SUMMARY REPORT
FUTURE PROGRAMS TASK GROUP

JANUARY 1965

NASA

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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WASHINGTON, D. C. 20546

FOREWORD

This summary report of the Future Programs Task Group, directed by Francis B. Smith of Langley Research Center, presents the results of studies made during 1964 to answer inquiries made by President Johnson as to criteria and priorities for space missions to follow those now approved for the decade of the 1960's.

The President's request was for a review of space objectives in relation both to what we have learned from our space efforts and to the most important emerging concepts of missions needed for scientific purposes and for advances in technology. The President requested that our evaluation be made in relation to estimates of time and funds required to complete programs already approved and under way.

The Future Programs Task Group was established to develop materials to meet the President's request. It has studied: (1) the capability being created in the present aeronautical and space effort; (2) next-step or intermediate space missions that could use or extend this capability; and (3) a number of long-range missions which deserve serious attention. This summary report, resulting from these studies, provides a source of information on accomplishments to date and indicates the general time periods within which we can assume or forecast the availability of further scientific and technical knowledge. It is, in addition to providing a review for the President, a timely and valuable working document for use within NASA and other agencies as a foundation for further analysis and discussion looking toward decisions that can be based on a broad consensus as to values and timing.

A major concern of the Task Group has been to identify the areas and levels of technology required to accomplish the most likely future missions and to provide a basis for informed decisions relating to the allocation of resources and timing for those which may be approved. Considerable attention has been given to steps we need to take to insure that these areas and levels of technology are available as needed.

The long range developments section of this report contains a discussion of the technology development programs which are under way in NASA, and a number which should be given careful consideration in making future plans. Many of these programs are broadly based, but are also essential to provide optional means to accomplish the missions under study and also provide a strong basis for judgments bearing on the value, time and cost elements.

James E. Webb

James E. Webb
Administrator

CONTENTS

FUTURE PROGRAMS TASK GROUP SUMMARY REPORT

I. INTRODUCTION

The successful flight of Sputnik I, in its most fundamental aspect, meant that man had taken the first step toward the exploration of a new environment by means of a new technology. It also meant that in the USSR, which accomplished this first step, new horizons were opened and there was a surge of national pride and accomplishment. An internal drive was created that changed the posture of Soviet society and lifted it above many of the frictions and tensions of the existing status. Horizons were widened. Internationally, the leadership and image of the Soviet Union were vastly enhanced. The flights of Gagarin and other Soviet Cosmonauts added impetus to a marked degree.

In the United States and in the Free World, as we all know, the immediate effects were quite the opposite. However, since then, we have made tremendous progress under a broad based and balanced program aimed at achieving pre-eminence in aeronautics and space.

Down through the course of history, the mastery of a new environment, or of a major new technology, or of the combination of the two as we now see in space, has had profound effects on the future of nations; on their relative strength and security; on the relations with one another; on their internal economic, social and political affairs; and on the concepts of reality held by their people. From the elements of each such new situation which history records, all or most of the developments listed in Figure 1 have materialized.

The long-range effects of man's entry into space, in person and by instruments and machines, can be best forecast in terms of these considerations. As a new environment, space may well become as important to national security and national development as the land, the oceans and the atmosphere; rockets and spacecraft as important as automobiles, trucks, trains, ships, submarines and aircraft. The foreseeable returns from scientific advances, technical advances, and practical uses compare favorably with the returns yielded by the most vigorous past periods of exploration of newly opened segments of man's expanding frontier.

DEVELOPMENTS WHICH GENERALLY FOLLOW A NATION'S MASTERY OF A NEW ENVIRONMENT AND A NEW TECHNOLOGY

I. AN INCREASE IN POWER AND POSITION THROUGH:

   A. THE PRESTIGE OF BEING FIRST IN NEW ACCOMPLISHMENTS; OF BEING IN CONTROL OR SHARING CONTROL OF THE NEW ENVIRONMENT; AND OF POSSESSING NEW KNOWLEDGE AND TECHNOLOGY.

   B. THE ESTABLISHMENT OF STRATEGIC INTERNATIONAL POSITIONS FOR TRAFFIC, COMMUNICATIONS, AND TRADE.

   C. WIDE USE OF NEW RESOURCES.

   D. MILITARY CAPABILITY THROUGH USE OF THE NEW ENVIRONMENT AND TECHNOLOGY.

   E. AN INCREASE IN INITIATIVE, PRIDE AND DRIVE TOWARD ACCOMPLISHMENT IN ALL WALKS OF LIFE.

II. THE APPEARANCE OF NEW DEVELOPMENTS IN THE RELATIONS AMONG NATIONS:

   BY NEGOTIATION, BY COOPERATION, OR BY CONFLICT.

III. CHANGES WITHIN NATIONAL SOCIETIES AS A RESULT OF THE FORCES LISTED ABOVE; OF ACTIONS TAKEN TO COMPETE IN THE NEW ENVIRONMENT AND TO DEVELOP AND USE THE NEW TECHNOLOGY; AND OF THE INTERPLAY OF NEW KNOWLEDGE, NEW THOUGHT, INCREASED RESOURCES, AND CHANGED SOCIAL RELATIONS.

Fig. 1

If these larger considerations of the space effort are to be adequately dealt with in terms of national policy, they must be translated into broad objectives in order that particular programs and missions can be defined and evaluated. For the United States, these objectives relate aeronautics to space and are contained in the Space Act of 1958. They are outlined in Figure 2.

BASIC NASA AERONAUTICAL AND SPACE OBJECTIVES

I. THE SCIENTIFIC MEASUREMENT AND UNDERSTANDING OF THE SPACE ENVIRONMENT.

II. THE DEVELOPMENT OF A BROAD-BASED NATIONAL CAPABILITY FOR MANNED AND UNMANNED OPERATIONS IN SPACE AND CLOSE COOPERATION WITH THE DEPARTMENT OF DEFENSE AND OTHER AGENCIES HAVING CURRENT OR POTENTIAL NEEDS RELATED TO SUCH CAPABILITIES.

III. THE DEVELOPMENT OF THE PRACTICAL USES OF SPACE.

IV. CONTINUED ADVANCEMENT IN ALL AREAS OF AERONAUTICS IN ORDER TO MAINTAIN WORLD LEADERSHIP IN THIS FIELD.

V. AN ADEQUATE LEVEL OF RESEARCH AND DEVELOPMENT TO SUPPORT OTHER GOVERNMENT AGENCIES WITH NEEDS OR INTERESTS IN AERONAUTICS AND SPACE.

VI. THE BRINGING TOGETHER OF GOVERNMENT, INDUSTRY, AND UNIVERSITY CAPABILITIES INTO AN EFFECTIVE NATIONAL SYSTEM FOR MEETING THE NEEDS OF SPACE EXPLORATION AND USE.

VII. THE MAINTENANCE OF A TECHNOLOGICAL BASE IN AERONAUTICS AND SPACE ADEQUATE TO MEET ALL NON-MILITARY NEEDS.

VIII. THE STRENGTHENING AND EFFICIENT UTILIZATION OF THE NATION'S AERONAUTICAL AND SPACE-RELATED RESOURCES IN SCIENCE, ENGINEERING AND TECHNOLOGY.

IX. THE MAXIMUM UTILIZATION OF THE SCIENTIFIC AND TECHNICAL RESULTS OF THE SPACE EFFORT FOR NON-SPACE PURPOSES.

X. THE USE OF SPACE FOR FURTHERING INTERNATIONAL COOPERATION AND UNDERSTANDING AND FOR THE GOOD OF ALL MANKIND.

Fig. 2

Under the Space Act, NASA bears the general responsibility for continuously providing an adequate underlying aeronautical and space capability and cooperating with the military services and other agencies which have, or anticipate, specific missions and uses. In 1958, and again in 1961, two major periods of wide debate and assessment brought decisions to undertake missions and programs which accelerated our progress toward the achievement of these objectives. The capability which has been created through the work thus begun and now under way will be the basis for this analysis.

First, however, we need to understand that we face certain conditions and constraints.

II. SUMMARY OF CONDITIONS AND CONSTRAINTS FOR FUTURE PLANNING

In planning future missions in space, there are a number of conditions and constraints which must be considered. These are:

a. The space activity of the Soviet Union indicates a vigorous program in near-Earth, lunar, planetary, and manned space fields. The Soviet announced program is still broader, and extends to communications and meteorology. The Russians have exploited their initial advantage in launch vehicle power, have upgraded that power, and have shown great skill in exercising their systems. The United States must, of course, meet its own needs in space rather than accept the judgment of another nation. We must decide the pace at which our needs will be met. Our decisions must be related to other national needs and priorities and we must recognize that at this early stage in space exploration the full meaning of space cannot be forecast. Still, Soviet actions must be taken into account as indicating values that they see and seek. Their skill in exploiting space spectaculars to their advantage in the areas of national prestige and international politics must be recognized and countered. At a minimum, the United States must achieve a basic knowledge of space environments and systems, and must maintain an operational capability sufficient to guarantee full access to and use of space.

b. As a result of the work of the past 6 years, we already have a broad base of scientific and technical knowledge about many factors of space and are entering a period of rapidly expanding launch capability which we will use to achieve a far broader scientific and technical base and to gain wide experience in manned space flight. Our seven successful Saturn I test launches point to the operational use of the much greater boost power of the Saturn IB by 1966 and to the use of the giant Saturn V booster by 1967. The Defense Department's Titan III-C booster is expected to begin flight testing in the near future. The application of Centaur as an upper stage can augment considerably the capabilities of the larger vehicles.

In the critical area of determining man's capabilities in space, Gemini operations with two-man crews, supported by a world-wide net of stations and recovery forces and managed from our new mission control center at Houston, will begin in 1965. Hundreds of man hours of flight experience with mission durations up to 14 days will provide experience in rendezvous, docking, manned performance outside the spacecraft and other operations, adding large increments to our knowledge. Apollo operations with three-man crews beginning in 1967 will significantly extend the Gemini experience so that by the time we undertake the first manned landing on the Moon, the Gemini and Apollo programs will have provided thousands of man hours of flight time. Additional general and specialized manned flight experience is expected from the Manned Orbiting Laboratory (MOL) under development by the Department of Defense.

In science, the measurements and knowledge acquired over the next few years will become increasingly valuable as they are used and refined. More sophisticated questions will be asked by scientists and more sophisticated spacecraft, such as the Orbiting Astronomical Observatory (OAO) and the Surveyor, together with manned spacecraft, will be used to search for answers.

In communications and meteorology, the imminent operational use of satellite systems will answer many questions as to the current value of these systems. Further research will answer many questions as to their potential for the future.

These activities will uncover new uses of space, force the solution of many emerging technical problems, and reveal others not now identified. This has been the way of all new areas of scientific and technical development, and it will certainly be true in space.

