chelomey's first entry into the space program came in late 1963, although, in an ironic twist, he needed Korolev's assistance to facilitate it. By the end of 1962, it was clear that the first launch of his coveted UR-200 ICBM would be delayed past the original deadline. Tests to qualify it as a

129. Kryukov, "The Brilliance and Eclipse of the Lunar Program."

130. Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p. 251; I. A. Marinin and S. Kh. Shamsutdinov, "Soviet Programs for Piloted Flight to the Moon" (English title), *Zemlya i vselennaya* no. 5 (September-October 1993): 77–85.



This is a model of the first space vehicle developed by the Chelomey design bureau, the "IS" anti-satellite spacecraft. Upon launch in November 1963, the satellite was named Polet-1. (copyright Dietrich Haeseler)

space launch vehicle would take even longer. Chelomey's first space vehicle, the IS anti-satellite, would in the meantime be ready for a first test launch, but without the booster needed to put it into orbit. On January 20, 1963, Chelomey, escorted by a large entourage, paid an official visit to see Korolev at Kaliningrad. An agreement was hammered out whereby OKB-1 would provide a number of R-7–based boosters for launches of the early Chelomey satellites in the "IS" and "US" series until the UR-200 came on line. The visit itself was remarkably amiable, and the two were polite and friendly with each other in contrast to the dismal relationship between Korolev and Glushko. As Sergey N. Khrushchev later recalled, "Although their rivalry [in space] was growing, their personal relationship remained friendly. This was not insignificant when one considers the complexity of their characters."[131] There was a little conversation on the N1, but Korolev did not go into great detail on the project in front of his primary competitor. Meanwhile, Chelomey neither conveyed his grave doubts on the N1 program, nor did he express any curiosity about its current status; to do so would have been indiscreet in the given circumstances. Through the ensuing years, despite the intense professional competition, both remained on friendly terms whenever they met at government receptions, meetings, or the launch range.

Using a variant of the basic R-7 ICBM, named the 11A59, Chelomey launched his first "IS" satellite into orbit on November 1, 1963, from site 1 at Tyura-Tam. The general designer could not resist being different from the other space designers. Unlike all other generic military satellites, which were named "Kosmos," Chelomey picked the name *Polet* ("Flight") for his little vehicle. The spacecraft became the first-ever satellite to maneuver in space by changing orbits, a crucial capability needed for anti-satellite operations.[132] Just two days after the Polet-1 launch, which caused quite a stir among Western observers, Chelomey launched the secret UR-200 ICBM on its first test flight with only a live first stage. It was the first visible manifestation of Chelomey's emerging dominance in the space and missile programs, and coincidentally or not, it came during the most difficult financial time for Korolev.

While Chelomey's rising star may have played a role in the funding problems for the N1, clearly the most important factor in the equation was the indifferent attitude of OKB-1's

131. A long description of this meeting between Korolev and Chelomey is covered in Sergey Khrushchev, *Nikita Khrushchev: krizisy i rakety: uzglyad iznutri: tom 2* (Moscow: Novosti, 1994), pp. 441–43; See also Rudenko, "Space Bulletin: 25 Years From the Landing."

132. A second such satellite, Polet-2, was launched in April 1964. For descriptions of the Polet-1 and Polet-2 missions, see V. Polyachenko, "In Orbit—'Polyot'" (English title), *Aviatsiya i kosmonavtika* no. 12 (December 1992): 36–37; Mikhail Rudenko, "Designer Chelomey's Rocket Planes" (English title), *Vozdushniy transport* 51 (1995): 7–8; Khrushchev, *Nikita Khrushchev: tom 2*, pp. 465–66; Asif A. Siddiqi, "The Soviet Co-Orbital Antisatellite System: A Synopsis," *Journal of the British Interplanetary Society* 50 (June 1997): 225–40.

primary financier and client, the Ministry of Defense. The original 1962 decree approving the N-1's development had tasked the Ministry of Defense to formulate a set of missions for the use of new spacecraft for exclusively military purposes. But the powerful N1 simply did not "fit into then-existing notions of defense" of the Soviet Union.[133] As one Soviet journalist later wrote:

> *. . . the work [on the N1] was influenced by the nonavailability of resources and financing. It was clear there was an absence of interest from the main client of rocket-space technical issues—the Ministry of Defense, because the objectives and the payloads for the N1 had not been specified.*[134]

The disinterest from the military was catastrophic for the N1 program as a whole. As the primary financier of the N1 project, the Ministry of Defense refused to let loose its purse strings, being more interested in achieving strategic parity with the United States. In 1964, OKB-1 was allocated only 23 million rubles of the 45 million requested, OKB-276 received 20 million even though 50 million was needed, and the Kuybyshev Council of National Economy was apportioned 9 out of the 23 million rubles requested. Through all this, under the supervision of Kryukov and Okhapkin, OKB-1 finished the preparation of the "primary set" of design documentation for the N1 in March 1964, thus ready to move into the actual manufacturing of flight articles.[135] But with money completely drained, by early 1964, the unthinkable had happened: work on the N1 was at a complete standstill as plants, institutes, and design bureaus ceased work on the vast program, leaving idle all that had been built. Faced with a serious situation, Korolev, in effect, took the problem out of the hands of the Ministry of Defense. If the military would not define a payload for the N1, then he himself would.

The Decision to Go to the Moon

Piloted exploration of the Moon had been discussed seriously in the early 1960s at the top levels of the Soviet leadership, but only as it concerned circumlunar missions. By 1963, Chelomey was exploring the possibility of sending his Raketoplan with crews around the Moon, while Korolev had received full-scale approval in December 1963 with his 7K-9K-11K Soyuz proposal. Both efforts suffered delays that stemmed more from technical considerations rather than institutional factors. Originally, Chelomey had considered a wingless Raketoplan capable of a ballistic reentry from lunar distances, but such a profile would impose too high thermal stresses on the returning spacecraft, in addition to severe gravitational loads on a potential crew. In late 1963, he dropped all his ballistic circumlunar plans and adopted a "new" plan, which allowed for a guided reentry into the atmosphere.[136] Unlike the Vostok's spherical return capsule, he chose to adopt a design that had originated elsewhere—in the United States. Kept abreast of NASA's Gemini project, it seems that Chelomey had appropriated its design into a Soviet version of the vehicle, named the LK-1 ("Lunar Ship No. 1"). Khrushchev's son Sergey, who was an engineer at OKB-52 at the time, later recalled, "I think he used the Gemini idea, because he began to speak about this after [Gemini] was published."[137] Original or copied, the LK-1 was to be Chelomey's grand entry into the Soviet piloted space program, by sending the first Soviet cosmonauts around the Moon.

133. G. Vetrov, "The Difficult Fate of the N1 Rocket" (English title), *Nauka i zhizn* no. 5 (May 1994): 20–27.

134. Afanasyev, "N1: Absolutely Secret: Part II," p. 3.

135. Kryukov, "The Brilliance and Eclipse of the Lunar Program"; Dolgopyatov, Dorofeyev, and Kryukov, "At the Reader's Request: The N1 Project."

136. Interview, Gerbert Aleksandrovich Yefremov with the author, March 3, 1997.

137. Khrushchev interview, October 10, 1996.

Chelomey pursued the idea with great vigor and spoke personally to Khrushchev about it during the summer of 1964 while the Soviet leader conducted an official visit to his design bureau.[138] Although the topic of the meeting was ICBMs, Khrushchev apparently sanctioned Chelomey's LK-1 idea at the time, another in a long line of new projects for the general designer. An official decree on the program was apparently issued on May 22, 1964. The same governmental decision also formally terminated all further work on Chelomey's ambitious Martian Kosmoplan project and the circumlunar Raketoplan.[139] After close to five years of pursuing a pipe dream, Chelomey was forced to admit that his ideas were a little ahead of his time. While he would vigorously continue wide-ranging efforts to develop new spaceplanes, conceptions of lunar and interplanetary flight by such vehicles receded out of view. The focus would be on competing with Apollo.

Compared with the Apollo program, Soviet piloted circumlunar projects were a poor second. Even now, it is difficult to rationalize the persistence with which designers such as Korolev and Chelomey pursued these efforts. If public accolades formed the primary objective of a circumlunar effort, what gain could be extracted in the face of Apollo, which would actually *land* Americans on the Moon? The only possible explanation is that the Soviets simply never believed that the U.S. lunar landing effort was serious enough to warrant a response. This mode of thinking is, in fact, borne out by the unusually indifferent response to Apollo during the 1961–63 period. The primary N1 missions were either for defense or for piloted Martian flights; while the former was never defined, the latter was pursued with some vigor up to about mid-1963, when there was a major shift in thinking at OKB-1.[140]

The Central Committee of the Communist Party, in the persons of Khrushchev and Frol R. Kozlov, had no serious cause to feel threatened by the murmurs of activity from NASA. By the end of 1963, the Soviet Union continued to maintain its undisputed lead in space exploration, springing one "first in space" after another at a continually shocked American audience. The Central Committee's primary concern, as with the military, was achieving strategic parity. In a bid for common resources, the space program had a sparse chance of being a priority over the development of newer long-range ballistic missiles. Contrary to conventional wisdom, the space program was not a central component or instrument of Soviet state policy. At best, it was an added bonus—a perk that allowed the Party and the military to add to its résumé in extolling the virtues of a socialist state. The unprecedented successes of Gagarin, Tereshkova, and others formed a useful but not indispensable tool in helping destroy the standard image of the Soviet Union as a nation of obsolete tractors and factories. And while Kennedy may have made Apollo an instrument of American state policy, given the track record of the U.S. space program up to the early 1960s, there was no reason to believe that the United States would actually put a human on the Moon before the end of the decade.

The earliest serious indication that highly placed Soviet space officials such as Korolev and Academician Keldysh were moving their thinking from a Mars expedition to a lunar landing

138. The visit is described in Khrushchev, *Nikita Khrushchev: tom 2*, pp. 476–78.

139. E-mail correspondence, Igor Afanasyev to the author, November 23, 1997; E-mail correspondence, Igor Afanasyev to the author, November 28, 1997.

140. In the document dating from July 1962 defending the N1 project to the Keldysh Commission, OKB-1 listed five major goals for the N1 rocket, presumably in order of their importance: (1) defense objectives; (2) scientific objectives; (3) "research and mastery of human [flight] to the Moon and near planets of the solar system (Mars, Venus); launches of automatic apparatus to the Sun and planets of the solar system with scientific goals"; (4) "solution of separate applied objectives such as universal communications and radio broadcasting and television, weather service, solar service, etc."; and (5) problems involving ballistic flight. This document is reproduced in full as "Report on the Powerful N-1 Carrier-Rocket at the Meeting of the Expert Commission" (English title), in B. V. Raushenbakh, ed., *S. P. Korolev i ego delo: svet i teni v istorii kosmonavtiki: izbrannyye trudy i dokumenty* (Moscow: Nauka, 1998), pp. 363–82.

came in late April 1963. At the time, Keldysh held a meeting of his Interdepartmental Scientific-Technical Council for Space Research to discuss a response to the Kennedy speech almost two years earlier. Besides Korolev, in attendance was his "high guard": Deputies Mishin, Bushuyev, Chertok, Kryukov, and Okhapkin. In a report, Korolev summarized the progress on the N1 program and argued that its capabilities would allow a lunar landing mission as well as various military tasks in Earth orbit. The council acknowledged "the advisability of reporting to the [Central Committee] on issuing a special decree on accelerating this work."[141] Deputy Chief Designer Kryukov recalled later that this reassessment toward the Moon had taken place because of "reports of American work on Saturn and the start of flight work of this complex." By this time, NASA had conducted four (Block I) Saturn I launches as part of the "first step to perfecting the Saturn V vehicle for lunar missions."[142] Although fired with only a live first stage, the launches, all successful, were hard evidence of NASA's commitment to the lunar landing goal.

If before there had been some doubts about the seriousness of the U.S. commitment, there was ample evidence of it in 1962 and 1963. By the summer of 1962, NASA engineers had finalized the basic external configuration of the Apollo spacecraft complex, and on July 11, 1962, NASA officials announced that they had selected the lunar-orbit rendezvous (LOR) profile to accomplish the lunar landing mission.[143] The LOR profile used the launch of two separate lunar spacecraft. One would serve as "a mother ship" and orbit the Moon, while a second would land on the surface of the Moon. Once surface exploration was over, the lunar lander would lift off, dock with the "mother ship," and be discarded. Following lunar operations, the crew would boost the orbiter on a trajectory back to Earth. All elements of the Apollo complex would be launched on a single Saturn V. Work on the actual Apollo spacecraft was also progressing at an impressive pace. On August 14, 1963, NASA signed a definitive contract with the Space and Information Systems Division of North American Aviation to design and manufacture the Apollo Command and Service Module that would carry three astronauts to the Moon. A contract for the lunar lander, called the Lunar Excursion Module, was signed with Grumman Aircraft Engineering Corporation on March 11, 1963.[144]

Acutely aware of falling behind the Americans, Korolev took his case to the top. During a meeting in early June 1963, days before the launches of Bykovskiy and Tereshkova, Khrushchev invited Korolev and Glushko to his private dacha ostensibly to try and "make peace" between the two warring designers. Later in his memoirs, Khrushchev recalls the conflict and his mediation efforts:

> *. . . differences of opinion started to pull them apart and the two of them couldn't stand to work together. I even invited them to my dacha with their wives. I wanted them to make peace with each other, so that they could devote more of their knowledge to the good of the country, rather than dissipate their energy on fights over details. It seemed to me that they were both talented, each in his own field. But nothing came of our meeting. Later Korolev broke all ties with Glushko. He switched to . . . Kuznetsov, a young, talented engine designer.*[145]

141. Chertok, *Rakety i lyudi*, p. 230. This meeting was held on April 28, 1963.

142. Ezell, *NASA Historical Data Book, Volume II*, p. 56. The first four Saturn I launches were accomplished on October 27, 1961, April 25, 1962, November 16, 1962, and March 28, 1963.

143. *Ibid.*, p. 182. See also Roger D. Launius, *Apollo: A Retrospective Analysis*, Monographs in Aerospace History, No. 3 (Washington, DC: NASA History Office, July 1994), pp. 10–12, which is an excellent account of the battles over the decision to opt for the LOR profile for the Apollo program. NASA Administrator James E. Webb officially announced the LOR decision on November 7, 1962.

144. Ezell, *NASA Historical Data Book, Volume II*, pp. 172, 183.

145. Nikita Khrushchev, *Khrushchev Remembers: The Glasnost Tapes* (Boston: Little, Brown & Co., 1990), p. 186.

Khrushchev, Korolev, and Glushko spent the morning of their meeting discussing, among other things, the N1 and its role in a piloted lunar landing. Using a number of beautifully illustrated drawings of his N1 rocket and proposed lunar spacecraft, Korolev painstakingly explained the requirements and mission profile of a Soviet lunar landing project. At the time, OKB-1 plans seem to have involved an Earth-orbit rendezvous profile using three N1 rockets to launch portions of the lunar ship into Earth orbit. These components would link together and then fly toward the Moon carrying its cosmonaut crew. According to Khrushchev's son, Sergey, who was also present during this private discussion, the elder Khrushchev was:

> *enthralled by Korolev's idea. But he could also not forget Earthly concerns. He inquired how much this project would cost. This time Korolev had a separate list stating all the computations. By his estimation, approximately ten to twelve billion [rubles] would be necessary to accomplish the project over the same number of years. [Hearing the amount] Father wavered.*[146]

Korolev continued his presentation with a display of the N1, its emerging configuration, its launch complexes, and logistical problems, such as modes of transporting the booster to the launch site. Korolev expressed confidence that given the right amount of financial support, the N1 program could beat Apollo. At the end of his monologue, Khrushchev merely replied, "I'll think about it, you prepare your proposals. We will discuss and decide this in the Presidium of the Central Committee."[147]

Cost was a particularly important factor in space policy planning at the time, particularly because of an agricultural crisis that peaked around 1963 that prompted the Soviet Union to rely increasingly on imported grain. Despite phenomenal industrial growth in the late 1950s, the poor record of the agricultural sector may have served as a catalyst for more conservative levels of funding in areas not essential for national defense.[148] The enormous amounts of money pouring into the development of nuclear weapons and ballistic missiles were clearly taking their toll, and attempts to downsize conventional weapons systems to compensate did not alleviate the crisis.[149] Food shortages and rising prices across the Soviet Union may have given pause to Khrushchev's consideration for a highly expensive space extravaganza whose political utility was dubious at best.

Khrushchev's wavering on the lunar landing issue did little to deter Korolev's single-mindedness. A little over a month after the high-level meeting, on July 27, 1963, Korolev sent a formal

146. Khrushchev, *Nikita Khrushchev: tom* 2, p. 446. The *official* conversion rate of the ruble to the dollar at the time was one to one.

147. *Ibid.*, p. 448. This meeting in early June is said to have occurred on June 13, 1963, in another source. See Rudenko, "Space Bulletin: 25 Years From the Landing." It seems, however, that Korolev was at Tyura-Tam on June 13 for the Vostok 5/6 launches. As for as the personal conflict between Korolev and Glushko, the issue was the subject of a forty-minute discussion among the three men behind closed doors. No one knows what was said, but all three emerged gloomy and obviously disturbed from the meeting. Sergey Khrushchev claims to have heard Korolev mutter under his breath that Glushko was "a snake in the grass." There were no further attempts by the Soviet leader to bring them together.

148. For mentions of the agricultural crisis, see Daniloff, *The Kremlin and the Cosmos*, pp. 143–44; Peter A. Gorin, "The Dark Side of the Moon: Political Decisions Behind the Soviet Lunar Programs," presented at the American Association for the Advancement of Slavic Science, Boston, MA, November 14–17, 1996; Alexander A. Danilov, Michael M. Gorinov, Sergei V. Leonov, Ekaterina P. Lugovskaya, Alexander S. Senyavski, and Alexander P. Naumov, *The History of Russia: The Twentieth Century* (North Sydney, Australia: Heron Press, 1996), pp. 288–89.

149. The new military doctrine of relying on ICBMs was outlined in a major policy speech by Khrushchev on January 14, 1960, at the 4th Session of the Supreme Soviet of the USSR. He ended his speech with the following call: "In modern times a nation's defense capability depends on firepower, not on [the] number of men under arms. Hence, due to possession of nuclear weaponry, the manpower of the Soviet armed forces would be reduced." See Harriet Fast Scott and William F. Scott, *The Armed Forces of the USSR* (Boulder, CO: Westview Press, 1979), p. 42.

proposal to key leaders in the defense industry that established clear, specific objectives the N1 could accomplish. He listed three primary goals in order of their importance: exploration of the Moon, exploration of the planets, and the launch of an Earth orbital station. Whereas before lunar exploration was consigned as a secondary objective, Korolev was unequivocal in his strategy:

> *The accomplishment of a [landing] expedition of humans to the surface of the Moon should be considered the primary goal in the program of study and familiarization of the Moon. All remaining goals enumerated here should be concurrently achieved to facilitate the solution of the primary goal—the accomplishment of a [landing] expedition.*[150]

In the July 1963 document, Korolev proposed eight specific projects, the first of which was a piloted landing on the surface of the Moon. The preliminary conception involved launching three N1 rockets to assemble a 200-ton complex in Earth orbit through rendezvous and docking. A five-ton lander would perform the landing itself. To ensure safety, a reserve lander would supplement the main lander. The second and third goals were the creation of robotic lunar rovers with masses of six to eight tons and piloted lunar spacecraft with masses of ten tons. The remaining five objectives pertained to missions to Mars and Venus: the piloted TMK-1 for circumplanetary flights, automated spacecraft to orbit the planets, robotic vehicles to land on them, a piloted landing on Mars, and the development of a family of spaceships for further planetary exploration.[151]

Ironically, just as Korolev was beginning to marshal all his skills to convince the Soviet leadership of the need to respond to Apollo, the *public* discourse on whether or not the Soviets were in a "race to the Moon" reached its apotheosis. Much of this near hysteria was set off by a letter from British astronomer Sir Bernard Lovell to NASA Deputy Administrator Hugh L. Dryden concerning future Soviet plans in space. Lovell had toured a number of important aerospace facilities in the USSR between June 25 and July 15, 1963, and met a number of prominent scientists from the Academy of Sciences. Based on his experiences, he informed Dryden in a letter dated July 23 that Academy President Mstislav V. Keldysh had informed him that the Soviet Union had rejected "(at least for the time being) . . . plans for the manned lunar landing."[152]

Lovell's assertion set off a remarkable level of parrying back and forth between the U.S. media and NASA as the space agency sought to quell suggestions that it was in fact racing to the Moon by itself.[153] The U.S. hoopla was not reported in the Soviet press, although it is less certain whether individuals such as Khrushchev, Keldysh, and Korolev were kept abreast of the

150. This document, addressed to S. A. Zverev (State Committee for Defense Technology), V. D. Kalmykov (State Committee for Radio-Electronics), and M. V. Keldysh (USSR Academy of Sciences), has been reproduced in full as S. P. Korolev, "Report on the Use of the N-1 (11A52) Carrier and the Creation of First-Order Space Objects on Its Basis" (English title), in Raushenbakh, ed., *S. P. Korolev i ego delo*, pp. 410–16. An identical letter was sent on July 30, 1963, to Chief Designers N. D. Kuznetsov (OKB-276), N. A. Pilyugin (NII AP), and M. S. Ryazanskiy (NII-885). See also Kryukov, "The Brilliance and Eclipse of the Lunar Program."

151. Korolev, "Report on the Use of the N-1 (11A52) Carrier." The circum-Martian TMK-1 would have a mass of seventeen tons. The piloted Mars landing, on the other hand, would be accomplished by creating a massive 330- to 660-ton complex in Earth orbit requiring between six and twelve N1 launches. Among supplementary goals mentioned in the document are robotic exploration of Mercury (six tons), Jupiter (three tons), Saturn (one and a half tons), Uranus (one ton), and Neptune (eight-tenths of a ton). The orbital station, called an "Orbital Space Institute," would be constructed in two stages. Initially, the N1 would launch a seventy-ton station in a 500-kilometer orbit, followed by a larger 200- to 300-ton version assembled by using three to four N1 launches. The station would be serviced by 7K Soyuz spacecraft.

152. Sir Bernard Lovell, letter to Hugh L. Dryden, July 23, 1963, file on Sir Bernard Lovell, NASA History Reference Collection, NASA History Office, NASA Headquarters, Washington, DC.

153. For a detailed discussion of the repercussions of the Lovell letter, see Dodd L. Harvey and Linda C. Ciccoritti, *U.S.-Soviet Cooperation in Space* (Miami, FL: Center for Advanced International Studies, University of Miami, 1974), pp. 114–19.

discourse in the United States. The issue was further muddied by President Kennedy's bold announcement, in front of a United Nations audience on September 20, proposing the discussion of "a joint expedition to the moon."[154] Judging by the response in the Soviet press, the USSR was simply not interested; Kennedy's offer was publicly ignored. Khrushchev added to the confusion with another ambivalent statement on Soviet lunar plans made at the third World Meeting of Journalists in Moscow on October 25:

> *At the present time we do not plan flights of cosmonauts to the Moon. I have read a report that the Americans wish to land on the Moon by 1970. Well, let's wish them success. And we will see how they fly there, and how they will land there, or to be more correct "moon" there. And most important—how they will get up and come back. We will take their experience into account. We do not wish to compete in sending people to the Moon without thorough preparation. It is obvious there would be no benefit from competition.*[155]

Once again, Khrushchev's pronouncements were taken as an indication of the Soviets' lack of interest in the Moon.

It is difficult to speculate on the true nature of events actually occurring within the Soviet leadership at the time without access to still-classified documents. But if we are to believe the Soviet leader's son, Khrushchev was close to making an about-turn in his thinking on the lunar landing issue. Sergey N. Khrushchev, then an engineer at Chelomey's design bureau, recalls that in the second week of September, just days after Kennedy's United Nations speech, his father for the first time openly spoke about jointly cooperating with the United States on a lunar landing project. Previous overtures from Kennedy on this issue had been rejected outright as a result of the Soviet military's great reluctance to engage in any major joint space endeavor. It seems that Khrushchev, however, had been steeling for a fight to change the military's position on the issue, certainly a difficult undertaking given the kind of secrets that would be put at risk in implementing such a joint project. When his son argued that cooperation was simply a bad idea, the older Khrushchev replied: "You don't understand that the Americans can design anything they want and our secrets will not be secrets forever . . . and now that we have enough missiles they already know that we are strong."[156]

There is no doubt that Khrushchev's intentions were partly motivated by economic considerations. Surprised by Korolev's estimated cost of a lunar landing at the meeting in June, Khrushchev was already backtracking on his lukewarm support from three months before. The fact that Khrushchev was indeed having a change of heart is evidenced by his only public comment on Kennedy's speech. On November 1, a little over a month after the call for cooperation, Khrushchev told the press:

> *We consider with due attention to the proposal of the U.S. President, that it would be useful if the USSR and the United States pooled their efforts in exploring outer space for scientific purposes, specifically for arranging a joint flight to the Moon. Would it not be fine if a Soviet man and an American woman flew to the Moon? Of course if would.*[157]

154. *Ibid.*, p. 123.
155. *Soviet Space Programs, 1962–65*, p. 360.
156. Khrushchev, *Nikita Khrushchev: tom 2*, pp. 459–61; Khrushchev interview, October 10, 1996.
157. Harvey and Ciccoritti, *U.S.-Soviet Cooperation in Space*, p. 125.

The chance to address a cooperative venture never came. Before Khrushchev could respond, President Kennedy was assassinated on November 22, 1963. The new administration of Lyndon B. Johnson was significantly less interested in a joint lunar landing program. Khrushchev also dropped the matter, never officially responding to Kennedy's United Nations speech.

Three factors—the rising interest from the Soviet leadership, the challenge from Apollo, and the question of how exactly to use the N1—all intersected in late 1963, prompting the Soviet space program to reassess its trajectory. The last issue, the utility of the N1, found its way into the debate in a roundabout way. A year before, in December 1962, an Academy of Sciences proposal had excluded the use of the N1 and ambitious piloted space expeditions from the immediate future of the Soviet space program. This suggestion apparently had the support of some highly placed defense industry officials.[158] Alarmed by this indifference to the N1, Korolev had fired off a letter on May 7, 1963, imploring the Academy of Sciences to revise its recommendation to include the N1 in its plans; fortunately, the academy responded favorably to Korolev's call. On August 10, Korolev received a revamped proposal from the academy that explicitly included both the N1 and human space exploration in its plans. Probably prompted by the increased visibility of the Apollo program, the academy suggested large-scale exploration of the Moon and planets. With the academy recommendation in hand, and also encouraged by Khrushchev's lukewarm interest, Korolev and his associates at OKB-1 produced a detailed technical document on September 23, 1963, titled "Proposals for the Research and Familiarization of the Moon." This document served as the first specific response to Kennedy's challenge to go to the Moon. Both robotic and piloted space missions to the Moon figured prominently in the report.[159]

Korolev divided his lunar plan into five major programs or "themes," each encompassing a specific goal, leading to a lunar landing in 1967 or 1968:

Type	Mission	Spacecraft	Launcher	No. of Launches
L1	Circumlunar	7K crew vehicle 9K upper stage 11K tanker	Soyuz	6
L2	Lunar roving	9K upper stage 11K tanker 13K rover	Soyuz	6
L3	Lunar landing	7K crew vehicle (modified) Lander	Soyuz N1	1 (Soyuz) 3 (N1)
L4	Lunar orbit	7K crew vehicle (modified)	N1	1
L5	Advanced lunar roving	Lunar rover	N1	1

158. State Committee for Radio-Electronics Chairman V. D. Kalmykov apparently proposed delaying the conceptualization of payloads for the N1 until a later time. See Raushenbakh, ed., *S. P. Korolev i ego delo*, p. 424.

159. This document has been reproduced in full as S. P. Korolev, "Proposal for the Research and Familiarization of the Moon" (English title), in *ibid.*, pp. 416–26.

Theme L1 was identical to the 7K-9K-11K Soyuz circumlunar complex that had been proposed by Korolev since about 1963. It involved launching a series of tankers into Earth orbit to fuel a translunar-injection stage, which would send a 7K Soyuz spacecraft around the Moon. Theme L2 was an initial concept for a robotic lunar rover to travel on the lunar surface for scientific research. This, too, would be assembled in Earth orbit with a combination of tankers and acceleration stages.

L3 was clearly the center of Korolev's plan. Although several different mission profiles were considered, engineers chose the conservative Earth-orbit rendezvous approach to accomplish the flight. The primary crew vehicle would be a modified Soyuz spacecraft. The main landing payload would be launched into Earth orbit by an N1, followed by two more N1 rockets, which would carry extra propellant for the translunar injection stage. A fourth launch of an R-7–derived booster was to carry a crew to the complex. Total mass in Earth orbit would be 200 tons; twenty-one tons would actually accomplish the landing on the Moon. Theme L4 was to conduct piloted lunar orbital missions using a modified Soyuz spacecraft with a special booster stage. Theme L5's primary goal was advanced roving missions on the Moon; cosmonauts could use these large five-and-a-half-ton rovers to travel long distances across the surface.[160]

On the same day that he signed his lunar plans, Korolev sent a letter to senior officials at his ministry proposing an eleven-point plan for space research during the period 1965 to 1975 and outlining the primary steps leading to a piloted lunar landing. Curiously, even as his financial troubles were rising, he refused to abandon old dreams. He continued to include as future goals piloted missions to Mars and Venus and giant Earth-orbital stations.

The September 1963 document laid the *conceptual* foundation for the Soviet reach for the Moon in the late 1960—a clear and unambiguous response to competition from Apollo. Korolev, however, had to address not only competition from the outside, but also competition from within. Starting with a primary focus on strategic ICBMs, Chief Designer Mikhail K. Yangel's OKB-586 had slowly moved into designing small military satellites for a variety of purposes. The design bureau also fielded a series of new launch vehicles for the most high-security military payloads. None of this would have any relevance to the piloted space program had it not been for Yangel's proposal for a heavy-lift launcher named the R-56, for which a development program had been approved in April 1962. From the beginning, it seems that Yangel had had his mind set on a particular goal for the R-56. As one of his deputies described:

> *This launch vehicle was predicted in a monoblock variant, and according to [the] evaluation of specialized institutes, it was the optimum rocket for realization of the programs given, including auxiliary tasks on Moon exploration. . . .*[161]

A draft plan for the vehicle and possibly its lunar spacecraft complex was prepared by 1964, thus positing it as a direct threat to Korolev's beloved N1. Chelomey, not content to watch his two rivals whiz past him, was also thinking of conceptions of a lunar landing spacecraft. His efforts were far behind the curve as compared to either Korolev or Yangel, and his participation in such a project did not figure in any significant way, at least not at the time.

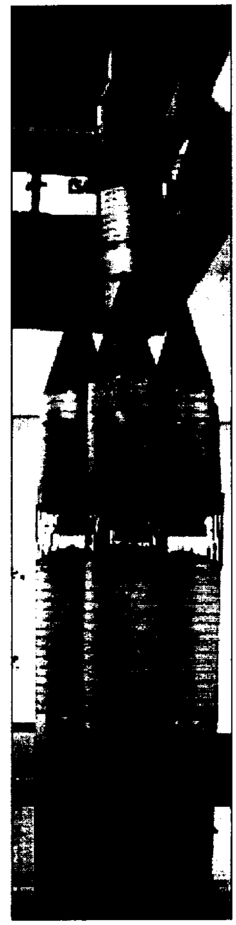
At the beginning of 1964, the complacency that had marked the Soviet response to Apollo no longer existed, and notwithstanding Yangel's R-56 idea, no one more than Korolev was

160. *Ibid.*

161. S. N. Konyukhov and V. A. Pashchenko, "History of Space Launch Vehicles Development," presented at the 46th International Astronautical Congress, Oslo, Norway, October 2–6, 1995. The R-56 was a three-stage rocket with a launch mass of 1,400 tons, capable of putting roughly fifty tons into orbit. The sixty-eight-meter-tall booster was derived from an earlier proposal for a giant booster named the RK-100, which was studied by Yangel in the early 1960s.

responsible for this change. Yangel may have been the best individual in the USSR to build missiles, but it was Korolev who had unbridled passion for space exploration. He clearly had more to lose if the "space race" was lost; he had bet his life on preeminence and was not about to lose it to a government that was unwilling to be sympathetic to his grand ideals. By early 1964, there were finally murmurs of political activity on the topic. On February 11, 1964, Air Force representatives visited the offices of the Military-Industrial Commission in the Kremlin, a visit prompted partially "by the appearance of a series of reports that the Americans already have trainers for work on a lunar landing."[162] One of the Air Force generals present, Lt. General Kamanin, wrote in his journal the following day:

> *. . . the Central Committee is approving a plan for sending an expedition to the Moon in 1968–1970. The N1 rocket, which is capable of putting into orbit a payload of 72 tons will be used for this purpose. The mass of all the systems (lunar ships), computed for flight to the Moon, lunar landing, and recovery on Earth, will comprise about 200 tons, i.e. it will require three N1 rockets and two dockings in orbit. The plan is still only on paper, while the Americans already have done much for carrying out flights to the Moon.*[163]



This is one conception of Mikhail Yangel's R-56 booster at a museum in Moscow. Yangel proposed the R-56 as a competitor to Korolev's N1 Moon rocket in 1962–64. The modular construction was based on clustering several heavy R-46 ICBMs. The R-46 was designed to carry fifty-megaton warheads. (copyright Mark Wade)

To accelerate the process, Korolev, accompanied by his First Deputy Mishin and Chief Designers Kuznetsov and Pilyugin, met with Khrushchev on March 17, 1964. Although the meeting was ostensibly about the general progress of the Soviet space program, a Moon landing seems to have been foremost on the agenda. After discussing robotic exploration and the Soyuz and Voskhod programs, Korolev raised the topic of the future of the N1 rocket. In his preparatory notes for the meeting, he had outlined several topics of discussion: the use of the N1 for the Ministry of Defense, a piloted lunar landing, piloted interplanetary missions, the development of liquid hydrogen rocket engines and nuclear rocket engines, and a global communications satellite system.[164] What was precisely said at the meeting still remains a mystery, but recent evidence suggests that it was that day that Korolev extracted a promise from Khrushchev to *politically* commit to a full-scale lunar landing program to compete with Apollo.[165] It is still unclear as to why the Soviet leader agreed at this time, when just six months before, financial considerations had prompted him to seriously consider cooperating with the United States. His son's observations on Khrushchev's views on the lunar landing allow some insight into his thinking at the time:

162. N. Kamanin, "A Goal Worth Working for . . .: The Space Diaries of a General" (English title), *Vozdushniy transport* 43 (1993): 8.

163. *Ibid.*

164. Korolev's notes have been reproduced in full as S. P. Korolev, "Plan of Notes to N. S. Khrushchev" (English title), in Raushenbakh, ed., *S. P. Korolev i ego delo*, pp. 442–44.

165. Interview with Georgiy S. Vetrov, Historian, RKK Energiya, November 15, 1996.

His feeling [on the lunar landing] was uncertain. He wanted to be ahead of the Americans, but for free. So when Kennedy announced the lunar program he did not accept Korolev's pressure that we have to do the same. And in the end, all of them [the chief designers] pressed him and said that it would be much less expensive than the Americans and that we have to do this, and [it was] then that he accepted this. . . . So he approved it, but I don't think that he spent too much of his own time thinking about this and discussing it. It was not such a national priority as in the United States.[166]

From Korolev's perspective, there were clearly two differing motivations to the decision to go to the Moon: one was to compete with Apollo and the second was to salvage the N1 rocket from the scrap heap of history. Consigned to oblivion by the lack of funding, the project was at a standstill in early 1964. No one, least of all the Ministry of Defense, had defined a reason for its existence. He had just given it one. Both these motivations are crucial to an understanding of the eventual fate of the program. The former—that is, to compete with Apollo—was a major and unprecedented shift in vision from the Tsiolkovskiy-influenced ideas of Earth-orbital stations leading to interplanetary flights. The latter—that is, to save the N1—was simply a management strategy. Within five days of the meeting, Korolev signed off on a new plan of action at his design bureau for 1964 through 1966, focused on the N1, with special attention to advanced liquid hydrogen engines for the upper stages.

Khrushchev had made the promise, but it was still a verbal commitment. There was a bureaucratic gridlock to address. The February–March discussions were to have led to a formal decree of the Central Committee and the Council of Ministers. This, however, was constantly delayed. Party and state officials were unconcerned with the N1 because it had not been included in the original program of research for the next five-year plan. As a result, money for the N1 remained tied up. In three letters dated May 15, Korolev wrote to the leading administrators in the defense industry to include the N1 as part of future funding allocations.[167]

The draft of a fourth desperate letter was prepared by Korolev on May 25 and addressed directly to Leonid I. Brezhnev, the Secretary of the Central Committee for Defense Industries and Space, the top space program leader in the country at the time. Declassified thirty years later, the draft stands testament to the complete disarray of the Soviet human space program by 1964. It began auspiciously with the phrase: "We have been wasting a lot of precious time on the N1." Through paragraph after paragraph, Korolev mentioned the litany of problems in the N1 program:

It will be sufficient to point out that the initial sum of 11 million rubles, which was decided on in 1964 by the Ministry of Defense for construction of the launch and technical position for the N1, was at [their] discretion unexpectedly reduced to 7 million rubles and now to 4 million rubles overall. The Ministry of Defense has refused to finance further the construction of the N1 despite the existing decrees. In May of the current year all the money will be used up for this [program], and construction of the launch [complex] of the N1 will completely stop in a few days. Up to now the plants have not been supplied with the necessary equipment and materials, and a lot of decisions and orders have not been carried out by the involved organizations. For more than two years, a whole number of assignments and orders agreed in decrees has remained

166. Khrushchev interview, October 10, 1996.

167. S. P. Korolev, "Report From S. P. Korolev to the Secretary of the TsK KPSS L. I. Brezhnev" (English title), *Nauka i zhizn* no. 5 (May 1994): 21–23, commentary to the document. The letters were addressed to Chief of the Defense Department of the Central Committee I. D. Serbin, Chairman of the Military-Industrial Commission L. V. Smirnov, and Chairman of the State Committee for Defense Technology S. A. Zverev.

unfulfilled, and no one is questioned about it. With regard to many problems and plans prepared for the N1, many months go by and no one even examines them. . . .[168]

Korolev then made a politically motivated plea:

This is an absolutely intolerable situation with the N1, not only for Soviet science and technology but also for maintaining the priority of our state in that most important and difficult sphere, space, as the first socialist country in the world, the birthplace of great revolutionary ideas and a progressive nation leading the world in the socialist system. Nikita Sergeyevich Khrushchev has always supported progressive science, and in particular, much new work in the sphere of new technology and space research, and he has said more than once that socialism—this is the hopeful starting point from where all our rockets and ships will be launched. Very recently Nikita Sergeyevich listened to and supported the proposal of a group of Designers to speed up work on the N1. Two months have passed since then and nothing has been accomplished and nothing has changed with the N1 . . . it's evidently clear that once again the N1 hasn't received enough attention while time is slipping away. . . .[169]

He then mentioned the U.S. space program:

The scope and progress of the work on "big space" in the U.S.A. is a reason for great alarm. Already in May of this year, the U.S.A. is preparing to fly the two-stage "Saturn" rocket with a full-scale model of the "Apollo" ship designated as part of the project to land American researchers on the Moon. This model is without people on board now, but this flight undoubtedly will be followed by others. At the present the U.S.A.'s "Saturn" rocket takes a useful payload of 11–12 tons with a total mass of around 17 tons into an initial orbit around the Earth. In this, the U.S.A. has already surpassed the Soviet Union.[170]

Conscious of the fact there was a real competition in the piloted circumlunar effort between Chelomey's LK-1 and Korolev's Soyuz, Korolev reminded Brezhnev of the pathetic state of the Soyuz program:

To fly around the Moon with a crew (without landing) it is sufficient for the U.S.A. to double this load [of 12 tons], for example, by using a single-docking method in the initial orbit. We have been working on such a theme, the "Soyuz," for a number of years, but unfortunately, just like the N1, it has never received adequate support, and [the work on it] has not been fully satisfactory. If urgent additional measures are not adopted on the "Soyuz" theme, the Soviet Union will lag behind the U.S.A. in this area too.[171]

Following more complaints about the poor state of the liquid hydrogen industry and the industry's favoritism in the use of toxic propellant components, Korolev finally ended with a focused and specific plea for a Soviet response to Apollo:

The U.S.A. is planning to land people on the Moon in 1969 (instead of the earlier date of 1970) and according to their plans, they will be in a position to fly around the Moon

168. *Ibid.*, p. 21.
169. *Ibid.*, pp. 21–22.
170. *Ibid.*, p. 22.
171. *Ibid.*

(in 1966); in 1967 the U.S.A. expects and evidently will have a working variant of the "Saturn-5" with a launch mass of 2,700–3,000 tons, at which time the U.S.A. will be able to fly into space many times without limitations. It's possible to visualize the following scenario: what is to prevent the U.S.A. from accelerating its work a little bit (which is of enormous scale and part of a well coordinated plan), to not only fly around the Moon, but also to land men on its surface in 1967, the year of the fiftieth anniversary of the first Soviet state on our planet? There are three years left *to that momentous date. In this time, we can pay attention to and organize our work to solve the problem of landing Soviet researchers on the surface of the Moon and secure their return to Earth. . . .*[172]

Only the draft of the letter has been declassified, but Korolev's language strongly hints at his priorities of the period. The piloted lunar program had clearly split into two disjointed efforts: a circumlunar track with proposals from Chelomey (LK-1) and Korolev (Soyuz) and a landing track with proposals from Yangel (R-56) and Korolev (N1). With Apollo rising, the chief designers all rushed to respond. There is no question that the leading space designers were indeed scared to the bone by Apollo. Although Western observers had nary a clue, the heydays of Sputnik and Gagarin were irrevocably over.

Just three days after signing the draft of the letter to Brezhnev, on May 28, 1964, the first dummy Apollo spacecraft was inserted into Earth orbit by the sixth Saturn I booster.[173] For those "within the know" in the Soviet space program, the contrast between the obsolete Vostok and the flying Apollo was crystal clear. The impetus to approve Korolev's program, if on shaky ground before, had a more imposing imperative. Within two months, the Central Committee and the Council of Ministers issued two landmark decrees that finally responded to Apollo. The first one, on June 19, guaranteed additional funding for the N1 lunar rocket and reset the start of flight testing to 1966 from the originally mandated 1965.[174] Given the damage caused by the inactivity in 1963–64, some engineers privately believed that even 1966 was too optimistic. To support the future Soviet space projects, a total of sixteen N1 boosters were to be manufactured between 1966 and 1968.[175]

172. *Ibid.*, p. 23. Author's emphasis.

173. Roger E. Bilstein, *Stages to Saturn: A Technological History of the Apollo/Saturn Launch Vehicles* (Washington, DC: NASA SP-4206, 1996), pp. 328–29.

174. Note that one source suggests that this decree was issued on July 27, 1964, not June 19. For the former, see Raushenbakh, ed., *S. P. Korolev i ego delo*, p. 444. For the latter, see pp. 692–93 in the same source. This decree also "invited" OKB-586 and OKB-456 to cooperate with OKB-1 on developing the N1.

175. Afanasyev, "N1: Absolutely Secret: Part II." Another reliable source states that twelve N1 boosters were to built as per the original plan. See Boris Arkadyevich Dorofeyev, "History of the Development of the N1-L3 Moon Program," presented at the 10th International Symposium on the History of Astronautics and Aeronautics, Moscow State University, Moscow, Russia, June 20–27, 1995. Four days after this decree was issued, on June 23, 1964, Korolev convened for the first time all the leading chief designers of the space program to discuss both the N1 and its use for a piloted lunar landing. The central point of debate was whether to directly develop a high-energy liquid hydrogen-equipped N1 or to begin with a conventional propellant variant and then move to the more advanced version. Given the government's poor response in supporting liquid-propellant engine development, the chief designers overwhelmingly supported initial development of the conservative "K" variant; Korolev proposed that they would "gradually" develop the most preferred liquid hydrogen version, the "V3," for future missions. Five different models of the N1 were considered: K, V1, V2, V3, and D-A. These differed as follows: K—liquid oxygen (LOX)-kerosene on all stages; V1—LOX-liquid hydrogen on first stage; V2—LOX-liquid hydrogen on second stage; V3—LOX-liquid hydrogen on third stage; and D-A—nitrogen tetroxide-unsymmetrical dimethyl hydrazine (UDMH) on all stages. The D-A was proposed by Chief Designer V. P. Glushko, who evidently had not abandoned his quest to use storable propellants on the N1 despite the July 1962 decision by the Academy of Sciences recommending the use of cryogenic propellants on the booster. Glushko believed that a "new" fuel, hydrazine-50, would allow better characteristics than his earlier proposal in 1962 to use UDMH. Korolev compromised with Glushko and agreed to let three teams assess the usefulness of Glushko's proposal. These teams were led by V. S. Budnik (OKB-586), V. P. Mishin

The following month, on July 24, 1964, at a meeting hosted at the Military-Industrial Commission, its Chairman Smirnov fully sanctioned Korolev's proposal on the L3 lunar expedition as well as further work on liquid hydrogen rocket engines.[176] A week later, on August 3, the second decree (no. 655-268), titled "On Work on Research on the Moon and Outer Space," was signed into law.[177] It was a comprehensive "five-year plan" on space, which covered everything—scientific satellites, probes to Venus and Mars, spaceplanes, military satellites, and the Soviet piloted space program. Within the framework of the piloted space program, the Soviet Union committed to two separate piloted lunar projects to retain its status as the world's preeminent space power. The first was a human circumlunar project, and the second was a lunar landing project. The former was tasked to Chelomey's OKB-52; his new LK-1 single-pilot spacecraft would be launched on a modification of the UR-500 ICBM to accomplish a circumlunar flight before the beginning of the second quarter of 1967—that is, in time for the fiftieth anniversary of the Russian Revolution later in the year.[178] Funding was apportioned for the construction of twelve LK-1 vehicles. In addition to the circumlunar program, a program of four test launches to convert the UR-500 missile into a space launch vehicle was approved. Each of the boosters would carry a new heavy scientific satellite to be developed by Chelomey in cooperation with the Scientific-Research Institute of Nuclear Physics of Moscow State University.[179]

The commitment to Chelomey's LK-1 circumlunar proposal was clear evidence of the astounding confusion inherent in the Soviet space program at the time. Less than two years before, the Soviet leadership had approved Korolev's 7K-9K-11K Soyuz complex for the exact same mission. Yet another victim of the rising and falling fortunes of chief designers, Korolev's program effectively received its death knell on August 3, 1964, despite at least two years of continuous work on elements of the Soyuz complex. What prompted this change of heart remains in the realm of speculation. Perhaps it was the complexity of the 7K-9K-11K plan, which required four to five dockings in Earth orbit. Perhaps Chelomey's plan offered advantages that Korolev's did not. Perhaps it was a case of Chelomey's charms winning over Korolev's charms. Or perhaps it was simply a decision made with no rational thought. What is clear is that Korolev fought hard for the Soyuz complex but lost. What is also clear is that true to character, he refused to give up on the circumlunar effort, raising the specter of many more battles between the two big designers.