It is, therefore, essential that in making plans for the future all elements required for a balanced program and the practice of maintaining maximum flexibility be preserved.

c. The United States decided in 1958, and reaffirmed the decision in 1961, to move rapidly in all areas of space exploration. The wide range of power in the boosters in our National Launch Vehicle Program and the wide scope of completed and on-going missions reflects this fundamental decision. Our missions extend from sounding rocket exploration of the near-Earth atmosphere; to orbiting solar, geophysical and astronomical observatories; to manned exploration of the Moon; and to probes out to Venus and Mars. New capabilities, both in science and in the practical uses of space, have been developed and these capabilities are being rapidly expanded.

As we emerge from this initial period of space exploration, we can see that our 1958 decision to mount a broad, balanced program was a wise one. The scientific and technical returns to date clearly indicate the value of continuing within this framework. In areas where a definitive point has not yet been reached, as in manned flight, we face the urgent need to push forward to such a point.

d. Of major importance to future planning is the fact that, in NASA, approved programs are making heavy demands on limited financial and human resources. At present budget levels, this situation will continue for at least another year. Manned flights of Gemini will begin shortly; the Saturn IB must be completed and mated to the Apollo spacecraft for manned flights in earth orbit; the Saturn V must be brought along and everything possible done to achieve a manned lunar mission in this decade. In addition, both the Lunar Orbiter and Surveyor programs must be pushed vigorously and in proper relation to the Apollo requirements in design, production and flight.

Unless the NASA budget is to be increased, the present situation requires that priority be given in the near-term period to insuring that these programs proceed without delay, under vigorous budgetary control, and produce successful results. As this is accomplished, we can, within present budgetary levels, begin to make plans to move toward other large goals in space and undertake new missions. The Saturn IB/Centaur booster can provide the power for a large Voyager mission to Mars by 1971. The Apollo system will gain in reliability through repeated use over the next several years and will then provide much of the launch and spacecraft capability to meet expanded goals.

Therefore, unless an urgent National need arises, large new mission commitments can, better than in previous periods, be deferred for further study and analysis based heavily on ongoing advanced technological developments and flight experience.

e. During the past 6 years, the United States, in addition to carrying out many specific missions, has been engaged in creating a large, basic space capability. This includes a versatile family of launch vehicles and spacecraft, and the trained manpower and facilities to continue to produce and use them. Other things being equal, these capabilities, with the resultant gain in reliability, should be used to the maximum degree in future missions. If such capabilities are not used they deteriorate. Their use can achieve lower costs and greater assurance of success for many desirable future programs than can otherwise be achieved.

In summary, the NASA manned program for the future, and the developments leading toward it, illustrated schematically in Figure 3, require that we must:

<u>First</u>, apply available resources to every aspect required for success in the on-going programs, especially the Apollo program, and to bring these to fruition as quickly and efficently as possible.

<u>Second</u>, define an intermediate group of missions and work toward them using the capability being created in the on-going programs.

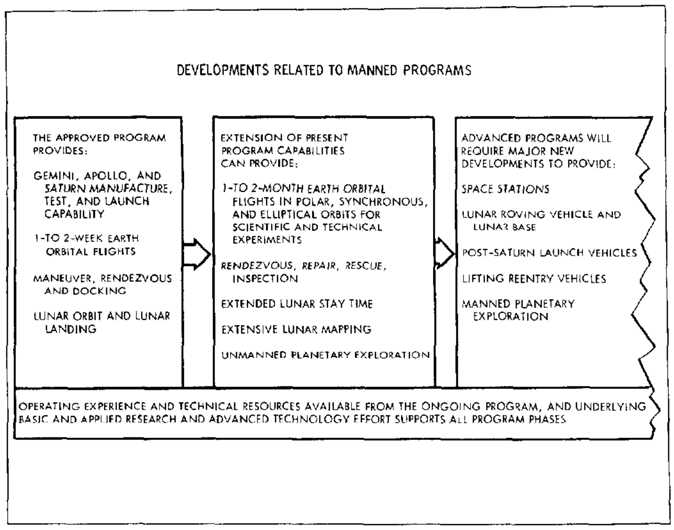


Fig. 3

The launch vehicles and spacecraft being developed in the Apollo program are of such size, versatility and efficiency as to be of decisive importance in achieving and maintaining pre-eminence in space during the next period. Significant use of this capability over and above the presently programmed Apollo mission can be made as early as Calendar Year 1968, if small increments of additional resources are committed soon.

As now planned, by 1969 the Apollo program will build up to a capability to launch six Saturn IB systems and six Saturn V systems annually. The Saturn IB will boost 35,000 pounds or more to Earth orbit and, when mated to the Centaur, can send up to 10,000 pounds of unmanned payload to Mars, of which up to 5,000 pounds can be landed on the planet. The Saturn V will place 250,000 pounds or more in Earth orbit or send 95,000 pounds to the vicinity of the Moon. These powerful boosters, in these numbers, will make it possible for the first time for this Nation to regularly launch large payloads in operational space systems for a wide variety of purposes, in manned and unmanned flights in the Earth-Moon region, and for unmanned planetary missions.

Further, the present program will provide the industrial base and operational capability for producing and using eight Apollo-LEM spacecraft systems annually. A broad spectrum of manned space flight missions can be carried out with these systems. In near-Earth space, missions can include low inclination, polar, or synchronous orbits to accomplish scientific, technological, and applications objectives. Such missions can utilize extensive maneuvering and extra-vehicular operations. Such flexible multi-purpose use of the Apollo-LEM system can be accomplished by reduction of crew size and utilization of payload margins either for expendable supplies or propellants. It is entirely feasible to extend the manned Earth orbital stay time of the Apollo-LEM system to 30 days and possibly to as much as 90 days. Similarly, the Apollo-LEM system capability for lunar missions can be extended to permit detailed mapping of the Moon from lunar polar orbit; and the Lunar Excursion Module can be used as a truck to provide supplies for longer stay time and increased exploration capability on the lunar surface.

For unmanned planetary exploration, the Saturn IB, using the Centaur as a third stage, can not only launch a 10,000-pound Voyager spacecraft with a 5,000-pound lander to Mars for the 1971 opportunity, but can meet the increased volume and power requirements for later years.

If one or more such missions are selected, intensive study should begin immediately and preparations be made for undertaking firm commitments for procurement of additional launch vehicles and spacecraft about July 1966. Program definition of the Saturn IB-Centaur mating should begin immediately, but major flight hardware expenditures need not begin until 1966. With respect to modification of spacecraft life support and power systems for extended manned operations, the fabrication of components required for specific missions would not be required until 1966, but supporting activity, including advanced development, should be expanded above the present level of effort.

Third, continue long range planning of missions that might be initiated late in this decade or early in the 1970's. Appropriate research and development work to provide the science and technology for these missions should be carried forward. Such long range plans could include, for example, such manned areas as an Earth-orbiting space station, a lunar base with roving vehicle, and a planetary spacecraft.

This suggested pattern for future planning is reflected in the following detailed presentation of (1) present capabilities; (2) intermediate missions; and (3) long-range missions. It should be noted that the boundary between categories (2) and (3) is subject to constant re-evaluation and possible revision in the light of increased knowledge and changing events.

III. MAJOR CAPABILITIES EXISTING AND UNDER DEVELOPMENT

The broad categories of capabilities which have been developed during the past 6 years, or are to be developed in current programs, are shown in Figure 4. The major categories are Aeronautics, Satellite Applications, Unmanned Exploration, Manned Operations, Launch Vehicles, and Technology.

MAJOR CAPABILITIES EXISTING OR UNDER DEVELOPMENT

AERONAUTICS
- R&D HYPERSONIC AIRPLANES
- OPERATIONAL SUPERSONIC MILITARY AIRPLANES
- COMMERCIAL SUPERSONIC AIRPLANES
- IMPROVED SUBSONIC AIRCRAFT INCLUDING V/STOL

SATELLITE APPLICATIONS
- SATELLITE PICTURES OF EARTH WEATHER
- INTERCONTINENTAL COMMUNICATIONS (INCLUDING TV)

UNMANNED EXPLORATION
- NEAR-EARTH EXPLORATION
- SOLAR EFFECTS
- PLANETARY AND INTERPLANETARY PROBES
- LUNAR PROBES AND LANDERS
- BIOSATELLITES

MANNED OPERATIONS
- MAN IN EARTH ORBIT (1 TO 2 WEEKS)
- MANEUVER & RENDEZVOUS
- LUNAR ORBITING, LANDING AND RETURN

LAUNCH VEHICLES
- UP TO 125 TONS IN EARTH ORBIT
- UP TO 47.5 TONS TO ESCAPE

TECHNOLOGY
- POWER SUPPLIES OF INCREASED POWER AND LIFE-TIME AND DECREASED WEIGHT
- MORE ACCURATE GUIDANCE AND CONTROL
- INCREASED COMMUNICATIONS CAPABILITY
- MORE ACCURATE STABILIZATION
- LIFE SUPPORT FOR LONG PERIODS
- IMPROVED LANDING CONTROL SYSTEMS
- INCREASED RELIABILITY

Fig. 4

Aeronautics

The aeronautical program of NASA represents a continuation of a pattern of research activity developed by the National Advisory Committee for Aeronautics (NACA) over a period of more than 40 years. The in-house effort of this program is primarily basic and applied research activity at four NACA centers which were in existence in 1958 (the Langley Research Center, the Lewis Research Center, the Ames Research Center, and the Flight Research Center). This consists of in house and contracted-out work aimed at practical solutions of advanced problems of flight, but excludes the development of complete aircraft. Over many years the latter has been the responsibility of industry and other branches of the government with whom the NACA and now the NASA has developed effective working relations of collaboration and support.

For a number of years, the major portion of the NASA aeronautics effort has been in two areas. First, a basic research program in atmospheric flight. Three significant areas have received increasing attention -- major increases in maximum flight speed, major decreases in minimum flight speed, and major increases in operational flexibility. Second, a continuing research and technology program in support of military and other government agencies and industry has pointed to continued evolutionary improvement of existing aircraft types.

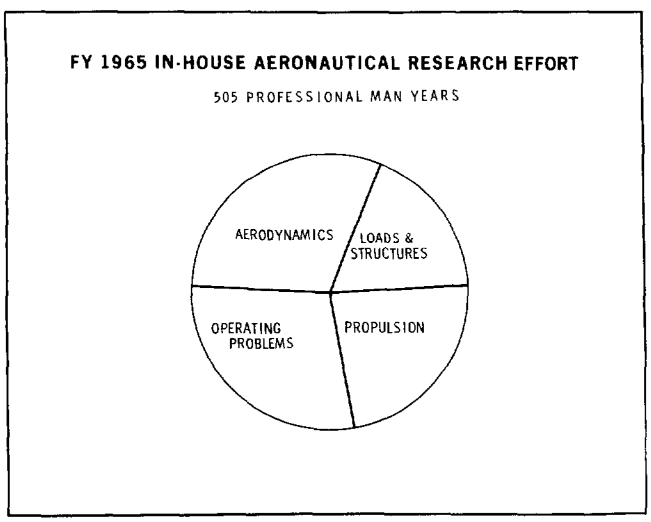


Fig. 5

Figure 5 shows the aeronautical research effort of NASA classified by broad areas and gives an idea of the size and distribution of the effort for Fiscal Year 1965. In-house effort is carried on by about 500 research professionals supported by 1500 additional in-house personnel. In addition to the costs of these personnel, $35.2 million of R&D funding for contracted-out research and development supports this effort.

Each of the four areas, Aerodynamics, Loads and Structures, Propulsion, and Operating Problems, is concerned with one of the major building blocks of aeronautics.

Aerodynamics, as the term is used here, is the study of the airflow around aeronautical vehicles and the resultant effects on the vehicles themselves. These effects lead to lift, drag, stability, controllability, and -- at higher speeds -- aerodynamic heating. The airflow also is responsible for the loads imposed on a vehicle. These loads must be predicted accurately for each vehicle and the vehicle structure designed to withstand them. To be efficient, each aircraft must use materials in a manner which will result in the lightest structure for a given design mission. Having determined the basic configuration, it is necessary to choose the appropriate type of propulsion system -- propeller, turbojet, ramjet, or rocket -- then to blend the structure and propulsion system into the best overall vehicle. This blending always requires compromises, and the strength of NASA's advanced research and technology programs is the Nation's foundation and main reliance for sound judgments.

The operating problems of aircraft, such as noise, sonic boom, flight safety, and aircraft flying and handling qualities, make up the fourth area of NASA's aeronautics work. In general, work in this area covers the many aspects of the aeronautical program not solely related to the other three academic-discipline areas.

Fig.6

Some illustrations of aircraft concepts that have drawn heavily on past NASA research, and are currently receiving heavy support to work out detailed problems of technology encountered in their development, are shown in Figure 6.

The novel aircraft are three V/STOL (Vertical-and Short-Take-Off-and-Landing) types. The upper tilt-wing type illustrates the tri-service, Vought-Hiller-Ryan C-142 that is currently undergoing initial flight tests. The tilt-duct type is another tri-service machine, the Bell X-22A now under construction. The fan-in-wing type shown at the bottom is the Army supported GE-Ryan XV-5A and is currently being flight tested.

F-III SUPERSONIC FIGHTER

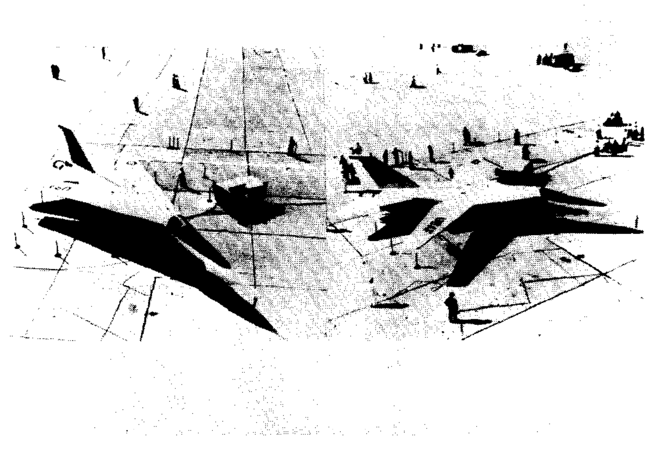


Fig. 7

Development of supersonic military airplanes such as the F-111 shown in Figure 7 has been made possible by years of cooperative work by industry, the military services and the NACA and NASA. NASA is now working with other government agencies and with industry toward the development of a supersonic commercial air transport (SCAT).

Figure 8 shows one model of the supersonic transport being tested in the 40-by 80-foot wind tunnel at the Ames Research Center.

LARGE WIND-TUNNEL MODEL OF SCAT 17

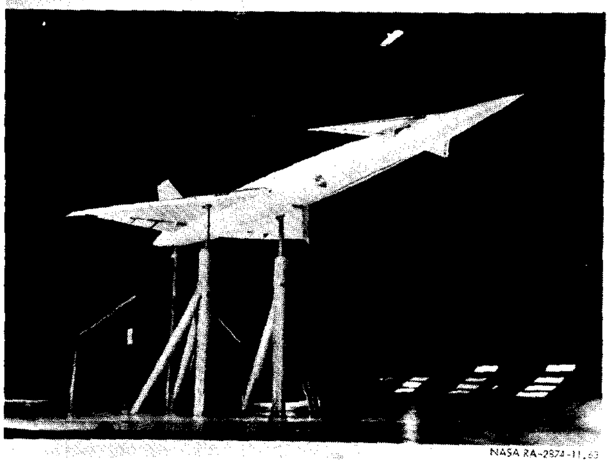


Fig. 8

Satellite Applications

Significant successes have been achieved in NASA's applications satellite program during the past 6 years and the results are now being used to establish operational systems.

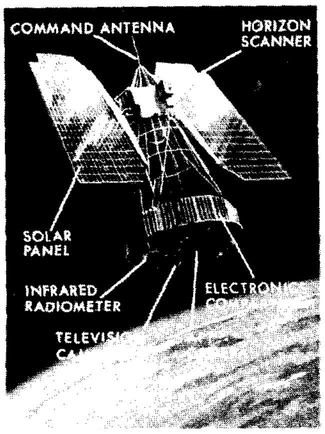
In the area of meteorology, nine TIROS satellites, launched since 1960, and one Nimbus satellite, launched in August 1964, have demonstrated the feasibility and value of Earth weather research and observation from satellites in orbit. One of the primary uses of the pictures returned by the TIROS satellite has been the identification and tracking of weather storms, including some 70 hurricanes and typhoons.

Based on NASA research and development success with TIROS, the United States Weather Bureau has adopted a modified TIROS system for its operational satellite system. This is expected to be ready during the winter of 1965-1966.

In the meantime, while we work toward operational systems, data from NASA's experimental TIROS weather satellites are used routinely by the Weather Bureau in the preparation of daily forecasts as well as for analysis in the area of climatology. The DOD also uses these data in the preparation of local forecasts in remote areas.

The Nimbus research and development weather (meteorological) satellite shown in Figure 9 is a significant advance over TIROS. Through three-axis stabilization and Earth orientation, continuous data on the Earth's weather is provided throughout its orbit. Its solar cells provide over 400 watts of power (10 times that of TIROS), and it can carry numerous types of meteorological experiments now emerging from our research program.

NIMBUS METEOROLOGICAL SATELLITE



GROSS WEIGHT	835 LBS.
SENSOR WEIGHT	150 LBS.
PEAK POWER	470 WATTS
STABILIZATION	ACTIVE 3 AXIS
DESIGN LIFE	SIX MONTHS TO ONE YEAR
LAUNCH VEHICLE	THOR-AGENA B
ORBIT	APOGEE-574 MI. PERIGEE-263 MI. PERIOD-98.2 MIN INCLINATION-98
FIRST FLIGHT	AUGUST 28, 1964

Fig. 9

In addition to its television transmission system, the first Nimbus carried an Automatic Picture Transmission (APT) system and a High Resolution Infra-Red (HRIR) system. The APT system permits read-out of local cloud cover pictures by inexpensive ground stations, as shown by Figure 10, and will provide weather information to Department of Defense installations and the numerous foreign countries that have purchased or built, or plan to build, ground stations.

A most significant achievement of Nimbus I was demonstration of the capability and value of the HRIR system, illustrated in Figure 11. This system enables us to obtain for the first time, in pictorial format and on a real time basis, cloud cover information from the dark side of the Earth. Cloud cover pictures such as these are reconstructed from measurements taken at night, and give an indication of cloud height as well as area coverage.

As illustrated in Figure 12, in the field of communications, the Echo passive satellite, and the Telstar, Relay and Syncom active satellites have experimentally proved out the technology for reliable, long-range point-to-point transmission of radio, television, telephone, teletype and facsimile via satellite. As a result, the Communications Satellite Corporation is now undertaking an international communications satellite system whose initial "Early Bird" satellite is based on NASA's Syncom.

Recently Syncom III, shown in Figure 13, transmitted real-time television of the Olympic Games from Japan to the United States. The precision achieved in the Syncom launch and positioning operations is indicated by the fact that Syncom III's period is almost synchronous and the inclination of the orbit is less than one-tenth of a degree from equatorial. This means that it moves north and south with respect to the Earth's equator less than 6 miles a day.

In addition to its primary communications function, Syncom has proved useful for scientific measurements used in better defining the shape of the Earth at the equator.

Unmanned Exploration

The basic objective of this NASA program is to acquire fundamental knowledge of the space environment and of those phenomena which can be studied best from spacecraft, for both scientific and practical purposes.

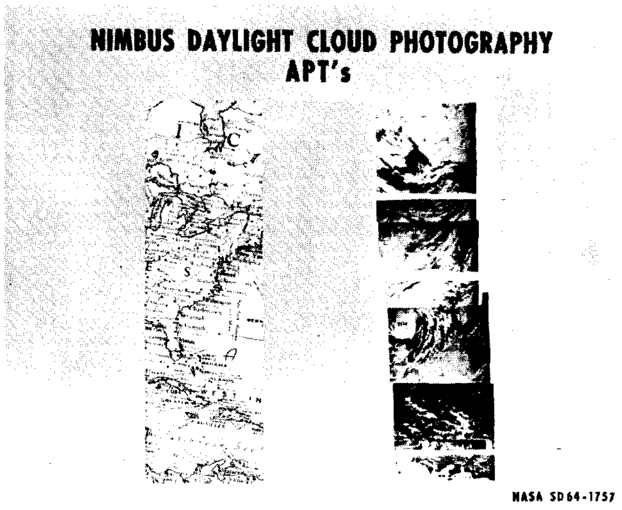


Fig. 10

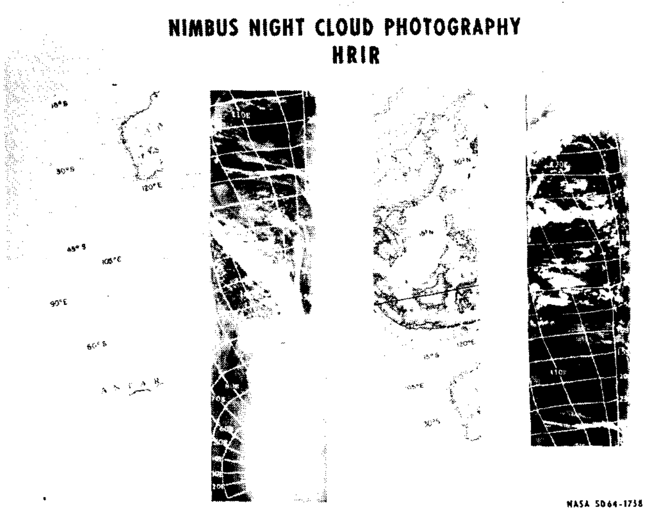


Fig. 11

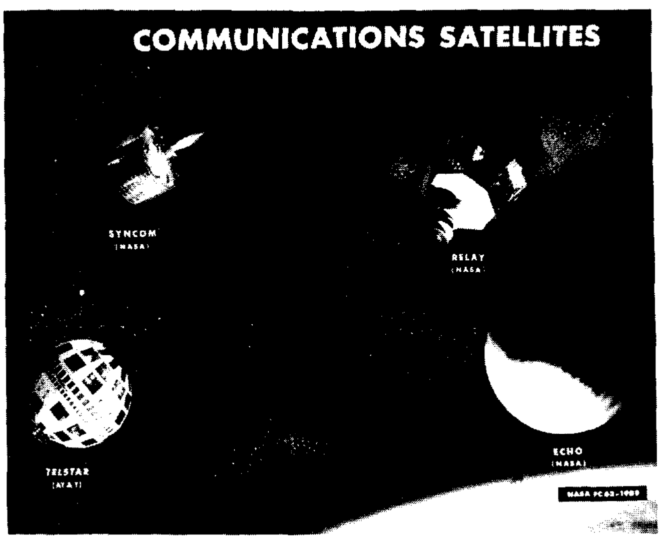


Fig. 12

Major areas of interest are summarized in Figure 14.