(OKB-1), and V. P. Radovskiy (OKB-456). Given the allegiances of Mishin and Radovskiy, their recommendations were no doubt a foregone conclusion. The overall meeting was attended by S. P. Korolev (OKB-1), A. F. Bogomolov (OKB MEI), Ye. Ya. Boguslavskiy (NII-885), V. P. Barmin (GSKB SpetsMash), V. S. Budnik (OKB-586), V. P. Glushko (OKB-456), M. A. Golubev (OKB-154), A. Yu. Ishlinskiy (AN SSSR), M. V. Keldysh (AN SSSR), M. A. Kuzmin (OKB-165), N. D. Kuznetsov (OKB-276), V. I. Kuznetsov (NII-944), A. M. Lyulka (OKB-165), V. P. Mishin (OKB-1), N. A. Pilyugin (NII AP), M. S. Ryazanskiy (NII Priborostroyeniya), M. K. Yangel (OKB-586), and A. P. Yeliseyev (OKB-2). OKB-1 notes on the meeting have been reproduced as "Minute Notes at the Meeting of Chief Designers on the Course of Work on the N-1 Heavy Carrier" (English title), in Raushenbakh, ed., *S. P. Korolev i ego delo*, pp. 455–60.

176. Raushenbakh, ed., *S. P. Korolev i ego delo*, p. 693. In attendance, besides Smirnov, were V. N. Chelomey, M. V. Keldysh, and S. P. Korolev.

177. Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p. 252; V. Filin, "At the Request of the Reader: The N1-L3 Project" (English title), *Aviatsiya i kosmonavtika* no. 12 (December 1991): 44–45; Vetrov, "The Difficult Fate of the N1 Rocket"; Afanasyev, "N1: Absolutely Secret: Part II"; N. Kamanin, "A Goal Worth Fighting for . . ." (English title), *Vozdushniy transport* 44 (1993): 8–9.

178. Kamanin, "In the Future His Name Will Probably Be . . ."; Igor Afanasyev, "Without the Stamp 'Secret': Circling the Moon: Chelomey's Project" (English title), *Krasnaya zvezda*, October 28, 1995. Note that the latter source suggests that the title of the decree was "On Research on the Moon and Future Development Work on Research into Cosmic Space."

179. Khrushchev, *Nikita Khrushchev: tom 2*, pp. 477–78; V. Petrakov and I. Afanasyev, "'Proton' Passion" (English title), *Aviatsiya i kosmonavtika* no. 4 (April 1993): 10–12. There were evidently other provisions of the decree related to Chelomey, including the development of more Raketoplans and winged and ballistic missiles.

The most important element of the August 1964 decree was clearly the commitment to a lunar landing competitive with the Apollo program. According to the guidelines of the document, which still remains classified, the lunar landing was to take place in 1967 or 1968, to roughly coincide with the fiftieth anniversary of the Great October Revolution. For the Soviets, the Kennedy deadline of 1969 was far less an important factor than the national celebration slated for 1967, a factor that was accurately picked up by both NASA and U.S. intelligence services in the mid-1960s. The actual landing was to be accomplished with the aid of the "L3" lunar complex launched on a single N1 booster. OKB-1 was given the contract to design and build the L3. While Korolev had lost out to Chelomey for the circumlunar program, he did win over Yangel's R-56 proposal. In the same decree approving further work on the N1, dated June 19, the Soviet government ordered the cessation of all work on the R-56 booster. In the world of political infighting among the designers, Yangel's engineers did not take the decision lightly. As one recalled, "[the R-56 was canceled] without any visible causes and reasons, this development work was suddenly stopped . . . [and] many specialists and scientists were sorry about this decision."[180] Perhaps there was some sense in the decision: Khrushchev, Brezhnev, and Smirnov may have been ready to squander piloted space program resources on both Chelomey and Korolev, but adding a third participant may have been simply too much. Khrushchev himself was reportedly reluctant to allow Yangel's heavy participation in space programs, believing that such a state of affairs might divert the otherwise focused designer from building better missiles for the Soviet state.[181]

It took the Soviet Union three years and three months to respond to Kennedy's speech to go to the Moon. Given what we now know about the relative poverty and ferocious infighting symptomatic of the Soviet piloted space program, this is not so odd. Westerners in the 1960s, with little information, naturally assumed that the piloted space program was a huge priority to the Soviet state—an indispensable vehicle for publicity relations that was at the center of Soviet science and technology policy. The blunt and sometimes caricatured propaganda that emanated from the Soviet press merely confirmed the worst fears of Western alarmists. In the Western writing on Soviet space history, it almost became customary to tout in every third paragraph how Khrushchev was continuously scheming to extract more propaganda benefits from his hapless pawn Korolev by ordering him to do this or that. The reality could not have been further from that. Khrushchev, it seems, was more concerned about money and missiles than he was about cosmonauts and the cosmos. Perhaps influenced by his son, or perhaps by his own instincts, he was never particularly interested in competing with Apollo.[182] It was only Korolev's singular persistence—in letters, at meetings, and during conferences—that resulted in the August 1964 decision. It may have been the most important decision in the history of the early Soviet space program for it set the stage for ten long years of elusively searching for the Moon. In the end, the Moon proved to be as elusive for the Soviets during the era of Apollo as being first in space was for the Americans during the era of Sputnik.

180. Konyukhov and Pashchenko, "History of Space Launch Vehicles Development." One factor that played against the R-56 was that it would only be capable of accomplishing circumlunar flight or robotic lunar exploration. Because it was even less powerful than the N1, the R-56 would have had to fly multiple missions to perform a single piloted landing on the Moon.

181. See, for example, Khrushchev, *Nikita Khrushchev: tom 2*, p. 169.

182. One Soviet journalist remarked in 1990 that one of the reasons for Khrushchev's apparent reluctance to commit to a lunar landing program may have been because of advice from his son Sergey, who was an engineer under Chelomey. See Leonard Nikishin, "Inside The Moon Race," *Moscow News*, April 11, 1990, p. 15.

Chapter Ten
"There Are More Things in Heaven and Earth..."

The Voskhod project effectively diverted attention from the natural progression of piloted space plans at OKB-1. The Soyuz program was temporarily in oblivion, having lost its primary *raison d'être*, while more adventurous plans such as interplanetary ships and huge space stations began to fall by the wayside in the competition with Apollo. As a result, the twelve months spanning the two Voskhod missions was a period best characterized as limbo for OKB-1: two spectacular missions emerged from the mysterious vacuum of the Soviet space program, disappearing forever, leaving no visible trace of exactly what gain had been extracted from the effort.

How to Design a Voskhod

A group of fifty engineers at OKB-1 under "lead designer" Yevgeniy A. Frolov were assigned the task of modifying the basic 3KA Vostok vehicle into the 3KV Voskhod vehicle within five months. The primary goal was to ensure a spaceflight by three crewmembers; all the other objectives were supplementary. There seems to have been a fair degree of opposition to the entire effort from Korolev's staff. Konstantin P. Feoktistov, the resourceful engineer who played a critical role in the design of the Vostok, was on the Voskhod design team. He later recalled how Korolev neutralized his internal opposition:

> *. . . we argued that it would be unsafe, that it would be better to be patient and wait for the Soyuz spaceship to be built. . . . In the end, of course, [Korolev] got his way. In February 1964 he outwitted us. He said that if we could build a ship based on the Vostok design which could carry three people, then one of those places would be offered to an [OKB-1] engineer. Well, that was a very seductive offer and a few days later we produced some rough sketches. Our first ideas were accepted. We unveiled our plans for this new ship in March or April.*[1]

Feoktistov was the first to propose omitting both the ejection seat and spacesuits from the Vostok, thus allowing three men to cram into the spherical capsule in regular clothing. There were "heated discussions" between physicians and engineers on the spacesuit issue, but the argument was settled by physical impossibility: it would have been simply impossible to fit

1. "The Russian Right Stuff: The Dark Side of the Moon," *NOVA* television show, #1808, WGBH-TV, Boston, February 27, 1991.

three men in a ship in pressure suits.[2] The deletion of the ejection seat had serious safety implications for both launch and landing. During launch, none of the three cosmonauts would be able to eject from the spacecraft in case of a launch failure; during landing, the cosmonauts would have to remain within the descent apparatus all the way to the dangerous impact on hard ground. Korolev addressed the first problem by tasking KB-2 of Plant No. 81 to speed up the development of a solid-rocket–propelled launch escape system that its Chief Designer Ivan I. Kartukov was creating for the Soyuz spacecraft. For the landing, OKB-1 engineers proposed the use of a "parachute-reactive" system first proposed for the modified Vostok missions in 1963. This was a three-level parachute system augmented by powerful solid-rocket motors to decrease velocity at the moment of landing. A final modification to the original Vostok design was the introduction of a secondary retrorocket engine. In the early Vostok missions, the cosmonauts could depend on natural atmospheric reentry if the retro engine failed. In the case of Voskhod, there would be no such luxury because the life support system would ensure optimal conditions for three people for only one day. If the retro engine failed after that day, the crew would die by the time of natural decay. The backup engine would ensure against such a possibility. Engineers benefited from the fact that almost all the major modifications to the original Vostok, such as the use of a reserve retro-rocket engine, had already been planned for the unflown "extended Vostok" missions in 1963. Thus the Voskhod design project was much less of a hurried process than typically described by Western historians.

Engineers completed the draft plan for the 3KV spacecraft in August 1964, and they began construction of two flight articles.[3] As plans stood at the time, the spacecraft would fly for one day in a 180- by 240-kilometer orbit with three cosmonauts. Unlike the earlier Vostok vehicles, the Voskhod spacecraft would be launched by an uprated three-stage booster known as the 11A57, which was originally developed for launching Zenit-2 reconnaissance satellites.[4]

The primary changes to the Vostok spacecraft were:

- The removal of:
  - Spacesuits with their air-conditioning systems
  - The catapult, its survival kit, and parachute system
  - The movie camera
  - Biological experiment instrumentation

2. G. Salakhutdinov, "Once More About Space" (English title), *Ogonek* 34 (August 18–25, 1990): 4–5; Yu. A. Mozzhorin, *et al.*, eds., *Dorogi v kosmos: I* (Moscow: MAI, 1992), p. 63.

3. The draft plan has been reproduced with disguised designations as S. P. Korolev, "On the Possibility of Creating the Three-Seat 'Voskhod' Space Ship" (English title), in M. V. Keldysh, ed., *Tvorcheskoye naslediye Akademika Sergeya Pavlovicha Koroleva: izbrannyye trudy i dokumenty* (Moscow: Nauka, 1980), pp. 470–76.

4. This rocket, also called "Voskhod," was yet another one in the long line of modifications of the basic R-7 ICBM that Korolev was producing to launch a variety of robotic payloads. The smaller Vostok spacecraft had been launched by the 8K72K booster, which was essentially the R-7 with a new upper stage with a thrust of just under thirty and a half tons. That rocket could put about just under five tons into orbit, far less than the five and a half tons needed for Voskhod. Instead of creating a new powerful engine for the upper stage, Korolev's people took the engine from the second stage of the R-9A ICBM and installed it in place of the old upper stage engine on the Vostok launcher. The new engine, the RD-0108 developed by Chief Designer Kosberg's OKB-154, had a vacuum thrust of 30.4 tons. The second-stage engine of the R-9A had the designation RD-0106 and had a thrust of about thirty tons. This engine was used as the basis for several different engines, each with a similar level of thrust for a variety of three-stage R-7 launch vehicles. See Timothy Varfolomeyev, "Soviet Rocketry that Conquered Space: Part 4: The Development of a Four-Stage Launcher, 1958–1960," *Spaceflight* 40 (January 1998): 28–30; Timothy Varfolomeyev, "Soviet Rocketry that Conquered Space: Part 6: The Improved Four-Stage Launch Vehicle, 1964–1972," *Spaceflight* 40 (May 1998): 181–84.

- The installation of:
  - Three shock-absorbing *Elbrus* couches
  - New survival kits
  - A reserve solid-propellant braking engine
  - A spacecraft orientation system using ion sensors
- The replacement of:
  - A TV system of ten frames per second in favor of a system of twenty-five frames per second
  - The old radio-channel system with a new one
  - The old landing beacon in the descent apparatus with a new one[5]

By the time that the draft plan was completed, it was clear that Plant No. 81 would not have a working version of a tower-equipped launch escape system ready for the Voskhod launch. Korolev and his engineers took the risky step of moving on with a launch despite this glaring disregard for safety. In its 3KV draft plan, OKB-1 merely stated that it would be "difficult" to rescue the cosmonauts up to the first twenty-five to forty-four seconds of a launch; a more accurate term might have been "impossible." After the forty-fourth second, if there was an explosion, an identical mission profile to Vostok would be used whereby the payload would simply separate from the launcher, travel along a ballistic trajectory, and land by parachute. Before T+501 seconds, this landing would be in Soviet territory; after T+501 seconds and up to orbital insertion at T+523 seconds, the landing would be elsewhere.

In orbit, the three cosmonauts would have little to do except monitor the ship's systems and take pictures. The new TV system, developed in a cooperative venture by the Experimental Design Bureau of the Moscow Power Institute and NII-380, would consist of a camera within the cabin to observe the crew and one on the outside of the vehicle that could be controlled by the crew. One of the goals was apparently to take video of the third stage of the 11A57 booster after orbital injection as well as of Earth's surface and the Moon. The cosmonauts would at most have one full day of safety in orbit: the engineers had predicted an outflow of air from the Voskhod at 180 liters per minute as opposed to the fifty liters per minute on Vostok—a significant regression in capabilities. The new automatic ion orientation was to supplement a manual system for positing the vehicle correctly prior to retrofire. The primary motivation for installing the new system was to allow the ship to orient itself during passage through the "dark" side of their orbit, when the Sun was not in view. This had been a problem during the Vostok missions in which the vehicles were equipped only with a solar sensor. Ion-sensitive sensors would use the thin ionization layer around Earth to provide information on the longitudinal axis of the ship relative to the primary velocity vector.

The spacecraft had the standard TDU-1 liquid-propellant engine for the reentry burn. The supplementary retro engine was fueled by eighty-seven kilograms of solid propellants; total mass of the engine itself was 143 kilograms. The engine would provide a single powerful burst of 12,000 kilograms thrust, lasting approximately two seconds, which was sufficient to deorbit the descent apparatus. Following reentry, a triple-level parachute system consisting of an exhaust, a braking, and two primary parachutes would bring the *sharik* down to the ground. A probe, formally called the "distance contact instrument," would be deployed from the base of the descent apparatus to a length of 1.2 meters to make contact with the ground in advance of the spacecraft itself. At contact point, just prior to landing, one solid-propellant engine affixed to the base of the parachute would fire, dropping final velocity from about eight to ten meters per second to a bearable two-tenths meter per second. The Elbrus couches were designed to

5. Korolev, "On the Possibility of Creating."

mitigate the effects of touchdown by reducing loads from twenty to thirty g's for only five-hundredths second by the use of a special spring suspension system, which would allow movement of 200 to 300 millimeters back and forth.[6]

Because of the placement of three new couches, the internal look of the spacecraft differed considerably from Vostok. The three seats were placed side by side in a triangular shape, with the middle one raised forward. The main instrument panel and the *Vzor* optical sight were located to the left side of the three couches instead of in front as in the Vostok vehicle. The dimensions of the 3KV Voskhod spacecraft were similar to the old Vostok: a length of five meters and maximum diameter of 2.43 meters. The spherical descent apparatus had a mass of 2,900 kilograms, about 500 kilograms heavier than Vostok. The complete two-module combination weighed 5,320 kilograms.

The landing profile of the Voskhod spacecraft with the parachute-reactive system and its landing probe was the focus of much testing throughout 1964, interrupted not only by failures but also by Korolev's own schedule. Astonishingly, OKB-1 did not have a single 3KV article to simulate landings, an indication of the poverty of the piloted space program. Meanwhile, there were literally dozens of similar vehicles coming off the factory line in support of the Zenit-2 and Zenit-4 reconnaissance satellite programs. In a desperate move, Korolev asked one of his old pre-GIRD associates, Petr V. Flerov, to take cosmonaut Titov's Vostok 2 descent apparatus from the OKB-1 museum, equip it with the necessary instrumentation, and test-drop it.

In the middle of the Voskhod development program, Korolev was allowed an unusual privilege: permission to leave the Soviet Union on a holiday. Through the year, he had been beset by worse-than-usual afflictions. On February 11, 1964, in the middle of a meeting at his office in Kaliningrad, he suffered a heart attack and spent several days in the hospital.[7] Doctors had prescribed a long holiday, which was delayed several times by more pressing work. Korolev had always wanted to go abroad and had a particular fascination for going to England, but Secretary of the Central Committee Brezhnev opposed any visit to the West. In the end, he and his wife were allowed to fly to Czechoslovakia on June 27, the only time between 1947 until his death that Korolev left the Soviet Union. Secrecy was tight, and he was not even permitted to register in the guest book of the Czech Communist Party's Central Committee, a standard honor for important dignitaries. At the end of his visit of three weeks, he told his hosts, "When I come to Czechoslovakia the next time, you will know who I am."[8]

Korolev was unusually ambivalent about his anonymity. Noted Russian journalist Yaroslav Golovanov, in his 800-page magnum opus *Korolev: fakty i mify* (*Korolev: Facts and Myths*), writes that the designer rarely, if ever, talked about the issue with anyone. If the conversation moved in that direction, he would only say that anonymity allowed him to live a calmer life. Golovanov argues convincingly that Korolev may have even liked it in some perverse way. He liked the aura that surrounded his existence. When he read press accounts that speculated that Academicians Sedov, Blagonravov, or others were possibly the anonymous "Chief Designer," he never felt angry or irritated, evincing only a kind of weariness and "secret joy" at the ignorance of the authors. Secrecy itself was a way of living for Korolev, and it seems that he did not outgrow it through his life. He never kept any diaries, never brought any secret documents

6. *Ibid.*; A. V. Ponomarev, "2 June—75 Years From the Birth of Academician A. F. Bogomolov (1913)" (English title), *Iz istorii aviatsii i kosmonavtiki* 59 (1989): 47–50; K. P. Feoktistov, "The Development of Soviet Piloted Space Ships (Up to the Early 1970s)" (English title), in B. V. Raushenbakh, ed., *Issledovaniya po istorii i teorii razvitiya aviatsionnoy i raketno-kosmicheskoy nauki i tekhniki* (Moscow: Nauka, 1981), p. 113.

7. Yaroslav Golovanov, *Korolev: fakty i mify* (Moscow: Nauka, 1994), p. 771.

8. Ye. Chernykh, "Was Gagarin Really in Space?: Cosmonaut No. 1 Flew Around the Planet One Time. But This Fairly Shabby 'Canard' Is Making the Umpteenth Orbit" (English title), *Komsomolskaya pravda*, September 22, 1990, p. 3.

home, and never jotted down unauthorized comments in private notebooks. He may have told his wife Nina Ivanovna about some of the people involved with the space program, but he never talked about the program itself. When, after Gagarin's flight, she pressed him for details, he made her repeatedly swear an oath of "eternal silence," explaining to her a dozen times the need for secrecy. Finally, all he would tell her was that the rocket Gagarin flew into orbit had three stages. Once when she innocently uttered the word "Tyura-Tam" in the kitchen, Korolev instantly pricked up his ears, interrogating her for a long time on where she had heard such a word.[9] About the secrecy in the Soviet space program, Golovanov writes insightfully that:

> *. . . this is exactly the path that we chose for the space program . . . during Korolev's time, everybody and Korolev included, naively believed that secrecy was necessary because we were ahead. Secrecy was necessary so that no one would overtake us. But later when they did overtake us, we maintained secrecy so that no one knew that we had been overtaken.*[10]

Upon returning to Moscow on July 16, Korolev immediately dove back into the Voskhod preparations. Flerov had finished outfitting Titov's capsule for the drop-test, which was carried out on September 6 at the testing range at Feodosiya in Crimea. The test was a disaster: the parachute hatch failed to open, jamming the parachute in its container, and the descent apparatus, the second vehicle ever to carry a human into space, was shattered into smithereens.[11] It was clear that there were deficiencies in the new parachute system. Engineers from the Scientific-Research and Experimental Institute of the Parachute Landing Service, the subcontractors for both the Vostok and Voskhod parachutes, were closely involved in diagnosing the problems with the systems over the following weeks. Originally, Korolev had promised Khrushchev that the first Voskhod mission would be carried out in August 1964. This deadline, for obvious reasons, proved to be too ambitious. Following the accident with the landing, the launch was moved back a complete month to troubleshoot the problem. As per original plans, OKB-1 planned to launch an automated version of the 3KV vehicle into orbit for a one-day shakedown flight, albeit without dogs as originally slated.

Pilots, Engineers, and Doctors?

The question of who would fly on the Voskhod mission was an issue that was completely grounded in bureaucratic politics and clouded by personal interests unrelated to the mission goals. For several years, Korolev had publicly spoken about sending "passengers" into space on his ships. "Passengers" for Korolev was at that time merely an euphemism for young engineers from his own design bureau. He was of the opinion that the ones who actually built the ships should also have a chance to fly in them. This opinion was stated in a letter to the Soviet government in February 1962, but it was only with the Voskhod mission that there was state action

9. Golovanov, *Korolev*, pp. 686–89.
10. *Ibid.*, p. 688.
11. There are contradictory dates referring to this accident. One source suggests that it was in "late August." See *ibid.*, p. 736. Kamanin implies in his diaries that the accident took place in early September. See N. P. Kamanin, *Skrytiy kosmos: kniga vtoraya, 1964-1966gg* (Moscow: Infortekst IF, 1997), p. 80. A third source suggests February 6, 1964, which is probably an error for September 6, 1964. See B. Ye. Chertok, *Rakety i lyudi: goryachiye dni kholodnoy voyny* (Moscow: Mashinostroyeniye, 1997), p. 243. Note that there were several earlier tests of the Voskhod parachute system, but these probably did not use full-scale descent apparatus modules. For example, Kamanin, in his diary entry for September 2, 1964, wrote that there was a failure on August 29 because of a "spurious" jettisoning of the parachute hatch. According to Kamanin, by August 14, 1964, there had been ten landing tests of the parachute system, all probably without descent apparatuses.

on the matter.[12] While one seat could be reserved for the usual Air Force pilot, the remaining two could be nonaviators. Korolev was well aware that the Air Force would find this completely unacceptable; the military had already firmly refused Korolev's earlier efforts to train OKB-1 engineers for spaceflight.

For Voskhod, Korolev wanted to fly an OKB-1 engineer and a doctor in the extra seats. For the engineer spot, he enlisted the support of President of the Academy of Sciences Mstislav V. Keldysh, although it is clear that Keldysh was more inclined to propose a *scientist* rather than an engineer, a difference in interpretation that later threatened to divide Keldysh and Korolev. Deputy Minister of Health Avetik I. Burnazyan, a veteran of the medical service for the nuclear weapons program, also threw in his support to Korolev for a doctor on the flight.[13] The pilot-engineer-doctor combination was specified in the March 13 decree of the Military-Industrial Commission, which had first approved the Voskhod mission. It seems that the Air Force had conceded its position, retreating under the combined lobbying of Korolev, Keldysh, and Burnazyan.[14] The fact that it was acceptable for these "passengers" to undergo training for a space mission for a period of only three or four months suggests something about the manner in which the leading officials viewed cosmonauts for the Voskhod and Vostok spacecraft—that they were more inert observers than active participants. With the exception of the politicians who flew on the U.S. Space Shuttle in the mid-1980s, it was quite possibly the most compressed training schedule ever for people preparing for spaceflight.

The Mandate Commission, responsible for approving individuals for cosmonaut training, examined applications from a number of physicians from various military and civilian institutions during April and May, naming the following four finalists on May 26:

- Lt. Colonel Vasiliy G. Lazarev (thirty-six years old)
- Major Boris I. Polyakov
- Aleksey V. Sorokin (thirty-two)
- Boris B. Yegorov (twenty-six)[15]

Yegorov and Lazarev were strong contenders, and both had influential supporters. By some twist of fate, Korolev had recently met with Yegorov's father, Boris G. Yegorov, who was an influential medicine specialist and a full member of the USSR Academy of Medical Sciences. The older Yegorov had confidentially told the chief designer of his young son's desire to fly in space. The latter clearly had the qualifications. Although a civilian, he had worked for a while at the Air Force's Institute of Aviation and Space Medicine and, in February 1962, was selected as one of the leading doctors who were part of parachute teams for recovering the Vostok cosmonauts. For some reason, Korolev was enamored with Yegorov, and with Deputy Minister Burnazyan's support, he was well placed as a primary contender for the mission. Yegorov's direct competitor was Lazarev, an accomplished Air Force officer and physician, also from the

12. Yu. P. Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya "Energiya" imeni S. P. Koroleva* (Korolev: RKK Energiya, named after S. P. Korolev, 1996), p. 425.

13. Golovanov, *Korolev*, p. 731.

14. At a meeting of Air Force officials on March 24, 1964, Air Force officers, including Kamanin and Gagarin, agreed that two OKB-1 engineers could fly in the "passenger" positions in the Voskhod. If such engineers were not ready for the flight, then they could be replaced by two Air Force pilots. The Ministry of Health proposal for a doctor seems to have been formalized by edict on April 2, 1964. See Viktor Mitroshenkov, *Zemlya pod nebom* (Moscow: Sovetskaya rossiya, 1987), pp. 337–38.

15. V. Semenov, I. Marinin, and S. Shamsutdinov, *Iz istorii kosmonavtiki: vypusk I: nabory v otryady kosmonavtov i astronavtov* (Moscow: AO Videokosmos, 1995), pp. 21, 24. The date of birth and age of Polyakov is unknown. There were four other doctor finalists: I. S. Ivanov, G. P. Prostakishin, Yu. A. Senkevich, and G. L. Yaroshenko. See Kamanin, *Skrytiy kosmos: 1964–1966*, p. 52.

Institute of Aviation and Space Medicine, with extensive research experience, exemplary flying skills, and the support of every Air Force general involved in the space program.[16]

To compete for the *third* seat, Korolev had sent fourteen of his engineers to participate in medical screening; only one was accepted for training on June 11, the ubiquitous Feoktistov, certainly one of Korolev's most accomplished protégés.[17] Even at this early point, it was clear that more than anyone else, it was the thirty-eight-year-old Feoktistov whom Korolev favored for the coveted "engineer-or-scientist" seat on Voskhod. But the aloof Feoktistov had stiff competition from a real scientist, one whose presence on a space mission would be a significant advance in bringing pure science into the Soviet piloted space program. Georgiy P. Katys, also thirty-eight, and a Ph.D. from the Institute for Telemechanics and Automation, was known informally as "Keldysh's man." He was then a researcher at the Institute of Automation and Heat Technology of the Academy of Sciences, having been involved in a variety of space-related projects through the 1950s and early 1960s. Keldysh was not his only supporter; several other academicians, all heavily involved in the space program, declared their support for the congenial Katys, who was chosen from a list of eighteen academy scientists on May 26, 1964.[18] There was an additional candidate, perhaps for the commander's seat, forty-year-old Vladimir N. Benderov, a test pilot from Tupolev's OKB-156, who was apparently proposed by the State Committee for Aviation Technology.[19]

Benderov, Feoktistov, Katys, Lazarev, Polyakov, Sorokin, and Yegorov arrived at the Cosmonaut Training Center in early June. Two of them, Benderov and Polyakov, dropped out of the program within a month because of medical problems, leaving five—Feoktistov, Katys, Lazarev, Sorokin, and Yegorov—to compete for the two "passenger" seats.[20] For the commander's seat, the Air Force selected 1960 batch pilots Komarov and Volynov.[21] Both had served extensively in a backup capacity during the Vostok program, although Komarov had been briefly grounded for a cardiac problem similar to the one that had plagued NASA astronaut Donald K. "Deke" Slayton. Even with the Air Force cosmonauts, Korolev put his personal imprint on the selection. During an early training session in the TDK-3V Voskhod simulator at the Cosmonaut Training Center, Korolev had quietly observed Komarov's performance during training, and he made an on-the-spot decision, telling one of his deputies, "Here is the comrade who will command the 'Voskhod'."[22] Although there were at least a dozen other powerful

16. Golovanov, *Korolev*, pp. 733–34. Another source says that Yegorov joined the parachute teams in January 1961. See "People and Fates: In Memory of Boris Yegorov" (English title), *Novosti kosmonavtiki* 19 (September 10–23, 1994): 57–58.

17. Of the fourteen OKB-1 engineers, six were eliminated at a very preliminary stage. These included O. I. Kozyuba and Ye. A. Frolov, the latter being the "lead designer" for the Voskhod spacecraft. The remaining eight men were K. P. Feoktistov, G. M. Grechko, V. N. Kubasov, O. G. Makarov, V. N. Volkov, A. M. Sidorov, V. A. Yazdovskiy, and V. P. Zaytsev. See Kamanin, *Skrytiy kosmos: 1964–1966*, pp. 51, 54.

18. The academicians in favor of Katys were A. Yu. Ishlinskiy, G. I. Petrov, and V. A. Trapeznikov. Apart from Katys, there was one other finalist from the Academy of Sciences, O. B. Moskalev. See *ibid.*, p. 52.

19. Benderov's candidacy as a cosmonaut had actually been put forward as early as February 9, 1964, before the initiation of the Voskhod program. See *ibid.*, p. 19.

20. Six of the seven men arrived at the Cosmonaut Training Center (TsPK) on June 1, 1964; the exception was Feoktistov, who arrived on June 12. Although Benderov was out of the running for the Voskhod mission, his candidacy for a cosmonaut seat was an issue of discussion as late as February 6, 1965. See *ibid.*, pp. 61, 138.

21. Initially, by April 1, 1964, the Air Force candidates for the commander position were V. F. Bykovskiy, P. R. Popovich, and G. S. Titov. By April 22, the list had been expanded to include P. I. Belyayev, Bykovskiy, L. S. Demin, Ye. V. Khrunov, V. M. Komarov, A. A. Leonov, Popovich, Titov, and B. V. Volynov. By May 21, the list was narrowed down to four: Khrunov, Komarov, Leonov, and Volynov. Of these, only Komarov and Volynov would train for Voskhod. The remaining two, Khrunov and Leonov, were to train for the forthcoming Vykhod EVA mission. See *ibid.*, pp. 33–34, 43, 51.

22. Golovanov, *Korolev*, p. 732.

individuals whom he had to go over, by late August, Korolev was publicly stating that one and only one crew would fly the Voskhod ship: Komarov-Feoktistov-Yegorov. Anything else would be unacceptable. As it turned out, a final decision on the crew was not made until just weeks before the launch.

On August 21, 1964, the Military-Industrial Commission met to discuss preparations for the Voskhod flight. Korolev, along with the leading chief designers and military officers, reported on the status of the program. Also present were the seven cosmonauts training for the flight, each of whom briefly reported that he was ready for the mission less than two months after selection. The commission agreed to launch an automated precursor with mannequins prior to September 5 and the actual piloted mission within the period of September 15–20. Lt. General Kamanin, one of the attendees, later wrote in his journal:

> *The Voskhod . . . has a number of shortcomings. Most important among them is the absence of crew rescue equipment . . . in the first 27 seconds of flight, and in the case of failure of the craft's parachute system during descent from orbit. Moreover, there is absolutely no way the Voskhod can land safely through natural deceleration—the reserves of air, water and food are small, and there is a high probability of over-heating. The crew is very cramped in the Voskhod: There is five times less space and air in the craft "per capita" than in the Vostok. In general, the life-support and safety conditions are considerably worse in the new craft than in the Vostok.*[23]

These feelings were no doubt exacerbated by the drop-test crash at Feodosiya in early September. The failure delayed the launch dates of both flights—the automated one to September 15 and the crewed one to late September or early October.

During this period, each side began to take its place in the battle to send its own representative into space in Voskhod. Kamanin insisted on Komarov, Volynov, and Lazarev—that is, an all-military crew with an Air Force doctor. This position was supported by higher Air Force officials until the hand of the Central Committee interfered. Volynov's mother was Jewish, and his candidacy was unacceptable to Chief of the Defense Industries Department Ivan D. Serbin, one of the most feared Party apparatchiks of the defense sector in the Soviet Union.[24] More commonly known by the moniker "Ivan the Terrible," Serbin had an impassive face but the "doctrinal" clout that could make or break people's careers. Officially, "all personnel issues and issues related to the dismissal, promotion, awarding or punishment of administrators needed Serbin's approval," but his *de facto* influence over the space program was obviously much wider, often encroaching into matters of policy.[25]

There was another casualty to political doctrine. The Mandate Commission was aware that scientist Katys's father had been arrested and shot in 1937 during the Great Purges. Although he had been fully exonerated of his "guilt" in 1957, his son was considered suspect because of

23. L. N. Kamanin, "I Would Never Have Believed Anyone . . ." (English title), *Sovetskaya rossiya*, October 11, 1989, p. 4.

24. Kamanin proposed the first tentative crews on July 6, 1964. They were: Volynov, Katys, and Yegorov (primary) and Komarov, Feoktistov, and Sokorin (backup). These pairings were offered at an official meeting of the State Commission on August 12, 1964. By September 14, 1964, Kamanin was proposing Komarov, Volynov, and Lazarev (primary). See Kamanin, *Skrytiy kosmos: 1964–1966*, pp. 63, 69, 84; Golovanov, *Korolev*, p. 737.

25. Boris Chertok, "At the Dawn of Russian Cosmonautics," *Aerospace Journal* no. 4 (July–August 1996): 77–78. See also John McDonnell, "The Soviet Defense Industry as a Pressure Group," in Michael McGwire, Ken Booth, and John McDonnell, eds., *Soviet Naval Policy: Objectives and Constraints* (Halifax, NS: Centre for Foreign Policy Studies, 1975), pp. 102–03. The Defense Industries Department was one of twenty-two sections in the Central Committee.

his father's fate. The KGB also discovered in August 1964 that Katys's stepbrother and stepsister had resided in Paris, although they had emigrated in 1910—a connection that cast suspicion on Katys's adherence to working-class ideology. Kamanin noted in his diary, "All this spoils the candidate for flight. More suitable candidates should be found."[26] In both cases, Korolev was put in a difficult position. Although he preferred Komarov over Volynov as commander, he was also resolutely not anti-Semitic but was helpless to make amends for the poor Volynov. Katys's predicament hit home deeper: Korolev himself had been incarcerated during the Purges, serving at Kolyma, and here was the Communist Party throwing insult in his face by refusing to "clear" the son of another Purge victim.

Feoktistov, Korolev's chosen man for the engineer spot, faced stiff opposition from the Air Force. Despite his undeniable talents as a designer—Feoktistov probably knew more about the design of the Vostok and Voskhod spacecraft than any other engineer at OKB-1—he was also "a difficult, unsociable, and uncompromising man." His health was also not up to par. When Kamanin first heard of Feoktistov's candidacy, he was reported to have blurted out, "How can you put a man into a space ship if he is suffering from ulcers, nearsightedness, deformation of the spine, gastritis, and even has missing fingers on his left hand?"[27] Doctors had in fact brought in all sorts of documents stating that Feoktistov was unfit for the mission. In the end, Deputy Minister of Health Burnazyan, under pressure from Korolev, signed a medical certificate in Feoktistov's favor, and Air Force officials backed down. The deletion of Volynov and Katys from the running and the support for Feoktistov meant that there were now two possible variants of the crew:

- Komarov-Feoktistov-Lazarev
- Komarov-Feoktistov-Yegorov

On September 14, Kamanin proposed the first version to Korolev. The chief designer, however, stuck to his earlier position and categorically refused to launch the crew without Yegorov aboard, perhaps as a result of a promise he made to the young doctor's father. Both Korolev and Kamanin came away from the meeting refusing to budge an inch, laying the ground for more battles in the ensuing days.

Korolev was clearly under great stress at the time, and it showed in his behavior toward other chief designers and junior engineers. Despite his poor health, he consistently tried to have his hand in the most trivial of operations, losing himself in fits of temper if he was displeased with something. There was also familial stress brought on by news that his wife would have to undergo a major operation on October 1. He twice flew to Moscow from Tyura-Tam to be with her during the most intensive prelaunch preparations.

On September 18, at a meeting of the State Commission for Vostok, OKB-1 Deputy Chief Designer Boris Ye. Chertok reported that the misfiring of the parachute cover during the earlier drop-test at Feodosiya was the fault of the design bureau itself. The main firing circuit would have to be redesigned and rebuilt from scratch. Engineers scheduled new drop-tests, although it was becoming clear that the automated precursor vehicle would have to be launched before the results of the new tests were in. After the main meeting, a smaller group of the leading State Commission officials met to discuss the makeup of the crew. Commission Chairman Tyulin fell in with Korolev and proposed the Komarov-Feoktistov-Yegorov crew, with only Air Force First Deputy Commander-in-Chief Marshal Sergey I. Rudenko and Kamanin in opposition. Korolev lost his temper, yelling, "The Air Force is perpetually jamming up the works! Looks like I'm

26. I. Marinin, "Russian Cosmonaut-Scholars" (English title), *Novosti kosmonavtiki* 3 (January 28–February 11, 1996): 49–54; Kamanin, *Skrytiy kosmos: 1964–1966*, pp. 76, 77.

27. Golovanov, *Korolev*, p. 737.

gonna have to train my own cosmonauts. . . ."[28] The following day, perhaps under pressure from the Central Committee back in Moscow, Marshal Rudenko buckled under Korolev's whims, and Kamanin was the only one remaining who supported Lazarev. He finally gave in from exhaustion over the issue. Komarov, Feoktistov, and Yegorov would fly, just as Korolev had predicted two months before.

For weeks, the seven cosmonauts had been in the dark about which of them would fly in space. Their only source was rumor. Katys, for example, noted that before flying out to Tyura-Tam for the launch, Feoktistov and Yegorov were given Volga automobiles for travel around Moscow, while he was given "a clunker." Kamanin, with his authoritarian character, did not bother to include the cosmonauts in any discussion of the issue. As one Russian journalist wrote, "True to form, Kamanin did not inform the cosmonauts of the State Commission's decision for a very long time, consciously keeping them in a state of suspense, helping him, or so he thought, to maintain control over them."[29] Over two weeks after the final State Commission decision, the seven cosmonauts were still relying on rumor, unsure of who exactly would fly.

Operation *Kedr*

The intense prelaunch preparations for Voskhod were punctuated by an important state event. On the morning of September 24, Khrushchev, accompanied by an entourage of the highest defense officials in the Soviet Union, flew into Tyura-Tam to view demonstration launchings of new ICBMs and space rockets.[30] The exercise, code named Operation *Kedr* ("Cedar"), was the second military event in September, following a similar demonstration near Moscow of tank, artillery, and naval weaponry. The main goal of the grandiose visit was evidently to decide between competitive ICBMs that were on display: Chelomey's UR-200 versus Yangel's R-36, and Yangel's R-16 versus Korolev's R-9A. The three main designers, Korolev, Chelomey, and Yangel, greeted Khrushchev at the airfield at Tyura-Tam before taking the Soviet leader immediately to the launch pads. Launches were carried out over the next two days as Khrushchev, Brezhnev, Ustinov, and the others watched. Although the decisions were not strictly based on the performance of the missiles, when Chelomey's UR-200 failed during its launch, he found himself in an embarrassing position. On the second day, Yangel successfully launched his new R-36, followed by spectacular simultaneous launches of three R-16 missiles from underground silos.[31]

28. Kamanin, "I Would Never Have Believed Anyone. . . ." The State Commission for the Voskhod launch was established by decree of the Central Committee and the USSR Council of Ministers on August 3, 1964. The commission consisted of Chairman G. A. Tyulin (GKOT), S. P. Korolev (OKB-1), M. V. Keldysh (AN SSSR), I. T. Bulychev (MO), L. I. Gusev (GKRE), N. P. Kamanin (VVS), A. A. Karas (TsKIK), Kasatikov (affiliation unknown), K. A. Kerimov (TsUKOS), A. A. Kobzarev (GKAT), A. G. Mrykin (GURVO), G. S. Narimanov (NII-4), V. N. Pravetskiy (Ministry of Health), S. I. Rudenko (VVS), Yakunin (affiliation unknown), and A. G. Zakharov (NIIP-5). See Kamanin, *Skrytiy kosmos: 1964–1966*, pp. 73–74.

29. Golovanov, *Korolev*, p. 738.

30. *Ibid.*, p. 740; Aleksandr Zakharov, "Operation 'Kedr' or How the 'Proton' Was Saved" (English title), *Krasnaya zvezda*, July 15, 1995, p. 4. Among those escorting Khrushchev were L. I. Brezhnev (TsK Secretary for Defense and Space), I. D. Serbin (TsK Defense Industries Department), A. P. Kirilenko (TsK KPSS), D. F. Ustinov (Chairman, VSNKh), L. V. Smirnov (Chairman, VPK), G. N. Pashkov (Deputy Chairman, VPK), R. Ya. Malinovskiy (Minister, MO), A. A. Grechko (Deputy Minister, MO), S. S. Biryuzov (General Staff Chief, MO), S. G. Gorshkov (Commander, VMF), N. I. Krylov (Commander, RVSN), V. A. Sudets (Commander, PVO), K. A. Vershinin (Commander, VVS), P. V. Dementyev (Chairman, GKAT), V. D. Kalmykov (Chairman, GKRE), S. A. Zverev (Chairman, GKOT), and G. A. Tyulin (First Deputy Chairman, GKOT).

31. Golovanov, *Korolev*, p. 740. The fact that these tests would occur was announced publicly by the Soviet press. See "Russians Schedule Pacific Rocket Test," *New York Times*, August 1, 1964, p. 8.

The Yangel-Chelomey battle over the new ICBMs had little to do directly with the piloted space program. The political maneuvering over the missile sector did, however, have a profound relevance to the Soviet space program. Khrushchev's son Sergey recalled later that the decision to pick Yangel's R-36 over Chelomey's UR-200 may have had less to do with technical considerations than with the whims of Ustinov:

> *The military men at the test range had already begun to show a preference for the Yangel missile. They were actively backed by Dmitry Ustinov. Although he was not directly involved in defense matters at the time, as one of the fathers of missilery in our country, he had extraordinary authority and his word meant a lot. As second secretary, Brezhnev was responsible for supervising the defense industry, but typically—with his softness of character—he had not expressed a definite opinion. . . . The energetic and single-minded Ustinov dominated the pliable Brezhnev.*[32]

This was definitely trouble for Chelomey and his plans to dominate the space program. Ustinov had consistently opposed any and every Chelomey plan; during the Khrushchev era, Ustinov had to be careful in opposing Chelomey because it was almost a matter of state policy to favor the general designer. Chelomey had continually ignored Ustinov by going directly to Khrushchev with this plans, although Ustinov served as the chair of the Military-Industrial Commission from 1957 to 1963. The battle between them was also personal. As Sergey N. Khrushchev recalled:

> *. . . the personal behavior of both of them was not very polite. . . . Chelomey tried to blame Ustinov for many things. Of course, Chelomey never did this openly in Ustinov's presence. He tried to [exercise self-restraint] but could not stop himself. And of course these people reported back to Ustinov. . . . I heard many times when Chelomey in his own circles used certain words for Ustinov . . . and I'm sure that somebody reported back to Ustinov on this.*[33]

Chelomey did not take kindly to Ustinov's hostility. Once when Khrushchev ordered Ustinov to go see Chelomey about his UR-500 rocket, Chelomey intentionally kept Ustinov waiting in his reception room while other designers and junior engineers were escorted into the general designer's office. Rumor has it that Ustinov never forgave Chelomey for this humiliation.[34] Ustinov and Chelomey would remain at loggerheads throughout the rest of their lives, and more often than not, Chelomey remained a victim to Ustinov's single-minded crusade to destroy any and every single program the ambitious general designer proposed, including space projects.

The results of Operation *Kedr* seriously threatened Chelomey's dominance, and Khrushchev did nothing to stop it. For the first time since 1961, Chelomey was witness to a cancellation of one of his projects. The UR-200 was the critical center of all of Chelomey's early plans for space exploration—the launch vehicle that would open the door to independence and more grand boosters such as the UR-500. Its cancellation was a severe blow because it was supposed to have launched the first series of "IS" and "US" military satellites into orbit, while also serving as a new generation of ICBM. Despite the embarrassing failure during Operation *Kedr*, the missile itself had performed without much trouble throughout its testing program, which had begun in November 1963. All at OKB-52 were apparently demoralized by the

32. Sergei Khrushchev, *Khrushchev on Khrushchev: An Inside Account of the Man and His Era* (Boston: Little, Brown & Co., 1990), p. 103.

33. Telephone interview, Sergey Nikitich Khrushchev with the author, October 10, 1996.

34. Golovanov, *Korolev*, p. 728.

cancellation. As an engineer recalled: "[Chelomey] was obsessed with the recent meetings at the test site and very upset about our failure. He blamed the latter mostly on Ustinov, for whom he found some choice epithets."[35]

True to Chelomey's ambitious disposition, he took the opportunity of Khrushchev's visit to Tyura-Tam to propose a new project—one that was far more adventurous than the UR-200 or any other ICBM. Before coming to the launch site, he had his assistants prepare colorful models and posters of his new conception, ready to unveil it in front of the gathered military-industrial complex of the Soviet Union. This opportunity came during a visit of the Khrushchev entourage to the first launch pad for the UR-500 ICBM. All those assembled were clearly awed by the beauty and grace of a full-size mock-up of the new booster, one that was being developed to launch the first Soviet cosmonauts around the Moon. Construction had also begun on two huge silos for the UR-500, possibly the largest missile silos anywhere in the world. Chelomey then unveiled a model of the two-stage UR-500, removed its payload, and put a third stage on top of it, stating that such a model would double the lifting capability of the rocket. Khrushchev pointedly asked, "Why not make a three-stage rocket from the beginning?"[36] Chelomey replied that he preferred developing rockets gradually, step by step, to ensure the greatest possibility of success; it was a pointed attack at Korolev's "all-up" testing idea for the N1. When Khrushchev, visibly pleased with Chelomey's diligent ways, asked Chelomey what the *next* step was, Chelomey unveiled a beautifully illustrated poster of his new proposal, the giant UR-700 booster. Dementyev, Smirnov, and Ustinov watched in stunned silence as Chelomey pointed to a drawing of the 4,500-ton heavy-lift launch vehicle that could send Soviet cosmonauts to the Moon.