The unmanned space exploration program was initiated in 1958 when instruments carried by the first of the Explorer series of satellites revealed the existence of the Van Allen Belts encircling the Earth. Since that date, 26 Explorer and Monitor satellites of the type shown in Figure 15 have been launched. These relatively small satellites, which have been placed in orbit by Jupiter C, Scout and Delta launch vehicles, are usually designed to make measurements of specific phenomena in space such as the distribution and energies of the particles trapped in the Earth's magnetic field (as with Explorers XIV and XV), ionospheric measurements to determine electron densities and their variation both diurnally and with changes in solar activity (as were made by Explorer VIII and the United Kingdom's Ariel I), or other phenomena such as micrometeoroid flux and atmospheric structure.

As an example of some of the findings of one of the newer Explorers (Explorer XVIII, launched November 27, 1963), Figure 16 shows the regions probed during the first 40 orbits of this Interplanetary Explorer (IMP-A). A transition region was found between the steady solar wind of interplanetary space and the magnetosphere, where the solar wind was turbulent and the magnetic field unsteady. Of extreme interest, also, was the discovery, on the fifth orbit, that the Moon as it moves through the solar wind apparently generates a wake that extends for a distance of at least 120,000 miles on the side away from the Sun.

This program of launching relatively inexpensive Explorer class satellites to make measurements of specific phenomena will be continued. A new series of Explorer satellites will carry payloads developed by universities and will also be used to continue international cooperation projects such as the U.K. Ariel I and II, the Canadian Alouette, and the Italian San Marco.

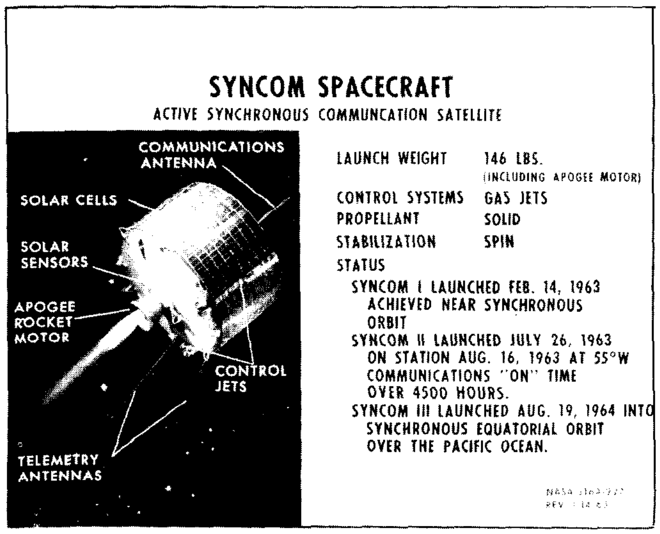


Fig. 13

SPACE SCIENCE OBJECTIVES

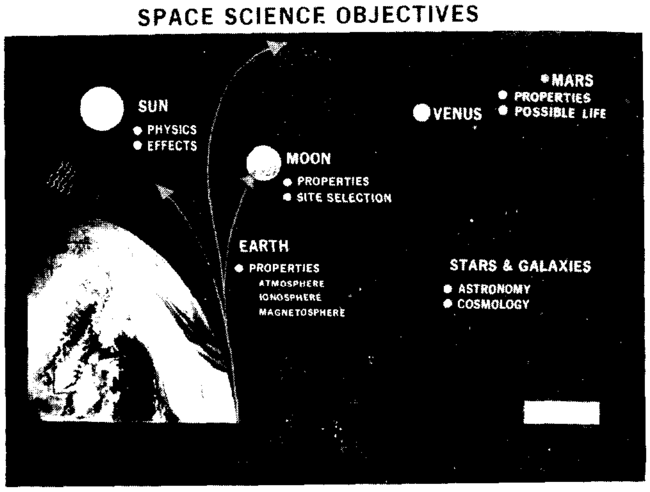


Fig. 14

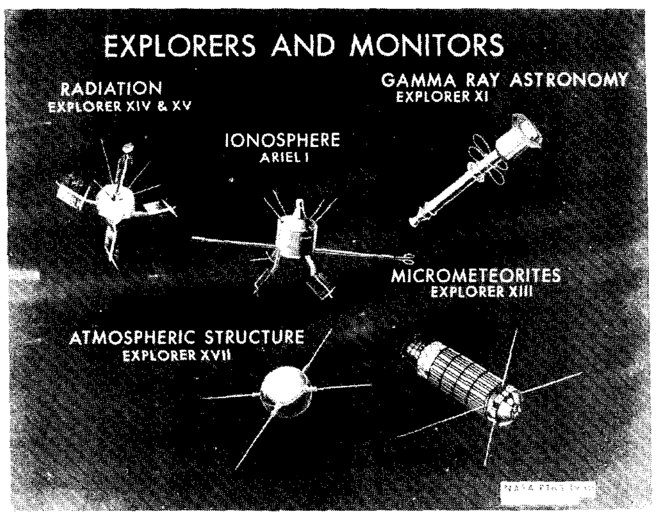


Fig. 15

The sounding rocket program is an important element of near-Earth exploration. It opens to investigation that vast region of the Earth's atmosphere that is too high for balloons to reach and too low for satellites. It also provides in-flight development testing of instruments and other equipment intended for later use in satellites. Further, new experimenters from universities, industry and foreign organizations are provided a logical and inexpensive way of gaining experience in space science techniques.

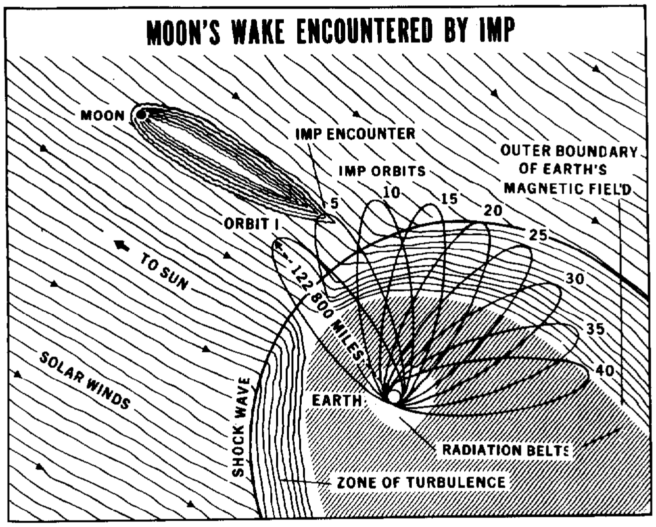


Fig. 16

Shown in Figure 17 is the second generation of scientific satellites, the orbiting observatories. These larger satellites are designed to make more precise, more complex and better coordinated measurements of stellar, solar and geophysical phenomena.

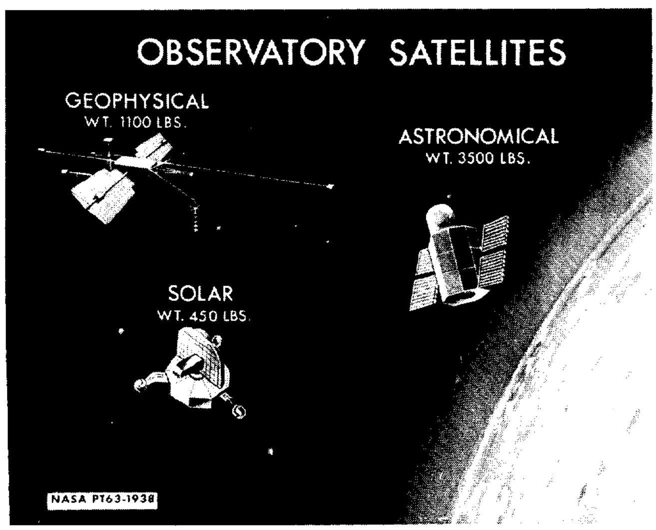


Fig. 17

The first Orbiting Solar Observatory (OSO), was launched in March 1962, and successfully reported data on solar phenomena for well over a year. The second OSO, launched in February 1965, will continue making solar measurements during the present quiet period of the solar cycle.

The first of the Orbiting Geophysical Observatories (OGO) was launched in September 1964 into a highly elliptical orbit. Although 2 of the long booms shown did not deploy properly and the satellite was not stablilized as intended, 18 of the 20 experiments are operating and many of the objectives will be accomplished. The OGOs are designed to carry 20 to 50 experiments and will allow correlated measurements of Earth-related phenomena at a single point in space.

The first Orbiting Astronomical Observatory (OAO) will be launched in late 1965 or early 1966 and will allow the first extended observations of stars and planets from above the Earth's atmosphere. An eventual goal in this series of satellites is to produce the capability of pointing a 36-inch telescope at a star to within plus or minus one-tenth of a second of arc, and one of its early experiments will be the mapping of the heavens in ultraviolet wave lengths.

Capabilities for interplanetary and planetary exploration were first successfully demonstrated by Pioneer V, launched in 1960, and by the Venus probe, Mariner II, shown in Figure 18, which was launched in August 1962. Pioneer V set a record for that time by communicating to Earth from a distance of 22,000,000 miles, and returned new data on the interplanetary environment. Mariner II, 109 days after it was launched, passed close to the surface of Venus and transmitted to Earth man's first close-up information about another planet. Although the data transmission capacity was limited, Mariner II gave us information on the surface temperature, magnetic fields, dust environment and radiation belts of Venus.

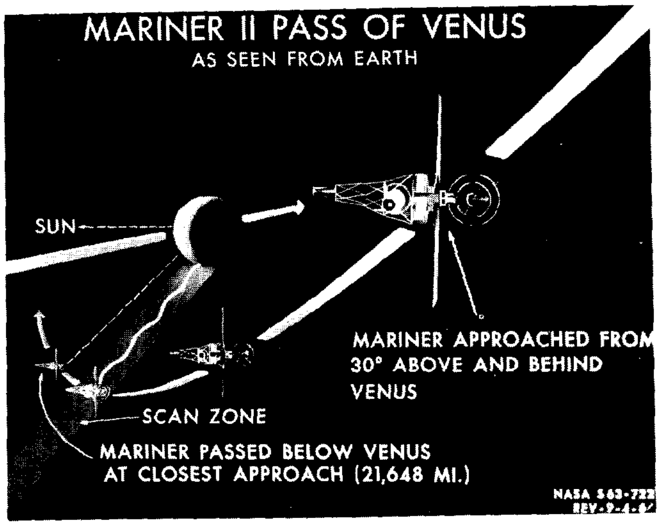


Fig. 18

Mariner II also demonstrated the value of the mid-course maneuver capability on which we have standardized for guiding a spacecraft to a desired destination - in this case to within approximately 20,000 miles of Venus when it was 35,000,000 miles from the Earth.

The Mars probe, Mariner IV, was launched during the November 1964 opportunity. During its 8-month trip to the planet, this 575-pound spacecraft is making interplanetary measurements of the magnetic fields and solar winds. On arriving at the vicinity of the planet, the spacecraft, if operating properly, will make measurements of the Martian magnetic fields and radiation belts, collect some data on the Martian atmosphere, and will transmit to Earth about 20 television pictures of the planet's surface.

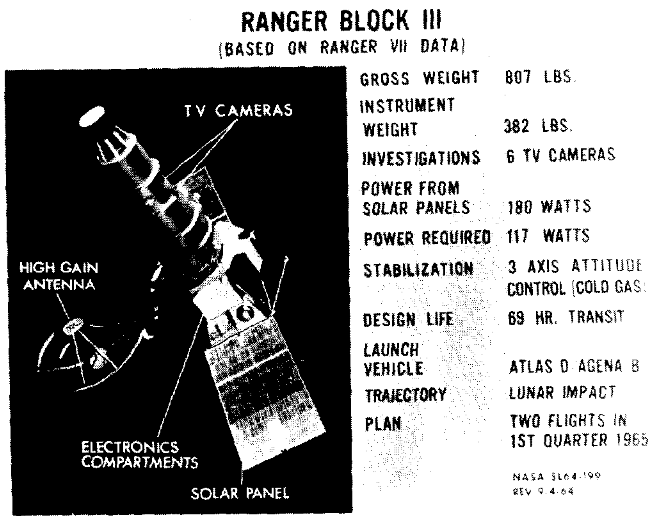


Fig. 19

The Moon probe, Ranger VII, illustrated in Figure 19, gave man his first close-up look at the surface of Earth's nearest neighbor in space by transmitting approximately 4,300 television pictures to Earth in the last 15 minutes before it impacted on the lunar surface. Ranger also demonstrated our increased competence in mid-course maneuver capability, in this case to carry television cameras to within 10 miles of a preselected spot on the Moon's surface. It also demonstrated a communications capability for transmitting wide-band information over the quarter-million-mile Earth-Moon distance.

As illustrated in Figure 20, NASA is also developing the Lunar Orbiter and the Surveyor spacecraft for unmanned exploration of the Moon. Initial Lunar Orbiters, scheduled for launch in 1966, are designed to obtain topographic information by photographing an area of about 15,000 square miles with a resolution of 25 feet and of about 3,000 square miles with a resolution of 3 feet. Furthermore, the mass distribution and shape of the Moon can be determined from perturbations in the spacecraft's orbit. Later Lunar Orbiters will carry scientific instruments, as well, that will increase our knowledge of the lunar environment and of the surface and sub-surface characteristics. The Surveyor spacecraft is designed to land on the Moon and make measurements of the bearing strength and composition of the lunar surface, to take close-up, continuous panoramic TV pictures of the lunar surface, to measure seismic activity, and to determine the flux of primary and secondary particles impinging on the surface. The Surveyor and Lunar Orbiter will serve as a team to survey and select suitable sites for manned landings.

The biosatellite program consists of orbital flights up to 30 days of recoverable capsules, which contain various biological experiments, illustrated conceptually in Figure 21. The experiments carried will range from studies of the effects of weightlessness and radiation on elemental cell functions to investigations of heart and nerve functions in primates immobilized for prolonged periods in a weightless condition. This program will use thrust-augmented Delta launch vehicles and take advantage of the recovery techniques developed by the Air Force in the Discoverer program.

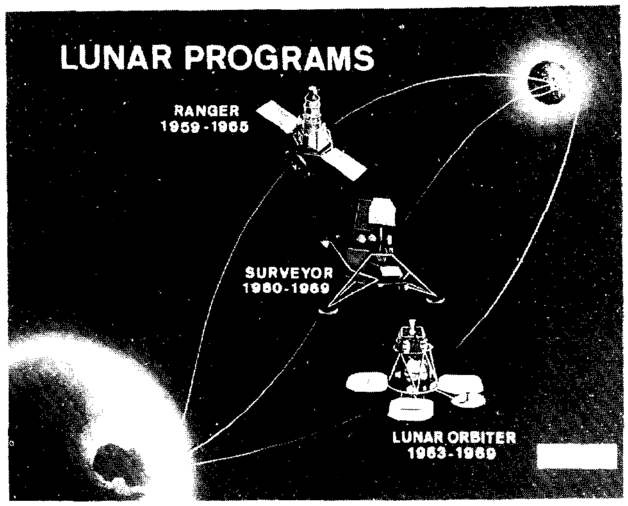


Fig. 20

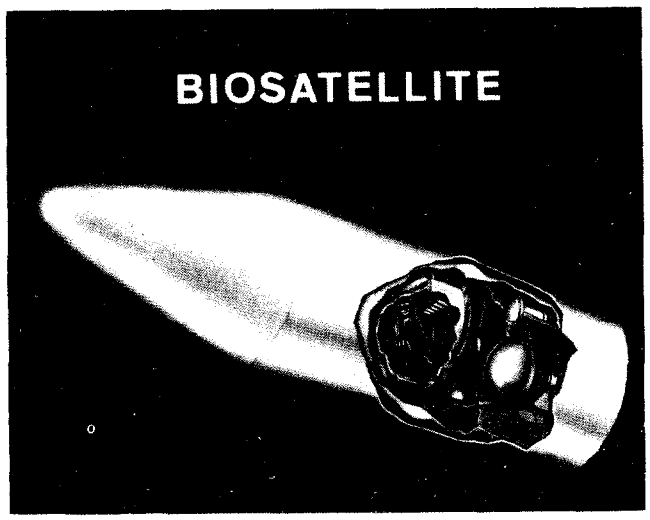


Fig. 21

Manned Operations

As illustrated in Figure 22, the current manned operations program provides an orderly progression of operational capabilities from the 2,900-pound Mercury spacecraft to the 7,000-pound Gemini, to the 95,000-pound Apollo-LEM system.

Figure 23 illustrates the progression of manned launch vehicles from the 368,000 pound thrust Atlas which launched the Mercury spacecraft to the 7 1/2 million-pound thrust Saturn V which will launch the Apollo.

The Mercury spacecraft, launched by the Atlas, provided this country's first capability for manned Earth-orbital flight and was used in the 3-orbit mission by John Glenn in 1962. The Mercury-Atlas system capability was later extended to accomplish Gordon Cooper's 22-orbit, 34-hour flight in 1963.

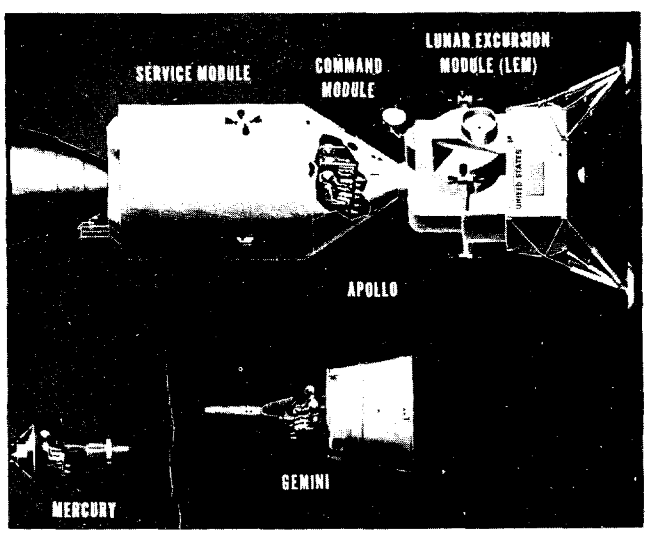


Fig. 22

The Gemini two-man spacecraft, with its Titan II launch vehicle, will make possible missions of up to 14 days in Earth orbit, beginning in 1965. New equipment will permit orbit change, rendezvous and docking, and will enable the astronauts to venture outside the spacecraft into free space. Dual launches of the Gemini by Titan and the Agena by Atlas will place an unmanned Agena target into orbit and enable the Gemini astronauts to perfect the rendezvous and docking systems. These missions will verify the operations and techniques to be used later in the more ambitious Apollo missions.

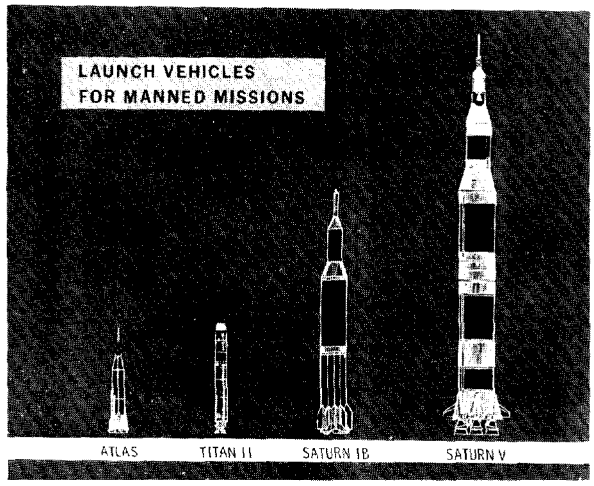


Fig. 23

In Project Gemini, NASA is providing a flexible, experimental space tool with which to flight test equipment, conduct scientific experiments, and develop techniques and provide training for Project Apollo. The Department of Defense Manned Orbital Laboratory will also make use of Gemini for the launch and return to Earth of the astronauts who will work in the laboratory.

As illustrated in Figure 24, the Gemini spacecraft consists of two major elements, the reentry module and the adapter, with a combined weight of 7,000 pounds. The reentry module provides life support and control equipment for the two crewmen, contains most of the experiments and also contains the rendezvous and recovery systems. The adapter element provides the link between the Titan II launch vehicle and the reentry module, and is composed of two sections, an equipment section to provide augmented life support, stabilization equipment and expendables for flight durations of up to 14 days, and a retrograde section to slow down the spacecraft from its orbital velocity.