The UR-700 booster, a multistage behemoth, emerged from 1963 to 1964 at OKB-52, partly as a result of Chelomey's strong belief that the N1 was a technically inferior competitor to the Saturn V. He had argued over and over that the combination of Earth-orbit rendezvous and lunar-orbit rendezvous for the N1 was technically dubious at best, that its development program was flawed, and that its design itself was haphazard. In his opinion, Korolev had little chance to "beat" the Americans to the Moon with the N1. What was needed was a larger booster capable of direct ascent to the Moon and back, something that would dwarf the Saturn V, and something that was designed on the basis of existing missiles such as the UR-500 to shorten development problems. This competitive proposal was the most ambitious attack on Korolev that Chelomey had ever mounted. This sort of chaotic design process, whereby *already* approved programs such as the N1 lunar landing project were threatened by continually new emerging proposals, was uniquely symptomatic of the Soviet piloted space program.

Chelomey explained to Khrushchev that with his UR-700, the Soviet Union could reach the Moon with less money and in less time than with Korolev's N1. Khrushchev, swayed by the dazzling presentation, asked Chelomey to prepare the necessary technical documentation while he instructed Military-Industrial Commission Chairman Smirnov to draw up the necessary decree ordering a high-level comparison of the merits of the N1 and UR-700 lunar landing proposals. A commission would examine the two projects and make a final decision.[37]

Khrushchev and the others also visited with Korolev during their short visit. On the first day, with his guests viewing, Korolev had launched a Zenit-2 reconnaissance satellite into

35. Khrushchev, *Khrushchev on Khrushchev*, p. 123. The ninth and last UR-200 missile was launched on October 23, 1964.

36. Sergey Khrushchev, *Nikita Khrushchev: krizisy i rakety: vzglyad iznutri: tom* 2 (Moscow: Novosti, 1994), 493–94; Zakharov, "Operation 'Kedr' or How the 'Proton' Was Saved"; V. Petrakov and I. Afanasyev, "'Proton' Passion" (English title), *Aviatsiya i kosmonavtika* no. 4 (April 1993): 10–12.

37. Khrushchev, *Nikita Khrushchev: tom* 2, p. 494; Khrushchev interview, October 10, 1996.

orbit.[38] Khrushchev visibly perked up on a visit to the assembly-testing building where the Voskhod ship was being mated to its 11A57 booster. He was also shown a mock-up of the Vykhod EVA-equipped spacecraft by cosmonauts Gagarin, Belyayev, and Leonov. The latter ably demonstrated how a cosmonaut would be able to exit and return to the spacecraft in orbit. There was also a successful launch of the much-delayed R-9A ICBM. Korolev had been informed of Chelomey's surprise lunar landing proposal before Khrushchev's visit to Tyura-Tam, but he seemed not to have been perturbed by it at the time.[39] The N1 program was well into its hardware-building stage, and despite its problematic genesis, it did have the support of Brezhnev, Smirnov, and especially Ustinov. Stressed by the state visit, the fate of his R-9A ICBM, the threat of Chelomey's UR-700, and various other issues, Korolev was working at his most strained level.[40] In a letter to his wife written immediately after the state visit, Korolev stated:

> *I passed these days as if I was in some sort of a toxic furnace. In essence all of our work of the past years was subjected to a review of effectiveness, and it wasn't only our firm but others also. Fortunately everything worked out extremely well and I am in a good mood. Tomorrow we start back up again with our usual work program.*[41]

The "usual program" was, of course, the Voskhod launch.

Three Men in a Capsule

There were numerous glitches as engineers counted down the days to the two Voskhod launches—one an automated test and one with a crew aboard. On September 29, Voskhod lead designer Frolov reported that the fastening bolts for the Elbrus couches were three millimeters out of alignment with the corresponding holes. The shell of the vehicle had apparently deformed during the flight from Kaliningrad to Tyura-Tam. During the same afternoon, the Tral-1P telemetry instrument on the spacecraft had failed. Chief Designer Aleksey F. Bogomolov, from the Experimental Design Bureau of the Moscow Power Institute, confirmed at the regularly scheduled State Commission meeting that the entire spacecraft would have to be completely dismantled and the suspect part replaced and tested, delaying the flight by a week. The fifty-one-year-old Bogomolov was not a new participant in the space program. It was in fact he who had provided the telemetry equipment for the first Sputnik launcher. He also directed the design of radio systems, on-board data recorders, telemetry systems, TV systems, and antennae for the ground communications segment. Despite his clearly significant contributions, for inexplicable reasons, his influence and earned respect were marginal at best. He had been perhaps unfairly blamed for the Sputnik 3 failure to detect the van Allen radiation belts, and with the latest Voskhod malfunction, Korolev tore into him during a meeting on October 5. Bogomolov desperately tried to defend his position for an hour. Kamanin commented that:

38. This was Zenit-2 no. 43, which was launched by an 8A92 launch vehicle. It was named Kosmos-46 upon entering orbit. See Zakharov, "Operation 'Kedr' or How the 'Proton' Was Saved."

39. That Korolev was cognizant of the UR-700 proposal is indicated in Kamanin's diaries in a description of a conversation between Korolev and Kamanin on September 14, 1964. Kamanin wrote: "In Sergey Pavlovich's opinion, a Moon orbit using Chelomey's UR-500 rocket would be impossible without intermediate docking. Korolev said that he asked Chelomey to work on the docking procedure, but the latter decided to make a new rocket, the UR-700, which would make it possible to avoid docking in space." See Kamanin, "I Would Never Have Believed Anyone . . ."; Kamanin, *Skrytiy kosmos: 1964–1966*, pp. 84, 91.

40. Sergey N. Khrushchev states that the R-9A program was actually terminated at the time, being reactivated only after the fall of Khrushchev. See Khrushchev, *Nikita Khrushchev: tom 2*, p. 492.

41. Golovanov, *Korolev*, p. 740.

> *all of [Korolev's] carryings-on are no longer as effective as they used to be three or four years ago. Korolev was going over the edge, and he did not want to understand that the main reason for the shortcoming and mistakes lay in the absence of a firm plan.*[42]

The possibility of a Voskhod launch to a great degree still depended on further drop-tests of the descent apparatus to verify the new parachute-reactive system. Underlining the importance of the exercise, Korolev visited Feodosiya on October 5 to observe the test himself along with his old cohort Flerov. Korolev flew in by airplane to Crimea, then directly transferred to a helicopter, which would escort the An-12 aircraft that would drop the *sharik*. Despite cloudy conditions, he was able to view the complete landing sequence as the engines under the parachute fired to slow the capsule down to almost zero velocity.[43] With the success behind him, Korolev flew back to Tyura-Tam on October 6, in time for the launch of the first 3KV vehicle, spacecraft no. 2, into orbit. The launch took place at 1000 hours Moscow Time on October 6, 1964. Upon entering a 177- by 413-kilometer orbit inclined at 64.77 degrees to the equator, the spaceship was designated Kosmos-47 to disguise its true mission. The spacecraft remained in orbit overnight while ground controllers tested various systems. There were no major anomalies during the mission, and the descent apparatus with its three mannequins safely landed by parachute on October 7 after a one-day, eighteen-minute flight. High-powered winds dragged the capsule about 160 meters from the landing point, but a crew on board would not have had to endure such an ordeal because they could have manually detached the parachute.[44]

The results of the Feodosiya tests, combined with the successful Kosmos-47 mission, allowed the State Commission to move ahead with a concrete launch schedule for the crewed flight. The commission, under Tyulin's chairmanship, met on October 9 to discuss final technical issues. A pestering problem during ground testing of the RD-0108 third-stage engine was attributed to problems with the test stands. Lt. General Kamanin at this time formally proposed the Komarov-Feoktistov-Yegorov crew for launch, and the commission members unanimously confirmed the choice. The cosmonauts themselves were present during the meeting; Korolev, Gagarin, Tyulin, Rudenko, and others wished them good luck on their flight. The launch was set for the morning of October 12.

Trouble struck on October 11, the night before the scheduled launch, when Chief Designer Bogomolov arrived at Korolev's office with news that there was an additional problem with the Tral-1P telemetry system, which would require the replacement of the transmitter (a delay measured in minutes). Korolev, under stress, completely lost his temper and humiliated Bogomolov in front of Tyulin, Rudenko, Kamanin, and others. Kamanin recalled:

> *That report enraged Korolev. He called Bogomolov a "cowardly gutter snipe" and announced: "I don't want to have anything more to do with you. Go away—I can't even be in the same room with you!" It was a very uncomfortable scene. . . . With that outburst of rage, Korolev toppled himself from his pedestal as a talented organizer into the mire of petty passions. In four years of joint work, that was the first time I had ever seen him in such a state. I was sad and sorry for Sergey Pavlovich [Korolev]. It was 15 minutes before he was able to calm himself down and coherently report tomorrow's flight to Ustinov by telephone.*[45]

42. Kamanin, "I Would Never Have Believed Anyone. . . ."

43. Golovanov, *Korolev*, p. 741.

44. Note that the apogee (413 kilometers) for Kosmos-47 was much higher than originally planned for the Voskhod mission (240 kilometers). At some point after issuing the draft plan, there was probably a modification to the planned orbital parameters. There was also a 10-percent decline in third-stage engine operation for three seconds during the ascent to orbit. The engine regained full-thrust mode soon after, and the spacecraft reached the desired orbit. See Kamanin, *Skrytiy kosmos: 1964–1966*, pp. 96–97.

45. Kamanin, "I Would Never Have Believed Anyone. . . ."

The fault was quickly repaired, and the launch did not have to be delayed.

There was a brief State Commission meeting on the chilly but clear morning of launch day, October 12, held only 200 meters from the launch pad. All the chief designers declared the ship ready for launch. The bus carrying the three cosmonauts arrived at the pad at 1015 hours local time. The crew were dressed in lightweight, gray woolen trousers and shirts and light blue jackets. Each had a headset with attached earphones and microphones. Tyulin, Korolev, Gagarin, and others saw the three men up to the elevator before the cosmonauts took the elevator up to their ship. At the top, the crew removed their jackets and boots, donned slippers, and entered the spacecraft: Yegorov first, then Feoktistov, followed by Commander Komarov. The tension was higher than perhaps any other mission since Gagarin's flight. Without a viable launch escape system during the first minute or so of the mission, there was absolutely no way that the crew could be saved in case of booster failure. Korolev was apparently so nervous that he was shaking.

From left to right, Vladimir Komarov, Boris Yegorov, and Konstantin Feoktistov, the crew of the first Voskhod spacecraft, make their way to the launch pad on October 12, 1964, prior to the launch. Note their casual attire, a contrast to the bulky suits worn on the earlier Vostok flights. (files of Peter Gorin)

The Voskhod spacecraft, 3KV no. 3, lifted off the pad at site 1 at exactly 1030 hours, 1 second Moscow Time on its 11A57 booster. On board were Lt. Colonel Vladimir M. Komarov (thirty-seven years old), Konstantin P. Feoktistov (thirty-eight), and Boris B. Yegorov (twenty-six), representing the Soviet Union in yet another "space spectacular." Controllers watched the booster take off, and there was a final collective sigh of relief once the clocks reached T+523 seconds: Voskhod had achieved orbital velocity and the launcher had worked without a flaw. Initial orbital parameters were 177.5 by 408 kilometers at 64.9 degrees, exactly as planned. Once again, the reaction from the West was unprecedented, prompting another round of discussions on Soviet plans to go to the Moon.[46] Following orbital insertion, there was the customary conversation with Presidium members Khrushchev and Anastas I. Mikoyan, as well as greetings transmitted to the participants of the Tokyo Olympic Games.

Each member of the Voskhod crew was trained to perform his own individual tasks during the daylong mission. Komarov, as crew commander of the flight, had overall responsibility for the functioning of the vehicle's systems. Among his specific duties was the operation on the sixth and seventh orbits of a set of electrostatic ion engines installed on the exterior of the ship. According to the Soviets, this was the first occasion when such engines were tested during orbital flight. Feoktistov carried out a number of visual, photometric, and photographic observations of Earth and its atmosphere, the polar aurora and luminescent particles, and azimuthal and stellar backgrounds for navigational and orientation purposes.[47] At several points during the

46. See, for example, *Soviet Space Programs, 1962–65; Goals and Purposes, Achievements, Plans, and International Implications*, prepared for the Committee on Aeronautical and Space Sciences, U.S. Senate, 89th Cong., 2d sess. (Washington, DC: U.S. Government Printing Office, December 1966), pp. 384–86.

47. George Wukelic, ed., *Handbook of Soviet Space-Science Research* (New York: Gordon and Breach Science Publishers, 1968), p. 59; G. V. Petrovich, ed., *The Soviet Encyclopaedia of Space Flight* (Moscow: Mir Publishers, 1969), p. 124. Note that the presence of ion engines was not described in the original draft plan.

flight, he described "luminous particles" outside the porthole, very similar to the famous "fireflies" observed by NASA astronaut John Glenn during his mission in 1962. An unnamed sextant was also used by Feoktistov as part of an experiment to accurately measure the elevation of the stars relative to the horizon.

The most extensive on-board research was focused on biomedical tests. For such a short and conservative mission, the breadth of the medical experiments was quite impressive. The *Polinom* instrument carried aboard the ship was used for carrying out several functional tests. These included: a series of eye movements in a predetermined sequence before and after ten turnings of the head while recording electro-oculograms; periodic closing and opening of eyes during the recording of electroencephalograms; and rhythmic pressing with the hand of a constant force for a duration of one minute, whose results were recorded by a dynamograph. The cosmonauts also carried out a test to measure the coordination of movements while writing four complex spirals, four figures of "6," and a signature with their eyes open and closed. The results were measured by an electromagnetic transducer. Yegorov, the first trained medical doctor in space, actively participated in seven areas of medical experiments:

- Observation of the condition and behavior of the crewmembers
- Research on tactile, pain, and tendon reflexes
- Observation of oral activity
- Psychophysiological tests to determine the rapidity and accuracy of processing data by using correction tables
- Measurement of arterial pressure
- Determination of thresholds of sensitivity to adequate and inadequate stimuli
- Determination of the acuteness of vision and fusion capabilities of the eye muscles

In addition, he took blood samples. Apart from the crew, other biological specimens carried in the ship included human cancer cells, amnion and human fibrolast cells, frog ova and sperm, *drosophila* insects, *tradescantia melanogaster* plants, winter wheat seeds, pine seeds, algae, and two types of bacteria.[48] *Drosophila* were carried on most of the piloted missions because they multiply so rapidly that the effect of microgravity and radiation on successive generations could be observed.

The extremely shortened training program for Feoktistov and Yegorov showed through in their reactions to weightlessness. Within two to three hours of the launch, both began to experience disorientation in space. Yegorov felt as if he was bent over face downward, while Feoktistov actually felt he was upside down. Although the sensations apparently did not impair their ability to work, both suffered these feelings throughout the entire length of the mission—an anomaly that had not been detected on any of the earlier Soviet space missions. Both cosmonauts also felt dizzy when they moved their heads sharply. It seems that Yegorov had been more afflicted, with his unpleasant sensations peaking about seven hours after launch.[49]

The short mission proceeded without much incident. On the sixth and seventh orbits, the onboard Topaz TV camera beamed down live pictures of the crew to the control center.

48. Yu. M. Volynkin, I. T. Akulinichev, P. V. Vasilyev, A. D. Voskresenskiy, I. I. Kasyan, and D. G. Maksimov, "Some Data on the Condition of Cosmonauts During the Flight of the 'Voskhod' Spaceship" (English title), *Kosmicheskiye issledovaniya* 4 (September–October 1966): 755–67; Wukelic, ed., *Handbook of Soviet Space-Science Research*, pp. 346–48.

49. Volynkin, *et al.*, "Some Data on the Condition of Cosmonauts"; P. V. Buyanov, V. V. Kovalev, V. G. Terentyev, Ye. A. Fedorov, and G. F. Khlebnikov, "Results of Medical Examination of the Crew of the Space Ship 'Voskhod' Before and After Its Flight" (English title), *Kosmicheskiye issledovaniya* 4 (January–February 1966): 151–55.

Communication with the cosmonauts was supported only by the Signal VHF transmitters because the UHF transmitters were not operational, due to interference from Earth's radiation belts. There was a communications blackout for six orbits, from the eighth to the thirteenth orbits, but when controllers regained contact, all the parameters aboard the ship were within acceptable ranges. The only anomalies on the flight involved minor issues. During the first six orbits, the temperature inside the ship rose from fifteen to twenty-one degrees Centigrade, suggesting some sort of component overheating. Later on the seventh orbit, Lt. General Aleksandr N. Babiychuk, the Chief of the Air Force Medical Service, raised some alarm when telemetry showed that Yegorov's pulse had fallen to forty-six while he was asleep! In panic, Kamanin asked Komarov to verify the value, and the latter reported that Yegorov's pulse was sixty-eight. This was later confirmed by other telemetry.[50]

The mission was set to last exactly one day, but as Korolev was ready to give the order to deorbit, Komarov evidently felt more adventurous:

Korolev:	*Are you ready to proceed to the completion of the final part of the program?*
Komarov:	*The crew is ready. But we would like to prolong the flight.*
Korolev:	*I read you, but we had no such agreement.*
Komarov:	*We've seen many interesting things. We would like to extend the observations.*
Korolev:	*"There are more things in heaven and earth, Horatio, than are dreamt of in your philosophy." We shall go nevertheless, by the [original] program.*[51]

With the quote from Shakespeare's Hamlet, Korolev ordered the cosmonauts to begin preparing for descent on the seventeenth orbit. As with several of the Vostok missions, there was no communication during the descent because of the failure of the short-wave transmitter, and controllers awaited tensely as the critical minutes passed by. No doubt, images of the smashed descent apparatus at Feodosiya passed through Korolev's mind. As the clock counted down, the chief of the Air Force search service finally radioed that one of his helicopter pilots had seen the capsule coming down by parachute at the designated area. There was a final report that the helicopter pilot was in visual contact with the Voskhod spacecraft, which was lying safely on the ground; all three of its passengers were outside waving at the search team. There was thunderous applause at the control room. Korolev was beyond relief:

> *Is it really true that it's all over, and that the crew has returned from space without a single scratch? I would never have believed anyone that the Voskhod could be made out of the Vostok, and that three cosmonauts would fly it into space. . . .*[52]

The men landed successfully 312 kilometers northeast of the town of Kustanay in Kazakhstan on October 13. The flight had lasted one day, seventeen minutes, and three seconds.

The cosmonauts were first flown to Kustanay, where they were scheduled to speak with Khrushchev on the telephone, but Military-Industrial Chairman Smirnov sent a message asking

50. Kamanin, "I Would Never Have Believed Anyone . . ."; Kamanin, *Skrytiy kosmos: 1964–1966*, pp. 102–03.

51. There are many different accounts of this exchange between the cosmonauts and Korolev. Some sources suggest that Korolev did not finish the quote from Shakespeare. See Nicholas Daniloff, *The Kremlin and the Cosmos* (New York: Alfred A. Knopf, 1972), p. 161; Evgeny Riabchikov, *Russians in Space* (Moscow: Novosti Press Publishing House, 1971), p. 209. Other sources suggest that Korolev *did* complete the phrase. See Golovanov, *Korolev*, p. 743. Another source claims that it was Feoktistov, not Komarov, who made the request for the extension. See Aleksandr Romanov, *Korolev* (Moscow: Molodaya gvardiya, 1996), pp. 474–75. Finally, one source suggests that Korolev never even quoted Shakespeare. See Chertok, *Rakety i lyudi*, p. 248.

52. Kamanin, "I Would Never Have Believed Anyone. . . ."

them not to wait and to fly directly back to Tyura-Tam. Although the three cosmonauts felt slightly fatigued, they were fit enough the next morning to give full postflight reports to a rapt audience of 200 individuals, including the State Commission. A lunch followed with boisterous toasts raised not only to the cosmonauts, but also to Korolev and those who had prepared the flight. It was late the same day when Korolev, Kamanin, and others first got wind of the monumental changes back in Moscow. News had come in that there would be a special meeting (Plenum) of the Central Committee the same evening, a complete surprise to the chief designers. By the morning of October 15, it was all clear: Khrushchev was no longer in power and had been replaced in his two posts by Aleksey N. Kosygin (Chairman of the Council of Ministers) and Leonid I. Brezhnev (First Secretary of the Central Committee). Kamanin had already been instructed to change the cosmonauts' prepared speeches: instead of saluting Khrushchev, they would salute Brezhnev and Kosygin.[53] Thus, in a twist worthy of Orwell, Khrushchev's name was scratched out and Brezhnev and Kosygin scribbled in. It was the end of one era and the beginning of another, not only for the Soviet space program but for the entire nation.

Khrushchev's Twilight

Nikita Sergeyevich Khrushchev was one of the most important political figures in the origin and emergence of the Soviet space program. More than any other Soviet leader since, he developed and nurtured the kind of personal relationships with the leading space chief designers that fostered a space era driven less by institutions than personalities. Institutions, of course, existed to administer and support his agenda. In particular, he was responsible for shifting the burden of directing missile and space program policy from the government to the Communist Party.[54] By introducing the specific post of Secretary of the Central Committee for Defense and Space in July 1957, Khrushchev effectively laid the blueprint of strict Party control over the space program, which lasted until the early 1990s. He successfully populated both Party and government positions with individuals such as Brezhnev, Kozlov, Ustinov, Nedelin, and Smirnov, who could be counted on to support his radical shift in military strategy from conventional armaments to ballistic missiles. There is no question that without this firm change in direction, a rethinking for which Khrushchev was singularly responsible, the Soviet space program might have been a pale imitation of what it really was. As funding for the ICBM programs grew to astronomical levels, the space program, being merely an arm of it, rode its coattails to glory for the cause of the Soviet state.

In the historiography of the Soviet space program, Khrushchev has been bestowed a character often approaching levels of caricature. This was to a great degree reinforced by his unwaveringly loud and often crude outbursts in the public eye—pronouncements that extolled the raw power of socialism against the capitalist world. Western historians have generally depicted a simple two-sided process, with the "reckless" Khrushchev always interfering with the apolitical "dreamer" Korolev. In this scenario, the former was always craftily manipulating the latter into meaningless circus extravaganzas, thus diverting talents from more worthy endeavors. The "manipulation paradigm," however, is far too simplistic a viewpoint to stand up to serious historical scrutiny. Khrushchev's policy on the space program largely depended on his support for the concurrent ICBM program—that is, the former was funded to the extent that it did not infringe on the latter. This is not to say that he did not use the space program as a propaganda playground not only abroad, but also to curb off his political opponents within the Soviet Union.

53. *Ibid.*
54. William P. Barry, "The Missile Design Bureaux and Soviet Piloted Space Policy, 1953–1974," draft of University of Oxford Ph.D. diss., 1995.

Soviet leader Nikita Khrushchev appears in this photo probably dating from the Vostok 3/4 mission in August 1962. During his visit to the Simferepol control center in Crimea, he personally spoke to both cosmonauts Nikolayev and Popovich in orbit. On the right is Maj. General Pavel A. Agadzhanov, the lead "flight director" of Soviet piloted space missions in the 1960s. (copyright Sergey N. Khrushchev)

Many of his speeches from the era clearly draw attention to his role in the successes of the space program. But this self-congratulatory prose did not take away from the fact that he was not particularly interested in micro-managing space policy in a manner that Western historians have attributed to him. Contrary to accepted notions, Khrushchev never ordered Korolev to launch anything because of a personal whim. The power came from implicit threats of support, which he had the power to cut off. In this respect, his personal relationships with Korolev, Chelomey, and Yangel over missiles were, in fact, far more important determinants of the space program's direction.

Khrushchev met all three for the final time in late September 1964 during his first and only visit to Tyura-Tam as part of Operation *Kedr*. His final brush with the space program was on the very last day of his reign. As was customary after each major space launch, a leading minister or general would call Khrushchev from the test range to inform him that such and such launch had gone off successfully. In the sycophantic world of Soviet Party politics, this was an honor that was literally fought over. On the day of the Voskhod launch, the phone call never came. The wheels of power had already begun to move ahead with the secret overthrow. After about forty minutes without word from Tyura-Tam, Khrushchev had an aide call Military-Industrial Commission Chairman Smirnov. Khrushchev's son later described their conversation:

> *"Comrade Smirnov," he began, restraining himself, "what's going on with Korolev's launch? Why haven't you informed me?" The irritation could be heard in his voice. Smirnov must have answered that the launch had gone as planned. . . . "Then why didn't you inform me?" The irritation was turning into anger. "You're obliged to report the results to me immediately." Smirnov must have said that he hadn't had time to call. Of course, he already knew everything and was in no hurry to telephone Father. For him, the change in power had already taken effect. . . . "What do you mean, you haven't had time? I don't understand you! Your behavior is disgraceful!" raged Father. Judging from the reaction, Smirnov was halfheartedly trying to justify himself. "Comrade Smirnov, bear in mind that I demand more efficiency from you! It's your fault that things are getting resolved so slowly!"*[55]

Soon Khrushchev had a brief conversation with the Voskhod crew in orbit, by which time, completely unknown to him, the change in the leadership was almost over. Within hours, with the cosmonauts still in orbit, he was under house arrest. During ceremonies to honor the three crewmembers of the Voskhod mission on October 23, Khrushchev, on a whim, got into his automobile and ordered his driver to take him to his dacha. The fact that Khrushchev was going in the direction of the public ceremonies was relayed immediately to Brezhnev, who was in the midst of the function at Red Square. Seen on TV by millions, Brezhnev's face darkened at the realization that Khrushchev might be heading to Red Square to cause a public scene with the

55. Khrushchev, *Khrushchev on Khrushchev*, pp. 129–30.

new leadership. Aides were sent scurrying off to telephones, until they discovered that Khrushchev was indeed heading for his dacha.[56] It was his last brush with the workings of the Soviet space program. He died, exiled from his past, on September 11, 1971, at the age of seventy-seven.

Ustinov, Smirnov, and Afanasyev

The immediate post-Khrushchev leadership was one characterized by a relative dilution of leadership responsibilities; power was spread out between the Communist Party and the government. As one Western analyst put it, "Khrushchev's simultaneous assumption of Party and government leadership was unacceptable to his successors, who restored the principle of collective leadership."[57] In the new Brezhnev-Kosygin era, at least initially, questions of policy were influenced by a set of checks and balances between the two arms of the Soviet state:

> *It [was] unlikely that a single official at the Politburo or other high-level would be able to intervene successfully and systematically without risking the combined wrath of his peers. This was one of the key charges leveled against Khrushchev.*[58]

This new "collective leadership" had deep repercussions for piloted space policy in the post-Khrushchev era. In the new climate, the lines of *de facto* authority and power among the competing designers were much less clear after 1964 as a result of the diffusion of power among their chief sponsors. By the end of 1965, within a year of Khrushchev's fall, a triumvirate of individuals rose to the top of the space and missile programs, and they each had varying motivations that drove these sectors for the next two decades.

Prior to Khrushchev's ouster in October 1964, there had been much discussion among the leadership on creating a new governmental entity to administer and manage the space and missile programs. Through the late 1950s and early 1960s, this function had been undertaken by the State Committee of Defense Technology, the "ministry" that had inherited ballistic missile development from the post–World War II era. Originally, the Seventh Chief Directorate within the State Committee carried out the management of the missile and space programs. Other directorates focused on weaponry, such as tanks, artillery, small arms, and ammunition. The Seventh Chief Directorate had clearly outgrown its initial mandate, and using it as a base, it seems that Khrushchev wanted to focus all missile and space-related design and production in a new "ministry." By the time this entity was formed, Khrushchev was out of power. In a move designed to reverse Khrushchev's drastic and failed decentralization attempts in the late 1950s, the new Brezhnev-Kosygin leadership recreated the centralized ministry system by official order on March 2, 1965.[59] Six State Committees concerned with weaponry were renamed ministries, while a seventh, the Ministry of General Machine Building, was created on the basis of the old Seventh Chief Directorate.[60]

The Ministry of General Machine Building, more commonly known by its Russian abbreviation "MOM," became the center of all missile and space-related design and production activ-

56. *Ibid.*, p. 173.

57. Arthur J. Alexander, "Decision-Making in Soviet Weapons Procurement," *Adelphi Paper* 147–48 (Winter 1978/9): 6.

58. Peter Almquist, *Red Forge: Soviet Military Industry Since 1965* (New York: Columbia University Press, 1990), p. 75.

59. McDonnell, "The Soviet Defense Industry as a Pressure Group," p. 90.

60. Yu. Mozzhorin and A. Yeremenko, "From the History of Space Science: From the First Ballistics to . . .: II" (English title), *Aviatsiya i kosmonavtika* no. 8 (August 1991): 34–35; N. Tarasenko, "Space Economics: Achievements, Problems, Prospects. S. Afanasyev: 'The Rain of Gold' is a Myth" (English title), *Ekonomika i zhizn* 16 (April 1991): 6–7.

ity in the Soviet Union. Whereas before, space and missile design bureaus, scientific-research institutes, and production plants were scattered among various ministries, the establishment of the new ministry was a giant step forward in knocking down bureaucratic walls by bringing them all together under one roof. MOM had official jurisdiction over almost all Soviet entities involved in the design, experimental production, and serial production of long-range ballistic missiles, space launch vehicles, artificial satellites, piloted spacecraft, liquid-propellant rocket engines, launch complexes, and guidance and control systems.[61] Curiously, one important element of the space program was not brought into MOM at the time, thus being the source of serious problems later. As one leading administrator later recalled:

> *. . . with respect to rocket-space radio-electronics we quickly fell behind since micro-electronics and radio-electronic technology remained outside of the influence of the MOM, instead remaining within the [Ministry of Radio Industry] and [Ministry of Electronics Industry]. . . . As a result, it was a great inconvenience to satisfy the MOM's demands for modern electronic equipment, and ultimately our [country's] space radio-electronic technology began to lag behind that of the Americans in terms of development periods, quality, and general scientific-technical level.*[62]

Among those actively involved in the piloted space program, the design bureaus and institutes that were brought into MOM were:

- From the State Committee for Defense Technology:
  - GSKB SpetsMash (V. P. Barmin)
  - OKB-456 (V. P. Glushko)
  - OKB-2 (A. M. Isayev)
  - OKB-1 (S. P. Korolev)
  - NII-88 (Yu. A. Mozzhorin)
- From the State Committee for Aviation Technology:
  - OKB-52 (V. N. Chelomey)
  - OKB-154 (S. A. Kosberg)
- From the State Committee for Radio Electronics:
  - Scientific-Research Institute of Radio Instrument Building (M. S. Ryazanskiy)
  - Scientific-Research Institute of Automation and Instrument Building (N. A. Pilyugin)
- From the State Committee for Ship Building:
  - NII-944 (V. I. Kuznetsov)[63]

61. There was apparently considerable resistance to transferring the guidance systems entities to MOM from their original positions within the Ministry of Radio Industries. See Mozzhorin, *et al.*, eds., *Dorogi v kosmos: I*, pp. 44–45.

62. Yu. A. Mozzhorin, *et al.*, eds., *Nachalo kosmicheskoy ery: vospominaniya veteranov raketno-kosmicheskoy tekhniki i kosmonavtiki: vypusk vtoroy* (Moscow: RNITsKD, 1994), p. 288. The comment is by L. I. Gusev, who briefly served as a deputy minister of MOM in 1965.

63. The remaining design bureaus and institutes of the Soviet space/missile program—that is, those that had little or no involvement in piloted spaceflight—were spread out over various ministries. They included: SKB-385 (V. P. Makeyev) and OKB-10 (M. F. Reshetnev) in the Ministry of General Machine Building (MOM); OKB-117 (S. P. Izotov), OKB-276 (N. D. Kuznetsov), OKB-300 (S. K. Tumanskiy), and OKB-124 (G. I. Voronin) in the Ministry of Aviation Industry (MAP); NII-627 (A. G. Iosifyan) in the Ministry of Electronics Industry (MEP); NII-1 (A. D. Nadiradze) and NII-125 (B. P. Zhukov) in the Ministry of Defense Industry (MOP); and OKB-41 of KB-1 (A. A. Raspletin and A. I. Savin) in the Ministry of Radio Industry (MRP).

The new ministry itself had several functional divisions formally called chief directorates, each one dedicated to a particular aspect of the space and missile industry. These thematic divisions included strategic missiles, space vehicles, liquid-propellant rocket engines, guidance systems, and launch complexes.[64] The development of piloted spacecraft seems to have been limited to the Third Chief Directorate, which probably functionally included both the Korolev and Chelomey design bureaus.[65]

This is the official portrait of Minister of General Machine Building Sergey Afanasyev. He served in that capacity from 1965 to 1983, during which time he managed the Soviet ballistic missile and space programs. (files of Peter Gorin)

The man appointed to lead the new ministry was a surprise: forty-seven-year-old Sergey A. Afanasyev, an individual who was *not* one of the many experienced deputies from the old State Committee for Defense Technology expecting a promotion. Afanasyev had an interesting background, heading various "technical directorates" in Ustinov's Ministry of Armaments through the 1950s. Although Afanasyev was one of the famous "Ustinov group" who rose to important national positions by the early 1960s, it seems that he made a break from his main sponsor sometime soon after. This may have had something to do with an incident in 1952 when Afanasyev was in danger of being shot by Beriya's henchmen because of problems with engine production. Ustinov did not bother to defend the young Afanasyev, and the latter was only saved when one of Ustinov's deputies risked his career for him.[66] Afanasyev left Ustinov's ministry in 1957, rising to become the chair of the All-Russian Council of the National Economy in June 1961, where he became primarily responsible for managing the defense economy. His appointment to head MOM seems to have been a move made to put a check on Ustinov's grip on the defense industry, and in particular the space program. Afanasyev had, by then, aligned himself not with Ustinov, but with Marshal Andrey A. Grechko, the Deputy Minister of Defense.

Most of those who remember Afanasyev recall someone with whom one should not trifle. A scientist later wrote:

> *[Afanasyev] was a huge man with large, sturdy hands. Like "a hammer striker," we said. When he chaired a meeting, the figure of the minister induced fear. His sentences for employees of the ministry, whether they were general designers or simple engineers, were brief and ruthless. . . . I was told that the man was vindictive and had a very long memory. Members of his team secretly referred to him as "the Big Hammer."*[67]

64. Not all the chief directorates and their specific functions have been identified. A pre-*glasnost* account identified four chief directorates in MOM—for ground equipment, for rocket engines, for guidance and control systems, and for missiles. See Alexander, "Decision-Making in Soviet Weapons Procurement," p. 22; Almquist, *Red Forge*, pp. 144–45. There were at least thirteen chief directorates in MOM by 1985.

65. The First Chief Directorate of MOM included OKB-10 and MZ Khrunichev, the Second Chief Directorate included OKB-456 and NII-1, the Fourth Chief Directorate included GSKB SpetsMash and the Progress Plant, and the Fifth Chief Directorate included NII Priborostroyeniya and NII AP.

66. For Afanasyev's own account of the event, see Mozzhorin, *et al.*, eds., *Dorogi v kosmos: I*, pp. 40–42.

67. Roald Z. Sagdeev, *The Making of a Soviet Scientist: My Adventures in Nuclear Fusion and Space From Stalin to Star Wars* (New York: John Wiley & Sons, 1993), pp. 198–99.

Afanasyev had one First Deputy Minister, Georgiy A. Tyulin, Korolev's old friend and the former artillery officer who was concurrently the chair of the *ad hoc* State Commission for Voskhod. The fifty-one-year-old Tyulin might have expected to head the new ministry after a distinguished and long career with good connections to both the military and the "Ustinov group," but his appointment as Afanasyev's chief deputy exemplified how latent friction was built into the space industry by that time, as different factions jockeyed for key positions. Afanasyev and Tyulin administered six deputy ministers, each with a different portfolio.[68]

Afanasyev was one point of the triumvirate that would dominate the missile and space program into the 1980s. The second individual was Leonid V. Smirnov, the forty-nine-year-old chair of the Military-Industrial Commission. More commonly referred to by its Russian abbreviation "VPK," the Military-Industrial Commission was the heart of the Soviet military-industrial complex. In the mid-1960s, VPK consisted of the heads of the seven ministries involved in the design and production of military equipment; the chair of the State Planning Organ (Gosplan) responsible for budget appropriation; the commanders-in-chief of the Air Force, the Strategic Missile Forces, the Navy, and the Air Defense Forces; the deputy minister of defense for armament procurement; and the president of the Academy of Sciences. The chair of VPK was also simultaneously a deputy chair of the USSR Council of Ministers.[69]

In some sense, Smirnov *was* the head of the Soviet military-industrial complex, overseeing the creation and manufacture of not only missiles and spacecraft, but also tanks, ships, fighter planes, bombers, helicopters, submarines, nuclear bombs, guns, cannons, and so on. Thus Smirnov was not only Afanasyev's boss, but also the boss of the remaining seven military industrial heads. What is most significant is that Smirnov had also served his apprenticeship in the space and missile industry. He was picked out by Ustinov in the late 1940s to head a research institute specializing in radar instrumentation and was launched on a spectacular career under the latter's sponsorship. Between June 1952 and March 1961, Smirnov served as the director of Plant No. 586 at Dnepropetrovsk, which was associated with Yangel's design bureau and was possibly the largest missile production facility in the world. When Khrushchev had boasted about building missiles like sausages, it was Smirnov's plant to which he was referring. The Soviet leader had been duly impressed with Smirnov's performance during a visit to the plant in 1959, and within four years, the young Smirnov had risen far ahead of contemporaries. On May 13, 1963, he was appointed chairman of VPK, replacing Ustinov, who had been "promoted" to a higher post.[70]

68. The six deputy ministers of MOM were L. I. Gusev (guidance systems), N. D. Khokhlov (quality control), V. Ya. Litvinov (space and missile programs), Ye. V. Mazur (material-technical supply), G. M. Tabakov (rocket engines), and G. R. Udarov (launch complexes). Gusev left his position in late 1965 and was replaced by M. A. Brezhnev. See Mozzhorin, *et al.*, eds., *Dorogi v kosmos: I*, pp. 38–39; Christian Lardier, *L'Astronautique Soviétique* (Paris: Armand Colin, 1992), p. 164; Almquist, *Red Forge*, pp. 141–45.

69. In March 1965, the seven industrial ministries that were part of VPK were the Ministry of Defense Industry (S. A. Zverev), the Ministry of Aviation Industry (P. V. Dementyev), the Ministry of Ship Building Industry (B. Ye. Butoma), the Ministry of Electronic Industry (A. I. Shokin), the Ministry of the Radio Industry (V. D. Kalmykov), the Ministry of Medium Machine Building (Ye. P. Slavskiy), and the Ministry of General Machine Building (S. A. Afanasyev). An eighth and ninth ministry were added in February 1968 and 1974, respectively. These were the Ministry of Machine Building (V. V. Bakhirev) and the Ministry of the Means of Communications (N. D. Psurtsev). See Alexander, "Decision-Making in Soviet Weapons Procurement," p. 22; McDonnell, "The Soviet Defense Industry as a Pressure Group," pp. 90–91; Chertok, *Rakety i lyudi*, pp. 311–13.

70. Michael Tatu, *Power in the Kremlin: From Khrushchev's Decline to Collective Leadership* (London: Collins, 1969), p. 330; V. Pappo-Korystin, V. Platonov, and V. Pashchenko, *Dneprovskiy raketno-kosmicheskiy tsentr* (Dnepropetrovsk: PO YuMZ/KBYu, 1994), pp. 54, 67, 70. Khrushchev's visit to the Dnepropetrovsk plant and his impressions of Smirnov are described in Sergey Khrushchev, *Nikita Khrushchev: krizisy i rakety: vzglyad iznutri: tom I* (Moscow: Novosti, 1994), pp. 432–33.

Leonid Smirnov was the Chairman of the Military-Industrial Commission (VPK) from 1963 to 1985. He was the effective head of the Soviet military-industrial complex during that period. (files of Peter Gorin)

Smirnov owed his entire career to Ustinov. Within the space program itself, he was clearly in favor of Yangel's projects and then perhaps Korolev. Certainly, given Ustinov's predilection for trying to curb Chelomey's efforts, Smirnov could be expected to do the same in given situations. He was, of course, ultimately responsible to the whims of Communist Party leaders. As one Russian historian wrote: "[Smirnov] knew that prior to deciding any kind of issue, he had to clearly understand what kind of a decision was expected from higher up." Like many other "cardinals" of the Soviet military-industrial complex, Smirnov instilled total fear in his subordinates. One Russian historian wrote later: "People always found it difficult to make a report to Smirnov because his face was so impassive that it was completely impossible to see a hint of any reaction that your words might arouse in him."[71] Smirnov's responsibilities were first detected in the West during negotiations of the first series of Strategic Arms Limitation Talks (SALT I) in May 1972. His active participation in the negotiations convinced U.S. diplomats that he was a "tough and skillful negotiator" with a "'technician's grasp of the issue' superior to anyone at the table."[72] Others remember him differently. Although he succeeded Ustinov as chairman of VPK, one engineer recalls that Smirnov was simply "a rote bureaucrat" who was "not as clever as Ustinov."[73] Rote bureaucrat or not, Smirnov had the distinction of managing the entire Soviet defense industry through nearly a quarter of a century, outlasting Khrushchev, Brezhnev, Kosygin, Andropov, and Chernenko. He would not retire until the Gorbachev era.[74]

Officially, Smirnov's VPK was "the principal coordinating body for military research, development, and production. It also [played] a key role in technical evaluations of new weapons proposals."[75] Given that the space program was simply an institutional arm of the military missile program, VPK did exactly the same for the space program. Every proposal that surfaced up from the design bureaus past ministry heads eventually ended up at the office of the Military-Industrial Commission, set deep within the fortress of the Kremlin. Because staff members of VPK composed the drafts of all defense research and development decrees, VPK's role straddled the boundaries between policy formulation and policy implementation. Even in the mid-1960s, U.S. intelligence officials seem to have been unsure of the very existence of VPK. In a top-secret brief on the Soviet space program dating from January 1965, the U.S. Central Intelligence Agency (CIA) wrote simply that "responsibility for the direction of the Soviet space program apparently rests with an unknown authority directly under the Council of Ministers." Much of the space program was still said to have been coordinated by "the Commission on the Exploration and Utilization of Cosmic Space," the 1950s-era front organization publicized by the Soviets. The CIA added that it had "been unable to identify many of the individuals responsible for research and development."[76]

71. Golovanov, *Korolev*, pp. 668–70.
72. Alexander, "Decision-Making in Soviet Weapons Procurement," p. 20.
73. Khrushchev interview, October 10, 1996.
74. Golovanov, *Korolev*, p. 670.
75. Alexander, "Decision-Making in Soviet Weapons Procurement," p. 21.
76. U.S. Central Intelligence Agency, "National Intelligence Estimate 11-1-65: The Soviet Space Program," Washington, DC, January 27, 1965, p. 29, as declassified in 1997 by the CIA Historical Review Program.

If Smirnov and Afanasyev were the managers of Soviet space policy, then Dmitriy Fedorovich Ustinov was its ultimate master. Since the formation of the Soviet rocketry industry in May 1946, he had served as the industrial manager for the Soviet ballistic missile and space program in a series of positions, culminating with his appointment as chairman of VPK in December 1957. Through the years, he had been involved on an almost day-to-day basis with chief designers such as Korolev, Glushko, and Yangel; it would not be an overestimation to say that with the exception of Korolev, Ustinov was the single most important figure in the history of the Soviet space program. His signature can be found in almost every single decree and decision of the early missile and space programs, spanning a period of almost forty years. Until 1965, Ustinov had remained a public servant of the Soviet government—that is, engaged in administering projects rather than formulating policy—and it was evidently a job at which he excelled. Sergey Khrushchev recalls that:

> *Ustinov was a brilliant man [but he] was very bad in strategy. He could not create a strategy . . . what to do, where to go . . . [things] like state policy or defense policy. But once he received the order from Stalin or Khrushchev to do something, he knew how to do it in the best way. When he was Chairman of the Military-Industrial Commission . . . when he received the order to do something, like putting together a decree of the Central Committee and the government on a Chelomey design, he did this in one shot. He knew how to do this.*[77]

On March 26, 1965, soon after the establishment of MOM, Ustinov was moved from the government (that is, management) to the Party (that is, policy formulation). His new title was Secretary of the Central Committee for Defense Industries and Space, the top-ranking leader of the Soviet space program. He was also inducted as a Candidate Member of the Presidium (which was renamed the Politburo in April 1966).[78]

As a secretary of the Central Committee, Ustinov was one of about a dozen individuals overseeing every sector of Soviet society as part of a smaller group called the Secretariat, roughly analogous to the Western concept of a cabinet. Officially, the Secretariat's goal was to provide "analysis and recommendations" to the members of the Politburo. In the case of the space program, however, Ustinov may have exerted a singularly powerful force that essentially laid the foundations of Soviet space policy. He decided which programs to emphasize, which directions to conduct research, how to compete with the U.S. space program, whether to time space missions for certain holidays, when and how to penalize chief designers, the appointment and dismissal of chief designers, and so forth. In Soviet publications of the time, Ustinov was said to have:

> *coordinated and led the work of institutions, design bureaus, [and] industrial enterprises with the goal of the most complete fulfillment of the tasks of the party and the government in the long-range strengthening of the economic and defense potential of the nation, [and he] took up active participation in organizational work in the area of the development of technology used for the research and mastery of space.*[79]

There were also, of course, other *full* Politburo members with varying degrees of stake in the Soviet space program. The son-in-law of one, Andrey P. Kirilenko, was a senior engineer at

77. Khrushchev interview, October 10, 1996.
78. Edward L. Crowley, Andrew I. Lebed, and Dr. Heinrich E. Schulz, eds., *Party and Government Officials of the Soviet Union 1917–1967* (Metuchen, NJ: The Scarecrow Press, 1968), p. 84.
79. Almquist, *Red Forge*, p. 21.

Dmitriy Ustinov is shown here in a photo from the mid-1960s. With the exception of Sergey Korolev, he was the single most important individual in the history of the Soviet missile and space programs. His influence was not limited to missiles and space: from 1965 to 1976, he was the ranking Central Committee secretary overseeing the entire Soviet defense industry. (files of Peter Gorin)

OKB-1. Brezhnev himself favored Yangel, both having come from Dnepropetrovsk in the Ukraine. Ustinov was a little more shrewd in his patronage. He clearly favored Korolev throughout the latter's career, defending his proposals at critical junctures, perhaps even saving his life during the Stalin era. But while most historians do not question Ustinov's support for Korolev, it is also an inarguable fact that Ustinov was a strong supporter of Glushko. For obvious reasons, this caused complications in his relationships with both.