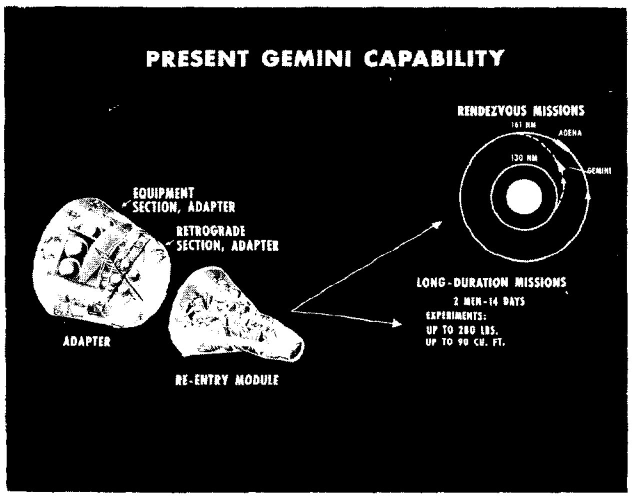


Fig. 24

Several of the Gemini missions are designated primarily as rendezvous missions to explore the feasibility of various modes of accomplishing rendezvous utilizing different levels of automation in the sensing and control equipment.

In a typical mission, an Agena engine will first be launched into a 160-nautical-mile circular orbit. The manned Gemini spacecraft will then be placed into a lower circular orbit at 130 nautical miles. The different periods of the two spacecraft in these concentric orbits will cause a continuing change in the relative position of the Gemini with respect to the Agena. When the relative positions are proper, the Gemini spacecraft will be accelerated in a transfer ellipse to the higher orbit where the rendezvous and docking will be accomplished. These missions will be short-lived because of the weight requirement for fuel which reduces the expendables that can be carried for life support, power supply, and stabilization.

On the Gemini long-duration missions, primary emphasis will be placed on biomedical and behavioral aspects of man in a weightless condition; however, scientific and technical experiments are being planned for all missions. Specific experiments range all the way from visual definition experiments requiring no equipment and astronomical observations made with a 2-pound ultra-violet camera to radiometric or astronaut maneuvering experiments using equipment weighing as much as 200 pounds. The experiment program is tailored to the available weight, volume, and power in the spacecraft on each mission, as well as to the participation and accessibility which can be provided for the astronauts. Although the volume available for experiments within the pressurized cabin is limited, extra-vehicular operations are planned for the astronauts to permit free-space experiments, maneuvering, and other external operations such as the testing of manual dexterity and the use of specialized tools for spacecraft repair functions.

The Gemini spacecraft is already undergoing flight test. The successful launch of the first and second unmanned Gemini's in April 1964 and January 1965 will be followed soon by the first manned orbital flight. The easy access to the crew compartment is emphasized in Figure 25, which shows the Gemini spacecraft mockup.

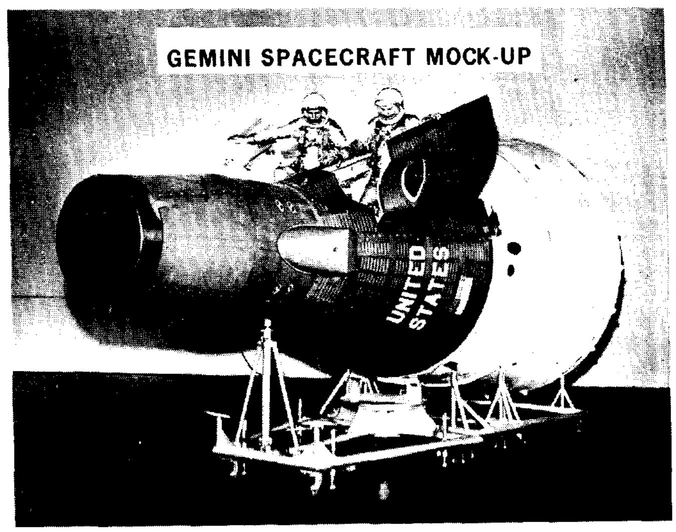


Fig. 25

The larger goals of the presently planned manned space flight program will be attained by the three-man Apollo-LEM system to be launched by the Saturn IB beginning in 1966 and by the Saturn V beginning in 1967. The Apollo Command and Service Modules, with fuel partially removed, will be launched first by the Saturn IB for Earth-orbital missions of up to 10 days duration. A number of such flights will be made in which rendezvous, docking, maneuvering, and other operations will be conducted.

Later, the total 47.5-ton Apollo-LEM spacecraft will be qualified in Earth orbit and eventually propelled to the Moon by the Saturn V, thus extending the area of space in which man can operate from near-Earth orbit to as far out as the Moon, and including the lunar surface.

The size of the Apollo-LEM spacecraft, shown previously in Figure 22, as compared with either the Mercury or Gemini spacecraft, is in part due to the longer duration of the Apollo missions, the larger heat-shield, and the increased crew; however, the major increase is due to the requirements for a large propulsion capability for maneuvering in space. The Service Module provides a propulsion capability for mid-course correction, lunar-orbit braking, and lunar-orbit escape, while the Lunar Excursion Module provides the capability for lunar landing and lunar takeoff.

The very large capability of the Apollo space exploration system (illustrated in Figure 26) will open a new era in manned space flight. Earth-orbital missions reaching out to synchronous orbit distances and of 14 days duration can be conducted, and lunar and other missions out to lunar distances will be possible, including one-day stays on the lunar surface for two men, or

4 days stay in lunar orbit for three men.

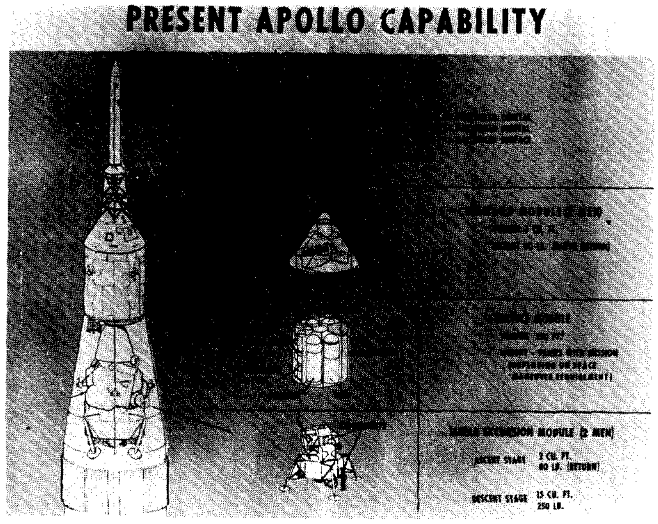


Fig. 26

On Earth-orbital, lunar-orbital, and lunar surface missions, provision is being made for the conduct of an extensive experimental program. Because of the increased size and the presence of man, these experiments will, in general, be more complex and extensive than those performed in unmanned vehicles. In the Command Module, volume has been provided for about 3 cubic feet of experimental equipment and with a return-to-Earth capability of about 80 pounds of instruments or lunar samples. In the Service Module, a complete empty bay provides an available volume of 250 cubic feet for the mounting of instruments; the weight available would depend upon the particular mission and the amount of fuel or other expendables required.

In the Lunar Excursion Module, 2 cubic feet of experimental equipment, weighing up to 80 pounds, can be installed within the existing ascent stage, and 15 cubic feet of instruments, weighing up to 250 pounds, on the descent stage in an area accessible to the astronauts while standing on the lunar surface. On all missions, however, the permissible weight of experiments must be evaluated against the comparable weight of expendables for fuel and life support, in order to extend the maneuver capability or duration of the mission.

A better impression of the room provided for experiments, as well as the progress that is being made in finalizing the design concept of the Apollo-LEM system, can be gained from the mock-ups of the major spacecraft elements shown in Figure 27. The area in the exposed bay in the Service Module could be utilized for installation of instruments that do not need direct monitoring by the astronauts. This space might also be used for carrying complete unmanned spacecraft in a piggy-back fashion for later deployment on unmanned space missions or for lunar surface probes.

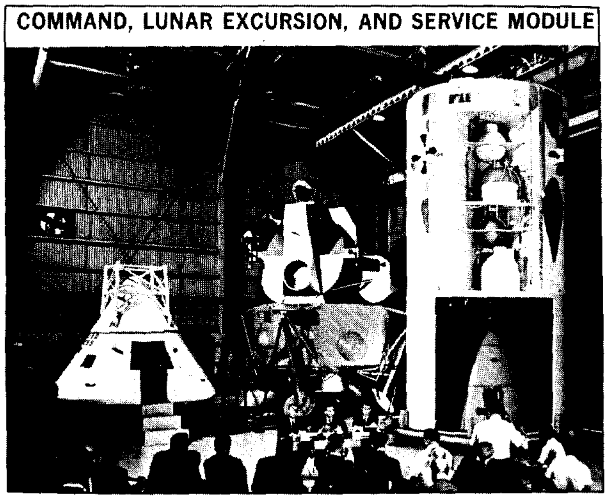


Fig. 27

Launch Vehicles

Figure 28 shows the boosters now included in the National Launch Vehicle Program which range from the Scout vehicle, capable of placing about 325 pounds in a 100-mile Earth orbit, to the Saturn V which will place about 250,000 pounds in the same orbit. The Thor/Delta vehicle, which will place about 930 pounds in a 100-nautical-mile Earth orbit or propel a 105-pound payload to escape velocity, has been the most successful of U. S. launch vehicles, placing 26 payloads in Earth orbit out of 29 attempts. The capacity of the Thor/Delta has been improved recently by the addition of three 33-inch diameter strap-on solid rocket motors, giving about 25 per cent increase in Earth orbital payload capability. The thrust-augmented Thor/Agena will be capable of placing about 1,800 pounds in Earth orbit, when launched from the Western Test Range.

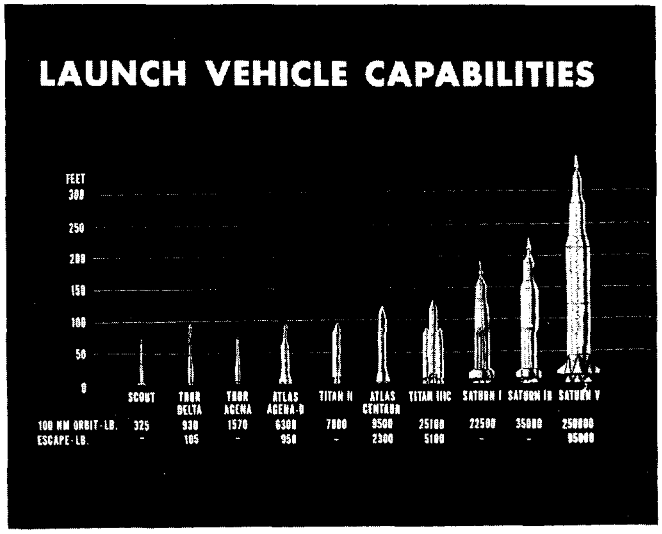


Fig. 28

The two Atlas-based vehicles are the Atlas Agena and the Atlas/Centaur. The Atlas Agena can place up to 6,300 pounds in Earth orbit. It has been used successfully to launch the 750-to 800-pound Ranger probes to the Moon; and, on November 28, launched the 575-pound Mariner IV to Mars. The Atlas/Centaur, nearing completion of development, will accelerate 2,300 pounds to escape velocity or 9,700 pounds to Earth orbital velocity. It will be used as the launch vehicle for the Surveyor spacecraft designed to achieve a soft landing on the Moon.

The Centaur was the first rocket stage to use hydrogen and oxygen as fuel, a combination which gives an increase in specific impulse from about 300 seconds, available with standard fuels, to more than 400 seconds. This is an improvement of particular importance to missions requiring velocities equal to, or higher than, that for Earth escape.

The Titan series of launch vehicles is under development by the Department of Defense. The Titan II is used by NASA to launch the 7,000-pound, 10-foot diameter Gemini spacecraft. The Titan IIIA (not illustrated) consists of the Titan II to which an additional stage, called the trans-stage, has been added. The addition of two 120-inch solids to the IIIA produces the IIIC (illustrated in Figure 28), which will place about 25,000 pounds in low Earth orbit or propel about 5,000 pounds to escape velocities.

In the Saturn family of vehicles, the Saturn IB is capable of placing 35,000 pounds in Earth orbit; and the Saturn V, 250,000 pounds. The Saturn V will also accelerate 95,000 pounds to Earth escape velocity.

The Saturn program indicates the use of standardized rocket engines. The first stage of the Saturn IB is made up of eight LOX-RP-1 fueled H-1 engines -- an up-rated version of the S-3 engines that were developed for the Atlas booster. The upper stage of the Saturn IB uses one hydrogen-oxygen J-2 engine which will also be used in a cluster of five to power the second stage of the Saturn V.

In the Saturn V, five 1,500,000-pound thrust F-1 engines power the first stage. The second stage will use five J-2 engines. The third stage uses one J-2 engine and is almost identical to the second stage of the Saturn IB.

These vehicles thus provide a wide range of launch capabilities based on a minimum number of engine types. However, it is important to note that there are wide gaps in escape payload capability between the 950 pounds of the Atlas/Agena, the 2,300 pounds of the Atlas/Centaur, the 5,100 pounds of the Titan IIIC, the 13,000 pounds of the Saturn IB/Centaur, and the 95,000 pounds of the Saturn V.

Technology

The technological base which supports the development of the mission capabilities described has been made possible by the experience gained by our military services in the ballistic missile program and the broad research and technology development programs carried on by industry and by NASA. When the space age began in 1957, the reserve of technology which could be tapped to meet the immediate needs of the United States proved insufficient. The reliability and thrust of the launch vehicles, for example, were far short of that required to meet the challenge of the Soviet space program. However, due to the foresight exercised at that time in undertaking, without specific end uses in sight, the development of the 1-1/2 million-pound thrust F-1 engine, and other important projects, this country was able to make sound technical decisions when it became necessary to expand its space program in 1961. This expanded program is designed to assure United States leadership in space and to be ready to respond when national needs or objectives require new aeronautical or space systems. With respect to such a large, complex, and unknown environment as space, and the still not precisely defined characteristics of the Earth's atmosphere, this Nation would be oblivious to the lessons of history if it required that all its exploratory research and development efforts be matched to completely defined missions. It is clear from the 1958 Aeronautics and Space Act that NASA was established to make sure we would develop the capability which was clearly lacking at that time, and to develop the kind of policies and priorities that would do the job needed. Where there is reasonable promise of success in the development of such things as new materials, propulsion systems, or techniques, it is NASA policy to pursue these directions even though a specific use is not clearly defined. We have found that we can organize these efforts so as to point at broad classes of possible uses, giving the necessary technical base for options as to missions and the best ways to accomplish them. In his testimony before the Committee on Science and Astronautics on February 4, 1964, Dr. Hugh Dryden recalled how the United States, despite initial positions of advantage, failed to carry forward work of which it was capable in aeronautics, in jet propulsion, in ballistic missiles, and in the launch vehicles and spacecraft necessary for space exploration. The result in each case was that other nations moved ahead, placing the United States at a disadvantage and requiring an enormous effort to catch up. Our present relative position in space leaves no room for complacency. As Dr. Dryden said, "We must not delude ourselves or the nation with any thought that leadership in this fast moving age can be maintained with anything less than determined, whole-hearted, sustained effort."

It is on this basis that NASA is continuing to carry out a broad, long-range program in research and technology development. This program is aimed at the establishment of future mission capability, and it can be expected that new advances in technology will be made and will provide a better basis of judgment than we have had before as to the value of missions and projects and as to when they can be undertaken at reasonable costs and risks.

In the next two sections of this report, dealing with intermediate and long-range missions, we shall attempt to identify, when possible, the technological advances that are required for their accomplishment. These research and technology development programs will be discussed in detail following the section on long-range missions.

Some examples of the capabilities which have been, or are being, developed to date are:

a. Solar cell power supplies capable of producing 650 watts.

b. Guidance and control capabilities for placing a spacecraft within a few thousand miles of a distant planet, or within a few miles of a given point on the Moon.

c. Communications technologies which provide almost continuous communications with manned spacecraft in Earth orbit, the transmission of about five television pictures per second from the Moon, or radio reception from a spacecraft over a 100 million miles in space.

d. Spacecraft stabilization technology which will enable precision instruments to be pointed, in some instances, to within 1/10 second of arc.

e. Life support systems which will enable three men to remain in space for as long as 14 days and to venture as far as 250,000 miles from the Earth.

f. The reliability of both spacecraft and launch vehicles. Spacecraft reliability has been improved to the point where many unmanned spacecraft now have lifetimes of well over one year, and manned spacecraft will be capable of dependable operation for 14 days or longer. Reliability of launch vehicles has been improved to such an extent that the per cent of successful vehicle launches has risen from about 60 per cent in 1960-61 to over 90 per cent at the present time.

g. A world-wide tracking, data acquisition, and communications system to support manned flight, scientific and application satellites, injection, monitoring, and deep space probes, as illustrated in Figure 29.

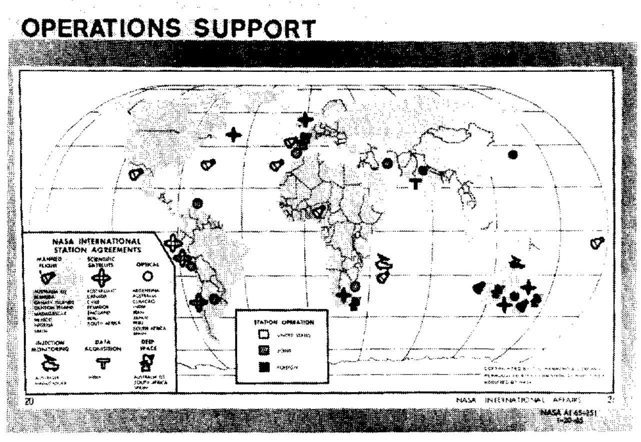


Fig. 29

Along with the missions which are being undertaken and the capabilities which are being developed, the first years of the Nation's effort in space have produced a broad scientific and industrial base, and the facilities and management systems needed for carrying out an effective program of space exploration.

A major part of our present space capability is found in the expansion of NASA since 1961. About 2-1/3 billion dollars have been invested in strengthening the industrial facilities and government laboratories associated with aeronautical and space research and in adding new installations. These include the Goddard Space Flight Center in Maryland, the Michoud Plant at New Orleans, the Mississippi Test Facility in southern Mississippi, the Manned Spacecraft Center at Houston, Texas, and the New Merritt Island Launch Facility at Cape Kennedy, of which the Saturn/Apollo Vertical

Assembly Building is shown in a cutaway view in Figure 30. The exacting demands of space systems in the electronics field have also required a new Electronics Research Center which will conduct and supervise research in this vital field from its location in Cambridge, Massachusetts.

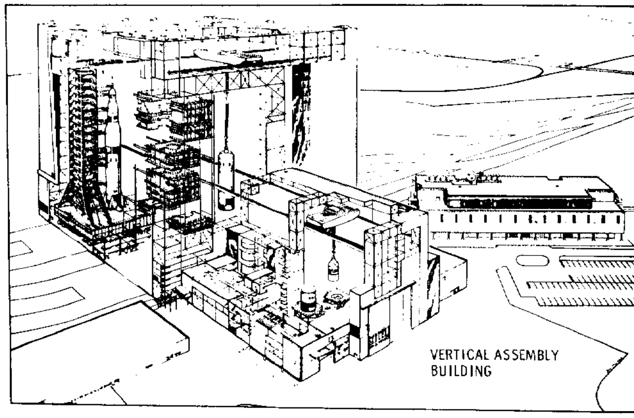


Fig. 30

NASA has contracted out more than 90 per cent of its research and development work. Over 1,600 manufacturing firms have held prime contracts of over $25,000 and about 20,000 firms have worked under prime or sub-contracts. Surveys made by 12 major prime contractors disclosed 3,000 sub-contracts of over $10,000 to sub-contractors located in all 50 states. During slightly over 6 years of operation, NASA contracts have totaled more than $13 billion, adding great strength to the country's industrial base.

The conduct of space research and development, involving the design and manufacture of the most complex systems ever attempted, is demanding major improvements in methods of conducting large-scale organized effort. Included are new methods of production control, systems integration and checkout, and reliability and quality control.

The substantial expense involved in launching space vehicles, and the intricacy of the devices involved, have imposed unusual requirements of precision manufacture and quality assurance. As a consequence, increasing reliance is being placed upon incentive contracts, and new ways of encouraging improved government personnel and contractor performance are being developed.

The space program is indeed a large and varied research and development effort. The harsh environment of space requires major advances in all areas of technology, in materials, in electronics, in propulsion, in guidance and control, in power sources, in lubricants and coolants, in communications, in the integration of systems and the establishment of high levels of reliability, and in the maintenance of human life in space. It is already clear that our balanced and broadly-based space effort is producing important scientific and technological advances that are not limited to space use.