Little is known about Ustinov's personal life or his character. As with a number of other Soviet bureaucrats of the time, people considered him "temperamental, impulsive, and rude."[80] MOM Minister Afanasyev, appointed to be a foil against Ustinov's bulldozing over the space program, recalled that for Ustinov, work was the only thing: "He seemed to have no other interests such as hunting or fishing."[81] Others say that:

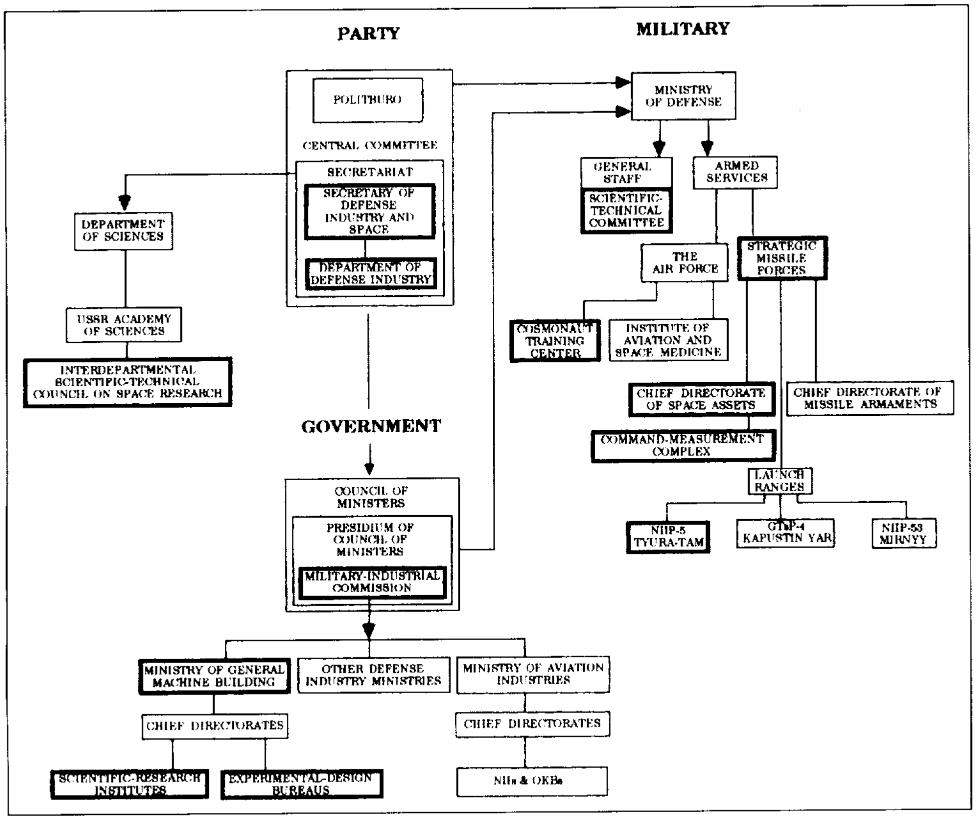
> *He made his decisions alone. . . . After D. F. made up his mind, a commission would usually be set up to study the issue. It was composed of people who knew the boss's mind and never missed a cue. The decisions of the Central Committee and the Council of Ministers were taken after a report of the commission. The minister's personal opinion was never cited to justify this or that decision.*[82]

It is known that VPK or MOM, rarely, if ever, failed to approve rulings originating from the Defense Industries Department in the Central Committee—that is, one of Ustinov's departments.[83]

Ustinov, Smirnov, and Afanasyev were the three men who ran the Soviet space program from the 1960s on. For Ustinov and Smirnov, the space program was only part of their responsibilities; both also administered the entire Soviet defense industry as it raced to reach strategic parity with the United States. It is in itself a significant fact that the men who facilitated most of the Soviet rise to gargantuan military superpower were also both intrinsically involved in the goings-on of the space program. It underlines that inseparability of the Soviet space program from military efforts and hints at the domination of former space program managers in the rule of the Soviet state.

The Ustinov-Smirnov-Afanasyev trio, part of the so-called "Ustinov group" from the armaments industry in the 1940s and 1950s, was obviously not a solid monolithic block.[84] The changes in 1965 had one institutional effect related to the military's position on space. Several major artillery officers were moved into the Ministry of Machine Building from the Strategic Missile Forces—all of them very strong supporters of a vigorous Soviet space program. Given

80. Nina Chugunova, "Notes on the Margins" (English title), *Ogonek* 4–5 (January 1993): 29–30.
81. Mozzhorin, *et al.*, eds., *Dorogi v kosmos: I*, p. 47.
82. Chugunova, "Notes on the Margins," pp. 29–30.
83. Stephane Chenard, "Twilight of the Machine Builders," *Space Markets* 5 (1991): 11–19.
84. For discussions of the "Ustinov group," see Julian Cooper, "The Elite of the Defence Industry Complex," in David Lane, ed., *Elites and Political Power in the USSR* (Cheltenham, UK: Edward Elgar, 1988), pp. 167–87.



The 1965 organization of the administrative bodies in the Soviet space program. (copyright Asif Siddiqi)

the cool attitude of the Strategic Missile Forces toward piloted space exploration, it is not clear whether this was done to punish the officers for their views or to infiltrate MOM to expand the influence of the Strategic Missile Forces.[85] Given the sketchy evidence, it seems that the former was more likely than the latter. One of those "moved out" was, in fact, the Commander-in-Chief of the recently established Central Directorate of Space Assets, Maj. General Kerim A. Kerimov, whom the more "trustworthy" Maj. General Andrey A. Karas replaced.[86] Thus, with the few

85. Barry, "The Missile Design Bureaux." Four officers of the Strategic Missile Forces have been identified in this move: Lt. General G. A. Tyulin, who was appointed the First Deputy Minister of MOM; Maj. General K. A. Kerimov, who was named the Chief of the Third Chief Directorate of MOM, Colonel Yu. A. Mozzhorin, who had been serving as Director of NII-88 since 1961, and Maj. General A. G. Mrykin, who was appointed First Deputy Director of NII-88 under Mozzhorin.

86. For Kerimov, see N. Kamanin, "A Goal Worth Working For . . ." (English title), *Vozdushniy transport* 44 (1993): 8–9. See also "Col.-Gen. A. G. Karas" (English title), *Krasnaya zvezda*, January 4, 1979, p. 3, in which Karas is said to have served as chief of a chief directorate in the Ministry of Defense between 1965 and 1979. The second officer, Lt. General A. G. Mrykin, had served as the First Deputy Chief of the Chief Directorate of Reactive Armaments (GURVO) since July 1955. Upon the formation of the Strategic Missile Forces, GURVO was transferred to their jurisdiction, and Mrykin had become one of the leading advocates of a stronger role for the Strategic Missiles Forces within the Soviet space program. He was next in line to command GURVO, but in August 1964, a junior officer (Maj. General A. A. Vasilyev) was picked to head GURVO. Mrykin evidently refused to work under Vasilyev, a former subordinate, and instead left the Strategic Missile Forces in March 1965 and joined the Ministry of General Machine Building's NII-88 as its First Deputy Director. Ironically, at NII-88, Mrykin ended up working for a former subordinate, NII-88 Director Yu. A. Mozzhorin. See Mozzhorin, *et al.*, eds., *Nachalo kosmicheskoy ery*, p. 256.

space proponents out of the way, the Strategic Missile Forces were even less likely than before to support "civilian" projects such as the Moon landing. The Air Force, fighting a losing battle, did not manage to put a single representative into the Ministry of General Machine Building.

There was a final element of the 1965 shake-up—one that was motivated by allowing Soviet scientists in space research. As early as 1959, Korolev and Keldysh had been calling for the establishment of an institution dedicated solely to conducting scientific research in space, but the scientific lobby, having served as lackeys for the military-industrial complex, were simply unable to fortify their position into action. After much discussion within the Academy of Sciences, in July 1963, Keldysh fired off a specific proposal on behalf of the scientific community for the establishment of the Institute for Space Research.[87] What changed the Soviet government's mind at the time is not apparent, but it may have been motivated by the need to have a public forum to represent Soviet space scientists abroad. Because the Soviets could hardly send Smirnov or Ustinov abroad to talk about their space programs, it would be much more convenient to have a real institution to indicate that the Soviet space program was one operating as a completely separate entity from the military. The institute was formally established on July 14, 1965, under the directorship of Academician Georgiy I. Petrov, a chain-smoking six-foot-tall, brilliant aerodynamics specialist who had contributed significantly to ICBM development.[88] It was officially subordinate to the USSR Academy of Sciences. Despite Petrov's best intentions, through its first few years of existence, the institute found itself mired in bureaucratic politics; different scientific communities all vied for a piece of the funding that they had all been waiting for since Sputnik. It would not be until the early 1970s that the institute finally became a world-class institution supporting high-quality scientific research on space phenomena.

Chelomey in Trouble?

Khrushchev's fall from power had immediate and dire consequences for the beleaguered Chelomey. Propped and supported for the preceding four years by the Khrushchev administration, Chelomey all of a sudden lost his chief sponsor. Khrushchev would say many years later: "I am not ashamed to say that I gave Chelomei my support back then. He fulfilled many of the hopes we placed in him. . . ."[89] One wonders what Chelomey must have thought in the days after October 13 when Brezhnev and Kosygin assumed power. Chelomey was reportedly nervous as gossip in and around the organization reached a feverish peak on the possible future for OKB-52 and its associated branches. Still reeling from the abrupt decision to terminate the UR-200 ICBM program, Chelomey's first move was to telephone Kosygin. Brezhnev would have been a more risky proposition given his close relationship with Ustinov. Kosygin was, however, inordinately rude to Chelomey, and he refused to even discuss the possibility of reconsidering the decision on the UR-200.[90] The UR-200 ICBM program was

87. This letter has been reproduced in full as M. V. Keldysh, "On the Organization of the Institute of Space Research" (English title), in V. S. Avduyevskiy and T. M. Eneyev, eds., *M. V. Keldysh: izbrannyye trudy: raketnaya tekhnika i kosmonavtika* (Moscow: Nauka, 1988), pp. 477–78.

88. Yu. I. Zaytsev, "14 July—25 Years Since the Organization of the Institute for Space Research of the AN SSSR (1965)" (English title), *Iz istorii aviatsii i kosmonavtiki* 64 (1990): 54–58. An official decree of the Academy of Sciences on the institute's formation was issued on July 9, 1965.

89. Nikita S. Khrushchev, *Khrushchev Remembers: The Glasnost Tapes* (Boston: Little & Brown, 1990), p. 188.

90. Khrushchev, *Nikita Khrushchev: tom 2*, pp. 514–15. The ninth and last UR-200 was launched on October 23, 1964, from Tyura-Tam. See S. A. Zhiltsov, ed., *Gosudarstvennyy kosmicheskiy nauchno-proizvodstvennyy tsentr imeni M. V. Khrunicheva* (Moscow: RUSSLIT, 1997), p. 58; Mikhail Rudenko, "Designer Chelomey's Rocket Planes" (English title), *Vozdushniy transport* 51 (1995): 8.

formally terminated soon after, squelching one of Chelomey's primary means to gain access to space.[91]

Because one of the early goals of the Brezhnev-Kosygin leadership was to "reverse" the decisions of the Khrushchev era, the entire OKB-52 came under great scrutiny. There was even talk of completely dissolving the design bureau. Several special commissions were established in October to investigate, among other things, "the value of storage materials, book-keeping, the completion of plans, [and] the observance of secrecy" at OKB-52.[92] Everything—from the size of the carpet in Chelomey's dacha to the finances for the UR-200 program—was audited or inspected. One of the first casualties of this unusual backlash was the size of Chelomey's empire. By late 1964, he was overseeing a design bureau and branches twice the size of Korolev's OKB-1. Thus, the first order of business was to deprive OKB-52 of its branches. The most vulnerable of these was Branch No. 3 located at Khimki. This subsidiary, consisting of the old Lavochkin design bureau and its associated plant, had been tasked by Chelomey to work on anti-ship cruise missiles, such as the P-70 Ametist in the early 1960s, allowing him to concentrate on ICBMs and space programs at the central office. The winds of change were, however, too quick for Chelomey. The very day after the change of power, on October 15, the Lavochkin bureau "unofficially" separated itself from Chelomey.[93] Many of Chelomey's representatives, including Chief Designer Arkadiy I. Eidis, returned to Reutov with their files and work on the Ametist missile, while the original Lavochkin people found a new calling: automated lunar and interplanetary spacecraft.

For some months, Korolev had been discussing the possibility of "farming out" specific themes related to space exploration to other organizations. While his OKB-1 had developed the first piloted spacecraft, communications satellites, robotic lunar vehicles, automated interplanetary spacecraft, scientific satellites, and reconnaissance satellites, Korolev's primary interest was piloted spaceflight. To allow him to focus on piloted spaceflight without a significant distraction of time and resources, Korolev separated three space efforts from his own design bureau and transferred them wholesale to other organizations. Reconnaissance satellites went to OKB-1's Branch No. 3 at Kuybyshev in 1964, while communications satellites went to OKB-10 at Krasnoyarsk-26 in late 1965.[94] A third thematic direction Korolev considered for transfer was work on robotic lunar and interplanetary spacecraft. As soon as the employees of the Lavochkin design bureau found themselves free from Chelomey's control, Korolev began discussions on handing over all his work on the Luna, Mars, and Venera spacecraft to them. The Lavochkin group officially separated from Chelomey on March 2, 1965, becoming the Experimental Design Bureau of the S. A. Lavochkin State Union Machine Building Plant. Georgiy

91. The "official" reason for the termination of the UR-200 varies in Russian literature. One source suggests that the cancellation was because of the belief that it had inferior characteristics as compared to Yangel's R-16 ICBM. See Petrakov and Afanasyev, "'Proton' Passion." A second source suggests that the cancellation was "owing to the urgency of the mission of creating a new generation of missile complex as a counterpart to the American 'Minuteman'." The UR-200 also had deficiencies in silo defense characteristics. See Zhiltsov, ed., *Gosudarstvennyy kosmicheskiy*, p. 58. In an official history of the Strategic Missile Forces, the authors write that work on the project was "terminated in connection with the successful completion of flight work and organization of military service of the R-16, R-16U and R-9A ICBMs." See Ye. B. Volkov, ed., *Mezhkontinentalnyye ballisticheskiye rakety SSSR (RF) i SShA* (Moscow: RVSN, 1996), p. 139.

92. Khrushchev, *Nikita Khrushchev: tom 2*, p. 515; Rudenko, "Designer Chelomey's Rocket Planes"; "Interview with Academician A. A. Dorodnitsyn" (English title), in Dmitriy Khrapovitskiy, ed., *Generalnyy konstruktor Akademik V. N. Chelomey* (Moscow: Vozdushniy transport, 1990), pp. 13–14.

93. N. G. Babakin, A. N. Banketov, and V. N. Smorkalov, *G. N. Babakin: zhizn i deyatelnost* (Moscow: Adamant, 1996), pp. 29, 32.

94. Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, pp. 101, 154–155. Note that OKB-1's Branch No. 3 was technically still subordinate to the OKB-1 main center at Kaliningrad. Formal separation did not occur until July 30, 1974.

Vladimir Chelomey (right) next to Academy of Sciences President Mstislav Keldysh. (files of Asif Siddiqi)

N. Babakin, a fifty-year-old radio-technical systems expert who had worked under Lavochkin for many years, was appointed the new chief designer of this design bureau. By late 1965, Korolev had handed over all work on automated deep space exploration to Babakin.[95] Thus, by a circuitous route, the Lavochkin design bureau went from designing airplanes in 1940s, intercontinental cruise missiles in the 1950s, and anti-ship missiles in the early 1960s to finally spacecraft beginning in the mid-1960s. It would eventually become one of the most important space research organizations in the Soviet Union.

The commissions that investigated Chelomey's fortunes did not only do away with his branches, but also his works. One of the commissions, headed by Academy of Sciences President Keldysh, was tasked with assessing each and every space and missile project at Chelomey's design bureau. Among the programs threatened with cancellation were the nation-wide anti-ballistic missile system known as Taran and the UR-500 ICBM/space launch vehicle; the former was simply terminated, while the latter came under severe attack. By this time, the Strategic Missile Forces were turning away from their earlier doctrine of super-heavy ICBMs to lightweight ICBMs; in this climate, the UR-500 lost its primary reason for existence. Luckily for Chelomey, the UR-500 program had strong supporters, both in the military and in the person of Academician Keldysh. The latter "firmly and persistently" argued that despite its shortcomings as an ICBM, the UR-500 would make an excellent space launch vehicle.[96]

The reasons for Keldysh's support remain obscure even today. He was, in fact, known more for his staunch attachment to the Korolev faction through the late 1950s and early 1960s. His connections to Chelomey did, however, go back a long way, and Keldysh may have even been instrumental in the original establishment of OKB-52 in 1955. Regardless of Keldysh's ultimate motivations, one academician recalls that "[the only reason] Chelomey remained standing was owing to the intervention of M. V. Keldysh."[97] Defended by Keldysh, Chelomey took advantage of the reprieve to quickly put together a test program for the launch of the UR-500. Originally, there had been plans to test-launch the vehicle as a two-stage ICBM, to be followed by three-stage orbital launches. Given the urgent situation, Chelomey revised these plans and decided to use the two-stage version directly for orbital launches. Activities at the M. V.

95. *Ibid.*, p. 145; S. V. Romanova, "13 November—70 Years From the Birth of G. N. Babakin (1914)" (English title), *Iz istorii aviatsii i kosmonavtiki* 51 (1984–1985): 62–68; Babakin, Banketov, and Smorkalov, *G. N. Babakin*, p. 29.

96. Petrakov and Afanasyev, "'Proton' Passion."

97. "Interview with Academician A. A. Dorodnitsyn," p. 14. Note that Keldysh had been the one to inform Chelomey in August 1955 of the order to establish OKB-155. See Nina Chugunova, "V. N. Chelomey. Highlights of His Biography" (English title), *Ogonek* 4–5 (January 1993): 24–29.

Khrunichev Plant in Fili were accelerated in support of this plan, as the "investigation commissions" continued to scour through Chelomey's design bureau in search of things to shut down.[98] If the four test launches were successful, then Keldysh would have a much better chance of defending the threatened booster.

A success on the first launch was mandatory, and engineers at OKB-52 and its Branch No. 1 were ready to ensure that this goal was achieved. One of the perks of the large amounts of financial support Chelomey received during the 1961–64 period was the ability to test-launch vehicle elements on the ground. Approximately 28,000 model and full-scale tests were conducted during the development of the UR-500; in addition, sixteen full-sized test stands were designed and built to verify the standard systems of the booster both separately and connected together. The design bureau also purchased powerful computers to extensively simulate flight conditions, allowing the elimination of numerous possible problems before actual flights. Between June 1963 and January 1965, Glushko's design bureau fired the first stage's RD-253 engine numerous times in tests that closely simulated actual flight conditions. There had been original plans to launch large scientific satellites into orbit using the three-stage version of the UR-500; these plans were modified and smaller variants of the satellites, designated N-4, were created at the design bureau. Chelomey contracted the Moscow-based Scientific-Research Institute of Automation and Instrument Building, headed by another of Korolev's allies, Chief Designer Pilyugin, to develop a modified control system for the space launcher version.[99]

In the spring of 1965, a flight-ready version of the UR-500 was transported to Tyura-Tam. During the heyday of the Khrushchev years, Chelomey had been allocated a vast area in the so-called "Left Flank" of the test range, about thirty-five kilometers northwest of the original city of Leninsk and thirty kilometers west of Korolev's main pad at site 1. Construction had begun on launch complexes for both the UR-200 and the UR-500 during 1960–62. The "Chelomey area" of Tyura-Tam was the focus of massive levels of construction during the early 1960s. To support operations with the UR-500, engineers had begun the construction of:

- Two launch complexes adjacent to one another (at sites 81 and 200), each with two launch pads 600 meters apart
- A refueling station
- An assembly-testing building for space objects (at site 92A)
- A building for integrating the upper stages
- An assembly-testing building for the complete launch vehicle (at site 92)

A residential zone (at site 95), designed to accommodate 10,000 people, was also in the process of construction at the time.[100] All this was in addition to the pads for the smaller UR-200 ICBM/space launcher; when the UR-200 program was terminated, its support complexes and pads were handed over to Yangel.[101]

98. V. A. Vyrodov, M. K. Mishetyan, and V. M. Petrakov, "16 July—25 Years From Beginning of Operation of the 'Proton' Rocket-Carrier" (English title), *Iz istorii aviatsii i kosmonavtiki* 64 (1990): 58–67.

99. Dmitriy Khrapovitskiy, "Absolutely Unclassified: The Ground Waves of Space Politics" (English title), *Soyuz* 15 (April 1990): 15; Petrakov and Afanasyev, "'Proton' Passion"; I. Afanasyev, "35 Years for the 'Proton' RN" (English title), *Novosti kosmonavtiki* 1–2 (1998): 45–48.

100. V. Menshikov, "Cosmodromes: Rockets and People: Baykonur" (English title), *Aviatsiya i kosmonavtika* no. 4 (April 1993): 8–9; Jacques Villain, ed., *Baïkonour: la porte des étoiles* (Paris: Armand Colin, 1994), p. 110.

101. V. L. Menshikov, *Baykonur: moya vol i lyubov* (Moscow: MEGUS, 1994), p. 158. A formal decision on transferring the UR-200 pads to Yangel's R-36 ICBM program was issued on August 24, 1965.

Chelomey's engineers prepared a flight-ready two-stage UR-500 booster for flight in July 1965 from site 81 with the N-4 satellite, which was a 12.2-ton (8.3-ton mass in orbit) scientific observatory designed to study cosmic rays and the interaction between high-energy particles and matter. The satellite was manufactured on the basis of the UR-500's third-stage tankage. The haste with which the launch was prepared affected the prelaunch preparations. During fueling operations, a nitrogen tetroxide leak threatened to seriously damage the booster itself; emergency inspections proved that the rocket was safe for liftoff. The UR-500 took off on July 16, 1965, and successfully inserted its payload into a nominal orbit. The unqualified success of the launch signaled the official entry of Chelomey into the "space club" that had been dominated by Korolev and Yangel. The Soviet press made much of the mass of the satellite, far heavier than anything yet orbited by the Soviet Union. Perhaps to affirm the connection with its scientific program, the satellite was named Proton-1. "Proton" was the name later used to refer to the launch vehicle itself in Soviet press reports, although engineers had originally planned to call the rocket *Gerkules* ("Hercules"), a name that was painted on the side of the booster on its first launch. The media releases at the time touted the launch as a new stage in Soviet space exploration. While the performance of the UR-500 booster may have been flawless, the same could not be said of the Proton-1 satellite. Once the satellite was inserted into orbit, ground stations failed to receive any word from the payload. For several orbits, desperate ground controllers at the General Staff of the Ministry of Defense in Moscow attempted to make contact with the satellite, and they finally gave up when they conclusively ascertained that there had been a major failure aboard the craft.[102]

Notwithstanding the failure of the Proton-1 satellite, Chelomey's people carried out three more orbital launches of the UR-500 in 1965 and 1966, of which only one was a complete failure—a good record for a completely new booster.[103] The successful tests of the Proton launcher were pivotal in convincing the Soviet leadership that perhaps this was one of Chelomey's projects best left untouched.[104] It seems that the faith that Keldysh and Chelomey invested in creating this launch vehicle had been well worth it. The Proton rocket would go on to become one of the most dependable and famous launch vehicles ever created by any nation, launching commercial satellites into space and serving well into the 1990s. It was a curious destiny for a missile originally conceived as a super-heavyweight ICBM capable of launching Armageddon-strength megaton warheads at the enemy.

Chelomey had two major piloted space projects under way at his design bureau when Khrushchev was ousted: the Raketoplan reusable hypersonic spacecraft effort and the LK-1 cir-

102. Col. (Res.) I. Zamyshlyaylev, "Supporting Space Flights: Signal Suitable for Processing" (English title), *Aviatsiya i kosmonavtika* no. 11 (November 1990): 44–45. The official TASS announcement for the Proton launch stated: "Analysis of the telemetric information received indicates that the apparatus on board the space station 'Proton-1' is operating normally. The coordination-computation center is processing the incoming information." See "'Proton-1' in Flight" (English title), *Komsomolskaya pravda*, July 17, 1965, p. 1. Another source suggests that although the controllers did not have initial contact, they did establish contact after a few hours. See Afanasyev, "35 Years for the 'Proton' RN."

103. The launches were on November 2, 1965, March 24, 1966, and July 6, 1966. The March launch was a failure. The November launch was the first from the second pad at site 81. See Petrakov and Afanasyev, "'Proton' Passion."

104. Ustinov was apparently one of those who was convinced of the need to continue with the program. See Zakharov, "Operation 'Kedr' or How the 'Proton' Was Saved." Note that without doubt, the most important work at OKB-52 during this period was the UR-100 ICBM project. The program had been formally approved on March 30, 1963. Due to strong support from Deputy Minister of Defense A. A. Grechko, the program was allowed to continue after Khrushchev's fall. The missile was launched for the first time on April 19, 1965, continuing its test launches until October 27, 1966. The missile was declared operational in July 1967 after approximately sixty launches. See Zhiltsov, ed., *Gosudarstvennyy kosmicheskiy*, pp. 58–60; I. D. Sergeyev, ed., *Khronika osnovnykh sobytiy istorii raketnykh voysk strategicheskogo naznacheniya* (Moscow: TsIPK, 1994), p. 38.

cumlunar program. Each suffered the repercussions of the leadership change, but in different ways. The Raketoplan project had stumbled forward through the years despite technical problems related to protecting the spaceplane from the stresses of atmospheric reentry—problems that had destroyed the M-12 spaceplane during its suborbital flight in 1963. Originally intended for piloted circumlunar missions, by May 1964, the Raketoplan had only military goals, such as anti-satellite operations, reconnaissance, and orbital bombing, all from Earth orbit. Chelomey's idea apparently interested powerful forces within the military. On June 18, 1964, USSR Minister of Defense Rodion Ya. Malinovskiy signed the ministry's five-year plan for space-based reconnaissance covering 1964–69. Among the projects included for approval was a spaceplane program designated "R."[105] By this time, Chelomey's engineers, based on their Raketoplan research from 1961 to 1963, had produced the technical designs for a new iteration of the design, comprising two different Raketoplans, the automated R-1 spacecraft, and the piloted R-2 vehicle.

The R-1 was essentially a test model for the piloted version. It would be used for testing all essential systems in Earth orbit, including:

> *the orientation and stabilization systems, heat shielding, systems for triggering separating components and [also for testing] the dynamics of uncoupling, ballistic and aerodynamic parameters of the Raketoplan and engine [and] the operation of all on-board systems.*[106]

The R-2, a heavier variant of the spaceplane, was designed to allow "the pilot-cosmonaut [to] check out control-monitoring, communication, and observation functions from space."[107] A nominal orbit for this single-pilot military spaceplane would be 160 by 290 kilometers with a total flight time of twenty-four hours. Maximum acceleration during reentry would be limited to three and a half to four g's. Presumably, both the R-1 and R-2 "boost-glide" vehicles would deorbit in a thermally protected container that would be discarded after atmospheric reentry, deploy wings, turn on a turbojet engine, and then land on a conventional runway. Either Korolev's R-7 or the UR-500 would serve as the launch vehicle for the R-1 and R-2 spaceplanes.

The primary goal of the R-2 spaceplane project was photo-reconnaissance and/or anti-satellite operations, and both were objectives that were vigorously supported by the Soviet Air Force in its quest to get a piece of the Soviet piloted space program. Marshal Vershinin, the Commander-in-Chief of the Air Force, publicly spoke of the Raketoplan effort in August 1964, saying that spaceplanes were not only feasible, but that Soviet engineers were engaged in a development program that was "not without success."[108] By 1964, OKB-52 engineers had evidently completed the design of the R-2 boost-glide vehicle "at the Air Force's request."[109] They had already begun the construction of flight models when Khrushchev's ouster threw the program into jeopardy, leading to the "temporary suspension" of work sometime in 1965 or 1966.

There continues to be conflicting information on why the project was closed down at the time. Some suggest that it was related directly to the post-Khrushchev vendetta against Chelomey. One engineer recalls that the termination order came from "upstairs" at a time when

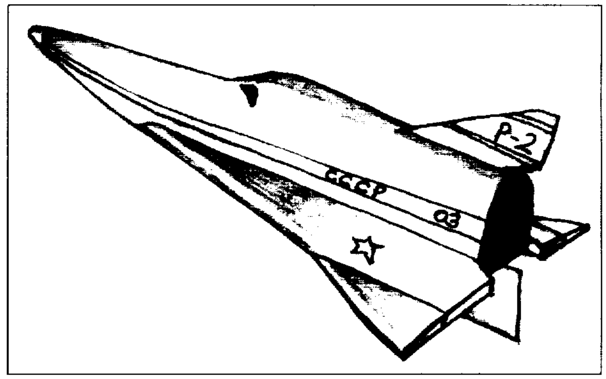
105. Kamanin, *Skrytiy kosmos: 1964–1966*, p. 58.

106. Anatoliy Kirpil and Olga Okara, "Designer of Space Planes. Vladimir Chelomey Dreamed of Creating a Space Fleet of Rocket Planes" (English title), *Nezavisimaya gazeta*, July 5, 1994, p. 6.

107. *Ibid.*

108. "Soviets Developing Spaceplane," *Space Business Daily*, August 18, 1964, p. 1.

109. I. B. Afanasyev, "Unknown Spacecraft (From the History of the Soviet Space Program)" (English title), *Novoye v zhizni. Nauke, tekhnike: Seriya kosmonavtika, astronomiya* no. 12 (December 1991): 1–64.



This is a drawing of the R-2 piloted spaceplane as it emerged during 1964–65 at the Chelomey design bureau. The program was suspended at the time, because of a combination of technical and political factors. (copyright Asif Siddiqi)

the most formidable technical problems had already been solved.[110] Five days after Khrushchev's fall, on October 19, 1964, Marshal Vershinin apparently telephoned to inform Chelomey that all materials related to the Raketoplan project would be turned over to another design bureau. By this point, OKB-52 had already finished the construction of a "life-size" model of the R-2 spaceplane with a functioning cabin for one cosmonaut. Despite the order, by March 1965, Chelomey had finished the final draft plan for the R-1/R-2 models. He apparently met with Brezhnev himself on August 3, 1965, to persuade him to sign an agreement with the Navy to develop a piloted Raketoplan, but nothing seems to have come out of the meeting.

There is a second version to the story that suggests that the work on the Raketoplan was terminated at the time because of internal reasons. Sergey N. Khrushchev suggests that "Chelomey understood that it would be impossible to enter the atmosphere with wings with that time's technology," prompting him to put the idea on hold.[111] A senior designer at OKB-52, Gerbert A. Yefremov, who would go on to succeed Chelomey, also recalled in an interview: "Termination (not prohibition from above) of the rocket-plane program in the first half of the 1960s was induced by [the] reorientation of [OKB-52] towards developing [the] LK-1 one-man space vehicle for a flight around the Moon."[112]

The most likely scenario is that Chelomey opted to temporarily suspend the program around 1965 because of both technical and political difficulties. The Air Force, still itching for a spaceplane of its own, ordered OKB-52's research database transferred to another organization. If Chelomey would not do it, then they would have someone else do it. This someone else turned out to be General Designer Artem I. Mikoyan, head of OKB-155 and the developer of the famous MiG jet fighter aircraft. In 1965, a number of Chelomey's best designers on the Raketoplan program left his design bureau, taking with them the results of their research to join Mikoyan's organization.[113] It was a strange irony. In 1953, when Stalin had closed down Chelomey's original design bureau, much of his research work had also been transferred to Mikoyan. The move to Mikoyan in 1965 was the end, at least temporarily, of Chelomey's persistent quest to fly a spaceplane into orbit. At the same time, it was the beginning of yet another Soviet spaceplane project, one named Spiral, which would continue on for more than a decade.

110. Mikhail Rudenko, "Space Bulletin: Lunar Attraction: Historical Chronicles" (English title), *Vozdushniy transport* 24 (1993): 11.

111. Khrushchev interview, October 10, 1996.

112. Interview, Gerbert Aleksandrovich Yefremov with the author, March 3, 1997.

113. Kirpil and Okara, "Designer of Space Planes."

The LK-1 Circumlunar Program

If, as OKB-52 designer Yefremov claimed, the Raketoplan project was suspended to focus resources on the LK-1 circumlunar project, then there was good reason to do so. When the UR-500/LK-1 project had been approved in August 1964, it was Chelomey's first solid entry into the piloted space program. Based on the design of the return capsule of NASA's Gemini spacecraft, the LK-1 spacecraft was to carry a single cosmonaut around the Moon by the second quarter of 1967—that is, before the fiftieth anniversary of the Russian Revolution. With a mandate like that, it was probably best to focus the limited resources on the most fruitful projects. This program to send humans around the Moon was curiously one of Chelomey's projects that survived the scrutiny of the days following Khrushchev's fall. The "investigation commissions" probably carried out some level of assessment of the project in late 1964, and it seems that they voted in favor of continuing work on the program.

This was in spite of the fact that Korolev possibly took advantage of the anti-Chelomey sentiment in the government to mount a vigorous attack on Chelomey's circumlunar project in the waning days of the year. This time, perhaps under pressure from his deputies, Korolev abandoned the highly unwieldy multiple-docking mission profile for the 7K-9K-11K Soyuz complex. Instead, he offered up the N11 booster, which would launch a twenty-ton spacecraft into Earth orbit. The payload, comprising a translunar-injection (TLI) stage and a Soyuz spacecraft, would then head for the Moon, carrying out a simple circumlunar flight.[114] For reasons that are unclear, the Soviet government was not interested at the time, perhaps unwilling to abruptly change directions in a program whose key determinant of success was doing it before the Americans. An unconfirmed source states that the Military-Industrial Commission signed a decree on October 28, 1964, essentially confirming Khrushchev's old plan of dividing up the piloted lunar program; Chelomey retained the circumlunar portion and Korolev retained the landing.[115]

Chelomey signed off on the "experimental design" of the LK-1 ship on August 3, 1964, the same day that the government passed the decree committing to the piloted lunar program.[116] Unlike Korolev, whose proposed 7K-9K-11K circumlunar effort would use a multitude of different spacecraft linking up in orbit, Chelomey completely bypassed the idea of Earth-orbit rendezvous as an element of *his* plan. His UR-500 booster was, after all, far more powerful than any booster in Korolev's canon. Originally, Chelomey's engineers conceived of a spaceship launched on the two-stage UR-500 booster, which would allow a payload of roughly twelve tons to be inserted into Earth orbit. This, however, proved to be inadequate to comprise a TLI stage as well as the spacecraft proper. Within a few months, boosters were switched in the circumlunar project; engineers opted to use a *three*-stage version of the UR-500, designated the UR-500K. More payload capacity was added by increasing the length of second-stage tankage and introducing slightly modified engines. The new *third* stage was essentially a shortened version of the second stage. This would allow a payload of almost eighteen tons to be inserted into Earth orbit, sufficient for a piloted spacecraft and its TLI stage. On November 11, 1964, Chelomey outlined the program of launches for the UR-500K and its lunar LK-1 payload.[117]

114. V. P. Mishin, "Why Didn't We Fly to the Moon?" (English title), *Znaniye: tekhnike: seriya kosmonavtika, astronomiya* no. 12 (December 1990): 3–43.

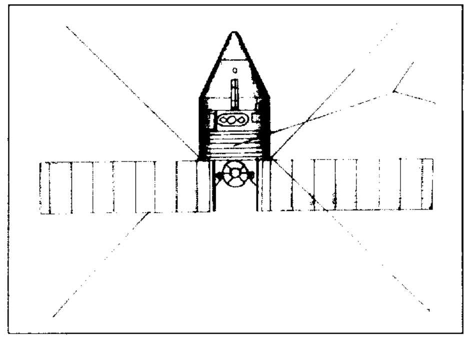
115. Rudenko, "Space Bulletin: Lunar Attraction."

116. Afanasyev, "Unknown Spacecraft."

117. Igor Afanasyev, "Without the Stamp 'Secret': Circling Around the Moon: Chelomey's Project" (English title), *Krasnaya zvezda*, October 28, 1995; Afanasyev, "35 Years for the 'Proton' RN." A conception of the original two-stage variant is shown in I. A. Marinin and S. Kh. Shamsutdinov, "Soviet Programs for Lunar Flights" (English title), *Zemlya i vselennaya* no. 4 (July–August 1993): 62–69. The new engines for the UR-500K second stage were the RD-0210 and the RD-0211. The third stage used the RD-0212, which consisted of the RD-0213 and the RD-0214.

The payload of the UR-500K would consist of the following four sections, each for a different part of the mission:

- Blok A—the TLI stage
- Blok B—the instrument-aggregate compartment or service module
- Blok V—the return apparatus, which would carry the crew
- Blok G—the launch escape system[118]



Chelomey's LK-1 spacecraft was designed in 1964–65 for a circumlunar mission. The ship would be launched by a three-stage Proton booster augmented by the special Blok A translunar-injection stage. (copyright Asif Siddiqi)

Blok A was powered by the R6-117 liquid-propellant rocket engine with a thrust of thirteen and a half tons in vacuum.[119] The propellants were the same as the UR-500K booster itself: unsymmetrical dimethyl hydrazine and nitrogen tetroxide. The development of the R6-117 engine was a first for OKB-52: not only did the organization have minimal experience in the design of rocket engines, it had never designed one for operation in vacuum. In comparison, Korolev's OKB-1, with years of experience, was facing severe problems during the same period with its own upper stage engine for the N1 and other boosters.

Bloks B and V comprised the LK-1 spacecraft itself. Blok B, similar to the Apollo Service Module, was a cylindrical compartment carrying power sources, electronic instrumentation, engines for mid-course corrections and attitude control, and propellant tanks. Soon after TLI and separation of Blok A, the spacecraft would unfurl a set of two solar panels to provide power during the remaining portion of the mission. Total wingspan was on the order of about seven meters. The panels were not attached to the side of the cylinder, but rather to pylons extending rearwards from the base of Blok B. OKB-52 also studied the possibility of using fuel cells working on hydrogen and oxygen in the spacecraft, but it is not clear whether this was adopted for the final design. A small high-gain antenna was located at the base of the module for communications. Blok V was a simple cone, similar to the Apollo Command Module, which was installed on the forward end of the cylindrical "service module." The single cosmonaut would spend the entire mission in here. Attitude control engines were installed on the exterior for motion control prior to reentry, while the internal space carried a single couch, scientific apparatus, communications systems, life support systems, and TV and still cameras for both live broadcast and stored film. The conical shape would allow the vehicle to use a better lift-drag ratio for a controlled reentry into Earth's atmosphere following the return from the Moon.[120]

Finishing up the payload was Blok G, which was the launch escape tower. It was the first such system installed on a Soviet piloted spacecraft and was powered by solid-propellant engines capable of taking the Blok V capsule far away from a malfunctioning launch vehicle. The complete LK-1 spacecraft was remarkably small for a piloted vehicle earmarked for flight to the Moon. Although spacecraft masses have still not been revealed, one Russian space historian with access to design bureau documentation has stated that:

118. Afanasyev, "Without the Stamp 'Secret'."

119. Yefremov interview, March 3, 1997.

120. Afanasyev, "Without the Stamp 'Secret'"; Afanasyev, "Unknown Spacecraft"; Marinin and Shamsutdinov, "Soviet Programs for Lunar Flights."

> *noteworthy in the LK-1 design was the rather small mass and size of the return apparatus. Gradually optimizing the characteristics of the systems of the spacecraft and the launcher, the designers managed to increase the return apparatus' mass and make room for another [second] cosmonaut.*[121]

The base diameter of the conical return apparatus was on the order of two and three-quarters meters, and mass of the entire LK-1 spacecraft was probably limited to about four tons. The return apparatus weighed approximately two tons, lighter than even the Vostok crew capsule.

Engineers at OKB-52 designed the UR-500K/LK-1 complex with very little margin for error. The very low mass of the spacecraft indicates that many systems were probably not backed up, even though the dangers of instrument failure were much greater for a circumlunar mission than for a simple Earth-orbital flight. The primary constraint on the whole mission was clearly the lifting power of the UR-500K and its capacity to insert into Earth orbit a fully fueled TLI stage plus a crewed spacecraft. Thus, the success of a mission would have to depend on the perfectly nominal performance of the UR-500K and the "booster unit," both working at the limits of their design levels. Perhaps to compensate, Chelomey planned a long and extensive flight program for the project. This plan, finalized in late September 1964, called for twelve consecutive launches during 1965 through 1967 using both the two-stage UR-500 and the three-stage UR-500K.[122]

Work on the project was uneven. This was the first serious attempt by Chelomey to develop life support systems, heat shields, high-thrust rocket engines, highly complex avionics, and spacesuits; there is no evidence to suggest that there was any osmosis of information on these topics from the Korolev organization to the Chelomey design bureau. Chelomey simply had to start from scratch. The draft plan for the LK-1 spacecraft was finished by July 1965, coincidentally during the same month that the UR-500 Proton booster was launched on its first flight.[123] The plan apparently "fully fulfilled the requirements" of the original conception of the circumlunar mission.[124]

For Chelomey, his whole claim to the cosmos depended on the UR-500K/LK-1 piloted circumlunar program. The immediate post-Khrushchev era was a time of great difficulty for the ambitious general designer and his organization. Two of his most coveted instruments for entering the Soviet space program, the UR-200 launch vehicle and the Raketoplan program, had been canceled or suspended. Thus, after almost five years as the reigning designer in the Soviet space program, he had little to show in terms of concrete achievements. A number of Soviet historians have argued that this period—1961 to 1964—when Chelomey was bestowed unlimited funds, was a gross miscalculation on the part of the Soviet leadership, for it primarily deprived Korolev of support to successfully carry out his own programs. The N1 had almost died a slow death because of a lack of money, while the 7K-9K-11K Soyuz program had been the subject of innumerable delays. Korolev had been forced to resort to one-off "spectaculars" such as the Voskhod mission in 1964 to maintain his apparent eminence in the space program. Georgiy S. Vetrov, a historian at Korolev's design bureau, has argued:

121. Afanasyev, "Unknown Spacecraft."

122. L. N. Kamanin, "In the Future His Name Will Probably Be . . ." (English title), *Ogonek* 7 (February 9–16, 1991): 28–31; Rudenko, "Space Bulletin: Lunar Attraction." Note that in the latter source, the author states that there would be *two* sets of twelve launches in the entire program.

123. Yefremov interview, March 3, 1997. More specifically, Dr. Yefremov stated that the "conceptual design" of the LK-1 was finalized at the time.

124. Afanasyev, "Without the Stamp 'Secret'."

The situation with the creation of V. N. Chelomey's OKB was only one example of the wasting of forces and resources which proved to be disastrous for the realization of [our] space program. The organizational context giving exclusive rights to the leading designer was good at the beginning, but eventually proved to be negative. The Chief Designers, feeding on their power and authority, started ruling without consulting anybody and their orders entirely determined the direction of the work.[125]

Vetrov's claim has some basis in reality. Because the institutional makings of the Soviet piloted space program were steeped so deeply amid the ballistic missile effort, the chief designers had to resort to personal machinations to sustain programs. Both Chelomey and Korolev were thus put in the position of steering space policy. Because Chelomey happened to be the favored designer during this period, his ideas and proposals benefited, to the detriment of Korolev. It would be difficult and, in fact, pointless to speculate what would have happened had the tables been turned. Georgiy N. Pashkov, the influential deputy chairman of the Military-Industrial Commission said many years later that favoring Chelomey wasted a full five years of the Soviet space program.[126] Chelomey's people, of course, had other opinions. Perhaps referring to the anti-Chelomey sentiment following Khrushchev's fall, Chelomey's deputy Yefremov recalled:

When you look back, you're surprised at how often, at the top, unsound decisions were made which delayed for many years the realization of some of the space developments of our collective or completely stopped developments. There's no doubt that had to do with the subjectivity and incompetence of certain leaders. Our "evil genius" turned out to be the Deputy Chairman of the Military-Industrial Commission G. N. Pashkov.[127]

Each side had their own views, and unable to redress their grievances in the press, they kept their complaints to themselves, bottled up for more than a quarter of a century. Such was the real tapestry of the early Soviet space program, hidden behind the glories of Vostok and Voskhod.

A Walk in Space

The Voskhod mission in October 1964 claimed more glories for the Soviets. While most of the Western press were understandably more interested in the change in leadership at the Kremlin, the general reaction in the West to the Voskhod flight was unprecedented. In the eyes of most people, the Soviet Union had again achieved another important milestone in the space race while the United States was still attempting to catch up. With little concrete information on which to depend, the media were awash with speculation, and as always, the Soviets did little to fill the black hole of information. There were no descriptions of the spacecraft, no indication that it was merely a modified Vostok, and no hint of its extremely limited capabilities. Many in the West simply believed that the Voskhod was a Soviet spacecraft comparable to NASA's Apollo vehicle, which was still on the drawing board.[128] At a press conference on October 21 following the Voskhod mission, Academy of Sciences President Keldysh added to

125. G. Vetrov, "The Difficult Fate of the N1 Rocket" (English title), *Nauka i zhizn* no. 5 (May 1994): 20–28.

126. Lardier, *L'Astronautique Soviétique*, p. 153.

127. Khrapovitskiy, "Absolutely Unclassified," p. 15.

128. On October 14, a journalist from *The Washington Post*, Howard Simon, reported that the Soviet Union was building a "giant new rocket which could be capable of taking Russian cosmonauts to the Moon." He added that the Soviets were preparing "to run the Moon race fast and hard, notwithstanding recent statements suggesting the opposite." See *Soviet Space Programs, 1962–65*, pp. 386–87.

the myth of the Soviet space program by stating: "In the Soviet Union purposeful and systematic work goes on in connection with manned space flights. This is not for effect, but in the interests of progress."[129] Such a claim was especially galling in the light of this particular flight, which had no other purpose than to upstage Gemini. Within OKB-1 itself, sentiments may have been different. Korolev's First Deputy Mishin recalled twenty-five years later: "The [Voskhod] program made no contribution whatsoever to the further development of space research. It was simply a waste of time. Sending three people into space together was done purely for prestige."[130]

The original decrees in March and April 1964 in support of Voskhod had specified five launches, two of which would be piloted; the first was scheduled for August and the second for November. Specific mission goals for the second mission were formulated from the hodgepodge of Air Force and OKB-1 proposals for "extended Vostok" missions over the previous two years. From about March 1964, it was clear to Korolev that the second Voskhod mission would include a "spacewalk" by one of the crewmembers.[131] These plans seem to have partly stemmed from earlier Air Force and OKB-1 suggestions to conduct extravehicular activity (EVA) with a dog on one of the later Vostok missions. Certainly, most of the motivations were external—that is, NASA's publicly announced plans to carry out EVA during the Gemini program. Once again, it was unacceptable for Korolev to lose the edge over the Americans. In fact, during early planning, Air Force General Staff Deputy Lt. General Kamanin had proposed sending a single cosmonaut into orbit as a test of the EVA-equipped ship. Korolev outright rejected this approach:

> *He was troubled not by technical considerations, but by purely political considerations—a one day test flight with one cosmonaut would not represent a new triumph in space. In the opinion of many, each manned spaceflight should be a new, major advance.*[132]

Korolev called the EVA project *Vykhod* ("Exit"), a term originally used in 1963 studies at OKB-1 to describe spacewalks.

The delays in the first Voskhod mission obviously pushed the Vykhod mission beyond the original November deadline, but it seems that Korolev had been insistent that the flight be carried out prior to the end of the year. In a diary entry from early September 1964, Kamanin wrote:

> *. . . Korolev is pestering all his associates, and assuring them that before the year is out, he will launch the Vykhod—a modification of the Voskhod adapted for an EVA by a cosmonaut. As always, Korolev is in a hurry: He prefers a cavalry charge to well-conceived and methodically prepared offensives on the "space fortress."*[133]

One of the reasons for Korolev's haste may have been political: he had apparently made a promise to Khrushchev that he would launch the Vykhod in November in time for the anniversary of the Great October Revolution. With Khrushchev out of power, the deadline no longer seemed as important, and by the time that the three Voskhod cosmonauts landed in October, the Vykhod mission was tentatively planned for early 1965.

129. *Ibid.*, p. 554.

130. "The Russian Right Stuff," *NOVA* television show.

131. The cosmonauts' training for the "spacewalk" mission began training in April 1964. See Peter Smolders, *Soviets in Space* (New York: Taplinger Publishing Co., 1973), p. 139.

132. L. N. Kamanin, "Pages From a Diary: He Soared Freely Above the Earth: On the 25th Anniversary of the Flight of Pilot-Cosmonauts P. I. Belyayev and A. A. Leonov in the Voskhod-2 and the First Spacewalk" (English title), *Sovetskaya rossiya*, March 17, 1990, p. 6.

133. Kamanin, "I Would Never Have Believed Anyone . . . ," p. 4.

The goal for engineers was of a similar scale to the first Voskhod: to modify a Vostok spacecraft in such a manner as to carry a crew of two cosmonauts, of whom one would conduct a spacewalk. The Vykhod team was headed by OKB-1 Deputy Chief Designer Pavel V. Tsybin, a veteran of a number of aerospace projects, including the infamous PKA piloted spaceplane, which was abandoned in the late 1950s. Tsybin's team never seriously considered the Gemini approach of depressurizing the entire spaceship during an EVA, evidently because of the less-than-stellar performance characteristics of the life support system. In addition, even if the spacecraft could be depressurized, the internal instrumentation in the ship would not function, because it had not been designed for operation in vacuum. Instead, Tsybin's engineers drew up a plan for the design and installation of an airlock on the side of the basic vehicle. Both cosmonauts would wear fully operational pressure suits throughout the mission. One of the three Elbrus couches from the three-person Voskhod vehicle was eliminated, allowing fully suited cosmonauts to fit into the small internal volume of the ship. Prior to the spacewalk, the pilot would crawl into the airlock, shut the hatch behind him, pressurize the airlock, open an outer hatch, and then step out into space. Given the limited mass and volume capabilities of the 11A57 launch vehicle, a large rigid airlock was out of the question. Consequently, an engineer at OKB-1, S. I. Aleksandrov, proposed the use of an inflatable cylindrical airlock—one that could be packed at launch on the ship's hatch and then unfurled to full length in flight. Korolev signed the draft plan for the "new" spaceship, designated product 3KD, sometime in late 1964.[134]

The principal modifications to the 3KD as compared with the 3KV were the installation of:

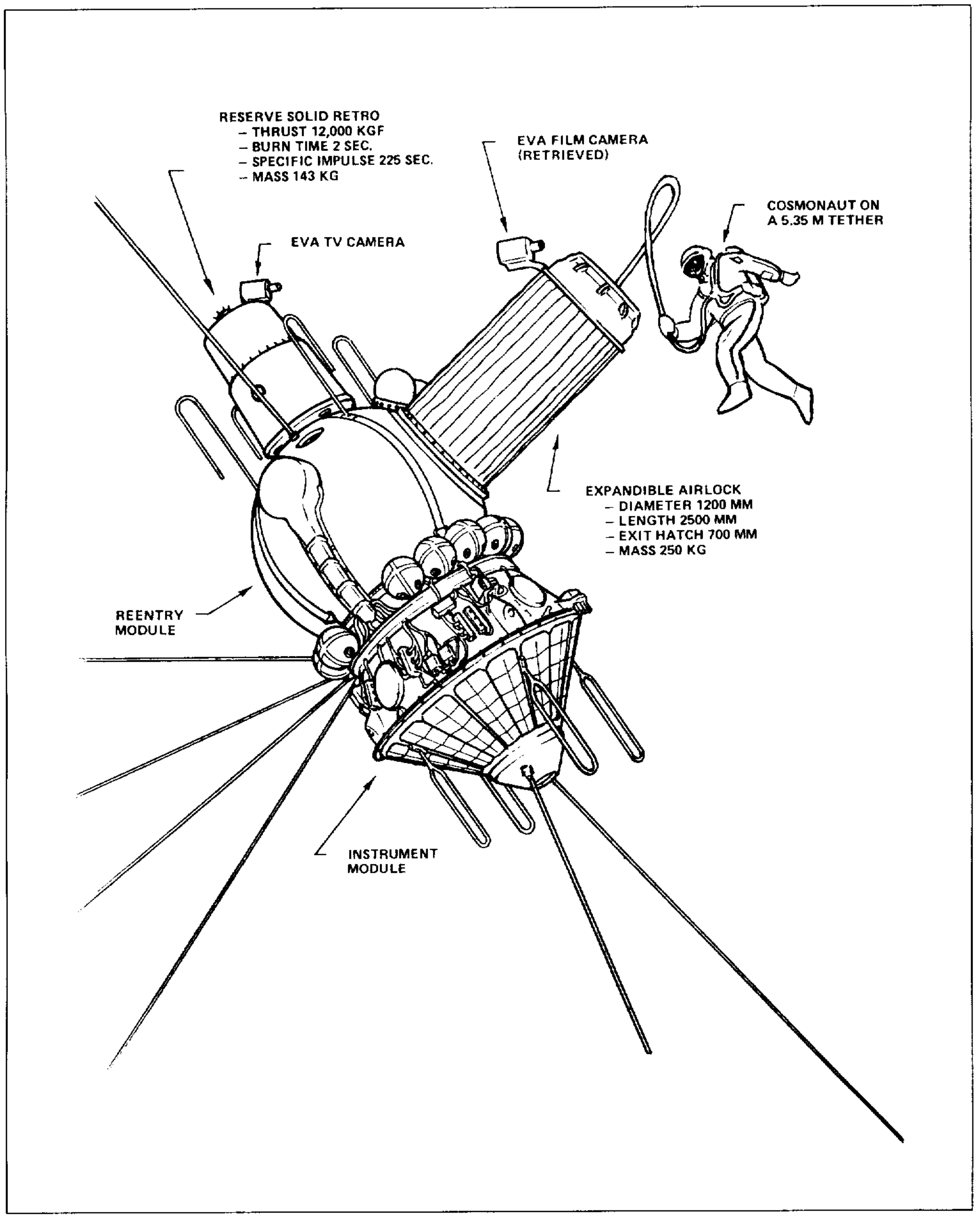
- The Volga airlock on hatch no. 3 on the descent apparatus
- Two Elbrus couches modified for spacesuited cosmonauts
- Air conditioning and life support systems for the cosmonauts' spacesuits
- An autonomous life support system in a backpack for the EVA cosmonaut
- An emergency oxygen-ventilation system for the cosmonauts during landing in case the spacecraft life support failed
- Automatic systems for the operation of the airlock, spacesuit life support, and the two hatches
- Special valves for equalizing pressure between the airlock and the descent apparatus capable of being operated both automatically and manually
- A control panel for manually operating the airlock and hatches
- Supplementary bottles of air for both the EVA spacesuit and the descent apparatus, which would be installed on the exterior of the instrument compartment[135]

In all other respects, the Vykhod was exactly like the first Voskhod. The mass of the "new" vehicle was approximately 5,685 kilograms. A nominal mission would last a single day.

Plant No. 918 located at Tomilino built the Volga airlock, although OKB-1 engineers designed it. This was the same organization that had designed the SK-1 suits and ejection seats for the earlier Vostok spacecraft. In January 1964, thirty-seven-year-old Gay I. Severin, an aeronautical engineer and former glider pilot, was appointed chief designer and director of the plant. More than any other individual, Severin was personally responsible for the design of the Volga as well as the EVA suit. When work on the project began in June 1964, Korolev told his senior

134. This document has been published with disguised designations as S. P. Korolev, "The 'Voskhod-2' Space Ship" (English title), in Keldysh, ed., *Tvorcheskoye naslediye Akademika*, pp. 477–88.

135. *Ibid.*



This diagram shows the EVA-equipped Voskhod spacecraft. (copyright D. R. Woods)

designer responsible for the Vykhod, "From now on there is another commander aside from me at our enterprise, and that's Severin. You should carry out his orders faster than mine."[136]

Severin's airlock was an ingenious creation. In a packed state, the Volga had a length of seven-tenths meter, extending to two and a half meters in its operational position. Each end of the

136. "To Save Man: A Conversation With the General Designer of Life-Support and Rescue Systems, Hero of Socialist Labor G. I. Severin" (English title), *Pravda*, June 26, 1989, p. 4.

cylinder was terminated by a rigid ring with a hatch with an external diameter of 1.2 meters. The internal diameter was one meter, while the diameter of the hatchway was only 0.65 meter, an extremely tight fit for a completely suited cosmonaut with a backpack. The complete airlock system had a mass of 250 kilograms. In typical Soviet fashion, the equipment was a sturdy technological marvel. An engineer recalls the first time Korolev visited Plant No. 918 to see the airlock:

> *"Gay Ilich [Severin]," Sergey Pavlovich addressed the director of the enterprise where various aggregates for the spacecraft were being developed, "demonstrate to us the durability of your airlock chamber." Gay Ilich, a tall, stately, athletic looking man who was still young, easily jumped up and hung on one end of the cylinder. . . . Sergey Pavlovich smiled coyly. He was happy with the technical design.*[137]

The airlock itself was made of a double-walled pressurized material made from rubber. The space between the layers was divided along its longitudinal axis into forty full-length partitions, which would be pressurized to extend the airlock to its full length, not unlike an inflatable water raft. The partitions were divided into three independent sections; two were enough to ensure that the airlock would unfurl to its operational state. An extra layer of thermal insulation covered the entire airlock. Four tanks at the base of the Volga carried pressurized air. One each were for the forty partitions and to pressurize the airlock after the EVA (which would take seven minutes), while the remaining two were emergency supply for the spacewalking cosmonaut. There were four cameras placed at various points to record the egress of the EVA pilot. Two sixteen-millimeter movie cameras were installed within the airlock, and a third sixteen-millimeter camera was on a boom outward from the airlock to record the spacewalk. A fourth TV camera, a Topaz developed by Leningrad-based NII-380, would provide live pictures to both ground control and the crew commander (the cosmonaut who would remain behind in the spaceship). Engineers designed the entire system such that the commander could carry each operation out both automatically or by manual control. In addition, there was a small control panel installed within the airlock itself to allow the EVA cosmonaut to control hatch openings, and so forth, in the case of an emergency.[138]

The *Berkut* ("Golden Eagle") spacesuit, also designed under Severin's leadership, was the first Soviet spacesuit created for EVA operations. It consisted of two primary "pressurized membranes" that allowed minimal mobility in an airtight state. There were two settings for pressure, one at 0.35 to 0.4 atmosphere (normal) and one at 0.2 to 0.27 atmosphere (for increased mobility during emergencies). The helmet had two pressurized visors and a filter for the Sun's rays. The Berkut also included a self-contained backpack, which contained a ventilation system as well as three two-liter tanks at 220 atmospheres pressure. Air was pumped into the helmet at a rate of twenty liters per minute from where it passed to the rest of the suit through a pressure regulator. A five-meter cord would connect the cosmonaut to the ship during the EVA. The total mass of the suit and backpack was forty-five kilograms (twenty plus twenty-five kilograms, respectively). The maximum time in an "open" exposed state would be limited to only ten to fifteen minutes during the mission. The self-contained backpack was designed to provide life support for a maximum of forty-five minutes, while the emergency tank on the outside of the airlock could provide eighty additional minutes of air. OKB-1 and Plant No. 918, how-

137. A. Yu. Ishlinskiy, ed., *Akademik S. P. Korolev: ucheniy, inzhener, chelovek* (Moscow: Nauka, 1986), pp. 421–22.

138. Korolev, "The 'Voskhod-2' Space Ship"; Dietrich Haeseler, "Leonov's Way to Space: Airlock of Voskhod-2," *Spaceflight* 36 (August 1994): 280–82. The Topaz used a 625-line, twenty-five-frames-per-second system.

ever, formulated mission plans to be as conservative as possible. A nominal EVA would last only ten to fifteen minutes, sufficient to achieve the main objective of the flight.[139]

In late 1964, Korolev and his engineers drew up a detailed test program leading to the actual EVA mission. The five-step program included testing the 3KD at plants, training and testing in conditions approximating microgravity in a Tu-104 aircraft, vacuum testing in the TDK-60 barometric chamber, the launch of an automated version of the 3KD into orbit, and finally the piloted flight. The first simulator for the Vykhod spacecraft, the TDK-3TD, arrived at the Cosmonaut Training Center in November 1964.[140] Four of the remaining 1960 batch of cosmonauts who had yet to fly a mission—Belyayev, Khrunov, Leonov, and Gorbatko—were grouped together by July 1964 to begin training for the challenging mission. Belyayev and Gorbatko trained for the commander's seat, while Khrunov and Leonov prepared themselves for the EVA position.

From the beginning, the training for the Vykhod mission was without doubt the most demanding of all the Soviet piloted flights to date. As part of a general calisthenics regimen, Leonov, the informal favorite to carry out the spacewalk, cycled about a thousand kilometers in less than a year, carried out more than 150 EVA training sessions, and jumped by parachute 117 times. Weightlessness simulations were carried out in a specially equipped Tu-104 aircraft, which flew parabolic arcs to simulate microgravity for about thirty seconds at a time. A complete replica of the 3KD spacecraft was installed in the airplane for the cosmonauts to rehearse each aspect of the EVA, including rigorous operation of the airlock. Vacuum tests with full spacesuit garb were also conducted in the ground-based TBK-60 barometric chamber, which simulated high-altitude pressure and atmospheric conditions. The cosmonauts were "launched" to altitudes of five, ten, and thirty-two to thirty-six kilometers to carry out their flight program. In addition, physicians were evidently unsure of the possible psychological state of a spacewalking cosmonaut and subjected Leonov to a month-long isolation chamber test when he was completely cut off from the rest of the world. Immediately after the end of his session, he was taken directly to a MiG-15, whose pilot performed several complicated flight maneuvers. The flight ended with Leonov ejecting out and landing safely by parachute as a test of his reflexes after an extended period of isolation.[141]

The State Commission for the flight, by then renamed Voskhod 2, met for the first time on January 13, 1965, under the chairmanship of Maj. General Tyulin. Engineers reported that two Voskhod vehicles and their associated launch vehicles were essentially ready for launch. Final testing would be completed on February 15. The launch of the robot variant was set for late January or early February, while the crewed mission was set for March.[142] By this point, the best candidates for the primary crew were Belyayev and Leonov. The thirty-nine-year-old Pavel Belyayev had been the oldest candidate selected among the "Gagarin group" of 1960. He had graduated from the Yeisk Higher Air Force School in 1945 and flew combat missions against the Japanese during the final days of World War II. Later, in 1959, he graduated from the famous Red Banner Air Force Academy, and thus he was only one of two cosmonauts in the 1960 class who had a higher education. Belyayev might have flown earlier into space had it not been for a severe ankle injury sustained in August 1961 during a parachute jump, which left

139. Korolev, "The 'Voskhod-2' Space Ship"; *Russian Space History, Sale 6516* (New York: Sotheby's, 1993), description for Lot 40.

140. Lardier, *L'Astronautique Soviétique*, p. 143.

141. *Ibid.*; Riabchikov, *Russians in Space*, pp. 212–18; Smolders, *Soviets in Space*, pp. 139–40; I. T. Akulinichev, *et al.*, "Some Results of Medical Supervision of the State of the Cosmonauts P. I. Belyayev and A. A. Leonov During Their Training and Orbital Flight" (English title), *Kosmicheskiye issledovaniya* 4 (March–April 1966): 311–19; Golovanov, *Korolev*, p. 747.

142. Kamanin, "Pages From a Diary."

him out of the loop for a whole year. His co-pilot on the flight was thirty-year-old Aleksey Leonov, one of the most colorful characters on the team. Born in Siberia, he graduated from the Chuguyev Higher Air Force School in the Ukraine in 1957 before serving as a jet pilot in East Germany. Certainly one of the most well-trained candidates on the team, he also had a passion for painting. The future author of many art books, in the early 1960s, he was the editor of a satiric cosmonaut newsletter called *Neptun* ("Neptune"). Leonov also had the distinction of being the first person whose name was uttered in space, during his shift as capcom for Gagarin's historic flight.[143]

Belyayev and Leonov, along with their backups Zaykin (who had replaced Gorbatko) and Khrunov, continued to train intensively for the mission throughout February, carrying out runs in both the Tu-104 and the TKB-60. By February 19, the State Commission had decided on a specific timetable for the two missions: the automated one would be launched on February 21 or 22, while the piloted flight was set for March 4 or 5. In addition to these two missions, three small satellites in the Kosmos series were set aside for launch prior to the piloted launch to ensure that radiation levels were safe for an EVA. The orbital parameters of Voskhod 2 were intended to be 180 by 500 kilometers, far higher than any previous piloted flight. The EVA itself would be carried out immediately after orbital insertion, at the end of the first orbit or at the beginning of the second one. In the case of abnormalities in the spaceship, the crew could elect to carry out the spacewalk on any orbit from the second to the sixth, ensuring that the vehicle would be over Soviet territory during the critical event.[144]

Throughout the preparations for the EVA mission, engineers were acutely conscious of yet another race with the United States. By February, the race began to have deleterious effects on the 3KD program. Chief Designer Severin recalled that "the Americans planned to do their EVA in three months and had announced it beforehand. So we felt very rushed. We were hurrying and were nervous. . . ."[145] In this climate, the first 3KD spacecraft was launched successfully into orbit at 1030 hours Moscow Time on February 22, 1965. Initial orbital parameters were 175 by 512 kilometers at a 64.77-degree inclination to the equator. As was usual, the Soviet press did not attribute the satellite any particular mission, merely naming it Kosmos-57. The fully equipped spacecraft was to simulate all the necessary airlock operations: checking the airlock, inflating the airlock, transferring air from the descent apparatus to the airlock depressurization of the airlock, turning on the air supply from oxygen bottles to a spacesuit, opening and closing the outer hatch, repressurizing the airlock, and finally ejecting the airlock assembly on the sixteenth orbit.[146] Despite Lt. General Kamanin's reservation that "we were most doubtful that the airlock would function reliably," all the preliminary operations, save for the ejection, were carried out without anomalies. Satisfied that the mission was going smoothly, Kamanin left the control center in Moscow. When he returned about five hours after launch, he greeted Korolev with "Good evening!" Korolev dryly replied, "No, Nikolay Petrovich, the evening, it seems, is not good. It looks like the craft has blown up. . . ."[147]

Kosmos-57 had evidently exploded into approximately 180 pieces. A cursory inspection by engineers revealed that for unknown reasons, the reentry cycle of the satellite had been spuri-

143. Rex Hall, "Soviet Air Force Cosmonauts," in Michael Cassutt, ed., *Who's Who in Space: The International Space Year Edition* (New York: Macmillan, 1992), pp. 219–20, 246–47; William Shelton, *Soviet Space Exploration: The First Decade* (New York: Washington Square Press, 1968), pp. 173–74.

144. Note that in the original document describing the 3KD mission, a nominal orbit is listed as 180 by 400 kilometers. Evidently, sometime between the issuance of that document and February 1965, the State Commission elected to raise the intended apogee to 500 kilometers. See also Kamanin, "Pages From a Diary."

145. "To Save Man: A Conversation With the General Designer."

146. Korolev, "The 'Voskhod-2' Space Ship."

147. Kamanin, "Pages From a Diary."

ously activated. The retrorocket engine had been fired, but being in the wrong attitude, the satellite had entered an incorrect orbit after engine cutoff. As per programming, the spacecraft's automatic self-destruct system had activated upon entering the incorrect orbit. The cause for the command to reenter remained a mystery until further examination of telemetry. On February 25, Chief Designer Armen S. Mnatsakanyan of NII-648, responsible for telemetry instrumentation, and Colonel Amos A. Bolshoy, the head of the Chief Operations and Control Group for the Voskhod missions, presented reports on the analysis of the data. The findings pointed to ground control error. As per original planning, the controller at one of the ground stations, Measurement Point No. 6 (IP-6) at Yelizovo in Kamchatka, sent a message, command no. 42, to transfer air to the airlock. By an amazing coincidence and contrary to orders, a controller at the backup station, IP-7 at Klyuchi in Ussuriysk, sent the same coded command at the exact same moment. The two commands were received simultaneously, thus becoming a new command, no. 5—that is, the command to descend.[148] Thus the spacecraft was exonerated of any fault.

The Kosmos-57 spacecraft had accomplished most, but not all, of the tasks necessary to instill faith in a piloted mission. Because the robotic precursor had exploded, there had been no test of the airlock release, nor a test of a full reentry of the descent apparatus with the large airlock ring attached to the side of the capsule. The ground tests for these aspects of the mission were beset by failures. When a test version of the descent apparatus was air-dropped from a plane at Feodosiya, the parachute system failed, smashing the capsule into pieces. Another airlock, one built for the flight, was destroyed on January 13, when it was accidentally dropped during mating with the flight version of the 3KD. The spate of failures seriously unnerved all personnel. Severin recalls, "The situation was really grave. Almost the entire testing program had been disrupted. Only part of it was completed in the unmanned flight. . . ."[149] There was even talk of postponing the flight until better results were obtained on the ground. The competition with Gemini reached such a state that Soviet security personnel arrived at Tyura-Tam. Severin recalls:

> *The Chairman of the KGB [V. Ye. Semichastnyy] appeared unexpectedly at Baykonur [on February 20]. He arrived at the testing area and came up to us at the engineering site, where we were preparing the airlock. . . . It's possible that the KGB thought that all of our accidents were the result of imperialist intrigue. I don't know. But they established strict monitoring, which made us very nervous.*[150]

The reliability of landing a capsule with the large airlock ring installed was still an issue of great concern because Kosmos-57 had never had the opportunity to land. The ring apparently induced sharp rotations as high as one revolution per second around the main axis of the reentry capsule during descent by parachute. By late February, Korolev, Pilyugin, and Ryazanskiy proposed a new revised testing program that would include more ground tests as well as in-flight testing of the airlock ring. The chief designers received permission from the State Commission to equip a Zenit-4 reconnaissance satellite with the suspect ring. A safe landing by the military satellite would clear the way for a piloted launch. On March 7, a Zenit-4 was launched into orbit as Kosmos-59. The descent apparatus successfully landed on March 15, about 170 kilometers south of Kustanay in Kazakhstan. Although the on-board data recorder

148. *Ibid.*; Yu. A. Mozzhorin, *et al.*, eds., *Dorogi v kosmos: II* (Moscow: MAI, 1992), pp. 34–35. The accident commission was headed by TsUKOS Commander Maj. General K. A. Kerimov.

149. "To Save Man: A Conversation With the General Designer."

150. *Ibid.*

failed to record the rotations of the capsule during landing, indirect evidence suggested that the descent apparatus was subjected to only a forty- to 100-degree-per-second rotation—within the acceptable limits for a crew.[151] The success was a much-needed boost to the morale of the engineers. Korolev wrote to his wife on March 8:

> *We are trying to accomplish all our work without hurry. Our chief motto is "the safety of the crew comes first." God grant us the strength and the wisdom to always live up to this motto and to never experience its opposite. I personally always believe and hope for the best outcome even though all my efforts, my mind, and my experiences are directed towards trying to foresee and outguess the worst that can happen—an ominous presence that stalks us every step into the unknown.*[152]

The mission of Kosmos-59 seems to have finally cleared the way for this "new step into the unknown," then scheduled for the third week of March 1965.

Under Tyulin's direction, the State Commission held a meeting at site 2 at Tyura-Tam on March 9 to discuss the composition of the crew who had arrived at the launch site the same day. Despite some reservations about Belyayev's health and his possible replacement by Khrunov, all unanimously approved Belyayev and Leonov as the primary crew. Khrunov would serve as the only backup cosmonaut, ready to take over from either of the primary members, as he had been trained for both positions.[153] Korolev met with the cosmonauts on March 13, saying: "I want to caution you once more that the most important thing in your flight is to return to Earth healthy. We do not need thoughtless heroics."[154] The primary and backup crews and the flight program were formally approved at a State Commission meeting on March 16. The launch was set for either March 18 or 19, less than a week before the first piloted Gemini mission, Gemini III.

Korolev was beset by poor health throughout the last few weeks leading up to the launch. At one point, he had had to spend some time under medical attention because of a pulmonary inflammation. Nothing, of course, deterred him from his work, and looking tired and gaunt, he showed up for the launch on the morning of March 18. It was a cold and snowy day at Tyura-Tam. Belyayev and Leonov arrived at the launch, the former "as always, completely unperturbed" and the latter "visibly excited."[155] Korolev, Gagarin, Kamanin and others were there to see the cosmonauts off. In a farewell message, Korolev told Leonov, "I won't give you a lot of advice and ask a lot of you Lyesha, just don't outsmart yourself. I only ask you one thing: just exit the ship and come back in, keeping in mind all the Russian sayings that have helped a Russian man during difficult times. May you have a fair solar wind."[156]

The Voskhod 2 spacecraft, vehicle 3KD no. 4, was launched successfully at 1000 hours Moscow Time on March 18, 1965. On board were Colonel Pavel I. Belyayev, thirty-nine, and Lt. Colonel Aleksey A. Leonov, thirty. As with the earlier Voskhod mission, the tension during

151. Kamanin, *Skrytiy kosmos: 1964–1966*, p. 166.

152. Golovanov, *Korolev*, p. 749.

153. The concerns about Belyayev's health were apparently misplaced. During a training session in the TDK-60 altitude chamber, Belyayev had begun gasping for breath. Physicians had attributed the problem to Belyayev's health. It was later discovered that Belyayev was not receiving any oxygen because of a malfunction in the equipment. According to Kamanin, Belyayev "displayed admirable composure, found the problem, and corrected it." See Kamanin, "Pages From a Diary." Note that Kamanin had decided that backup cosmonaut Zaykin was not suitable for a primary crew.

154. *Ibid.*

155. *Ibid.*

156. Golovanov, *Korolev*, p. 749; Lt. Gen. Georgiy Aleksandrovich Tyulin, "Task for the Future: Notes of the State Commission Chairman" (English title), *Krasnaya zvezda*, April 5, 1988, p. 4.

the first few seconds was without measure. There were apparently numerous alarms during the ascent. Korolev, a nonsmoker, lit up a cigarette once the spacecraft reached orbital velocity at T+530 seconds. Initial orbital parameters were 173 by 498 kilometers at a sixty-five-degree inclination. The two cosmonauts began preparations for the EVA as soon as they reached orbit. First, Belyayev expanded the Volga airlock to its full length. Then Leonov, aided by Belyayev, strapped on his life support backpack within the cramped capsule, making sure that all systems were operational. Once the pressure between the airlock and the ship was equalized, Belyayev flipped a switch to open the inner hatch. Leonov crawled head first into the airlock and hooked himself up to the 5.35-meter-long tether. After all the tests proved satisfactory, Belyayev commanded the first hatch shut and depressurized the airlock. Through all this strenuous activity, Belyayev kept up a constant stream of conversation, cautioning his crewmate, "Take it easy, Aleksey. . . . Be patient. Take it easy. . . ."[157]

Belyayev opened the external hatch by remote control just an hour and a half after liftoff, at 1132 hours, 54 seconds Moscow Time on March 18. Leonov was evidently impatient, eager to leave the airlock, and Belyayev had to order his pilot to stick to the preset program. Within two minutes, at 1134 hours, 51 seconds, Leonov emerged from the airlock, thus becoming the first human to walk in space. At first, he merely poked his head out, but then gradually pushed out his entire body. The Sun was evidently very bright, almost blinding, forcing the cosmonaut to squint as he held on to the outer rim of the spaceship. His first words upon entering free space were: "I can see the Caucasus."[158] As Voskhod 2 was flying over the Black Sea, Leonov stayed with his EVA program and removed the cover from the camera on a boom outside the spacecraft.[159] Toying with the cap, he eventually let it go, watching it fly into its own orbit. He removed one hand, then the other, and let go of the ship, floating out into space at 28,000 kilometers per hour over the surface of Earth. He recalled later:

> *It was an extraordinary sensation. I had never felt quite like it before. I was free above the planet Earth and I saw it—saw it was rotating majestically below me. Suddenly in the silence, I heard the words "Attention! Attention! Man has entered open space."*[160]

These three stills are from the external movie camera on Voskhod 2, which recorded Aleksey Leonov's historic spacewalk in March 1965. (files of Asif Siddiqi)

157. Riabchikov, *Russians in Space*, p. 219.
158. *Ibid.*
159. Golovanov, *Korolev*, p. 749. Some sources suggest that he manually installed the camera on the outside of the ship. See, for example, Kenneth Gatland, *Manned Spacecraft* (New York: Macmillan, 1976), p. 135.
160. "The Russian Right Stuff," *NOVA* television show.

The Topaz TV camera mounted on the inflatable airlock transmitted live pictures of Leonov's movements, not only to Belyayev but also to ground control. Leonov apparently had a still photo camera attached to his spacesuit, and during his short jaunt into open space, he tried several times to depress the shutter to take pictures of the exterior of the spaceship but was unable to do so. After about ten minutes, by which point he was over the Pacific, Leonov began preparations for reentering the airlock. First, he removed the movie camera from the boom, but evidently he had great difficulty in placing it in the airlock. In returning to the airlock, Leonov was to enter feet first, thus allowing him to slip back into his seat from the other side of the airlock. The internal diameter of the airlock was not designed for a somersaulting cosmonaut. But after twelve minutes and nine seconds in open space, Leonov found himself in a difficult situation:

> *Near the end of my walk I realized that my feet had pulled out of my shoes and my hands had pulled away from my gloves. My entire suit stretched so much that my hands and feet appeared to shrink. I was unable to control them. It was as if I had never tried the suit on even once.*[161]

With little control over his limbs, he had trouble entering the airlock:

> *I couldn't get back in straightaway. My space suit had ballooned out and the pressure was quite considerable. I was tired and couldn't go in feet first as I had been taught to do. But using a valve . . . I decreased the pressure to just under 0.27 atmospheres. Then I felt freer and I could move about more easily. Then I pushed myself into the airlock head first, with my arms holding the rails. I had to turn myself upside down in the air lock in order to enter the ship feet first and this was very difficult.*[162]

Leonov's pulse was racing as high as 143 beats per minute, his breathing rate was twice normal levels, and his body temperature was up to thirty-eight degrees Centigrade. He was drenched in sweat and in serious danger of fatigue.[163] An exhausted Leonov finally closed the outer hatch, pressurized the airlock, and opened his helmet in violation of instructions. After a short rest, he opened the inner hatch and slipped back into the descent apparatus. The outer hatch was closed at 1151 hours, 54 seconds, giving a total depressurized time of only twenty-three minutes and forty-one seconds.

Soviet leaders back in the Kremlin followed the EVA closely. It was the first big spaceflight of the new Brezhnev-Kosygin leadership, and as such, it was almost surely considered an important benchmark for future space programs. An operator from the main flight control center of the Strategic Missile Forces was driven twice to the Kremlin to explain the details of the EVA, which was piped in live on TV. Brezhnev, Kosygin, Mikoyan, Ustinov, and other members sat and watched the proceedings attentively. Brezhnev later recorded a congratulatory message for the two cosmonauts.[164]

161. Thomas O'Toole, "The Man Who Didn't Walk on the Moon," *New York Times Magazine*, July 17, 1994, pp. 26–29. The quote is on p. 28.

162. "The Russian Right Stuff," *NOVA* television show.

163. The official medical report on the flight included the following: "During emergence from the lock into space and return to the ship, Leonov's heart rate was approximately 1.5 times higher than the rates observed during the training session and reached 150–162 per min." See Akulinichev, *et al.*, "Some Results of Medical Supervision," p. 289. See also Golovanov, *Korolev*, p. 750.

164. Mozzhorin, *et al.*, eds., *Nachalo kosmicheskoy ery*, pp. 323–24.

Having completed the primary task of the flight, the crew cast off the concertina-shaped airlock and settled down to a one-day mission, not unlike that of the first Voskhod. The ejection of the airlock seems to have imparted a twenty-degree-per-second rotation rate to the spacecraft, several times greater than the nominal rate. The State Commission, after consulting with the crew, decided to rectify the rotation only prior to landing, possibly to conserve attitude control propellant. There was another problem: the EVA exit hatch on the ship had not been shut tight completely, causing an automatic mechanism on the spacecraft to overcompensate for the incremental drop in air pressure. Instead, the life support system filled the interior of the ship with oxygen, which reached levels as high as 45 percent. The danger was obvious: a tiny spark could set off a fire and explosion within the ship. The two men spent much effort trying to lower the oxygen content during the remainder of their mission, apparently managing to bring it down to manageable levels before the planned reentry. In terms of science, there were some minor experiments related to color perception in microgravity. The crew apparently also carried out some movie and still photography. The usual complement of biological samples was also carried aboard.[165]

The problems with the mission continued to accumulate as reentry approached. By the thirteenth orbit, pressure in the cabin pressurization tanks had dropped from seventy-five to twenty-five atmospheres, raising the threat of a complete decompression of the spacecraft. After careful analysis, Chief Designer Grigoriy I. Voronin, responsible for the life support systems, "firmly stated that the pressure in the craft's cabin could not fall below 500 millimeters, in which case there would be more than enough oxygen for three hours"—that is, until landing on the seventeenth orbit. Belyayev reported on the fourteenth orbit that the pressure had indeed stabilized at twenty-five atmospheres, although it seems that oxygen content was still sufficiently high to have made the last few hours nerve-racking for both ground controllers and the crew. Every minute was an agony as the specter of cosmonaut Bondarenko's death in a pressure chamber four years before passed through everybody's minds.[166]

On the seventeenth orbit, the controllers, along with Korolev, Keldysh, Tyulin, and Gagarin, waited expectantly for word that the reentry burn had occurred on time. After some tense minutes, Belyayev calmly reported, "Negative automatic retrofire"—meaning that the retrorocket engine had not engaged.[167] Within seconds, the controllers conjectured that the solar attitude control sensor had malfunctioned; a circuit to prevent retro-engine ignition in such cases had operated as planned. As the tension in the control room began to rise, there was a brief flurry of conversation among the leading members of the State Commission. The question was: What should we do now? An engineer at the control room recalled:

> *No one understood what the problem was. There were many guesses, frantic proposals—everyone had clearly begun to get nervous. . . . Korolev took supervision into his own hands. He established silence and asked everyone to sit down. Then he calmly listened to the work supervisor in charge of the control system. He asked him to tell him the possible causes and to give a suggestion for further action.*[168]

165. These included human lung cancer cells, frog ova and sperm, *drosophila melanogaster* insects, *tradescantia paludosa* plants, winter wheat and pine seeds, chlorella algae, and bacteria. See Wukelic, ed., *Handbook of Soviet Space-Science Research*, pp. 346–48. For general descriptions of their time in orbit, see Kamanin, *Skrytiy kosmos: 1964–1966*, pp. 167–69; Golovanov, *Korolev*, p. 751.

166. Golovanov, *Korolev*, p. 751; M. F. Rebrov, *Kosmicheskiye katastrofy: Russkiye sensatsii* (Moscow: IzdAT, 1993), p. 38; Kamanin, "Pages From a Diary."

167. Tyulin, "Task for the Future."

168. Ishlinskiy, ed., *Akademik S. P. Korolev*, p. 486.

After a short conference, Korolev proposed that Belyayev use the manual system of orientation for reentry. OKB-1 Deputy Chief Designer Yevgeniy V. Shabarov, responsible for flight testing, and control systems engineer Boris V. Raushenbakh began a frantic race to gather the necessary data to transmit to the crew to carry out manual reentry. Once the data were found, the numbered code was written on a piece of paper and signed by each of the engineers. The paper was then handed to Gagarin who, under Korolev's direct orders, transmitted the information to Belyayev.[169] Ballistics computations showed that the landing could be achieved on the eighteenth, twenty-second, or twenty-third orbit. In all cases, the landing area would be well north of the nominal site.

The exercise in simply orienting the spacecraft into its correct attitude using the Vzor optical device became an ordeal in itself, exacerbated by the fact that both men were clad in bulky spacesuits. In the cramped quarters of the ship, Belyayev had to place himself horizontally across both seats of the capsule, while Leonov remained out of the way *under* his seat. At the same time, Leonov manually held Belyayev in place so as to keep Belyayev in front of the orientation porthole. That way, Belyayev could use both his hands to orient the ship to Earth's terminator using hand controls. Having completed this task, both men quickly returned to their seats to reestablish the ship's center of gravity before firing the deorbit engine. It took the two men a whole forty-six seconds to get back into their original positions before Belyayev hit the engine fire button. This forty-six-second delay caused a serious overshoot of their original targeted landing point.[170] Other reliable accounts suggest that only Belyayev managed to get back into his seat by the time of engine ignition. Leonov was evidently still out of his seat, thus displacing the ship's center of gravity, raising the specter of a wildly spinning capsule reentering the atmosphere. In an amazing stroke of luck, the ship did not spin out of control, probably saving the lives of the cosmonauts.

The ordeal did not end there. As in several previous Vostok missions, the instrument compartment failed to separate from the descent apparatus; the two modules remained connected to each other loosely with steel straps. The unsteady mass of the two rocking modules linked to each other did not produce the required lift for a nominal ballistic trajectory. Instead, the capsules headed on a steep trajectory with severe loads on their bodies. The gravitational force burst blood vessels in both men's eyes as the load reached ten g's. Each man felt as if they weighed about 700 kilograms for a few seconds.[171]

Control centers at both Tyura-Tam and Moscow received word that the capsule had landed, but for an agonizing four hours, there was no communication on the health of the crew. One thing was clear: the ship had landed way off course in the dense forests of the Russian tayga. One of Korolev's greatest fears was that if the capsule landed in a densely forested area, the soft-landing sensor at the base of the descent apparatus would "think" that the ship was near ground if it hit a tree branch high up in the air. With such a premature firing, the capsule would hit the ground with a thunderous impact, seriously injuring the crew. Fortunately, one of the pilots in a search helicopter reported:

> *On the forest road between the villages of Sorokovaya and Shchuchino, about 30 kilometers southwest of the town of Berezniki, I see the red parachute and the two cosmonauts. There is deep snow all around. . . . The craft touched down in dense woods, far from any population center.*[172]

169. Mozzhorin, *et al.*, eds., *Dorogi v kosmos: I*, p. 179.
170. Kamanin, *Skrytiy kosmos: 1964–1966*, pp. 190, 197.
171. Golovanov, *Korolev*, p. 752; O'Toole, "The Man Who Didn't Walk on the Moon."
172. Kamanin, "Pages From a Diary."

The mission had ended with touchdown at 1202 hours Moscow Time on March 19, 1965, after a one-day, two-hour, two-minute mission. The ship had landed 386 kilometers from the designated target area, about 180 kilometers northwest of the town of Perm. The area in which they landed was so densely packed with trees that it was impossible for helicopters to land. Instead, thermal flight clothing was dropped from one helicopter while another landed five kilometers away. The area was completely covered with snow, and the temperature was minus five degrees Centigrade. The cosmonauts themselves had no clue where they were, being surrounded by dense forests and snow two meters deep at places. When Leonov asked how soon rescuers would pick them up, Belyayev joked, "Maybe in three months, they'll pick us up with dog sleds."[173] A helicopter found a place to land about five kilometers from the landing point, and a search team set off on foot to find the capsule. Another team in two vehicles from the Air Defense Forces was meanwhile attempting to reach the crew on land. Both parties were unable to find the spaceship before nightfall and had to cut short their searches. Fortunately for Belyayev and Leonov, a helicopter had dropped thermal clothing for the cosmonauts earlier during the day.

The men spent an extremely frigid and uncomfortable night in the woods. In the morning, a helicopter once again flew over the landing site and reported that two people, both wearing flight clothing, were spotted near the landing site, one chopping wood and the other arranging branches to start a fire. At 0730 hours, a group headed by a Colonel Sibiryak of the Air Defense Forces disembarked from an Mi-4 helicopter with the objective of reaching the crew on skis. It took the group three hours to cover the one and a half kilometers to the descent apparatus, finally arriving around 1030 hours. The cosmonauts were reported to be in good condition with no injuries. A twist was added to the whole rescue operation by the insistence of Soviet Air Forces Commander-in-Chief Marshal Vershinin that the crew only be evacuated by motorcycle, or if that was not possible, then by helicopter, but only if it landed near the capsule. Despite fierce objections from both Korolev and Kamanin, who advocated simply hoisting the cosmonauts onto hovering helicopters, the cosmonauts were forced to spend an additional night in uncomfortable conditions. Even Korolev's attempts at convincing the Soviet leadership were in vain; Vershinin had told Brezhnev that hoisting them to a height of five to six meters might be dangerous. The irony was that they were only three or four hours away from Tyura-Tam.[174]

The second night was more comfortable, as the cosmonauts had additional food, clothing, and tents. Finally, at around 1000 hours on March 21, Belyayev and Leonov arrived at Perm airport in an Mi-6 helicopter on their way to Tyura-Tam. At the launch range, all the leading personalities involved with the flight, including Korolev, Keldysh, Tyulin, Rudenko, Pilyugin, Barmin, Kerimov, and Kamanin, had gathered to greet the crew on their arrival. There was a mixture of euphoria and relief in the air as the months of grueling work had finally paid off in yet another spectacular advance for the Soviet space program. Korolev raised a toast to the future: "Friends! Before us is the Moon. Let us all work together with the great goal of conquering the Moon. Do you remember how our collective worked in such a friendly manner?"[175] This evidently elicited a quiet but sarcastic comment from Chief Designer Barmin, who muttered, "We worked in a friendly manner when we were all leaders. . . . Now there's one head theoretician [referring to Keldysh] and one head designer. . . ."[176]

173. O'Toole, "The Man Who Didn't Walk on the Moon," p. 29.
174. Kamanin, "Pages From a Diary."
175. Kamanin, "In the Future His Name Will Probably Be . . . ," p. 28.
176. *Ibid.*

The cosmonauts finally arrived at Tyura-Tam at 1730 hours, both in good moods. On the morning of March 22, Belyayev and Leonov briefed the State Commission on their mission. They were then flown to Moscow for a massive government reception in Moscow held the following evening. The requisite postflight press conference became the subject of much dispute, when Kamanin insisted that the truth be told about the cosmonauts' daring landing ordeal. As was typical, the more conservative Academy of Sciences President Keldysh was adamantly opposed, demanding that Belyayev write in his report to the press that the spacecraft landed at the precisely designated site, but had spent two days "resting" at the landing area. Kamanin was supported in his crusade by Korolev, but it seems that the latter's entreaties to Keldysh and Smirnov did not make a difference. The press conference on March 26 at the assembly hall of Moscow State University was filled with generalizations and half-truths. Keldysh maintained tight control over the proceedings. At one point, Belyayev was forced to say that the cosmonauts had been "delighted" that the automatic system of orientation had failed, because this provided them with an opportunity to use the manual system.[177] Belyayev also added that the Voskhod-class ships could change orbits in space, a blatant lie that was repeated by Keldysh in a journal article the following month.[178] The references to orbital maneuvering were clearly aimed to take the wind out of the Gemini III flight, when for the very first time a piloted spacecraft had changed orbits.

Cosmonaut chief Kamanin was party to an even more bizarre postscript to the Voskhod 2 mission at the premiere showing of the Leonov EVA film in Moscow on August 24, 1965, a couple of months after NASA astronaut Edward H. White II carried out the first American spacewalk. Kamanin announced that the White spacewalk had benefited greatly from information supplied by the Soviets. He added, "A small group of American specialists, with the permission of our government came to the Soviet Union and talked with Belyayev and Leonov about their flight, and we didn't hide anything." When a reporter asked who these "American specialists" were, Kamanin replied that either three or five persons had interviewed the Soviet cosmonauts for several days, but that he could not remember their names! Asked if the Americans were from NASA, Kamanin answered, "I don't know. . . . Officially, they were here with a television company—allegedly."[179]

The postflight hyperbole at the press conference did not in any way diminish the value of the Voskhod 2 mission. The flight was a major landmark not only for the Soviet space program, but for the human exploration of space as a whole. The importance of the event is more magnified by the story of the amazing resourcefulness of Soviet engineers and cosmonauts—a story that was hidden from the public for a quarter of a century. The Voskhod 2 flight had two other distinctions, neither of which were clear when Korolev raised his toast to the Moon. The first was the astonishing fact that the Soviets would not launch a single piloted space mission in the following twenty-four months, one of the longest gaps in the history of the Soviet space program. Voskhod 2 was, in effect, the last in the series of spectacular flights that had raised the specter of Soviet domination in space. It was the absolute zenith of the Soviet space program, one never, ever attained since. Voskhod-2's second distinction was of a more personal nature: it was Korolev's swan song. As he turned to finally run hard in a race to the Moon against the United States, he had little hope of knowing that he would not live to see another Soviet cosmonaut launched into space. It was truly the end of an era.

177. *Soviet Space Programs, 1962–65*, p. 557.

178. See *Priroda* (April 1965): 9–16, referenced in *ibid.*, p. 365. A Soviet journalist also reported in *Pravda* on March 19, 1965, that "This spacesuit may be used for prolonged work in space and for landing on the lunar surface."

179. "Russian Suggests Soviet Data Helped U.S. 'Walk' in Space," *New York Times*, August 25, 1965, p. 24. Kamanin also wrote about this claim in his diary entry for October 20, 1965. See Kamanin, *Skrytiy kosmos: 1964–1966*, p. 241.

Chapter Eleven

Three Steps to the Moon

When cosmonauts Belyayev and Leonov landed after their historic Voskhod 2 mission, it had been approximately four years since the first flight of Gagarin in 1961. Each of the eight piloted missions during that period had been proposed, directed, and executed under the auspices of one organization using essentially a single model of spacecraft. In this respect, the year 1965 was a watershed point in the history of the Soviet piloted space program, as several new vehicles were put on the drawing boards for a variety of long-range goals, including civilian and military operations in Earth orbit, circumlunar flight, and a lunar landing. The most important of these was a spacecraft that would eventually fly more missions than any other spaceship built in the Soviet Union, the Soyuz.

A New Direction for Soyuz

OKB-1 Deputy Chief Designer Konstantin D. Bushuyev, Korolev's *de facto* assistant for all piloted space projects, oversaw the early work on the 7K-9K-11K Soyuz program. Bushuyev and Korolev's First Deputy Mishin had come up through the same ranks. They graduated together from the Moscow Aviation Institute in the 1930s and joined Bolkhovitinov's rocket-plane group in the 1940s at the same time. The two would have gone to Germany together, but Bushuyev's wife's brother had been killed by lightning at the time, and Bushuyev had to attend the funeral. Later, Mishin invited Bushuyev to Kaliningrad to join Korolev's rocket design group. It was here that he would make his mark, working on a variety of design problems during the 1950s, including missile nose cones.

OKB-1 Deputy Chief Designer Bushuyev was the senior person at the design bureau responsible for piloted space programs. His identity was revealed in 1971 when the Soviets announced that he would head the Soviet team participating in the Apollo-Soyuz Test Project. This photo dates from early 1972. (NASA photo)

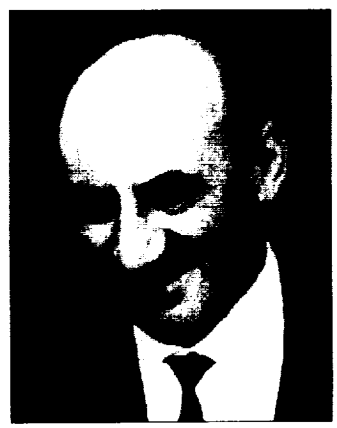
Bushuyev had a remarkably reticent and unassuming personality. He did not drink, he exercised regularly, and he liked to go hiking into the woods—a pleasure he rarely shared with anyone. Unlike many of his contemporaries, he never wore any of his medals and awards at official ceremonies, preferring to remain in the background. He may have been Korolev's principal aide for piloted space projects, but the two men had a very complex relationship. Russian historian Yaroslav K. Golovanov, who knew Bushuyev, wrote about him:

To be quite honest, I was never able to understand why Korolev would have named Bushuyev as his deputy for all space projects, or in other words—for all the projects which were closest to Korolev's heart. It was well known that Korolev treated Bushuyev with the utmost severity, and at times was downright unjust, that Korolev treated Bushuyev at times like an errant delivery man. Bushuyev was, in fact, the very antithesis of Korolev in character, behavior, and interpersonal relations.[1]

Bushuyev apparently considered resigning from the design bureau many times, but ultimately Korolev would invariably "call Bushuyev into his office and calmly, even gently—and what is more, with genuine trust—involve him in a discussion, ask for his views, share his own quandaries. . . ." In the end, Bushuyev stayed on.

In June 1959, Korolev sent Bushuyev to the so-called "Second Territory" in Kaliningrad, a recently acquired artillery plant with 5,000 new employees, to focus on spacecraft and solid-propellant ballistic missiles.[2] By late 1962, the Second Territory had come to focus exclusively on space-related projects, and Bushuyev took charge of a variety of important OKB-1 programs. He did not stay there very long. One story is that someone hinted to Korolev about Bushuyev's alleged ambitions to separate his branch from the main OKB-1 center, leaving Korolev to focus only on the development of missiles. Others claim that Bushuyev, although a brilliant engineer, was simply a poor manager. Either way, Korolev pulled the plug. In May 1963, Korolev abruptly ordered Bushuyev back to the central location to oversee other profiles at the giant organization.[3]

Perhaps to preclude any of his other deputy chief designers from harboring dreams of carving out a piece of the pie, Korolev redistributed various space-related programs across both the main OKB-1 center and the affiliate Second Territory. The Soyuz program came under the direction of Deputy Chief Designer Sergey S. Kryukov, also responsible for the N1 rocket, while Boris Ye. Chertok, one of Korolev's most senior men, was sent off to head the Second Territory. Chertok, fifty-one years old at the time, was the overseer of all work at the enterprise on control, guidance, and orientation systems for spacecraft and missiles. A tall, balding man with a powerful voice, he was also one of the few Jewish men in the top ranks of the Soviet space designers. He was born in the Polish town of Lodz, and he developed an interest in radio during his adolescence. In the 1930s, Chertok found a job at Plant No. 22 outside Moscow, the same plant that is today known as the M. V. Khrunichev State Space Scientific-Production Center. In 1946, he joined the famous NII-88. During Stalin's later years, then-Minister of Defense Industries Ustinov saved Chertok from imprisonment by demoting him to an innocuous position to divert attention away from his Semitic background. As his power grew within the Soviet space program, Chertok, like many of his other contemporaries, was allowed to write about space in the Soviet media in later years, but under the pseudonym "Boris Yevseyev." After the shakeup in 1963, Chertok was closely involved in the development of the Soyuz and was instrumental in saving the program from oblivion.



Boris Chertok was a Deputy Chief Designer at OKB-1 who participated in several key Soviet space projects such as Soyuz. In later years, he was also one of the principal flight controllers for piloted space missions at the Yeupatoriya center. (files of Peter Gorin)

1. Yaroslav Golovanov, *Korolev: fakty i mify* (Moscow: Nauka, 1994), pp. 589–90.
2. B. Ye. Chertok, *Rakety i lyudi: Fili Podlipki Tyuratam* (Moscow: Mashinostroyeniye, 1996), pp. 275–76.
3. Golovanov, *Korolev*, pp. 589–91; Chertok, *Rakety i lyudi: Fili Podlipki Tyuratam*, p. 276; Yu. P. Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya "Energiya" imeni S. P. Koroleva* (Korolev: RKK Energiya, named after S. P. Korolev, 1996), p. 167.

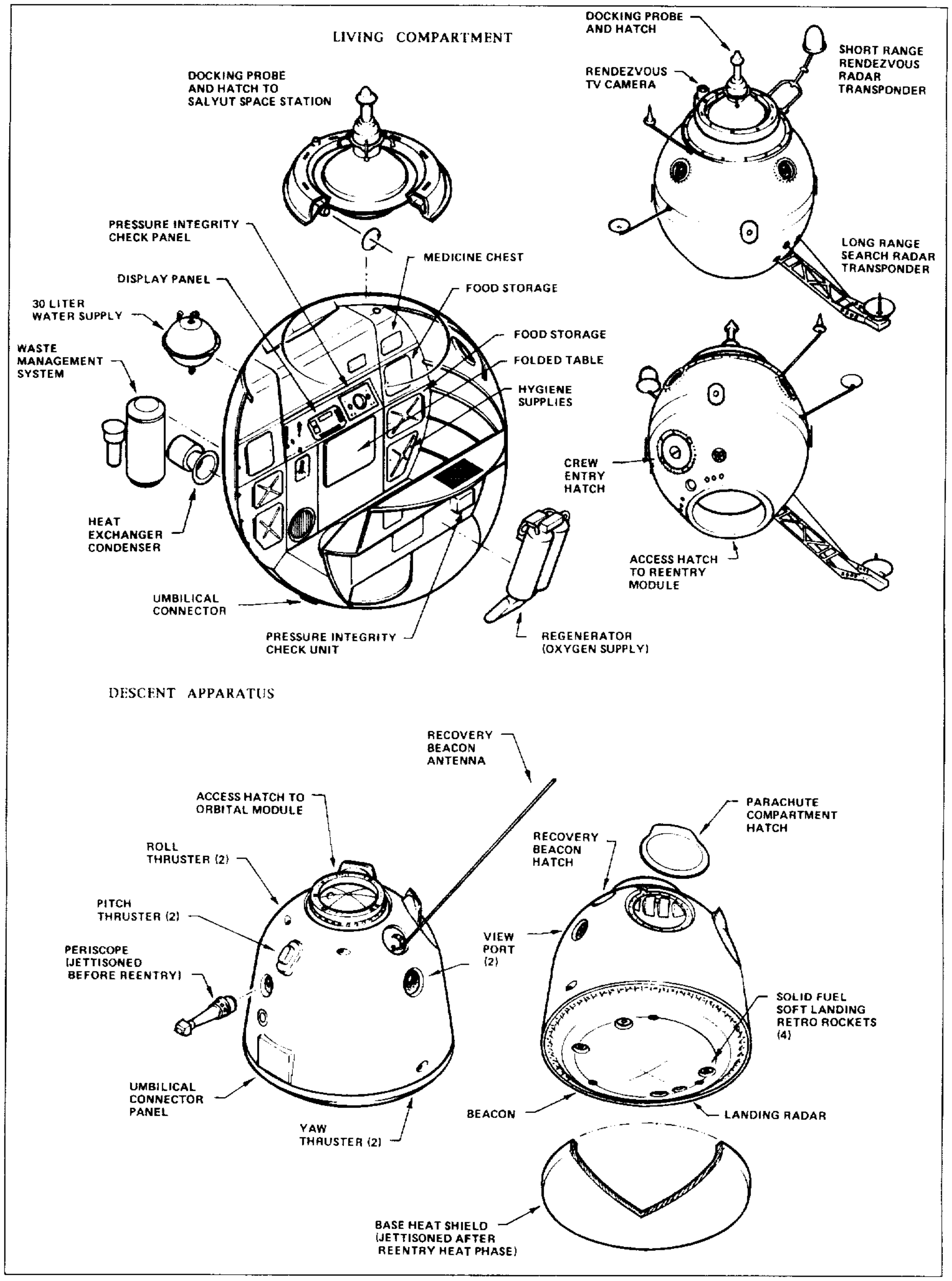
By the first months of 1964, OKB-1's Department No. 11, subordinated to Deputy Chief Designer Kryukov, had redesigned the basic 7K Soyuz spacecraft for flying not two, but three cosmonauts. Technical documentation for the vehicle had been prepared in early 1964, and by the spring, the first "boilerplate" had rolled off the plant at Kaliningrad. When Korolev first viewed the spacecraft, he allegedly told everyone present that "this was the machine of the future."[4] A full-size trainer of the 7K, along with one-thirtieth-size models of the 9K and 11K, was installed at TsNII-30 in Noginsk by February 1964 to allow cosmonauts to rehearse docking procedures in orbit.[5] A stripped-down mock-up of the Soyuz descent apparatus was also prepared for a suborbital flight from the old proving range at Kapustin Yar. OKB-1 engineers launched the mock-up on the morning of September 26, 1964, to test the aerodynamic qualities of the capsule, but the payload shroud broke up between T+33 and T+39 seconds because of excessive aerodynamic loads.[6]

Despite the advances in the Soyuz effort, the program was stopped dead in its tracks less than a year after it had received a formal go-ahead in December 1963. When in August 1964 the Soviet Communist Party and government selected Chelomey to carry out the circumlunar program, Soyuz effectively fell through the cracks. There were other factors—for example, Korolev was knee-deep in a variety of unrelated projects at the time, including the interim Voskhod missions. In addition, primary operations for piloted lunar exploration at OKB-1 had shifted subtly from circumlunar projects to a lunar *landing* effort, more specifically the N1-L3 project. By the second half of 1964, the overall Soyuz program was "practically paralyzed," and it was ready to join the many other projects of the time as a footnote in Soviet space history.

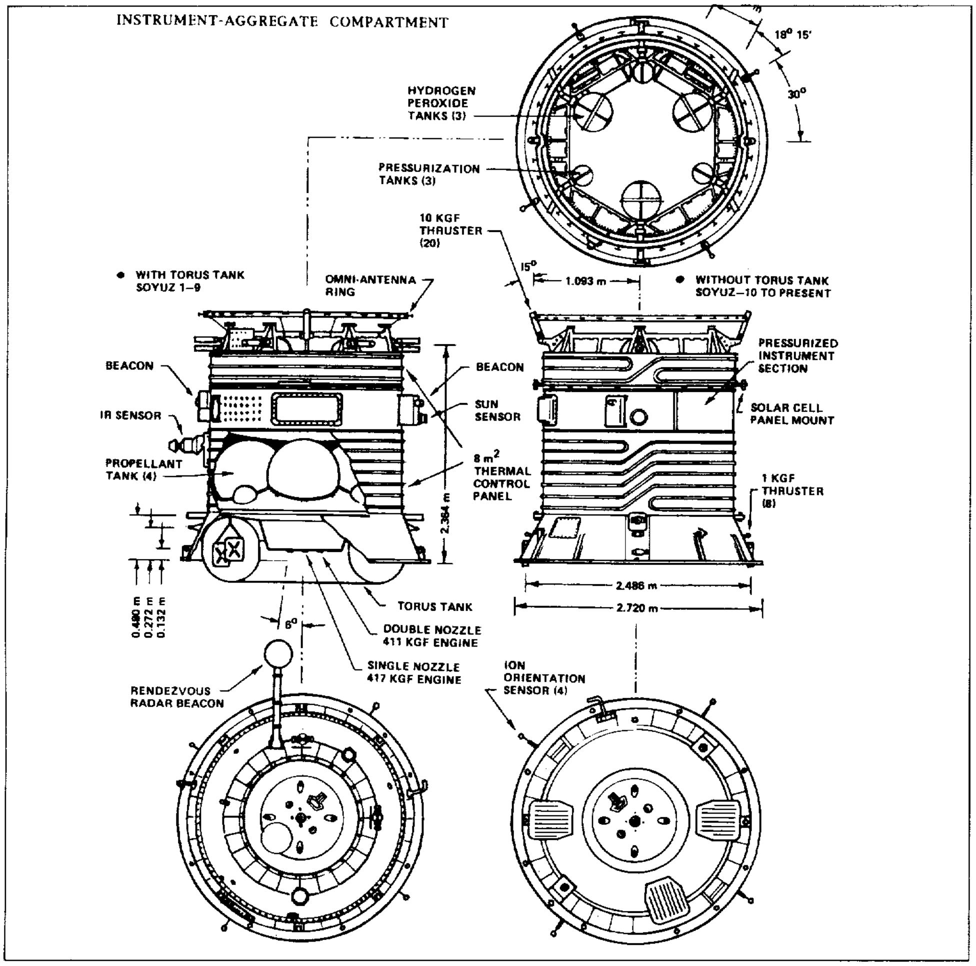
In the fall of 1964, Korolev established a small group under Chertok to come up with proposals on the potential use of the basic 7K Soyuz spacecraft. In late 1964, Chertok's team suggested that the docking of two 7K vehicles in Earth orbit should be considered the primary goal of a redirected Soyuz program. Such a docking mission would aid in the development of rendezvous and docking systems, as well as provide experience in carrying out EVA operations in orbit from one Soyuz to another. Although the experiment had merits of its own, there were more pragmatic reasons for picking such a project as the primary goal of the Soyuz program. In early conceptions of the N1-L3 landing project, the engineers had proposed an elaborate scheme of crew transfer from one spacecraft to the other in lunar orbit via EVA. The 7K Soyuz could test out this complicated maneuver in Earth orbit before actual operations in lunar orbit.

In February 1965, Korolev presented his new conception of the Soyuz program, restructured from a circumlunar objective to operations in Earth orbit, to the Scientific-Technical Council of the State Committee for Defense Technology. The "ministry" granted approval for the program, taking into account that the design bureau had already finished the initial technical plan for the 7K vehicle, that it had been coordinated with a specific launch vehicle, that engineers had issued the complete design documentation, and that the manufacturing of portions of the vehicle had already begun. The 7K Soyuz would also enable cosmonauts to master complex Earth-orbital operations as a true second-generation spacecraft to follow the Vostok.[7]

4. Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p. 168.
5. N. P. Kamanin, *Skrytiy kosmos: kniga vtoraya, 1964–1966gg* (Moscow: Infortekst IF, 1997), p. 24; Viktor Mitroshenkov, *Zemnya pod nebom* (Moscow: Sovetskaya rossiya, 1987), p. 330.
6. Yu. V. Biryukov, "Materials from the Biographical Chronicles of Sergey Pavlovich Korolev" (English title), in B. V. Raushenbakh, ed., *Iz istorii Sovetskoy kosmonavtiki* (Moscow: Nauka, 1983), p. 251; V. Semenov, I. Marinin, and S. Shamsutdinov, *Iz istorii kosmonavtiki: vypysk II: zapuski kosmicheskikh apparatov po programmam pilotiruyemykh poletov* (Moscow: AO Videokosmos, 1995), p. 51; E-mail correspondence, Igor Lissov to the author, June 10, 1997. This was evidently the first launch of the R-5V variant of the R-5 missile.
7. Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, pp. 168–69.



This and the next page show the three main sections of the Soyuz spacecraft. This particular model is the 7K-T, a slightly different variant than the 7K-OK, which was used during 1966–70. The primary difference was in the docking equipment. At the top of this page is the living compartment, which provided life support functions during independent flight. At the bottom of this page is the descent apparatus, which carried the crew during launch and recovery. The next page shows the instrument-aggregate compartment, which provided electrical power, thermal control, attitude control, and maneuvering capability. (copyright D. R. Woods)



In early 1965, all work on the Soyuz spacecraft was moved to Department No. 93 at OKB-1. As per Chertok's original recommendations, the Soyuz program was reduced to the development of a single spacecraft, the product 7K-OK, with the "OK" standing for the Russian acronym of "orbital ship." Like all other missiles and spaceships, the vehicle also had a production index, the 11F615, which was the designation used in all plant documentation. The two remaining portions, the 9K tanker and the 11K translunar-injection (TLI) block, which would have been developed by other design bureaus, were eliminated from the program. Engineers delivered the draft plan for the 7K-OK ship in May; because of delays it was not until October 23 that they completed a final version, thus allowing designers to issue the technical documentation for the manufacture of the spacecraft. A new tactical-technical requirement was issued by the chief client, the Ministry of Defense, in August 1965.[8]

The 7K-OK variant was an evolutionary design stemming from the years of work on the abandoned Sever, L1, and 7K spacecraft in the early 1960s. It would be this model, publicly called the Soyuz, that the Soviet Union would launch on thirty-eight piloted flights between 1967 and 1981.

8. *Ibid.*, p. 636.

The general design scheme of the 7K-OK variant was quite similar to the original 7K variant intended for circumlunar missions. Like its predecessor, the spacecraft had three major compartments from the forward end to the rear end, the living compartment, the descent apparatus, and the instrument-aggregate compartment. The descent apparatus and the instrument-aggregate compartment retained their earlier shapes, but the living compartment was redesigned to be more like a spheroid rather than the earlier cylinder because the former provided a better mass-volume ratio. The total length of the spacecraft was about just over seven and a half meters, and total mass was 6,460 to 6,560 kilograms, up from the Vostok's modest 4,800 kilograms. A nominal mission would last three to ten days.

The cylindrical instrument-aggregate compartment—often called the "service module" in the West—like the one on the 7K, was divided into four separate sections along the length of its cylinder from the aft end to the forward end: the jettisonable compartment, the aggregate compartment, the instrument compartment, and the transfer compartment. The jettisonable compartment was a remnant of the original 7K vehicle's mission: circumlunar flight. It was originally a toroidal section at the base of the vehicle that would carry electrical systems for rendezvous and docking and be discarded following translunar injection. In redesigning the 7K to the 7K-OK, early models of the Soyuz evidently retained this compartment for chemical batteries, while all rendezvous and docking instrumentation was moved to the spheroid living compartment at the forward end of the vehicle.

The unpressurized aggregate compartment carried the thermo-regulation radiator system, the main and attitude control engines of the spacecraft, and two large solar panels (which charged the chemical batteries in the spacecraft). Each solar array was made up of two four-segment wings approximately a little more than three and a half meters in length, with a total surface area of fourteen square meters, that would provide thirteen and a half volts, for a total of twenty-seven volts. The solar arrays were folded up flat against the side of the aggregate compartment during the launch phase, unfurling to their full lengths once in orbit. During an Earth-orbital mission, the panels would be turned toward the Sun by orienting the entire vehicle by means of a solar sensor system and attitude control engines. The aggregate compartment also contained the main 7K-OK engine, located at the center rear of the spacecraft. This engine, the S5.35, had a thrust of 417 kilograms. The system also included a backup engine with two additional nozzles around the main exhaust, with a thrust of 411 kilograms, operating from the same propellant supply. The propellants of unsymmetrical dimethyl hydrazine (fuel) and nitric acid (oxidizer) were carried in four spherical tanks mounted at the base of the aggregate compartment. The engine's development had begun in 1962 for the original 7K variant at OKB-2 in Kaliningrad. In addition to the main engine system, the Soyuz also carried a set of twenty-two attitude control motors. Of these, ten thrusters of ten kilograms thrust were placed on the exterior of the transfer compartment; four at ten-kilogram thrust and eight at one-kilogram thrust were installed elsewhere. A backup system of eight thrusters consisted of four at one-kilogram thrust and four at ten-kilogram thrust.

Forward of the aggregate compartment was the instrument compartment, a pressurized section containing the guidance and rendezvous system instrumentation, radio communications systems, environmental control systems, and attitude control engines on the exterior. The final section, the transfer compartment, was a small part of the spacecraft, located between the crew capsule and the service module, carrying hydrogen peroxide tanks for the attitude control thrusters.

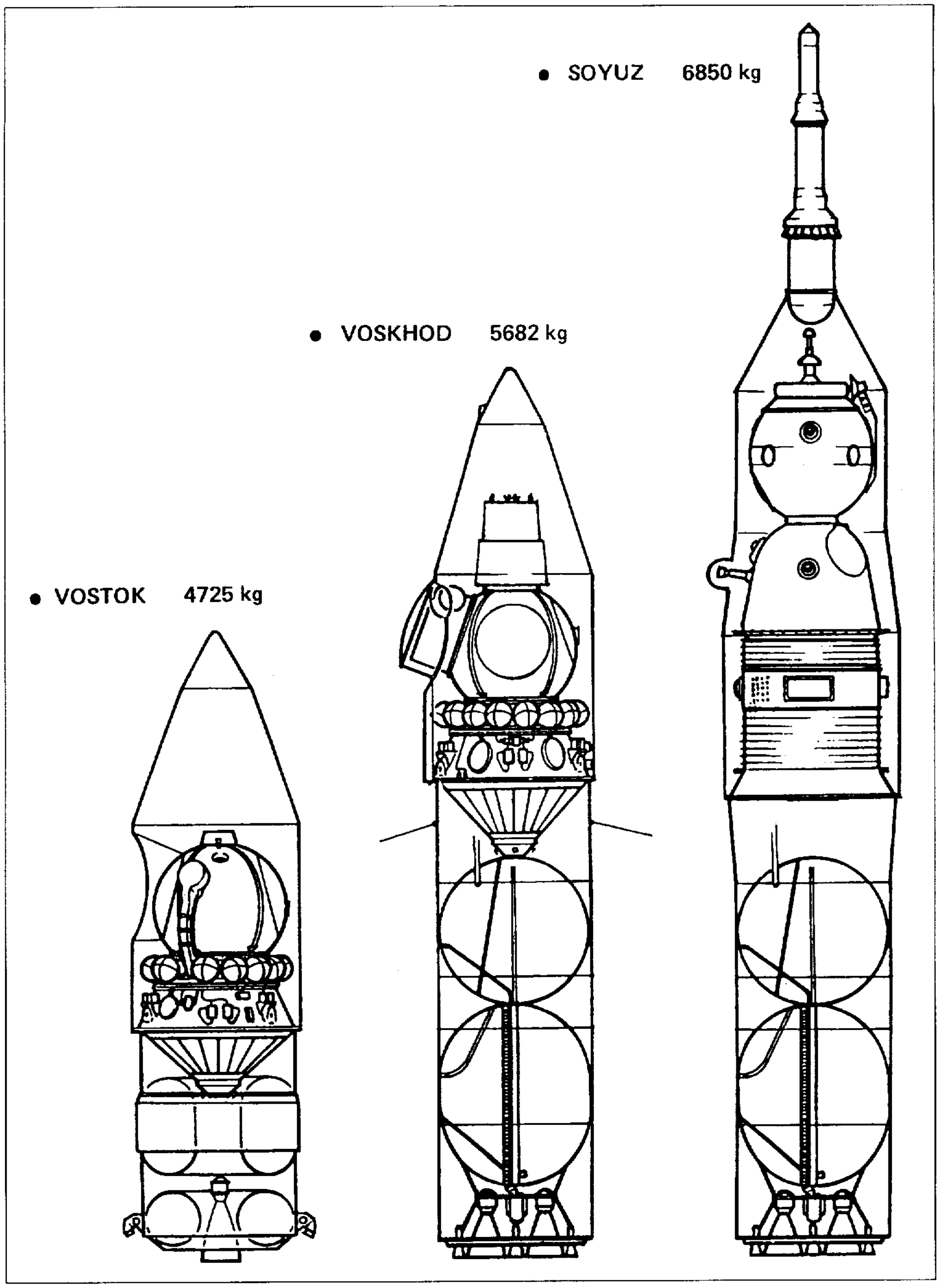
The complete instrument-aggregate compartment had a mass of 2,560 kilograms. The cylinder had a diameter of 2.2 meters flaring out to a skirt-shaped base, with a diameter of 2.72 meters for attaching to the upper stage of the launch vehicle. The length of this section, including all its four sections, was approximately 2.3 meters.

The descent apparatus—that is, the crew module—was affixed forward of the instrument-aggregate compartment. Affording an internal habitable volume of two and a half cubic meters, the capsule included one, two, or three seats for the crew, depending on the mission. The shock-absorbing seats were angled at eighty degrees to the horizontal. Forward of the center seat, belonging to the commander of the crew, was the main instrument panel, comprising only readouts and visual displays of various on-board systems; most system operations were preprogrammed or controlled from the ground. The panel also included the *Globus* instrument for identifying the location of the ship over the planet, a TV screen used in conjunction with two TV cameras on the exterior of the spacecraft, and the *Vzor* viewfinder for use during attitude control maneuvers. The Vzor was connected to a periscopic protrusion from the top of the descent apparatus, which allowed the crew to orient the ship relative to Earth. Two joysticks—the left one for changing velocity during maneuvers and the right one for attitude control—were located below the main panel. There were two smaller control panels on each side of the main one, each called a command and signal instrument (KSU). These included switches for various primary and backup systems and medical instrumentation—that is, a means for allowing the crew to tweak with on-board functions. Of the approximately 200 buttons and 250 warning lights on the control panels, seventy and ninety-six, respectively, were for the spaceship's movement—for attitude orientation, rendezvous and docking, and reentry. The lights had a fairly rudimentary system of operation, with red denoting failures and green and blue for various states of nominal operation. A fourth set of switches was installed below the left KSU for regulating the spacesuit environment in the case of accidental depressurization. All the control panels were designed and built by the Special Experimental Design Bureau of the Flight-Research Institute headed by Chief Designer Sergey G. Darevskiy, the same institution that was responsible for the development of ground simulators.

Apart from the couches and control panels, the crew module also included a black-and-white TV camera at 625 lines per frame and twenty-five frames per second, one among a total of four in the Soyuz spacecraft as part of the *Krechet* system. Two others were fixed outside the ship for use during rendezvous, and one was inside the living compartment. One porthole on each side of the capsule was for visual cues during rendezvous as well as for celestial observations. For attitude control prior to and during reentry, six ten-kilogram-thrust hydrogen peroxide micro-engines were installed in pairs on the exterior at critical points for pitch, roll, and yaw. These would come into use once the module had separated from the instrument-aggregate compartment. The base of the crew module consisted of an outer shield manufactured from high-temperature-resistant ablative material for protection during reentry. After passage through the atmosphere and the opening of parachutes, this heat shield would be discarded, exposing the actual base of the descent apparatus, equipped with a set of solid-propellant engines for ensuring a soft-landing.

The precise shape of the descent apparatus was determined not only by the earlier studies on "headlight-shaped" modules in the early 1960s, but also by studies at the NII-1 aeronautics institute, where scientists by 1964 had developed a highly efficient principle of guided reentry using a low lift-drag ratio. NII-1 also contributed to computations of heat exchange and thermal protection, which were confirmed by experimental results. The crew capsule had a nominal mass of 2,800 kilograms and a length of two and two-tenths meters.

Directly forward from the center couch of the descent apparatus was the circular hatch leading to the spheroid living compartment, often called the "orbital module" in the West. It had a mass of 1,200 kilograms and a maximum diameter of two and a quarter meters. The module had a bunk, a cupboard, certain elements of the life support systems, a control panel for operating scientific instruments, TV cameras, hatch controls, spacesuit functions, radio equipment, and so on. Given a particular mission, spacesuits would be packed below the cupboard for the cosmonauts to don in the compartment. The cupboard could carry a food and water supply for a potential month-long mission. Internal volume for the crew was six and a half cubic meters. The living compartment also had four portholes and a set of rendezvous antennas on the exterior.



Here are the early generations of Soviet piloted Earth-orbital spacecraft side by side. The Voskhod variant shown in the middle is the 3KD or spacewalk version. Almost identical versions of the R-7A core plus strap-on would be below each of these payloads. The launch vehicles are the 8K72K for the Vostok, the 11A57 for the Voskhod, and the 11A511U for the Soyuz. (copyright D. R. Woods)

The module, apart from being an additional space for cosmonauts to sleep, rest, or conduct scientific experiments, also had an additional but very important role: to serve as an airlock for EVA operations when depressurized as "a buffer" between the descent apparatus and outer space.[9]

The Soyuz development program, beginning with the 7K and leading up to the 7K-OK, lasted over half a decade. During that period, engineers made a number of evolutionary changes as a result of testing and research. For the first time in a Soviet piloted space project, the designers introduced a true launch escape system, much like the one used on NASA's Mercury spacecraft. The system consisted of a tower fixed on top of the Soyuz shroud with a set of nozzles for a single seventy-six-ton-thrust solid-propellant rocket engine. During the period from T-20 minutes up to T+160 seconds, in the case of a booster accident, the payload shroud would split into two, the descent apparatus and living compartment of the Soyuz would separate from the instrument-aggregate compartment, and the tower engine would fire to lift the stack away from the booster. Four grill-like petals would then open at the base of the shortened spacecraft to stabilize the vehicle during its trajectory. Three asymmetrical engines would ignite to guide the stack on a proper heading, following which the backup parachute would open. A crew could potentially expect to endure a load of up to ten g's in such a system, landing about three kilometers away from the pad in the case of a pad abort. Engineers completed the design of this system in 1964 at OKB-1 in cooperation with its Branch No. 3. The critical main solid-propellant engine was built by the Design Bureau No. 2 of the Moscow-based Plant No. 81, headed by Chief Designer Ivan I. Kartukov.[10]

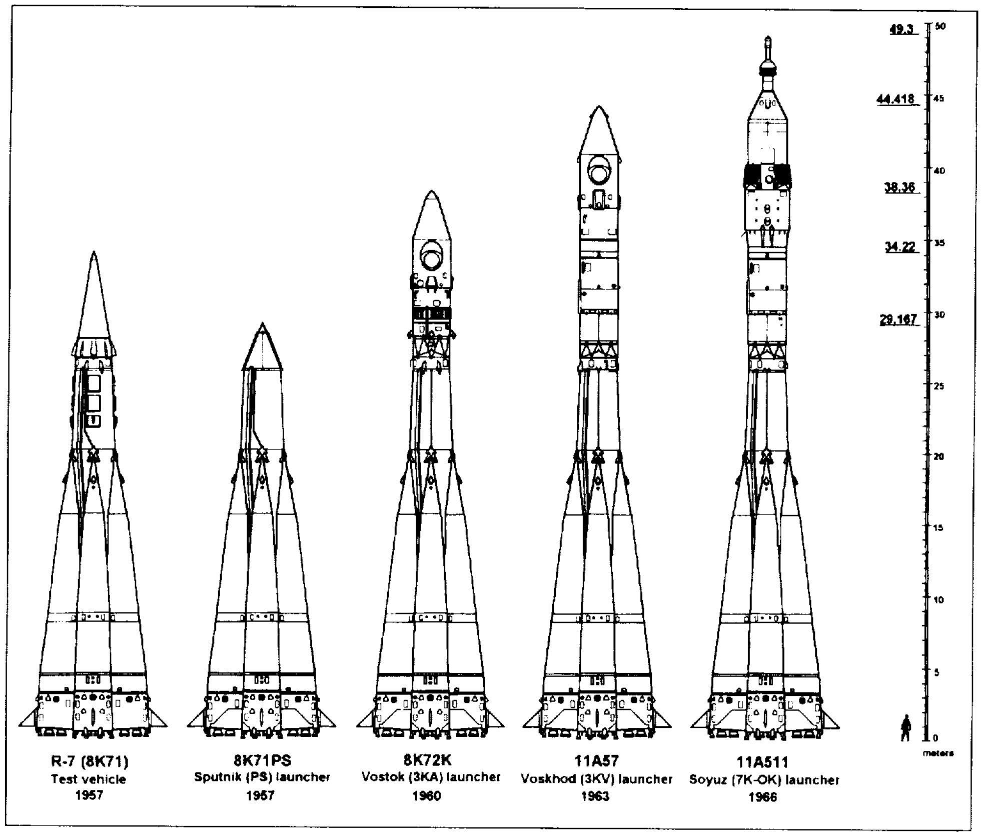
The Soyuz and all its variants would use a modification of the 11A57 booster that had launched the Voskhod spacecraft during 1964–65. This "new" variant had essentially the same configuration—a basic R-7A missile topped off with an upper stage from Chief Designer Kosberg's OKB-154. The primary difference was the use of an uprated engine for the third stage, the RD-0110 instead of the earlier RD-0108, thus increasing thrust from 30.0 tons to 30.4 tons. The new booster, known as the 11A511, was specifically developed for the Soyuz program, an extremely rare case of a Soviet launch vehicle developed first for "civilian" goals. With a Soyuz spacecraft, the length of the booster was 49.91 meters. Total launch thrust at sea level was 411.1 tons. The rocket, which was itself also called the Soyuz, could launch a 6,900-kilogram payload into a 200- by 450-kilometer orbit.

One of the most challenging tasks for designers at OKB-1 was developing on-board systems for the 7K-OK that were far superior to the ones used on Vostok. OKB-1's Department No. 27, under the leadership of Boris V. Raushenbakh, was responsible for designing the System of Orientation and Motion Control (SOUD), which allowed the craft to orient in orbit using both an inertial system and an orbital coordinate system, to carry out orbital maneuvers, to conduct rendezvous approach profiles, and to orient the solar panels to the Sun. The system consisted of four components:

- The attitude control sensors and the Vzor sighting device
- Gyroscopes and an "electronic computer"
- The *Igla* radar system for searching and homing other vehicles
- Attitude control engines

9. *Ibid.*, p. 169; Christian Lardier, *L'Astronautique Soviétique* (Paris: Armand Colin, 1992), pp. 180–82; G. S. Narimanov, ed., *Ot kosmicheskikh korabley - k orbitalnym stantsiyam* (Moscow: Mashinostroyeniye, 1971), pp. 23–29; Peter Smolders, *Soviets in Space* (New York: Taplinger Publishing Co., 1973), pp. 152–54; Kenneth Gatland, *Manned Spacecraft* (New York: Macmillan, 1976), pp. 260–61; A. Koroteyev, "From the History of Space Science: The Scientific-Research Institute of Jet Propulsion" (English title), *Aviatsiya i kosmonavtika* no. 6 (November–December 1993): 39–41.

10. Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p. 172–73; Lardier, *L'Astronautique Soviétique*, p. 182.



This shows the evolution of Soviet space launch vehicles in the early years. From the left are the R-7 ICBM, the Sputnik launcher, the Vostok launcher, the Voskhod launcher, and the Soyuz launcher. (copyright Peter Gorin)

To face the solar arrays toward the Sun, the cosmonauts would roll the Soyuz using the attitude control thrusters until the Sun appeared in the cross hairs of the Vzor device below the main control panel. A second command would put the vehicle into rotation around the Sun-spacecraft axis, allowing direct continuous illumination of the panels. For orbital maneuvers, the cosmonauts would roll the ship until Earth appeared in the Vzor, activate a set of gyroscopes, and fire the main engine. For guidance, the engineers developed a three-step gyroscope system, two with two degrees of freedom each (for inertial orientation) and one with three degrees of freedom (a sensor for angular velocity). There were also devices for effecting orientation using infrared sensors relative to Earth's vertical, as well as stellar, solar, and ion sensors (for the velocity vector), all installed on the exterior of the instrument-aggregate compartment. Celestial orientation would be carried out by setting an optical sensor in such a position that the angle between the sensor and a solar sensor corresponded to the relative locations of the Sun and a given star.

The Igla radar system for measuring parameters relative to motion was developed by the Moscow-based NII-648 headed by Chief Designer Armen S. Mnatsakanyan. The primary elements of the system were two long antennas (short- and long-range transponders) attached on the exterior of the living compartment at a ninety-degree angle to each other, a rendezvous TV camera, a third antenna attached at the rear of the spacecraft to allow an approach from "reverse," and the *Stels* system for protecting the system from secondary radio interference. The

Igla system would automatically bring the spacecraft to a distance of only 200–300 meters relative to its target vehicle from a distance of hundreds of kilometers by continually measuring the relative velocities and distances between the two spacecraft and carrying out attitude control and main engine boosts. The cosmonauts would take over manual control from 200–300 meters. The complex approach algorithms and the great volume of data exchanged in guidance circuits during rendezvous necessitated extensive ground testing of the Igla and the SOUD as a whole in three-stage rotating stands named the *Kardan* and *Platform*, simulating a spacecraft's motion through space. Igla itself was tested in a nonecho radio chamber built by NII-648. Engineers eliminated at least ten major defects in the SOUD during testing in 1965–66.

As early as 1962, engineers had begun the development of a docking system for the Soyuz spacecraft. A team led by OKB-1 engineers Viktor P. Legostayev and Vladimir S. Syromiatnikov developed a "pin-cone" scheme, which allowed two spaceships, one with an active docking unit and one with a passive unit, to connect together. No provision was made for internal transfer because the original conception was for a circumlunar mission, with dockings with various tankers. In 1965, when the Soyuz program was redirected, Korolev proposed that the system be changed to allow for the internal transfer of crews, but because of the significant amount of work already done on the original system, as well as a lack of time, Korolev accepted designer Feoktistov's proposal to keep the original design. This system included a pin on the active vehicle that would be captured in the cone-like funnel of the passive vehicle, canceling any remaining velocity and angular displacement. The system required a significant degree of precision because the docking system included electrical umbilical connectors in the face of the docking ring to link the two spacecraft. These multiple prong and socket connectors were precisely aligned by using 152-millimeter- and twenty-five-millimeter-diameter guide pins. Once capture was made, an electric motor would retract the probe for final structural latching. Unlike the Apollo spacecraft, the system allowed repetitive dockings and undockings.

Given that originally the Soyuz was meant for circumlunar flight, the designers had created a long-range communications system for the spacecraft, which was later modified for Earth-orbit operations in 1964. The multifunctional long-range version was developed by NII-885, under Chief Designer Ryazanskiy of the Council of Chief Designers, and it included command radio links, television and telemetric channels, and voice communications. Later, these components were split up between different organizations. The Krechet TV system was designed by NII-380 at Leningrad under Chief Designer Igor A. Rosselevich, the same team that had developed the famous imaging system that first photographed the far side of the Moon in 1959. The radio-telemetry system for the 7K-OK Soyuz was created by Ryazanskiy's NII-885, while the *Zarya* voice communications system was the work of NII-695, led by Chief Designer Yuriy S. Bykov. Both had worked in the same capacity for Vostok. The telemetry system was composed of forty small T-shaped antennas around the aft end of the descent apparatus. The Zarya was a comprehensive ultra-shortwave and shortwave system ensuring communications in orbit, during reentry, and after landing. The *Mir-3* autonomous data recorders developed under Chief Designer Ivan I. Utkin at NII-88 rounded out the telemetry and communications systems on the Soyuz spacecraft.

Engineers developed the life support system for the 7K-OK using the experience on the Vostok and Voskhod vehicles. It included systems for maintaining internal atmosphere, ensuring a supply of water, food, and clothing, providing a means of waste collection, controlling medical indices, and providing an emergency kit for use in the case of an emergency landing. Like the earlier spacecraft, the Soyuz maintained normal atmospheric conditions at temperatures of twenty plus or minus three degrees Centigrade. Cabin pressure was set at 710 to 850 mm Hg and relative humidity at 40 to 55 percent. Temperature and humidity were controlled by a single-loop series of heat exchangers. The ratio of oxygen to carbon dioxide was ensured by a superoxide chemical, which released oxygen, and lithium hydroxide for absorbing carbon dioxide. On-board sensors constantly measured the atmospheric conditions and adjusted them accordingly. OKB-124 developed the primary atmospheric regeneration systems. Plant No. 918 created the flight suits, water holders, emergency kits, and sewage disposal systems. The Institute of Biomedical Problems developed the food and medical instrumentation. The Analytical Instrument Building Special Design Bureau provided the gas analyzer for the atmosphere.

Engineers expended much effort on the development of a landing system. Despite Korolev's interest in exotic schemes, such as helicopter rotors, a more conservative parachute system was the frontrunner and was eventually adopted. Starting in 1961, OKB-1, in cooperation with the famous M. M. Gromov Flight-Research Institute, Plant No. 918, the Scientific-Research and Experimental Institute of the Parachute Landing Service, and Plant No. 81, carried out coordinated work on a parachute system leading to the development of a "bi-cascade" system with a solid-propellant braking engine at the base of the primary parachute, much like in the Voskhod spacecraft. The parachute-reactive system would reduce velocity down to eight and a half meters per second. In the case of engine failure, the velocity would be a barely tolerable ten meters per second. The backup system of parachutes would not employ any engine. Such a system was tested at the Flight-Research Institute beginning in 1962 in mass models of the 7K Soyuz. Subsequent modifications of the parachute-reactive system in 1963 and 1964 by Plant No. 918, however, revealed inconsistencies in the operation of the backup system, when used in conjunction with the primary parachute.

In late 1964 and early 1965, on orders from Deputy Chief Designer Bushuyev, engineers began a search to revamp the whole system. The engineers had two requirements: that the landing velocity with the primary system be reduced to at least six and a half meters per second, and that the braking engines be removed from the parachute and installed instead at the base of the descent apparatus. A reduction of velocity was achieved by increasing the dome size of the primary parachute from 574 to 1,000 square meters. In addition, Chief Designer Kartukov's Plant No. 81 developed a set of four small solid-propellant engines positioned at the bottom of the descent apparatus that would be exposed following the jettisoning of the outer thermal base. The engines were extremely compact and capable of operating after a lengthy stay in vacuum and even in conditions of soil blockage.[11]

The landing sequence of the Soyuz 7K-OK was standard for all Soviet piloted missions for thirty years. At an altitude of nine and a half kilometers, the parachute system would go into operation by shooting off the parachute hatch and issuing a primary fourteen-square-meter drogue parachute, followed in seventeen seconds by the main parachute. Both would be compressed and folded in a container with a volume of only 0.3 cubic meter. Subsequently, the thermal shield would be discarded at three kilometers, and at about one and a half meters prior to touchdown, a gamma-ray altimeter would issue a command to fire the four solid-propellant motors at the base of the descent apparatus to reduce landing velocity to a final two to three meters per second. In the case of a main parachute system failure, a second hatch would fire off and deploy a drogue plus backup parachute combination, the latter with a dome area of 574 square meters. These two would be packed in a second container with a volume of 0.2 cubic meter. When using the smaller parachute, the landing would be rougher, but certainly survivable. A worst-case scenario, with the backup parachute and loss of soft-landing engines, would subject a crew to four- to nine-meter-per-second velocities at landing.

The parachutes were built by the Scientific-Research and Experimental Institute of the Parachute Landing Service, an aviation industry enterprise headed by Chief Designer Fedor

11. Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, pp. 170–77; Edward Clinton Ezell and Linda Neumann Ezell, *The Partnership: A History of the Apollo-Soyuz Test Project* (Washington, DC: NASA Special Publication (SP)-4209, 1978), pp. 116–17; Lardier, *L'Astronautique Soviétique*, pp. 180–82; Narimanov, *Ot kosmicheskikh korabley*, pp. 21–54.

D. Tkachev, who had also designed the Vostok and Voskhod parachutes. They were tested through the mid-1960s in various conditions, including sea landings and drops from An-12 aircraft from altitudes of ten kilometers. The aircraft drops consisted of seven tests in 1965 and 1966 at the Air Force's testing station at Feodosiya. It was during this time that engineers identified and eliminated problems with hydrogen peroxide leaks on the parachutes.[12]

The 7K-OK was not the only variant of the Soyuz spacecraft developed in the mid-1960s. Given that the primary financier of the project would be the Ministry of Defense, Korolev proposed parallel variants in 1962 for exclusively military purposes. These were part of the Soyuz-P and Soyuz-R projects. The former was a piloted anti-satellite interceptor program, while the latter was a piloted reconnaissance station effort. In 1963, because of the workload at OKB-1, Korolev transferred further work on the two projects to his Branch No. 3 at Kuybyshev, whose primary area of work at that point was work on the Zenit-2 and Zenit-4 automated reconnaissance satellites and R-7 booster manufacturing. The head of the branch was Deputy Chief Designer Dmitriy I. Kozlov, one of Korolev's old protégés who had served as the "lead designer" of the R-7 ICBM during the 1950s.

The Soyuz-P used the 7K-PPK variant of the basic Soyuz craft. Few details on the vehicle have been declassified; Kozlov's engineers evidently designed a mission-unique launch vehicle, the 11A514, specifically for the project. The project was put on hold in mid-1964 and terminated in 1965, evidently because of the military's preference for *automated* anti-satellites, such as Chelomey's "IS" system, which had already flown two successful missions in 1963 and 1964.

The Soyuz-R consisted of two separate vehicles, a small space station named the 11F71 and a ferry craft, the 11F72 (or 7K-TK), to take crews there. The former was designed by using the instrument-aggregate compartment of the basic Soyuz craft as crew living quarters and substituting the remaining two modules with a single compartment housing equipment for electronic- and photo-reconnaissance. The 7K-TK ferry was similar to the basic Soyuz, but it included an internal hatch transfer system to allow cosmonauts to move from the ferry to the station without having to exit into space. On June 18, 1964, the USSR Ministry of Defense signed its five-year plan on space-based reconnaissance covering the years 1964–1969. The Soyuz-R complex was included as part of that plan, which also included several other programs, including Zenit (photo-reconnaissance), Morya-1 (ocean reconnaissance), and Spiral (military spaceplane).[13] Soon after, Kozlov's engineers prepared the predraft plan for the Soyuz-R, which was approved by the Interdepartmental Scientific-Technical Council for Space Research, the interministerial structure supervising space program proposals.

The Soyuz program as a whole was not guaranteed implementation despite OKB-1's signing off on a draft plan for the spacecraft as well as ministerial support. Sometime in 1965, the Soviet government may have even considered transferring the whole project to another design bureau. In a perhaps desperate move, Korolev ordered his subordinates to organize an exhibit on the Soyuz program for Communist Party and government officials to demonstrate that it would be a gross mistake to move the project to another enterprise. An engineer who participated in organizing the displays recalled Korolev's visit to evaluate the exhibit:

> *Our many years of work, said Sergey Pavlovich [Korolev], may go for naught. The topic may be assigned to another enterprise, and the experience of our collective, which has*

12. Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, pp. 170–71.

13. Konstantin Lantratov, "Dmitriy Kozlov's 'Zvezda'" (English title), *Novosti kosmonavtiki* 3 (January 27–February 9, 1997): 50–55. Kozolv signed the predraft plan for the Soyuz-R complex on July 15, 1965.

gone through such a difficult path, will remain unused. Korolev spoke quietly and thoughtfully. We all understood that this was very difficult for him. It was painful to see this willful, fearless man suppressed by such circumstances. But he was able to control his feelings and concluded his conversation on an upbeat note: we will fight and defend our brainchild.[14]

Defend it they did, and the Soyuz program remained behind at OKB-1. On August 18, 1965, the Military-Industrial Commission signed decree no. 180 titled "On the Order of Work on the '*Soyuz*' Complex," which for the first time approved a schedule for the execution of the project, thus legitimizing the new, redirected Soyuz. Final air and sea testing of the descent apparatus was set for the third and fourth quarters of 1965, while the beginning of flight tests in Earth orbit for automated versions was scheduled for the first quarter of 1966. In total, seven Soyuz 7K-OK spacecraft were approved for manufacture by the second quarter of 1966.[15]

The redirection of the Soyuz program in 1964 and 1965 laid the basis for the most prolific Soviet piloted spacecraft in its history. In 1965, the 7K-OK Earth-orbital Soyuz was, however, only one of three thematic directions of research at OKB-1. The other two were aimed at the exploration of the Moon in competition with the United States. In the interconnected world of Soviet space politics, by a fortuitous set of circumstances, designers would use the Soyuz spaceship as a starting point to develop vehicles for both Moon programs.

From EOR to LOR

From 1961 to mid-1964, all conceptions of possible piloted lunar landings studied by Soviet engineers used the Earth-orbit rendezvous (EOR) mission profile, whereby a lunar spacecraft would be assembled in Earth's orbit through multiple launches of the N1. This spacecraft complex would then fire itself toward the Moon to carry out its designated mission. In 1963 and 1964, at a time when the lunar landing began to eclipse a circumlunar flight as a primary objective of the Soviet piloted space program, OKB-1 designers considered a quadruple launch scheme. The plan involved launching three N1s into Earth orbit—that is, assembling a 200-ton behemoth spacecraft in Earth orbit. The crew would fly into orbit on a fourth rocket, a standard Soyuz launcher such as the 11A511.[16] Despite the high costs and multiple dockings, the increased payload afforded a sufficient margin to build large spacecraft equipped with redundant systems to ensure the safety of the crew and spacecraft systems.

All this changed with the August 1964 decree in support of a Soviet lunar landing program. It was at that point that OKB-1 decided to effectively shift the focus from an EOR profile to a sin-

14. A. Yu. Ishlinskiy, ed., *Akademik S. P. Korolev: ucheniy, inzhener, chelovek* (Moscow: Nauka, 1986), pp. 337–38. The identity of the other design bureau is not known. One unconfirmed source suggests that the Soyuz program was to have been transferred to Chelomey's OKB-52 so that OKB-1 could focus exclusively on the N1 program. See Lardier, *L'Astronautique Soviétique*, p. 158.

15. I. Marinin, "The First Civilian Cosmonauts" (English title), *Novosti kosmonavtiki* 12–13 (June 3–30, 1996): 81–87. The manufacturing schedule was two ships by the fourth quarter of 1965, two by the first quarter of 1966, and three by the second quarter of 1966. See Kamanin, *Skrytiy kosmos: 1964–1966*, p. 220.

16. For alternative proposals, such as a double-launch scheme, see I. B. Afanasyev, "Unknown Spacecraft (From the History of the Soviet Space Program)" (English title), *Novoye v zhizni, Nauke, tekhnike: Seriya kosmonavtika, astronomiya* no. 12 (December 1991): 1–64. For different triple-launch schemes, see I. A. Marinin and S. Kh. Shamsutdinov, "Soviet Programs for Piloted Flight to the Moon" (English title), *Zemlya i vselennaya* no. 5 (September–October 1993): 77–85; N. Kamanin, "A Goal Worth Working for . . .: The Space Diaries of a General" (English title), *Vozdushniy transport* 43 (1993). See also Yu. A. Mozzhorin, *et al.*, eds., *Dorogi v kosmos: II* (Moscow: MAI, 1992), p. 59; V. P. Mishin, "Why Didn't We Fly to the Moon?" (English title), *Znaniye: tekhnike: seriya kosmonavtika, astronomiya* no. 12 (December 1990): 3-43.

gle-launch lunar-orbit rendezvous (LOR) profile, identical to the one adopted for Apollo. Despite the historical importance of the decision, the reasons for this abrupt shift still remain obscure. Korolev's First Deputy Mishin recalled years later: "The American program nudged our country's highest leaders into issuing the assignment for the development of designs for launch vehicles that could support a lunar mission with a *single* launch."[17] Another engineer at OKB-1 attributes the switch to the single-launch idea to Mishin himself. Others say it was Korolev.[18] There were probably two motivations behind the shift in strategy. There may have been pressure from the industrial leaders of the space program to adopt a mission profile similar to the American one. This sort of "parallel" response was chronically evident in weapons systems development. While less common in the space program, there was precedent throughout the history of the Soviet space program for technical decisions driven by mirroring American technical choices. A second motivation was most likely simple economics. One rocket would cost less than the two or three required for EOR, and cost was certainly a big factor in the N1 program.

The decision to move with a single-launch profile came hand in hand with the adoption of LOR for the lunar landing mission; a direct ascent plan, the third option, was out of the reach of the N1 booster's capability. The LOR profile had originally been proposed as early as 1929 by a Russian contemporary of Tsiolkovskiy named Yuriy V. Kondratyuk.[19] Korolev, Glushko, and others were, in fact, intimately familiar with the approach even before the Apollo selection, although its adoption in the N1-L3 program raised a Pandora's box of problems that plagued the project throughout its existence.

The N1 design of mid-1964 had a lifting capability of approximately seventy-five tons. All calculations had conclusively proven that this figure was simply not enough to comprise a TLI stage, a lunar orbiting module with one pilot, and a lunar landing vehicle with two cosmonauts. By comparison, the payload in Earth orbit projected for NASA's Saturn V was close to 130 tons. Korolev evidently promised the space industry leaders at the time that he would be capable of carrying out a single launch for a lunar landing by two means: decreasing the mass of the payload and increasing the effective carrying capacity of the N1. For Korolev, both roads became "maniacal" obsessions as, through the end of 1964 and the first part of 1965, engineers explored every avenue to shave off kilograms, even grams, from the L3 stack that would go to the Moon. One engineer working on the lunar lander recalled:

> *At the time, the developers were racking their brains about how to keep within the rigid framework of the initially adopted energy capabilities of the launcher. The search went out in all directions. For each saved or "found" kilogram of mass, the Chief Designer paid a bonus of 50–60 rubles. To us young engineers, that was a lot of money.*[20]

There was even an apocryphal story that one engineer had managed to get a bonus for proposing to suck out all the air from the tubular design of the rocket, because even air had mass. All proposals, no matter how outlandish, were given consideration. But the gains proved to be incremental. Korolev, in frustration, told his Deputy Chertok, "I don't need your ten kilograms. I need a ton."[21]

17. Mishin, "Why Didn't We Fly to the Moon?," Author's emphasis.

18. For Mishin, see Peter Smolders, "It Made Sense to Build a Space Station," *Spaceflight* 38 (April 1996): 113–15. For Korolev, see Mozzhorin, *et al.*, eds., *Dorogi v kosmos: II*, p. 59.

19. Golovanov, *Korolev*, p. 757.

20. V. Filin, "At the Request of the Reader: The N1-L3 Project" (English title), *Aviatsiya i kosmonavtika* no. 12 (December 1991): 44–45.

21. Golovanov, *Korolev*, pp. 757–58.

The first approach was to incrementally raise the payload of the rocket. Korolev asked his designers to improve the lifting capabilities of the N1, first from seventy-five tons to eighty-five tons, and then finally to ninety-five to 100 tons. Studies at the design bureau had in fact shown that ninety-five to 100 tons would be the absolute minimum to achieve a lunar landing mission.[22] Engineers under Deputy Chief Designer Kryukov altered the original N1 design in six fundamental ways to increase the N1 payload:

- Increase the number of engines on the first stage from twenty-four to thirty
- Lower the altitude of the orbit around Earth prior to lunar boost from 300 to 220 kilometers
- Shift the launch azimuth further to the south to a more favorable 51.6 degrees
- Increase the propellant load for the booster by having cylindrical inserts in the equatorial part of the tanks and lowering the fuel and oxidizer temperatures
- Install four latticed stabilizers at the tail of the Blok A first stage
- Increase the thrust of the engines on the first three stages by an average of 2 percent by introducing a "flexible" program for controlling engine thrust[23]

With these changes, especially the addition of six new engines to the first stage, the N1's total launch mass increased from 2,200 tons to 2,750 tons. Payload capability would theoretically increase to ninety-two to ninety-five tons, just barely enough for its slated mission.

Korolev signed the predraft plan for the uprated N1 booster and its L3 lunar stack, specifying the new requirements of the mission—single launch, increased payload mass, and LOR—on December 25, 1964.[24] The document contained "initial data for the development of working documentation" for the L3 complex.[25] While the N1 consisted of three stages called Blok A, Blok B, and Blok V, the L3 comprised the following:

- Blok G (the fourth stage, for translunar injection)
- Blok D (the fifth stage, for lunar-orbit insertion and lunar descent)
- The Lunar Orbital Ship or LOK (the "mother ship")
- The Lunar Ship or LK (the "lunar lander")

In the interest of conserving mass, OKB-1 decided to dispense with the idea of a three-person crew like on Apollo, reducing the total crew size to only two. One cosmonaut would stay in orbit in the LOK, while the other would land on the Moon in the LK. The risks in the plan increased almost day by day as the plan was continuously revised.

This whole effort to optimize the capabilities of the N1, and the N1-L3 program as a whole, was the source of much discord within OKB-1—an unusual situation for a design bureau that had displayed a united front on all previous space projects. Ilya V. Lavrov, one of Korolev's best

22. R. Dolgopyatov, B. Dorofeyev, and S. Kryukov, "At the Readers' Request: The N1 Project" (English title), *Aviatsiya i kosmonavtika* no. 9 (September 1992): 34–37.

23. Mishin, "Why Didn't We Fly to the Moon?"; Dolgopyatov, Dorofeyev, and Kryukov, "At the Readers' Request: The N1 Project"; Boris Arkadyevich Dorofeyev, "History of the Development of the N1-L3 Moon Program," presented at the 10th International Symposium on the History of Astronautics and Aeronautics, Moscow State University, Moscow, Russia, June 20–27, 1995; Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p. 255. Fuel temperature was reduced to minus fifteen to minus twenty degrees Centigrade, while oxidizer temperature was reduced to −191 degrees Centigrade. There were also additional structural changes made to later N1 boosters to increase lifting mass.

24. Afanasyev, "Unknown Spacecraft"; Igor Afanasyev, "N1: Absolutely Secret: Part II" (English title), *Krylya rodiny* no. 10 (October 1993): 1–4; Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p. 636. Another source notes that OKB-1 and OKB-586 jointly finished the N1-L3 predraft plan on December 30, 1964. See B. V. Raushenbakh, ed., *S. P. Korolev i ego delo: svet i teni v istorii Kosmonavtiki* (Moscow: Nauka, 1998), p. 628.

25. Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p. 254.

engineers, at the time working on Mars spacecraft, recalled that the L3 program "was on the brink of fantasy."[26] Another engineer, Gleb Yu. Maksimov, one of the pioneers of Soviet space technology who had participated in the earliest landmark studies on artificial satellites in the 1950s, wrote a personal letter to Korolev in August 1964, imploring Korolev not to go ahead with the L3 single-launch approach. Maksimov, who had led the design teams for automated lunar probes and piloted Martian spaceships, was reassigned, on Korolev's orders, away from the central branch so that the autocratic Korolev would not have to deal with his criticisms. Feoktistov, the engineer behind the Vostok spacecraft, also disagreed with Korolev:

> *From the beginning I rejected this project because the parameters of the N1 were not right. . . . The flight to the Moon did not appeal to me very much, because the N1 could not place more than 90 tons in low Earth orbit . . . 90 tons was not enough: the Americans had calculated 120 tons in low Earth orbit and we were building everything heavier than the Americans. So I was not in favour of our approach and we constantly had conflicts about it.*[27]

The conflict over the N1-L3 plan prompted Korolev to request the formation of an "expert commission," under Academy of Sciences President Keldysh, to examine the technical pros and cons of the project. But Korolev had resistance even from the outside. Yuriy A. Mozzhorin, the director of the space policy advisory NII-88, came out against the single-launch scheme at a meeting of the commission in July 1965. Keldysh for the first time also sided against Korolev. The usually imperturbable scientist was furious: "What kind of nerve must we have to disembark one man on the Moon?! . . . Imagine for a minute being alone on the Moon! That's a straight road to the psychiatric hospital."[28] Psychological considerations aside, Keldysh's objections were in fact based on more concrete concerns: he believed that the whole program had evolved by pushing systems to the extreme—that is, there were no reserves at all, a sure road to failure.

Perhaps the biggest casualty of the N1-L3 project was OKB-1 Deputy Chief Designer Leonid A. Voskresenskiy. One of Korolev's most beloved deputies, he was also certainly the most colorful. He had been born to the family of a priest and therefore was penalized later by the Communist Party, which prevented him from getting a higher education. Perhaps the only deputy of Korolev without a college education, Voskresenskiy had an intuition about testing rockets that outshone many of his more scholarly colleagues, whom he dismissed as "men burdened by higher education." His utter fearlessness in the face of danger characterized not only his work with rockets, but also his passion for riding fast cars and motorcycles—a hobby that landed him in the hospital on occasion. One associate described him as "a baron with aristocratic manners. On the other hand, he came across as a peasant full of crude jokes. Paunchy, unsmiling, and wearing a tie, he made a majestic impression, and he was clearly well-respected."[29] Voskresenskiy was appointed a Deputy Chief Designer in October 1953 and oversaw flight and ground testing of every single missile and spacecraft from the days of the A-4 up to the Vostok and R-9 launches during the early 1960s.

By 1963, perhaps as a result of his misadventures, Voskresenskiy's health was seriously failing. He gave up his coveted role as director of flight testing at Tyura-Tam, preferring to work indoors. Despite a serious heart attack in early 1964, Voskresenskiy was closely involved in

26. Golovanov, *Korolev*, p. 758.
27. Smolders, "It Made Sense to Build a Space Station," p. 114.
28. Golovanov, *Korolev*, p. 758.
29. Yu. A. Mozzhorin, *et al.*, eds., *Nachalo kosmicheskoy ery: vospominaniya veteranov raketno-kosmicheskoy tekhniki i kosmonavtiki: vypusk vtoroy* (Moscow: RNITsKD, 1994), p. 46; Yu. A. Mozzhorin, *et al.*, eds., *Dorogi v kosmos: I* (Moscow: MAI, 1992), pp. 83–84.

work on the N1, especially in the preparation of its draft plan. When work on the giant launch complexes for the N1 began at Tyura-Tam the same year, Voskresenskiy was of the opinion that OKB-1 needed to fund the construction of a full-sized test stand for the first stage despite the delay it might cause. Korolev was enraged at Voskresenskiy's tone, perhaps precisely because he knew that Voskresenskiy was right. One engineer recalled an altercation between the two over the issue in 1963:

> *Korolev came up to Voskresenskiy, walked around him, raised his fist to the latter's face and said between clenched teeth: "You should be beaten with a stick for what you did! With a stick . . . a stick . . . a stick!" Korolev was punctuating every word with his fist. I had not seen the Chief Designer in such a state of anger for a long time. But Voskresenskiy parried with his words: "I'm fifty years old, this is not the time to be threatening me with a stick." After a short pause, Korolev stepped up to him, embraced him and said, "Sorry Leonid. No offense intended. I was overreacting."*[30]

Leonid Voskresenskiy was the person responsible for flight-testing all missiles and spacecraft at OKB-1 from the 1940s on. He led the launch teams for both the first Sputnik and Vostok launches and was perhaps the most well loved of all of Korolev's deputies. (files of Peter Gorin)

When Khrushchev released the first 500 million rubles for the N1 program, it was Voskresenskiy who stated that OKB-1 would need ten times more to achieve the goals set forth in the program. Korolev merely replied that if they asked the government for such enormous amounts of money, the project would be terminated.[31]

Voskresenskiy eventually refused to sign a single document related to the N1 until Korolev agreed to a test stand. The stalemate came to an end when Voskresenskiy offered his resignation from OKB-1 in 1964. Korolev accepted. It was an enormous loss to the fortunes of the design bureau. Voskresenskiy stayed on as a consultant to Korolev, participating in operations at the new space-launching base at Mirnyy, but he was no longer involved with the N1-L3 project. Just a year later, on December 14, 1965, he had returned from a concert with his wife when he collapsed and died from a brain hemorrhage at dinner. The fifty-two-year-old legend was buried with honors at the Novodevichiy Cemetery in Moscow. Korolev, who openly cried at the funeral, in his eulogy said, "Leonid, you were the first to open this road [to space]."[32] In typical fashion, in his obituary, the Soviet press described Voskresenskiy only as "a scholar in the field of the elaboration and testing models of new machinery."[33]

The objections from Voskresenskiy, Keldysh, Lavrov, Maksimov, Mozzhorin, Feoktistov, and others notwithstanding, Korolev bulldozed his own version of the N1-L3 project through

30. Mozzhorin, *et al.*, eds., *Nachalo kosmicheskoy ery*, p. 48.
31. S. Leskov, *Kak my ne sletali na lunu* (Moscow: Panorama, 1991), pp. 21–22.
32. Mozzhorin, *et al.*, eds., *Dorogi v kosmos: I*, p. 84; Golovanov, *Korolev*, p. 760.
33. "L. A. Voskresenskiy" (English title), *Izvestiya*, December 18, 1965, p. 6.

the members of the "expert commission" in 1965. The commission was a temporary body probably related to the Interdepartmental Scientific-Technical Council on Space Research, also headed by Keldysh, which had been created in 1958 to serve as an advisory body to recommend particular space projects to the government. Composed of various high representatives of the Ministry of General Machine Building, the Strategic Missile Forces, the Air Force, the design bureaus, and the Academy of Sciences, the council was supposed to prevent a single faction from pushing a program without oversight by other branches. It was not uncommon, however, for the important chief designers to "recruit" important allies on the council to support their positions.[34]

On February 10, 1965, the Keldysh Commission, no doubt crumbling under Korolev's headstrong opinions, capitulated and formally approved Korolev's predraft plan for the creation of the L3 lunar system. According to the signed document, OKB-1 and its subcontractors were to come to an agreement on the technical goals for developing the primary systems by the end of the month and finish the final draft plan for the L3 lunar complex by August 1965. If all went according to plan, flight testing of the N1-L3 complex would begin in late 1966.[35] Predictably, delays crept into the schedule, and throughout 1965, OKB-1 engineers, led by the so-called "high guard"—Mishin, Bushuyev, Chertok, Kryukov, and Okhapkin—directed an intensive revision process to fit the N1 into the stringent conditions set by the preliminary requirements. By late 1965, the draft plan had still not been finished, and the designers were still engaged in heated debates on the virtues of particular technical choices, some even arguing at this late stage if one booster was sufficient. By early September 1965, engineers had pushed the payload up to ninety-one and a half tons. On October 23, Kryukov presented his ideas on changing the inclination and other structural redesigns to increase mass to ninety-three tons. At the same time, Chertok was engaged in cutting systems from the lunar orbiter.

Apart from the internal dissent at OKB-1, Korolev's N1-L3 also had more organized opposition. Despite any formal involvement in the project, Glushko's plans continued to pose a threat to the project. In 1962, Glushko had begun the development of a new powerful engine, designated the RD-270, with a sea level thrust of 640 tons, more than four times more powerful than the modest NK-15s slated for use on the first stage of the N1.[36] It was powered by unsymmetrical dimethyl hydrazine and nitrogen tetroxide, the combination that Korolev called "devil's venom." The new engine was quite possibly the most powerful storable propellant engine ever built and had unusually high chamber pressures. By 1965, still supporting his stand on storable propellants, Glushko evidently proposed that the N1 be completely redesigned to use the RD-270 engine instead of the NK-15. His argument was that a smaller number of RD-270s could achieve the same performance as the thirty NK-15s, thus bypassing the complex problems associated with synchronizing thirty engines.[37]

34. Descriptions of the organizational underpinnings of the Interdepartment Scientific-Technical Council on Space Research and its associated *ad hoc* commissions are still rare. One source describes an N1 commission in the early 1960s to determine the adequacy of seventy tons [sic] for a piloted lunar mission. This commission had four subcommittees, headed by Chief Designers N. A. Pilyugin (NII-885), V. I. Kuznetsov (NII-944), V. P. Barmin (GSKB SpetsMash), and Colonel A. S. Kalashnikov (Chief of the Third Directorate in GURVO in the Strategic Missile Forces). See Mikhail Rebrov, "The Secrets of Rocket Codes" (English title), *Krasnaya zvezda*, June 3, 1995, p. 6.

35. Other deadlines set in the document were: to finish the working documentation for manufacture between April and June 1965; to begin the manufacturing of experimental units, systems, and samples of the rocket (technological-model samples) in the first quarter of 1966 and (the first flight sample) in the fourth quarter of 1966; and to finish experimental work on the aggregates and blocks by 1966. See Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p. 254.

36. Dietrich Haeseler, "Soviet Rocket Motors on View," *Spaceflight* 35 (February 1993): 40–41.

37. The "number of engines" argument between Korolev and Glushko is summarized in Sergey Leskov, "How We Didn't Fly to the Moon" (English title), *Izvestiya*, August 18, 1989, p. 3; Mozzhorin, *et al.*, eds., *Dorogi v kosmos: I*, pp. 30–31.

In three years of development, Glushko's design bureau had not achieved any significant progress with the engine, but in 1965, Glushko mounted an unprecedented lobbying effort in support of the engine. He enlisted the support of Ustinov and newly appointed Minister of General Machine Building Sergey A. Afanasyev, two of the most powerful leaders of the space program. Afanasyev evidently supported exploring a redesign of the N1 with the use of Glushko's engines. This was a full three years after the commencement of work on the N1, when the manufacturing of booster portions had already begun at plants all over the Soviet Union. It was the apotheosis of organizational and managerial chaos inherent in the lunar programs. Glushko himself attacked the N1 with "unrelenting fervor," eventually "securing the support of every chief designer in a letter to the Central Committee of the Communist Party, blaming Korolev for every imaginable shortcoming."[38] Korolev, hurt by the abrupt changing of alliances among his old comrades-in-arms, such as Barmin, found himself with his back to the wall. The absurd proposal to redesign the N1 eventually came to naught. A formal recommendation from NII-88 Director Mozzhorin may have finally convinced Afanasyev that it was an option not worth pursuing.[39]

The N1 retained its old engines, but the RD-270 development program was not by any means over. Instead, once again Glushko found an ally in General Designer Chelomey. It was an eerie repeat of the events of 1961–62 when Glushko had offered another engine for the N1, the RD-253, which had been refused by Korolev and eventually used on a Chelomey booster. What made the more recent challenge particularly ominous for Korolev was that this time Chelomey and Glushko vigorously supported a competitive proposal for landing a Soviet cosmonaut on the Moon. In the final days of Khrushchev's reign, Chelomey had first emerged with his UR-700 booster plan for competing with N1-L3. Khrushchev had given an order to make an informed and technical comparison between the two projects. Despite Khrushchev's ouster, this order hung over the fates of both efforts, threatening to either destroy Korolev's hard-earned gains or put a cap on Chelomey's ambitions—two outcomes that were mutually exclusive.

On October 20, 1965, Minister Afanasyev, a growing supporter of Chelomey's plans, issued an official order allowing Chelomey to draw up a formal draft plan in support of the UR-700. The proposal was supported not only by Glushko, but also by two of Korolev's oldest friends, Chief Designers Viktor I. Kuznetsov and Vladimir P. Barmin.[40] Both their "defections" were paramount to treason in Korolev's eyes because both were significant participants in the N1-L3 project. Kuznetsov, head of NII-944, was developing guidance systems for both the N1 and the L3, while Barmin's GSKB SpetsMash was responsible for the design and construction of the giant launch complexes for the N1 at Tyura-Tam. Barmin evidently believed that the two pads for the N1 could be redesigned with minimal structural readjustments for Chelomey's UR-700. Georgiy S. Vetrov, the official historian of Korolev's design bureau, later called the RD-270 program "a useless initiative," adding:

> *Its development was supported by D. F. Ustinov and led to wasting a lot of time and resources. There was a scientific consensus that this engine would not be usable. In spite of this, a new project was started based on it—the heavy carrier UR-700. This diverted attention from the N1 heavy carrier project meant to carry out promising space and military programs.*[41]

38. Rebrov, "The Secrets of Rocket Codes."

39. Georgiy Stepanovich Vetrov, "Development of Heavy Launch Vehicles in the USSR," presented at the 10th International Symposium on the History of Astronautics and Aeronautics. Glushko also evidently attempted to elicit Korolev's interest in engines using more exotic propellants. There is an account of a visit by Korolev to Glushko's ground static stands at Primorsk to inspect the testing of a fluorine oxidizer-based engine in 1964. See Golovanov, *Korolev*, pp. 711–12. Glushko also developed the RD-502 engine, which used highly concentrated hydrogen peroxide (oxidizer) and pentaborane (fuel), in 1960–66.

40. Interview, Georgiy Stepanovich Vetrov with the author, November 15, 1996.

41. G. Vetrov, "The Difficult Fate of the N1 Rocket" (English title), *Nauka i zhizn* no. 5 (May 1994): 20–27.

In "a desperate attempt to stop the dispersal of funds" to the UR-700, Korolev prepared a number of letters to Afanasyev. One letter dated September 29, 1965, co-signed by OKB-1 Deputy Chief Designers Mishin, Bushuyev, Kryukov, and Melnikov, was a virtual testament to Korolev's belief in the use of high-energy propellants during the future Soviet space program.[42] In a second letter from early November 1965, prepared but apparently never sent, Korolev referred to the decision in 1962 to move ahead with the liquid oxygen (LOX) and kerosene combination, arguing that the future lay in liquid hydrogen and LOX combinations, only a step away from LOX-kerosene. He also engaged in a vitriolic attack on Glushko's design bureau:

> *One cannot but mention that for a number of years, the OKB-456 . . . ceased to work effectively on development of realistic engines which could be used for practical purposes. The OKB is completely isolated from the demands of life and spends its "activities" in unneeded developments, spending tremendous sums of money for that. All this is at a time when there is an acute need for good engines.*[43]

There was also an acute need for money. At the very moment when the N1-L3 project required the most investment into fixed resources, such as ground testing stations, launch complexes, transport systems, and manufacturing jigs, the abrupt support for the UR-700 seems to have had a deleterious effect on Korolev's dream. Mozzhorin recalled later:

> *Work on the N1 project in 1964–1966 was carried out under difficult conditions. Production capacities were inadequate: plans called for the fabrication of four N1 rockets in a year's time, but only one and a half were constructed. There were delays in the timetable. Delivery of completed units was stalled. There were difficulties in solving the problem of constructing the necessary stands and experimental installations. The Chief Designers allowed serious deviations from the requirements for the final ground tests: "Too long and costly," they said. "We'll debug it in flight."*[44]

Marshal Malinovskiy, the USSR Minister of Defense, told Air Force officials during a meeting in January 1965, "We cannot afford to and will not build super powerful space carriers and make flights to the Moon. Let the Academy of Sciences do all that."[45] Mishin recalls that "construction of the production base [for the N1] was delayed two years."[46] Compared to the Saturn V project, the N1 was a disaster waiting to happen. There were the inevitable accusations that the N1's capabilities were markedly inferior to those of the Saturn V. Korolev tried his best to respond. For example, in a memorandum dated May 29, 1965, he put his persuasive capabilities to work with new Minister Afanasyev, making the outlandish claim that the performance differences between the two vehicles were "insignificant," despite the fact that the N1 weighed 20 to 40 percent more than its American counterpart.[47] Through all the setbacks and problems, Korolev remained surprisingly optimistic. During a conversation with an Air Force officer on

42. S. P. Korolev, V. P. Mishin, S. S. Kryukov, K. D. Bushuyev, and M. V. Melnikov, "On the Inexpediency of Development of the AT-NDMG Engine" (English title), *Nauka i zhizn* no. 5 (May 1994): 27–28.

43. James Harford, *Korolev: How One Man Masterminded the Soviet Drive to Beat America to the Moon* (New York: John Wiley & Sons, 1997), p. 273.

44. M. Rebrov, "But Things Were Like That—Top Secret: The Painful Fortune of the N1 Project" (English title), *Krasnaya Zvezda*, January 13, 1990, p. 4.

45. N. Kamanin, "A Goal Worth Working for: General Kamanin's Space Diaries" (English title), *Vozdushniy transport* 44 (1993): 8–9.

46. A. Tarasov, "Missions in Dreams and Reality" (English title), *Pravda*, October 20, 1989, p. 4.

47. Harford, *Korolev*, p. 266.

September 1, the latter recalled, "[Korolev] told me with visible satisfaction about the state of the N1 rocket. It was his baby, and it should be ready in metal by the end of 1965."[48]

The testing program for the N1 greatly depended on the fate of the GR-1 orbital bombardment system, because the former used modified versions of engines used on the latter. To add to the almost incomprehensible level of problems with the N1, the GR-1 came under severe attack in January 1965. The thinking from the Soviet leadership was not without good reason. The Soviet government had already invested in Yangel's R-36-O orbital bombardment system, later designated the Fractional Orbital Bombardment System (FOBS) by Western observers. There was simply little reason to proceed with Korolev's GR-1, especially because the R-36 ICBM, in its basic missile version, had already flown several successful test flights from Tyura-Tam. All activity related to the GR-1, meanwhile, was limited to work in the plants. There were also serious delays in developing the NK-9 engines for the first stage, which did not bode well given that similar engines were set to be used on the first stage of the N1. Ustinov and Afanasyev terminated the GR-1 project sometime in mid-1965, although Korolev was not easily convinced and evidently tried to continue manufacturing some elements. In early August, Deputy Minister of General Machine Building Gleb M. Tabakov expressly forbid the OKB-1 plant from continuing the construction of the missile's second stage. Later in the month, Korolev made an aborted attempt at getting Ustinov interested in a space launch vehicle version of the GR-1, designated the 8K513, for orbiting military satellites. It was, however, too little too late. The project was permanently terminated.[49] Vetrov recalled later:

> *[The GR-1's] engines were similar to the N1 engines. Many N1 problems would have been solved beforehand, if the [GR-1] had been tested. It was ready for test flights, but Korolev was not allowed to launch it. Why? Apparently, somebody was afraid it would have been a success.*[50]

The missile was later called the "Intercontinental Missile From Moscow to Leningrad," because that was about how far it had traveled—from one plant to another. Although it was never flown, full-size models of the GR-1 were displayed with much fanfare at Moscow parades celebrating the Great October Revolution.

The loss of the GR-1 was a severe blow to the N1 program. Its death knell effectively meant that all elements of the N1 would have to be tested in flight without any prior research and development tests on smaller vehicles. Originally, the N1 project had included smaller versions of the giant booster designated the N11 and the N111 for exactly this purpose. But with the delays in work on the base N1, work on the other two variants progressively moved into the background. Throughout 1965, after the GR-1's demise, Korolev continued to desperately push the N11 booster, a launch vehicle using the second, third, and fourth stages of the N1, as the only means to ensure a rational development program for the N1. On September 28, 1965, Korolev signed internal documents in support of developing the N11, in addition to the development of nuclear rocket engines for future boosters, but as the months passed by, it was increasingly clear that the Ministry of General Machine Building was not interested. As Korolev discovered painfully throughout 1965, the glory days of blank checks from the late 1950s were over. The Soviet piloted space program was in the midst of acrimony and fragmentation unimaginable during the Sputnik days. By comparison, the work on Apollo and Saturn V was

48. L. N. Kamanin, "In the Future His Name Will Probably Be . . ." (English title), *Ogonek* 7 (February 9–16, 1991): 28–31.

49. The 8K513 is mentioned in Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, pp. 129–30. See also I. Afanasyev, "The Mysterious 'Nine'" (English title), *Aviatsiya i kosmonavtika* no. 8 (August 1992): 34–35.

50. Vetrov, "Development of Heavy Launch Vehicles in the USSR."

virtually a designer's dream. There were, of course, technical and managerial problems in NASA's development of the Apollo-Saturn system, but the chronic waste and infighting that characterized the Soviet lunar program at the time was of a remarkable level. It is surprising that engineers managed to get anything done at all.

At the same time, the Western perception of the Soviet space program was one of deliberate and sustained progress. NASA Administrator James E. Webb, in testimony before the Senate Space Committee on March 8, 1965, told his audience:

> *We do not know whether they have selected some specific goal, such as a lunar landing, or even a duplication of our Apollo mission. . . . There is no evidence that they are building a booster as large as the Saturn V. . . . I think the information of most value to the U.S. Government is that they are conducting a very broadly based program, developing every competence necessary to select those missions that they believe will be to their advantage as they develop their competence.*[51]

The N1 Rocket

One of the "competences" that the Soviets were not busy developing was a high-energy cryogenic engine for the N1. From 1960 to 1964, every technical plan for the N1 had included LOX–liquid hydrogen rocket engines for the upper boost stages of the N1, much like the Saturn V. As a result of Korolev's vigorous push, and despite Glushko's attempts at smothering such attempts, Chief Designers Isayev and Lyulka were tasked with the creation of three different engines:

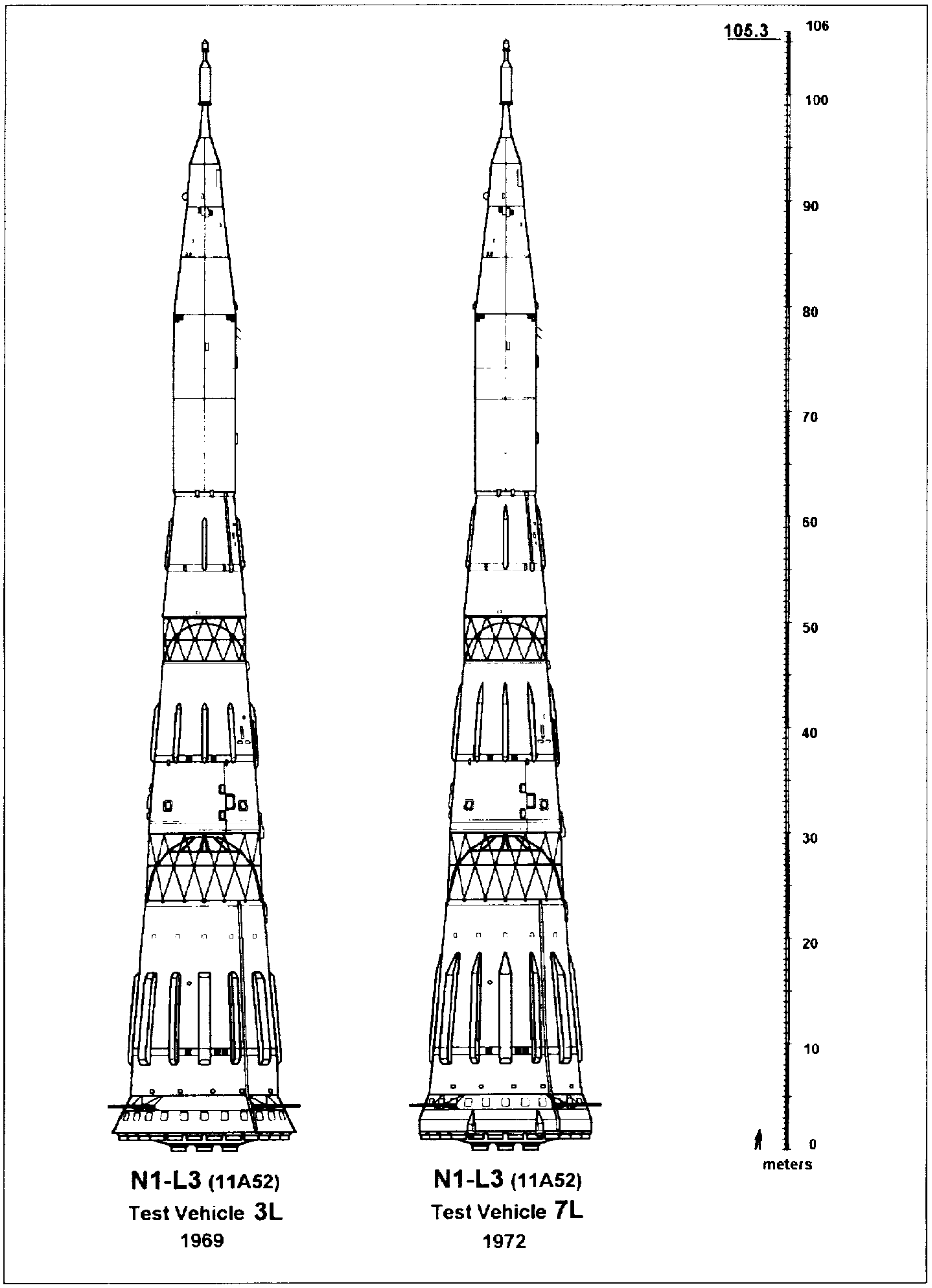
- The 11D54, with a thrust of forty tons for the N1's Blok V third stage
- The 11D56, with a thrust of seven and a half tons for the N1's Blok R upper stage
- The 11D57, with a thrust of forty tons for the N1's Blok S upper stage[52]

The 11D56 was developed by Isayev's design bureau, while the remaining two were developed by Lyulka's organization. By 1965, work on the engines was moving at a snail's pace. Isayev's engine was further ahead in the development program, but the lack of adequate testing facilities at NII-229 in Zagorsk forced significant delays in ground testing. Not one engine, in fact, had been fired on the ground by the end of 1966. With continuing delays in the liquid hydrogen program, Korolev and Isayev decided to delay the use of such engines to later versions of the N1. Thus, OKB-1 engineers had to explore other options in redesigning the N1. The solution was simple, but it cost the N1 significant losses in lifting capabilities. Gone were the liquid hydrogen third stages and Bloks S and R; instead, the engineers introduced two additional stages as part of the L3 payload, both powered by the more traditional LOX and kerosene. To minimize significant new work, OKB-1 engineers decided to use already prepared stages and engines. The first of the two additional stages, Blok G, was merely a single engine of the same type as the N1's third stage, but it was modified for higher altitude operation. The second of the stages, Blok D, was appropriated from the canceled GR-1's third stage.[53]

51. *Soviet Space Programs, 1962–65; Goals and Purposes, Achievements, Plans, and International Implications,* prepared for the Committee on Aeronautical and Space Sciences, U.S. Senate, 89th Cong., 2d sess. (Washington, DC: U.S. Government Printing Office, December 1966), pp. 388–89.

52. Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya,* p. 262. The 11D54 had a fixed chamber, while the 11D57 was capable of gimbaling.

53. *Ibid.,* p. 252. Strictly speaking, the 11D58 engine on Blok D was developed on the basis of both the 8D726 engine (GR-1 third stage) and the 11D33 engine (8K78 fourth stage). See *ibid.,* p. 226.



On the left is the early test variant of the N1 rocket as originally conceived in the mid-1960s. On the right is a slightly modified version designed in the early 1970s. The main external differences were in the fairing at the bottom of the first stage and the length of the vertical conduits on the first and second stages. (copyright Peter Gorin)

The adoption of LOX-kerosene for the first five stages of the N1-L3 complex allowed OKB-1 engineers to inch slowly to the completion of the final draft plan, which was completed and signed by Korolev and Mishin on November 11, 1965, amid the cacophony of uncertainty surrounding the fate of the project. Once again, the Keldysh Commission convened to examine the technical details and characteristics of the N1-L3, this time within the framework of the more detailed draft plan rather than the predraft plan. The approval was quick. In December 1965, the commission approved the plan, giving it the formal recommendation to begin manufacture based on the revised specifications.[54]

The Soviet N1 booster had the highest liftoff thrust of any rocket built in the history of space exploration. The basic rocket consisted of three conical rocket stages—Blok A (first stage), Blok B (second stage), and Blok V (third stage)—with a total length of 61.55 meters. The first stage was powered by thirty NK-15 engines, each having a ground level thrust of 154 tons. Of the thirty engines, twenty-four were installed around the perimeter, while the additional six were located at the center in the form of a ring. Total liftoff thrust was 4,620 tons, compared to the Saturn V's 3,404 tons. Burn time for the stage was in the range of 114 to 120 seconds. The stage also had four independent engines for roll control developed by OKB-1, each with a thrust of seven tons. The upper portion of the stage was not a solid frame, but rather was composed of a lattice-type structure that served as an interstage section between the first and the second stages. The top portion of the gigantic kerosene tank was visible through this lattice. A total of twelve conduits installed around the lower part of the exterior of the stage served as a means to carry fuel from the upper propellant tank to the engines at the base of the stage. The 30.09-meter-long stage had a base diameter of 16.87 meters, which did not include four large grating-type stabilizers near the base positioned orthogonally at ninety degrees to the main vertical axis.

The 20.46-meter-long second stage was powered by eight NK-15V engines, each with a thrust of 179 tons, giving a total stage thrust of 1,432 tons. Burn time was in the range of 130 seconds. The NK-15Vs were essentially NK-15 engines modified for work at high altitudes with longer and thinner nozzles. There were eight conduits for propellant transfer attached around the exterior of the stage. A lattice structure connected this stage to the next one, while roll control was effected by means of three small engines, each with six tons thrust. The third stage was powered by four NK-21 engines, each with a thrust of forty-one tons, giving a total third-stage thrust of 164 tons. The length of the third stage was just over eleven meters. Four external conduits on the exterior allowed propellant transfer, while four 200-kilogram thrusters provided roll control. All the engines of the first three stages used LOX as oxidizer and kerosene as fuel, were of the staged combustion cycle type, and were developed by OKB-276 under Chief Designer Nikolay D. Kuznetsov.

There were some unique features of the N1 that set it apart from most other space launch vehicles of the time. The propellant compartments of the first three stages of the vehicle were suspended spherical tanks separate from the external frame of the booster. The load-bearing configuration, and the relatively low density of the layout because of the use of spherical tanks, resulted in a significant diminution of the payload mass of the rocket. To circumvent this weakness, the engineers designed the tanks with unusually low specific mass, which, when combined with the high performance of the engines, effectively compensated for the drawbacks of having a nonmonocoque main rocket body. The spherical tanks were subject not only to loads from the pressure associated with tank pressurization but also the hydrostatic pressure of the liquid in them. Inertial loads and engine thrust were absorbed by the propellant compartments' load-bearing structure.

54. Vetrov interview, November 15, 1996.

There were both advantages and disadvantages to the spherical design of the tanks, certainly one of the most unusual features of the rocket. Spheres have minimal surface area relative to volume, and thus they are subject to lower heating loads and require minimal surface insulation. The engineers also concluded that with spherical tanks and prepump engine assemblies, the mass of propellant tanks would be smaller than those of rockets with regular propellant tanks as load-bearing structures. Although participants in the N1 program later claimed that the selection of tanks separate from the main body was primarily motivated by the search for better characteristics, in truth there was a more pressing reason for such an unusual design: the Soviet metallurgical industry was unable to produce aluminum sheets more than thirteen millimeters thick. For integral tanks, the engineers calculated that the thickness would have to be much greater; therefore, the only option was to use nonintegral tanks. One major deleterious factor was the fixed cost resulting from the design and construction of numerous size-specific welding jigs and dies, one for each of the six tanks. The booster's six spherical tanks, two in each stage, had diameters between 12.8 and 4.9 meters. The tanks themselves were built from a special magnesium-nickel alloy named AGM6, while the external casings of the N1 were built from duralumin D16. The Ye. O. Paton Institute of Electrical Welding at Kiev, led by Academician Boris Ye. Paton, developed a new method of arc argon welding with subsequent tests by x-rays, which allowed for the creation of lighter tanks than possible with earlier assembly methods.

Superior engine performance was achieved by the use of built-in impeller-type preliminary pumps and automatic control with igniters, a first for Soviet rocket engines and possibly in the world. This design was evidently based on the earlier NK-9 for the abandoned GR-1 booster, which had removable preliminary pumps. The idea stemmed from attempts to boost the performance of the engines for conditions that were more severe than projected launch conditions. The exhaust from the starter turbine of the engines of all the N1 main engines was directed below by using a diverter duct outside the nozzle exit area. This particular duct, in fact, was the reason why the engines themselves had a peculiar appearance—that is, they were closed-cycle (staged combustion cycle) engines, but with an exhaust duct outside the nozzle originating from the turbopump assembly. Through the entire period of development, Kuznetsov was forced to make significant changes to his original conceptions from 1962. One of Korolev's stringent requirements was that the engines be extremely lightweight. Despite major difficulties, Kuznetsov's NK-15 engine had one of the best dry mass–thrust ratios of rocket engines of this class and type.

A third unusual feature of the rocket was the built-in redundancy of the engines installed on the stages. Because there were so many engines on the first stage, Korolev's engineers raised the total reliability of the propulsion system by means of the in-flight shutdown of faulty engines. For example, if there was a malfunction in one of the engines on Blok A, signals from the Engine Operation Control (KORD) system's sensors were immediately sent to valves that mechanically cut off the feed of propellant components to the malfunctioning engine. In addition, the engine diametrically opposite to the faulty one would be switched off simultaneously to preclude unbalanced loads during the powered portion of the trajectory. In such a situation, the remaining engines would continue to burn for an extended period of 168 seconds with slightly increased thrust. If two pairs of engines failed, the remaining engines would burn to as much as 210 seconds, depending on the parameters of the trajectory. The KORD system also operated on the second and third stages. It could shut down two engines on Blok B and one engine on Blok V, with other engines continuing to fire.

Guidance and control systems for the N1, including the KORD system, were developed by Chief Designer Pilyugin at the Scientific-Research Institute of Automation and Instrument Building. OKB-1 developed the N1's tri-level telemetry system. This included the RTS-9 for slow-changing parameters, the BRS-4 for fast-changing processes, and the APG-4 automatic data recording system.

Another departure from previous Soviet rockets was the manner in which thrust vectoring was accomplished on the vehicle. Pitch and yaw on the first two stages were effected by mismatching the thrusts of opposing fixed peripheral engines. The third stage had the ability for traditional gimbaling. Roll maneuvers were accomplished by the small swiveling nozzles on the periphery of the rocket, the gases for which were transferred from the turbines of the turbopumps of the main engines.

Power for on-board systems was ensured not by batteries, as on all previous Soviet rockets, but by a special "electrical station" developed by Chief Designer Andronik I. Iosifyan's NII-627 in cooperation with Chief Designer Arkhip M. Lyulka's OKB-165. Electric turbogenerators operating on pressurants such as air or helium from the propellant tanks provided twenty kilowatts of power that was essentially "free of charge," fully automated, and maintained to a stable output by the use of a quartz oscillator.[55]

The N1-L3 lunar complex as a whole was designed at OKB-1's Department No. 3 headed by Yakov P. Kolyako, under the overall direction of Deputy Chief Designer Kryukov.[56]

The L3 Lunar Rocket Complex

The total length of the complete N1-L3 on the pad was 105.3 meters, of which the L3 portion was 43.2 meters. The L3 complex consisted of the following sections: Blok G (fourth stage) of the N1-L3 complex and the Lunar Orbital Station consisting of vehicles for work in lunar space. Blok G served as the TLI stage and was powered by a single NK-19 engine, almost identical to the engine used on the N1's third stage. With an external diameter of just over four meters and a length of eight meters, the stage was sufficiently small to be transported by rail to the launch site much like Chelomey's Proton booster, which had the same external diameter. Blok G would ensure a 480-second burn sufficient to reach 11.2 kilometers per second—that is, enough to boost the Lunar Orbital Station toward the Moon.

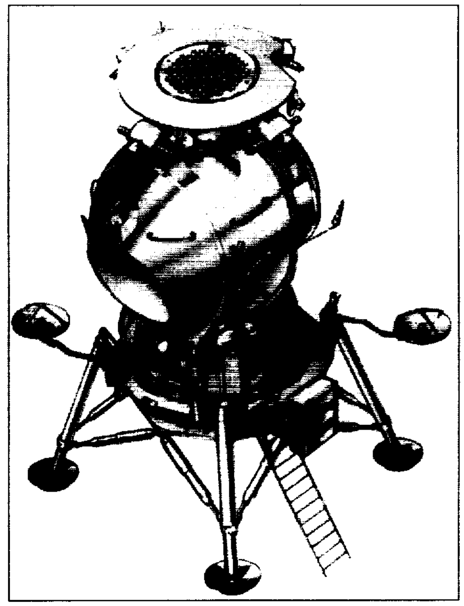
The Lunar Orbital Station consisted of the following components, in order from bottom to top on the launch stack:

- Blok D
- The Lunar Ship (LK)
- The Lunar Orbital Ship (LOK)

The Blok D stage, effectively the fifth stage of the N1-L3, was one of the most important components of the entire complex, because it would perform several burns critical to a successful lunar landing. These would include two to three burns on the way to the Moon for course corrections, the lunar-orbit-insertion burn, two to three corrections in this orbit, and the initial portion of the powered descent burn from lunar orbit. The stage thus had to be equipped

55. V. A. Lebedev, "The N1-L3 Programme," *Spaceflight* 34 (September 1992): 288–90; Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, pp. 248–55; Lardier, *L'Astronautique Soviétique*, p. 166; Afanasyev, "N1: Absolutely Secret: Part II"; Igor Afanasyev, "N1: Absolutely Secret: Part III" (English title), *Krylya rodiny* no. 11 (November 1993): 4–5; Dorofeyev, "History of the Development of the N1-L3 Moon Program"; N. I. Panichkin, "Some Results of N1 Development with Multi-Engine Powerplants," presented at the 10th International Symposium on the History of Astronautics and Aeronautics; Rebrov, "But Things Were Like That"; Mishin, "Why Didn't We Fly to the Moon?"; Marinin and Shamsutdinov, "Soviet Programs for Piloted Flight to the Moon."

56. Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, p. 252.



The Lunar Ship (LK) of the L3 lunar landing complex would carry a single cosmonaut to the surface of the Moon. Note the honeycomb structure on the docking plate at the top of the lander, which was capable of receiving the active docking probe on the LOK lunar orbiter. (copyright VideoCosmos Co., via Dennis Newkirk)

with a rocket engine that not only could function reliably in conditions of vacuum and weightlessness for more than a week, but also be capable of repeated firings. The critical engine used on the stage, derived from work on the GR-1 and the fourth stage of the 8K78 Molniya space launcher, was the 11D58 with a vacuum thrust of eight and a half tons and a specific impulse of 349 seconds. Engineers used a new kerosene derivative named RG-1 as the fuel, which ensured better cooling characteristics than earlier kerosene derivatives such as T-1. Propellant boiloff during space operations was also prevented by thermal insulation on Blok D itself. The oxidizer was LOX. In addition to the main engine, the Blok D stage also included two System for Ensuring Firing (SOZ) engine units, each with two throttle-capable motors of ten kilograms thrust (one reserve). These engines were for settling the remaining propellant of Blok D prior to firing in weightless conditions and were developed by TMKB Soyuz (formerly the Turayevo branch of OKB-300) headed by Chief Designer Vladimir G. Stepanov. The Blok D engine was one of the few rocket engines developed in-house at OKB-1, whose derivations can be traced back a decade to the steering thrusters used on the original R-7 ICBM. Like the earlier engines, Blok D work was overseen by OKB-1 Deputy Chief Designer Mikhail V. Melnikov.[57] The stage was 5.7 meters in length, with an outer jettisonable cylindrical shell, and had an external diameter of 3.7 meters.

The central component of the entire lunar stack was the LK lander, positioned on top of Blok D on the pad. Engineers at OKB-1's Department No. 93 under Ivan S. Prudnikov were responsible for designing and developing the vehicle under the overall supervision of Deputy Chief Designer Bushuyev. Although the predraft plan for the spacecraft was finished at the end of 1964, the primary elements of the design of the lander underwent significant changes by the time that the final scheme was adopted in 1967 or 1968.

The primary constraint that dictated the eventual design of the LK was mass. Computations showed that with the new and improved N1, along with Bloks G and D, such a lunar lander could weigh a maximum of five and a half tons. This was in comparison to the almost fifteen tons that NASA's Lunar Module weighed. Given the generally heavier microelectronics components and the relatively poor capabilities of Soviet computers, this was indeed a tall order for Korolev's engineers. The Soviets benefited from having only one cosmonaut in the lander, although this raised a number of other questions that would compromise safety. The mass limit meant that the Soviets would have to do with one set of engines for both landing and liftoff, instead of the two separate units as on the Apollo Lunar Module. This meant that unlike the two-stage Lunar Module, the Soviet lander would essentially be a one-stage vehicle.

57. *Ibid.*, pp. 226–28.

Save for its landing supports and some associated instrumentation, at liftoff, the LK would essentially be the same vehicle that had landed. After several changes in design in 1964, the basic chosen design was of a rocket stage with landing supports, topped off by a crew cabin. The crew cabin went through four different iterations before arriving at its roughly spherical shape. The final layout of the LK consisted of the following three sections:

- The Lunar Landing Aggregate
- The Lunar Takeoff Apparatus
- Blok Ye

The Lunar Landing Aggregate and the Lunar Takeoff Apparatus were analogous to the descent stage and the ascent stage, respectively, of the Apollo Lunar Module.

The Lunar Landing Aggregate was a 2.27-meter-diameter frame shaped like two truncated and ribbed cones with their bases attached to each other. The dimension of the chassis was determined by the distance from the main engine's nozzle exit section to the mainframe of the oxidizer tank, a scant 600 millimeters. A pressurized suspended instrument compartment with the *Planeta* ("Planet") landing radar and research equipment, with a mass of 105 kilograms, was attached on the exterior of the Lunar Landing Aggregate. This compartment included an "operational manipulator" (59.17 kilograms) and a lunar surface drill, which was capable of operating for sixty minutes. The Lunar Landing Aggregate also included two folding pencil-beam parabolic antennas of the radio communications system, in addition to three storage batteries, a fold-down ladder to allow the single cosmonaut to step down onto the surface, and four water-filled cylinders for the evaporator of the thermal regulation system. Later models were to include a small automated four-wheeled rover as well as a second scientific experiments package.

The actual landing supports for the ship, four legs attached to a frame, were collectively known as the Lunar Landing Unit. Because knowledge of the lunar surface in 1964 was still rather sparse, it was a challenge to set specifications for the landing supports. Korolev gave his engineers two primary requirements: (1) the ship should be able to safely drop from a height of one meter with a lateral velocity of one meter per second and (2) the landing gear should be able to prevent the lander from capsizing, even if the surface was sloped. Assuming that the "most likely" diameter of lunar craters would be seven meters, the slope limit for a landing was set at twenty degrees to the horizontal. These two restrictions served as the basis for almost twenty different proposals for landing supports, including a supporting ring much like an inflatable inner tube at the base of the vehicle. After examining tripod-support schemes, engineers finally settled on a four-support design as the most stable in the given conditions.

In its final conception, the Lunar Landing Unit was simply a honeycomb shock-absorbing structure with four legs, on which the spacecraft would rest on the Moon. Lateral supports for the legs muffled loads by compression and extension, while compressible near-vertical struts that ended in saucer-shaped footpads were for setting down on the surface. Four solid-propellant "hold-down" engines at the upper end of the landing legs were to fire at the exact moment of touchdown to ensure that the vehicle would not topple over on the surface or "hop" following first contact with the lunar surface.

The Lunar Takeoff Apparatus was the roughly spherical crew module for the lone cosmonaut during the lunar surface stay. It consisted of a pressurized cabin, a stubby cylindrical instrument compartment enclosed by a dome stuck to the side of the sphere, and a section for attitude control engines attached at the top. The cramped cabin itself was two and three-tenths meters by three meters in size and had an internal volume just enough for a standing cosmonaut in a spacesuit who would be harnessed securely in front of the instrument display and main control panel. The latter was designed and built by the Special Experimental Design

Bureau of the Flight-Research Institute at Zhukovskiy-2, near Moscow, under the leadership of Chief Designer Sergey A. Borodin. The panel was located to the right of the cosmonaut, allowing the pilot's right hand to control key parameters of the vehicle. All systems had both an automatic mode of control and a manual override.

A hemispherical concavity in the forward portion of the module contained a view port and a collimator device with a seven-degree angle of view on which an image of the landing site would be projected. During descent, the device would allow the cosmonaut to observe the landing area and the landing supports visually and take over manual control in an emergency situation. A large control stick would allow the cosmonaut to align the landing site on the collimator with the planned landing site, forcing the ship to travel to the desired location. A second port with a wide-angle sight was located above the concavity for the pilot to observe docking operations in lunar orbit with the "mother ship." The exterior of the cabin included four antennas, two omni-directional ones and two for rendezvous operations. Most of the instrumentation associated with the functioning of the crew cabin (orientation and control instrumentation, radio communications devices, and so on) was "pushed out" into the laterally placed oval instrument module. Two batteries, similar to the ones on the Lunar Landing Aggregate, were also installed on the instrument section to power the spacecraft after liftoff. The docking unit of the LK was installed on top of the vehicle much like on the U.S. Lunar Module. A flat annular radiator screen of the thermal regulation system around the docking unit protected the cabin against collision during a potentially incorrect alignment during docking in lunar orbit.

The designers chose the internal atmospheric pressure based on careful analysis because the pressure influenced the thickness of the main shell of the spacecraft, which in turn affected the mass. Unusually for the Soviet piloted space program, engineers initially chose a pure oxygen atmosphere, but because that would require the creation of extra accessories, special production technologies, and more safety measures, they fell back on the traditional ordinary air composition, but with a reduced nitrogen content. In the 560-mm Hg pressure, the cosmonaut would be able to remove his spacesuit helmet for eating and drinking. At the time, Soviet space engineers overwhelmingly preferred using airlocks for extravehicular activity (EVA), but installing an airlock on the LK was out of the question because of mass constraints. Depressurization, as with the Apollo Lunar Module, was the only remaining option. The cabin was designed such that both ground control and the cosmonaut could manually lower pressure. The internal climate of the cabin was maintained by a gas-liquid heat-exchange system and ventilator. The life support system was designed for a nominal operation of forty-eight hours, also limited by the power of the on-board batteries. All life maintenance systems, including the thermal regulation systems, were designed and developed by Chief Designer Voronin's KB Nauka (formerly OKB-124).

Throughout all operations from lunar orbit to landing and then subsequent takeoff, the commander of the mission would wear a special new semi-rigid spacesuit developed by KB Zvezda (formerly Plant No. 918) based at Tomilino under the leadership of Chief Designer Severin. The suit had to be flexible enough to allow for not only surface operations on the Moon, but also EVA in lunar orbit, when the moonwalking cosmonaut would transfer from the lander to the mother ship via a spacewalk. Severin's engineers developed a "portable suit" with armored head and torso portions and soft arm and leg sections. Instead of donning the suit like a typical article of clothing, the cosmonaut would literally enter the suit via a door at the backside. The suit's life support system was mounted in a large backpack attached to the door at the back of the suit. The backpack, nicknamed *Kaspiy*, included a life support system that would ensure thermal control, suit pressurization, air collection, purification, and dehumidification via a network of water-cooled plastic tubes. A hinged control panel on the chest of the cosmonaut provided control over eleven parameters of suit operation in addition to communications, each with a primary and backup loop. The suit also included a beacon system to allow ground controllers to determine the exact position of the cosmonaut relative to the lander. Within the lunar lander, because of mobility constraints, the cosmonaut would use a special finger control unit to reach inaccessible control buttons. The size of the spacesuit necessitated the use of a large *oval* hatch on the side of the Lunar Takeoff Apparatus, the first in the history of the Soviet space program. Severin's engineers named the suit *Krechet-94* ("Falcon"), with the "94" coming from the production index of the lunar lander, which was 11F94.

The guidance and control system of the LK was the heart of the ship. Several different design bureaus and institutes under the leadership of the Scientific-Research Institute of Automation and Instrument Building, headed by Chief Designer Pilyugin, designed and developed this system. The goal of the system was to control powered descent from lunar orbit, the landing, the takeoff, and the subsequent docking with the LOK. For the first time in a Soviet piloted vehicle, engineers used an on-board microcomputer to evaluate all incoming information from a variety of sensors, to evaluate the state of the lander based on preprogrammed algorithms, and then to take a course of action. The primary sensor system consisted of a set of gyroscopes as part of a three-axis gyrostabilized platform for spatial orientation, the Planeta landing radar for measuring velocity and altitude, the collimating sight, and other electronic measurement systems. These gyroscopes were developed by the Scientific-Research Institute for Applied Mechanics headed by Chief Designer Kuznetsov. Pilyugin's guidance system also included a semi-automatic system for controlling horizontal movement and angular velocity during rendezvous and docking operations, as well as a manual control system that would allow the pilot to select a landing site using the collimating sight. The pilot would use a two-channel lever for controlling attitude and relative change of horizontal velocity of the lander. Using the collimator to view the landing site, the pilot would feed data to the computer to produce commands for the necessary maneuvers to achieve an on-target and safe landing. Solar and planetary sensors would verify the accuracy of the orientation of the axes of the gyrostabilized platform.

At the time of liftoff from the Moon, the Lunar Takeoff Apparatus would detach itself from its landing supports (the Lunar Landing Unit) and additional instrumentation (the Lunar Landing Aggregate) attached to it. The Lunar Takeoff Apparatus would lift off with only the pressurized spherical compartment with the cosmonaut and the same engine unit that had landed it. Electrical and hydraulic connections between the two spacecraft, provided via an umbilical tower, would move away at a safe range prior to liftoff. One of the advantages of the design was that there was no need to develop a special and separate landing stage. For landing, the Blok D stage would reduce velocity in lunar orbit sufficiently so that only a relatively small engine was required for the disembarking operations. The throttleable main engine would enable the cosmonaut to hover over the lunar surface for a very short time to select a safe landing area. The hover time was less than a minute and was dictated by fuel volume of the main engine. Because of mass constraints, any science package aboard the LK would be very small, thus limiting actual scientific exploration.

The primary attitude control complex was located on top of the crew cabin in a 0.68-meter-tall compartment underneath the docking collar. The system consisted of two vacuum-fueled tanks (fuel and oxidizer) carrying 100 kilograms of liquid propellant and a propellant delivery system. There were four sets of engines, each with four thrusters, of which eight would have a thrust of forty-nine kilograms and eight would have a thrust of ten kilograms. The complex was divided into two independent circuits to overcome failure in one circuit. Each circuit controlled two forty-kilogram thrusters for pitch, two forty-kilogram thrusters for yaw, and four ten-kilogram thrusters for roll. The impulses from the thrusters were accurate enough to provide only nine milliseconds of thrust. Although Chief Designer Stepanov's TMKB Soyuz designed and developed the engines for the attitude control system, the organization declined to develop the remaining components, such as the actuator system, the propellant tanks, and the propellant-feed system, which were all created at OKB-1 under First Deputy Mishin's direct leadership.

During a nominal mission, the LK would communicate with Earth and the lunar orbiter via antennas that would operate in the meter, decimeter, and centimeter ranges. One antenna was installed on the docking ring for "weak" signals, while two omni-directional antennas were at the base of the crew cabin and two TV antennas were on the Lunar Landing Aggregate. A TV camera installed above the ladder would transmit live pictures of the cosmonaut's disembarkation onto the lunar surface.

A large docking assembly was installed on the top of the Lunar Takeoff Apparatus. Because of the mass and constraints, Korolev's engineers opted to design a system that, like the Soyuz 7K-OK, did not allow for internal transfer. While this considerably lightened and simplified the docking systems on the lunar lander and the lunar orbiter, this also meant that the landing cosmonaut would have to spacewalk his way from one ship to the other during transfer operations. Engineers rationalized this extra EVA by arguing that the cosmonaut would have to leave the spacecraft for surface operations anyway, and two more EVAs would not significantly add to mission complexity, as would a heavy and unique internal transfer system. In contrast to the Soyuz docking system, which had a pin-cone system, the lunar lander-orbiter system was designed exclusively for one docking. The active assembly on the orbiter ship had a pin and simple shock absorbers, while the passive assembly on the lander consisted of a flat circular honeycomb structure one meter in diameter. This plate contained 108 recessed hexagonal honeycomb components. During the single docking required in lunar orbit, it would be sufficient for the lunar orbiter to place the pin in any location in the plane of the passive assembly. The pin would penetrate the honeycomb structure and be captured by "claws" within, pulling the two spacecraft together. The connection was only mechanical; there were to be no electrical or power transfers between the two vehicles. The main rendezvous radar was placed adjacent to the passive docking unit, somewhat similar to a chimney, and was part of the *Kontakt* system designed and developed by NII-648 under Chief Designer Mnatsakanyan, the same organization responsible for Soyuz's Igla radar system. Two more antennas, also part of the Kontakt system, were installed on the exterior of the crew module.

Blok Ye, with a mass of two tons, was the main propulsion unit for landing on and lifting off from the surface of the Moon. This most critical component of all was not developed by OKB-1. When Korolev had first begun planning for the L3 complex, he had repeatedly stressed that the effort be a collaborative effort with some of the other major design bureaus involved at the time in aviation and missile development. As part of this conception of the lunar effort, Korolev had signed a preliminary agreement with Chief Designer Mikhail K. Yangel of OKB-586 to design and develop the rocket stages for the entire L3 complex: the Blok G, Blok D, Blok Ye, and Blok I stages. In January 1965, Yangel's First Deputy Chief Designer Vasiliy S. Budnik, one of Korolev's old protégés from the 1940s, wrote back to Korolev that OKB-586 would be unable to honor its commitment because of an overload of other work. In the following months, however, Korolev and Yangel eventually came to an agreement: the latter agreed to create only the engine for the LK.

The project to create this engine was fraught with difficulty, not the least because of its paramount importance in the N1-L3 lunar landing profile. Engineers calculated that the main and backup engine of Blok Ye had to have a reliability of 99.976 percent, certainly an unheard-of level in Soviet rocket engine industry. The overall responsibility for the stage's development fell on the shoulders of OKB-586 Chief Engineer Boris I. Gubanov, the same man who would twenty years later go on to head the development of the giant Energiya booster.

Being the heaviest element of the spacecraft and accounting for half the total mass, the Blok Ye engine unit was installed as low as possible within the lunar lander to ensure maximal stability. Its oxidizer (nitrogen tetroxide) tank was installed as a torus around the main engine itself. There was also a lenticular tank (unsymmetrical dimethyl hydrazine) for the fuel. It was rigidly attached to the lower part of the Lunar Takeoff Apparatus and had a throttleable single-chamber engine (RD-858) and a two-chamber nonthrottleable backup engine (RD-859), each with a thrust of 2.05 tons. The backup engine had two nozzles, one on each side of the primary engine nozzle in the center underneath the vehicle. The engine nozzles had covers to prevent debris from blocking the exhaust pathway. At liftoff, both engines were to fire until the primary one reached full thrust, at which time, following a computerized diagnosis of the operational characteristics of the primary engine, the backup unit would be turned off. The main engine of Blok Ye was designed to ensure vertical braking and horizontal maneuvering from an altitude of one to three kilometers down to a few hundred meters off the surface. Thrust could be reduced from two tons down to 860 kilograms.[58]

The third major component of the lunar stack, after Blok D and the LK, was the LOK. The spacecraft was designed as a modification of the early Soyuz 7K spacecraft, upgraded for operations in lunar orbit. Also known as the 7K-LOK, the lunar orbiter would be yet another variant of the basic 7K spacecraft, underlying the status of Soyuz as truly a universal spaceship for the next generation of Soviet piloted programs.[59]

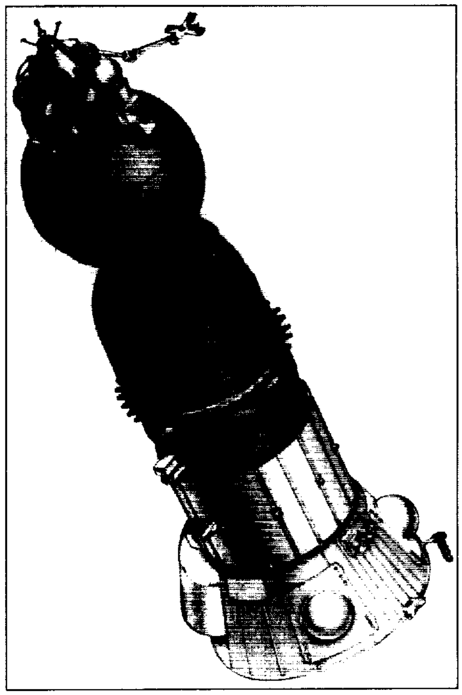
Like the basic Soyuz spacecraft, the 7K-LOK consisted of three major compartments; the major difference was the addition of a fourth section. These compartments were, from the forward end of the ship to the aft end:

- The living compartment
- The descent apparatus
- The instrument-aggregate compartment
- The Blok I engine

The first three sections served in much the same capacity as they would on Earth-orbital Soyuz missions. The living compartment was a spheroid section, which would allow the crew to rest on the long lunar trip and also serve as an airlock chamber for EVA operations. The 2.26-meter-long module had two hatches, one in the rear for transfer into the descent apparatus and one on the lateral side for exit into open space. The module also included a cupboard, one *Orlan* ("Bald Eagle") EVA suit, food, water, cameras, and life support systems. A control panel at the forward end of the sphere would allow the flight engineer cosmonaut to control the vehicle during approach and docking in lunar orbit. One major difference from the Earth-orbital Soyuz was the installation of the large orientation engine complex at the forward end of the entire spacecraft. This 800-kilogram section with a length of just over one and a half meters

58. *Ibid.*, pp. 252–54; V. Filin, "At the Request of the Reader: The N1-L3 Project" (English title), *Aviatsiya i kosmonavtika* no. 1 (January 1992): 28–29, 40; Afanasyev, "Unknown Spacecraft"; Marinin and Shamsutdinov, "Soviet Programs for Piloted Flight to the Moon"; Luc van den Abeleen, "Soviet Lunar Landing Programme," *Spaceflight* 36 (March 1994): 90–92; K. Lantratov, "The Fall From Orbit of the Last Soviet Lunar Ship" (English title), *Novosti kosmonavtiki* 25 (December 3–16, 1995): 32–36; *Russian Space History, Sale 6516* (New York: Sotheby's, 1993), description for lot 49; Yu. V. Biryukov, "Seventieth Birthday of Vladimir Fedorovich Utkin" (English title), *Zemlya i vselennaya* no. 3 (May–June 1994): 45–50; S. N. Konyukhov and V. A. Pashchenko, "History of Space Launch Vehicles Development," presented at the 46th Congress of the International Astronautical Federation, IAA-95-IAA 2.2.09, Oslo, Norway, October 2–6, 1995; S. Konyukhov and L. Andreyev, "M. K. Yangel: The Unknown Pages of Biography," presented at the 45th Congress of the International Astronautical Federation, IAA-94-IAA.2.2.619, Jerusalem, Israel, October 9–14, 1994; Interview, Vladimir Agapov with the author, September 30, 1996; A. Yasinskiy, "To Touch the Moon" (English title), *Apogey* 3 (January 1993): 2–3.

59. By 1965, the following variants of the Soyuz were under study or in design: 7K-OK for Earth-orbital operations; 7K-VI for Earth-orbital military operations; 7K-LOK for lunar-orbital operations; and 7K-PLK, 7K-OK-T, and 7K-L1 for circumlunar missions.



The Lunar Orbital Ship (LOK) of the Soviet L3 lunar landing complex would play an analogous role to the Apollo Command-Service Module, remaining in lunar orbit while the lander carried a single cosmonaut to the surface of the Moon. Note the skirt at the base of the spacecraft, a visible difference from the basic Earth-orbital Soyuz. (copyright VideoCosmos Co., via Dennis Newkirk)

included six spherical tanks containing a total of 300 kilograms storable propellant (unsymmetrical dimethyl hydrazine and nitrogen tetroxide) as well as four gas-filled cylinders for supercharging the tanks. The tanks would service four sets of engine units placed around the forward end of the spacecraft with their own rendezvous antennas. This orientation engine complex would carry out all attitude control for the large spacecraft during the critical operations in lunar orbit. The active end of the Kontakt docking system was placed at the very apex of the orientation engine complex, allowing for a single docking with the lunar lander.

The beehive-shaped descent apparatus was similar to the one on the basic Soyuz. It was 2.19 meters long and 2.2 meters wide and would carry the two-person crew during launch and landing. It contained control panels for the ship's systems, life support systems, an on-board computer, and a hatch at its apex for transfer into the living compartment. Throughout the flight, the capsule would be covered by thermal shielding insulation and a strengthened heat shield at the base, which would be cast off following reentry, but prior to touchdown on the ground. Like the 7K-OK Soyuz, the lunar 7K-LOK Soyuz was equipped with hydrogen peroxide engines for guiding the ship during reentry.

The cylindrical instrument-aggregate compartment was analogous to the one on the basic Soyuz, and it had a diameter of 2.2 meters and a length of 2.82 meters. It consisted of three sections: the pressurized instrument compartment, the unpressurized transfer compartment, and the aggregate compartment. The instrument compartment carried equipment for the ship's radio communications, telemetry, and command radio-link systems, as well as several attitude control engines for use during rendezvous, all of which were vastly improved from the version carried on the Earth-orbital Soyuz.

The fourth and final section of the Lunar Orbital Ship was the one that distinguished it from the original Soyuz, the Blok I engine stage. Unlike the Soyuz, the aft end of the ship ended in a unique skirt-shaped compartment, which contained the restartable Blok I engine as well as the power compartment. This engine, known as the 5D51, had a singular mission: to fire the spacecraft out of lunar orbit on its way back to Earth. The engine consisted of a two-chamber propulsion unit with a thrust of 3.388 tons, whose exhaust nozzles were located at the base of the large skirt. A separate single-chamber engine with a thrust of 417 kilograms, which was almost identical to the primary engine of the Soyuz spacecraft, was also installed at the rear end of the skirt. Capable of multiple firings (up to thirty-five times), this smaller engine would ensure orbital changes during lunar-orbit operations. Both engines were fed by a common propellant supply composed of a large 1.9-meter-diameter spherical tank separated by an internal partition for isolating the unsymmetrical dimethyl hydrazine and nitrogen tetroxide. The major portion of the tank was within the cylindrical aggregate compartment, with part of it jutting into the skirt. Although Yangel had agreed initially to build the Blok I engine, by May 1965, Korolev had signed a technical requirement with Chief Designer Isayev of OKB-2 to design, develop, and deliver the engine. Isayev was also responsible for the smaller engine, which was virtually identical to the one he was designing for the Earth-orbital Soyuz. The skirt at the end of the 7K-LOK spacecraft also included sixteen tiny engines for attitude control, fueled by the same tanks for the two main engines. The power compartment contained the *Volna-20* ("Wave") fuel cell for ensuring an electrical supply throughout the mission. It would be the first time that hydrogen-oxygen fuel cells were used on a Soviet piloted spacecraft. On contract to the Ural Electrochemical Company, the system had a mass of seventy kilograms and was capable of providing one and a half kilowatts at twenty-seven volts for a period of 500 hours. Maximum flight time for a fully equipped ship was about thirteen days. The LOK as a whole was just over ten meters in length, with a maximum diameter of 2.93 meters and a mass in lunar orbit of 9.85 tons.[60]

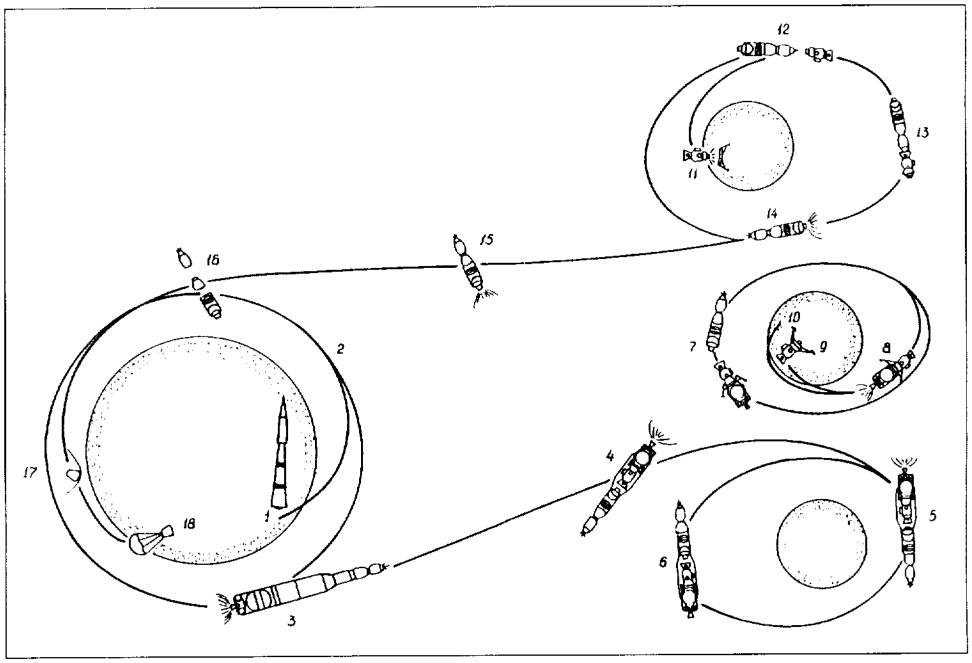
The final element of the N1-L3 stack was a launch escape tower, similar in design to the one on the Soyuz booster, but scaled upwards to support the increased masses of the living compartment and descent apparatus. The system, consisting of two levels of solid-propellant engines fixed to a tower above the launch stack, was equipped to remove the crew a further distance away from the pad than for standard R-7-class boosters, because the power of an N1 explosion on the pad would have a far wider radius of destruction.

The complete N1-L3 profile, as tweaked and modified over 1965–69 was as follows. The 2,750-ton complex is launched from Tyura-Tam with its two-cosmonaut crew. During operation of the Blok B second stage, the huge external fairing of the L3 and the emergency rescue system is jettisoned. The first three stages—Bloks A, B, and V—of the N1 then insert the entire ninety-one-and-a-half-ton L3 stack into a 220-kilometer orbit around Earth nine minutes after launch. Following a thorough systems checkout in Earth orbit for about 24 hours, the Blok G stage fires at a predetermined point on the complex's seventeenth orbit with a burn of 480 seconds at orbital perigee to insert the stack on a "free-return" translunar trajectory. A few minutes later, the Blok G stage is discarded. If something prevents the burn, the crew can try again two orbits later. During the 101-hour coast to the Moon, the Blok D stage is used for two minor mid-course corrections, the first about eight to ten hours after translunar injection and the second about twenty-four hours prior to the start of deceleration as the ship approaches the Moon.

After the approximately four days in coast, during the final approach to the Moon, the Blok D stage fires again for several seconds to reduce velocity of the stack to enter lunar orbit at an altitude of 150 kilometers. On the fourth and fourteenth orbits, the cosmonauts fire the Blok D engine to lower the altitude and insert the combined spacecraft into its operational landing orbit at 100 by twenty kilometers. The crew then checks all systems of the LOK-LK-Blok D stack from the living compartment of the LOK. At this point, the LK is still located inside a cylindrical adapter section, part of the internal fairing of the L3 complex; the commander of the crew then exits the LOK via a hatch in the living compartment wearing the Krechet-94 suit. A mechanical arm/boom is used to transfer the commander from outside of the orbiter to the fairing outside the lander. Once there, the cosmonaut opens an outer hatch and then an inner one to enter the crew compartment of the LK. The flight engineer of the crew wearing the Orlan spacesuit remains in the depressurized living compartment the entire time of the EVA to assist the commander if necessary.

After the commander checks all the systems in the lander, the LOK and the LK-Blok D combination separate from each other. The adapter sections then open around the LK and separate

60. Marinin and Shamsutdinov, "Soviet Programs for Piloted Flight to the Moon"; Afanasyev, "Unknown Spacecraft"; Lardier, *L'Astronautique Soviétique*, pp. 167–68.



The N1-L3 lunar landing mission profile: (1) launch; (2) insertion of L3 complex into Earth orbit by three-stage N1; (3) firing of Blok G (fourth) stage for translunar injection, jettisoning of Blok G, and discarding of lower and median payload fairings over Blok D; (4) mid-course correction by Blok D; (5) lunar-orbit insertion by Blok D; (6) EVA by commander from the LOK orbiter to the LK lander; (7) separation of the LOK from the LK and Blok D combination, followed by jettisoning of upper payload fairing over the complex and deployment of lander legs; (8) firing of Blok D for initial powered descent from lunar orbit until three kilometers altitude, followed by Blok D separation and LK ignition to complete landing; (9) exit of commander from LK onto lunar surface, with lunar surface time limited to twenty-four hours; (10) point of impact of spent Blok D stage; (11) Lunar Takeoff Apparatus liftoff from the Moon; (12) lunar-orbit insertion for the Lunar Takeoff Apparatus, followed by rendezvous operations between the LOK and LK; (13) docking of the LOK and Lunar Takeoff Apparatus, followed by EVA for commander to transfer from the apparatus to the orbital ship and then the undocking of the two ships; (14) LOK main engine firing for trans-Earth-injection maneuver; (15) mid-course correction by the LOK; (16) separation of the descent apparatus with the two cosmonauts from the rest of the LOK; (17) guided descent into Earth's atmosphere; and (18) landing of the descent apparatus by parachute onto Soviet territory. (files of Asif Siddiqi)

from the vehicle, revealing the lander for the first time. At this point, the Blok D stage fires for the last time to begin the landing phase. As a result of a command from the Planeta landing radar, at an altitude of one and a half to two kilometers, the Blok D stage ceases to fire, separates from the LK, and crashes near the landing site. The lander main engine, Blok Ye, then begins to fire, allowing the lander to hover over the landing site, with the engine being manually throttled by the cosmonaut. The commander has about twenty-five seconds to select a landing site and begin terminal descent procedures. The moment the landing pads touch the lunar soil, the four "hold-down" engines on the lander legs ignite to stabilize the lander; the entire time from Blok Ye engine ignition to landing takes one minute. If for some reason the landing fails, the commander has the option of throttling the Blok Ye engine back to full power and reentering lunar orbit to dock with the LOK.

Following landing, the cosmonaut rechecks the lander systems and the Krechet-94 lunar surface suit, depressurizes the LK, and exits through the small oval hatch on the side of the vehicle. A TV camera monitors the descent to the surface along a ladder. The cosmonaut, after disembarking on the surface, deploys a small set of scientific instruments on the surface, plants the Soviet flag, and takes photographs. The time on the surface is limited from one and a half to six hours. After reentering the spacecraft, the cosmonaut then pressurizes the lander cabin, removes the suit, and begins a rest period. At a predetermined time, the electrical, pneumatic, and mechanical links to the Lunar Landing Aggregate are severed, and the Blok Ye engine refires to lift the Lunar Takeoff Apparatus off the surface and enter a low lunar orbit.

The LOK then takes over the active role and performs a rendezvous using the Kontakt radar scanning system unique to the LOK. The complete rendezvous and docking regime is carried out automatically without the intervention of either the crew or ground control, although the flight engineer in the LOK has the option of taking over manual control. The maneuvering in orbit is carried out by the smaller engine similar to the Soyuz. After docking, the commander reenters the LOK via another EVA, bringing along surface samples. On the thirty-eighth lunar orbit, the docked lander crew cabin is jettisoned. On the following orbit, attitude control thrusters at the base of the LOK are then used to position the vehicle to fire its main Blok I engine on the far side of the Moon to boost itself on a trans-Earth trajectory. The total time in lunar orbit is limited to seventy-seven hours. During the eighty-two-hour coast back, the same engine carries out two mid-course corrections, the first at twenty-four hours and the second at forty-four hours after leaving lunar orbit. Near Earth, about two hours prior to reentry, the LOK separates into its three component parts, and the small descent apparatus with the crew performs a double-skip reentry to reduce velocity and reenters the atmosphere. Parachutes subsequently deploy for a crew landing on Soviet territory.[61]

Above and beyond the technical arcana, the N1-L3 complex was the most visible manifestation of the Soviet Union's response to U.S. President Kennedy's 1961 challenge. It was the mirror image to Apollo-Saturn, a shadow project given birth, designed, and created in complete and utter secrecy, whose only *raison d'être* was to send a Soviet citizen to the Moon before an American. Perhaps in the distant future, Apollo will probably be seen as a representation of the human imperative to explore space and leave the planet—an effort devoid of boundaries and races and cultures. But in the 1960s, both N1-L3 and Apollo were borne of more nationalistic and ideological concerns. These two behemoth projects were the representatives of two countries in a race for technological supremacy. For the Soviets, however, the race to the Moon was not only one to reach the surface of our only natural satellite, but also one to reach its vicinity first. This latter goal, a circumlunar mission, underwent some profound changes in 1965, creating yet another schism in the loosely held conglomerate of the Soviet space industry.

The Birth of the New L1

Chelomey had signed the draft plan for his LK-1 circumlunar spacecraft in mid-1965. A special commission, composed of several subcommittees representing leaders from the government, military, Academy of Sciences, and design bureaus, was then supposed to examine the complete technical plan for the complex and approve further work. Rarely in the piloted space program had a project come to a stop at this late stage, and Chelomey no doubt fully expected to begin producing flight models at this point. Korolev, however, had other plans. Since 1961, he had repeatedly put forward his own piloted circumlunar proposals on an almost annual basis, but all had fallen victim to either political expediency or simply poor planning on the part of Korolev's engineers. Some of these proposals, such as the 7K-9K-11K plan, depended on the use of smaller boosters to achieve their mission. A more pragmatic approach was to use

61. Afanasyev, "Unknown Spacecraft"; Marinin and Shamsutdinov, "Soviet Programs for Piloted Flight to the Moon"; Harford, *Korolev*, pp. 309–10.

the N1 booster, thus making the circumlunar mission simply a step in the achievement of a lunar landing. Korolev's First Deputy Mishin later recalled:

S. P. Korolev made repeated attempts to consolidate both our programs [circumlunar and landing] or to at least use the developments of one for the other as much as possible. The first attempt was made in 1961, when he proposed using the N1 (the first version, but with a 75-ton payload mass) for sending two cosmonauts around the Moon. . . . He made a second attempt in 1964, when, for that same purpose, he proposed using a rocket consisting of the [N1's] upper rocket stages B, V, and G. . . .[62]

Korolev doggedly pursued the latter idea, designated the N11, despite the Soviet government's full sanction of Chelomey's competitive circumlunar project. In retrospect, Korolev's idea seems to have made much more sense, given the exigencies of the Soviet lunar program at the time. Making the circumlunar project a part of the landing would have significantly alleviated the financial burden of moving ahead with two separate, parallel, and unrelated piloted lunar projects—Chelomey's to circle the Moon and Korolev's to land on it.

In January 1965, Korolev and his deputies commenced discussions to coordinate OKB-1's lunar plans. The N1 would launch the L3 to land on the Moon, while the smaller N11 would launch the new L1 spacecraft to circle around the Moon. Although details are still lacking on the L1, it seems to have been a modified Soyuz spacecraft, one designated 7K-PLK, intended exclusively for lunar orbital missions. Depending on the variant chosen, the mass of this new spacecraft would be in the range of 6.8 to 7.7 tons. On February 5, 1965, Korolev signed a preliminary technical prospectus on the L1 lunar *orbital* spacecraft, in anticipation of mounting a last-minute attack on Chelomey's project, which had the more modest goal of *circumlunar* flight. Such was the import given this shoestring effort that by March, Korolev and Mishin were both seriously considering making the L1 the primary thrust of OKB-1 instead of the L3, despite the complete absence of any official support. This effort may have been motivated by news of the "unhappy state of affairs" of Chelomey's program.[63] It seems that Korolev was simply waiting for the most opportune moment to attack his competitor's ambitions. In June 1965, Korolev ordered his deputies to prepare working documentation for the N11-L1 proposal in anticipation of the impending conflict between the two designers.[64]

Between August 5 and 12, 1965, the Interdepartmental Scientific-Technical Council for Space Research conducted a detailed evaluation of Chelomey's LK-1 project. According to a respected Russian historian:

All the subcommissions that reviewed the various sections of the design commended its feasibility and recommended it for implementation following the rectification of individual reproofs. However, the representatives of S. P. Korolev's OKB-1 expressed their dissent, which came down to the fact that the creation, within the OKB-52 [that is, Chelomey's design bureau] of a special vehicle for flying around the Moon was inadvisable, since the Soyuz ship produced in Podlipki [that is, at OKB-1] for the achievement of the same objectives was already in the process of being readied for flight testing.[65]

62. Mishin, "Why Didn't We Fly to the Moon?"
63. Semenov, ed., *Raketno-Kosmicheskaya Korporatsiya*, pp. 232–33.
64. Vetrov interview, September 30, 1996.
65. Igor Afanasyev, "Without the Stamp 'Secret': Circling the Moon: Chelomey's Project" (English title), *Krasnaya zvezda*, October 28, 1995.

Korolev's engineers ardently criticized the LK-1 for its limited number of crewmembers, its cramped internal volume, and its poor technical characteristics. In their opinion, many of the concepts used in designing the LK-1, which was Chelomey's first serious foray into piloted space vehicles, were based on half-baked ideas. In Korolev's written testimony at the end of the inspection phase, he alluded to the inability to fulfill deadlines for lunar missions and contended, "The development of a circumlunar vehicle in isolation from the primary objective [of a lunar landing] would be irrational." Thus, flying around the Moon should be "an experimental stage that will make it possible, under field conditions, to perfect the design and the systems of a spacecraft intended for carrying out a [landing] expedition to the Moon."[66] One of the few factors in Chelomey's favor during this period was the recent first successful orbital launch of the UR-500 booster, the same launcher intended for the circumlunar project.

At this time, Military-Industrial Commission Chairman Smirnov announced that he would preside over a meeting in late August to determine, once and for all, the course of the piloted lunar program. To fortify his position, Korolev prepared a letter to Soviet leader Brezhnev on August 14, which he intended to be the final blow to Chelomey. Speaking of the piloted lunar project, he wrote:

> *The problem is being solved in both the Soviet Union and the U.S.A. There are the following two stages to the solution of this problem: flying around the Moon with automatic apparatus and crews with the goal of carrying out observations and research of a preliminary character close to the Moon; and the landing of automatic apparatus and manned stations on the surface of the Moon with the goal of the continuous study . . . of the Moon. In our opinion, both these goals can be successfully solved with the N1 complex. The N1 complex will allow a more complete achievement of the first stage of work—circular flight around the Moon with a crew by creating a heavy artificial satellite of the Moon, carrying the necessary apparatus which would release lunar probes, radio-beacons, etc.[,] to the surface of the Moon. In this case with the first launch of the N1, the crew can be brought into [Earth] orbit with the aid of the well-tested carrier of the R-7 type. The second stage—landing on the surface of the Moon[—]can be accomplished with the aid of one flight of the N1 to . . . lunar orbit with the subsequent return of the lunar ship from its surface. The state of work on the N1 complex gives hope that within a year we can start flight work of the carrier and lunar system.*[67]

Once again, he invoked the Apollo program:

> *In the U.S.A. work on preparations and accomplishment of landing American astronauts on the Moon . . . has been accepted as a major national priority. The scale of work on the Saturn-Apollo theme with the effective utilization of liquid hydrogen and oxygen and the investment of forces and resources is huge. Judging from the work achieved, the U.S.A. will be able to accomplish a landing on the Moon in 1968.*

66. *Ibid.* That Korolev was personally opposed to Chelomey's LK-1 project is testified in N. P. Kamanin's diaries. His diary entry for August 16 includes the following: "Korolev called me and expressed his dissatisfaction with the fact that Chelomey was beginning to build a spacecraft to fly around the Moon. A long time ago Korolev had expressed the idea of a monopoly on the construction of spacecraft in his Special Design Bureau, and turned to find support on this issue from the military . . . [but] to develop cosmonautics it was useful for spacecraft to be created not by one but several firms." See Kamanin, "In the Future His Name Will Probably Be. . . ."

67. S. P. Korolev, "Report on the Organization of Work on the N1 Carrier" (English title), *Nauka i zhizn* no. 5 (May 1994): 24–26.