Experiments or pilot model efforts, through which these advances constituting major National resources for both security and economic growth can be made available quickly and efficiently for non-space use, are being carried out. NASA has established a program in technology utilization, with headquarters in Washington and with offices in each of the NASA centers. Innovations are being identified and described in appropriate publications; these are disseminated widely. Regional dissemination centers have been established on a trial basis at a number of universities. At each of these, NASA material is put on computer tapes and access provided to industrial concerns who support these centers through user fees and contributions. This system makes this material available within about 6 weeks of it's reporting date to Headquarters from both NASA centers and contractors, and makes it available on a selective basis conforming to the interests of the users. The system also provides a method by which the user can secure complete, in-depth information on any advance in an area of particular interest. The objective of this program is to spread the advanced technical industrial capabilities developing in the space program within and beyond the government contractor population to the maximum extent practicable, and particularly to bring about the identification and practical utilization by American industry of new processes and products developing in the space program.

Scholars in the Nation's universities conduct much of the basic research, and prepare many of the experiments required for advances in space science. The breadth of the program has produced, at many universities, new requirements for interdisciplinary cooperation and participation among the scientific specialties, and between science and engineering.

NASA-supported research effort in universities involves both project-related research, as illustrated in Figure 31, and a Sustaining University Program comprised of training, research and facilities grants. Under the training program, 142 universities have received grants to support a total of 3,132 candidates for predoctoral training fellowships in space-related fields. Research grants under the Sustaining University Program have been made to 53 educational institutions, most of them involving interdisciplinary effort, and many of them "seed grants" aimed at strengthening research activity at universities capable of expanding their research programs. A total of 27 facilities grants (shown in Figure 32) have been made to universities to provide additional laboratory space required in the performance of space-related research.

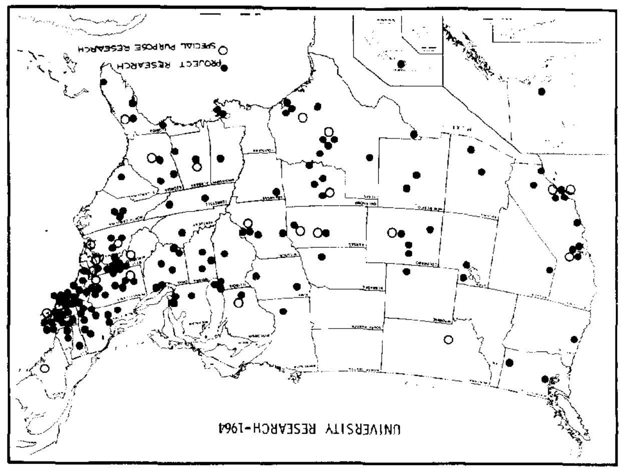


Fig. 31

A significant element in the overall NASA-university effort, particularly in the case of those universities receiving facility grants, is the encouragement of a closer working relationship between the university research activities and those businesses and industries with which the university already has close relations. This aims to facilitate the transfer of space research results to practical, industrial application. Memoranda of understanding accompanying the facility grants provide that the university will, in an organized and interdisciplinary manner, seek ways in which such transfers can be achieved, and strive for closer relationships with the business community.

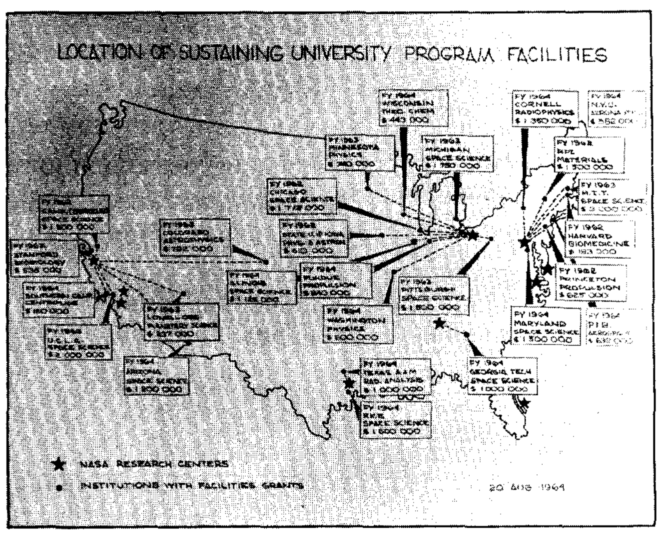


Fig. 32

Participation in the U. S. space program has not been limited to this country. Individuals or agencies in 69 nations throughout the world have joined the United States in space projects, including the establishment of tracking and data acquisition stations, as illustrated in Figure 33. In all of these projects, cooperation has been literal and substantive, requiring significant contributions from both sides, without financial exchange, and meeting the test of scientific value.

NASA has launched four satellites in cooperation with Great Britain, Canada, and Italy and has existing agreements to launch others with all of these countries as well as with France and the European Space Research Organization. The present practice in these projects is that the cooperating country conceives and engineers the complete satellite, using its own resources.

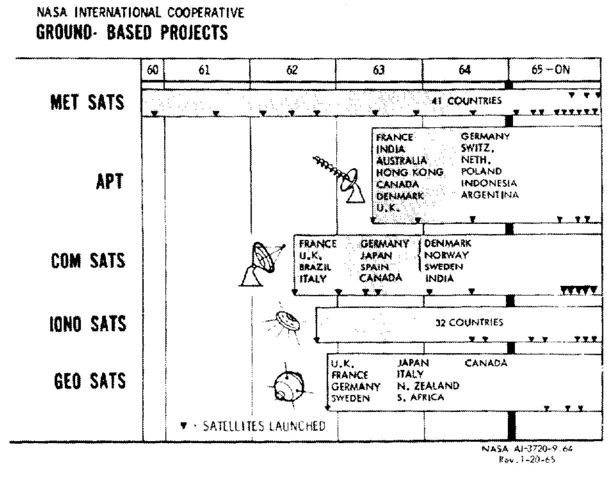


Fig. 33

Individual experiments proposed by foreign scientists, sponsored by their governments and selected on their merits, are also accommodated in NASA satellites. One British experiment flew on Explorer 1, and 12 other British, Dutch, and French experiments are scheduled for inclusion on NASA satellites which will be launched over the next few years.

NASA has participated in cooperative sounding rocket projects with 14 countries, involving more than 100 cooperative launchings, and currently has agreements for launching nearly 50 more in such projects. The multitude of foreign sites established for this program and the extent of capability stimulated by it vastly increase the possibilities for synoptic research, while reducing its cost.

A wide variety of ground-based cooperative projects involving foreign scientists has been organized to produce observations or measurements enhancing, and sometimes even necessary to, NASA's orbiting experiments. Thus, 42 countries have collected local meteorological information for correlation with TIROS observations, and 11 countries have already built, or will soon complete, ground terminals necessary for test transmissions in connection with our communications satellite programs.

Under international scientific and technical personnel exchanges, 103 gifted foreign Research Associates have contributed their talents to work in NASA centers, 84 International Graduate Fellows have trained in U. S. universities, and 180 foreign technicians have trained at NASA centers in support of cooperative projects and ground facility operations.

This completes the review of the capabilities which have been developed during the first 6 years of space exploration, or which will be developed within this decade.

IV. INTERMEDIATE MISSIONS

The intermediate missions to be discussed in this section and shown in Figure 34 meet three major tests:

a. They support immediate needs for continued developments in space science and technology.

b. They make efficient use of the boosters, spacecraft, and ground facilities developed and paid for within the current program.

c. They provide for steady progress toward the ultimate accomplishment of longer range goals in space.

INTERMEDIATE MISSIONS - EXTENSIONS OF PRESENT CAPABILITIES

AERONAUTICS

- SUPERSONIC TRANSPORT
- HYPERSONIC ENGINE DEVELOPMENT
- V/STOL

SATELLITE APPLICATIONS

- APPLICATIONS TECHNOLOGY SATELLITES
- DIRECT BROADCAST FM
- COMMUNICATIONS/NAVIGATION SATELLITES
- METEOROLOGICAL OBSERVATION TECHNOLOGY

UNMANNED EXPLORATION

- OBSERVATORIES, PIONEERS AND EXPLORERS CONTINUED
- PLANETARY FLY BY, ORBITERS, AND LANDERS

MANNED OPERATIONS

- EARTH ORBIT APPLICATION (1 TO 2 MONTHS)
  - EQUATORIAL ORBITS
  - POLAR ORBITS
  - SYNCHRONOUS ORBITS
- RENDEZVOUS, INSPECTION, REPAIR, AND RESCUE
- LUNAR MAPPING
- EXTENDED STAY IN LUNAR SURFACE (3 TO 14 DAYS)

LAUNCH VEHICLES

- SATURN IB/CENTAUR
- 7000 LB. HIGH ENERGY STAGE

TECHNOLOGY

- ISOTOPE POWER SUPPLIES (1 TO 2 KW)
- GUIDANCE & CONTROL (WITHIN MILES OF POINT ON MARS)
- COMMUNICATIONS (3000 BITS/SECOND FROM MARS)
- STABILIZATION
- PROPELLANT STORAGE
- LIFE SUPPORT (3 MEN, 1 TO 2 MONTHS)
- STERILIZATION
- RELIABILITY

Fig. 34

As in the preceding section, the major subjects to be covered in the discussion of intermediate missions will be aeronautics, satellite application, unmanned exploration, manned operations, launch vehicles and technology.

Aeronautics

In the field of aeronautics, NASA is continuing its work in aerodynamics, structures, propulsion, and flight operations to insure the continued superiority of U.S. aircraft. NASA research capabilities will continue to be utilized to provide technical guidance to those agencies and industrial concerns engaged in the supersonic transport development. In the near future, an experimental flight program using the Air Force XB-70, to investigate more fully the characteristics of flight at Mach 3, will be jointly carried out with the Air Force.

In the realm of subsonic flight, NASA research will continue to encompass aircraft of conventional type, and V/STOL aircraft. Work now in progress indicates that the technology for subsonic jet transports of improved efficiency and safety will be forthcoming within the next few years. Research on STOL aircraft will be continued to encourage development of aircraft of this type. The continued improvement of the personal owner and light business type aircraft will be supported by research aimed at obtaining greater flexibility of operation, easier flying characteristics, and increased safety and utility.

Work will also continue in the field of VTOL aircraft for both military and civil uses. It is anticipated that flight research studies of these and other similar type aircraft, together with continued wind tunnel, simulator, and analytical studies, will provide additional design and operational data. These data will make possible development of practical military V/STOL aircraft capable of operating out of relatively unprepared areas, as well as larger vehicles which might satisfy commercial passenger transportation needs in highly developed areas. In addition, research on hypersonic propulsion and aerodynamics will be continued.

Several studies have been made which indicate a real potential for useful flight missions in the atmosphere at hypersonic speeds (Mach numbers 4 to 8) using air breathing ramjet engines - - if theoretical engine performance can be achieved in practice. Engines of this type may eventually be needed for long-range, high-speed commercial and military aircraft applications, and may find a useful application in recoverable boosters.

A difficult problem associated with development of a production engine of this type is that the ground facility needed for testing such a full-scale engine might be as difficult and as expensive to develop as the engine itself, and may even be beyond the present or foreseeable state-of-the-art. For this reason it has been proposed that the X-15 airplane be used as a flying test bed in conjunction with modest ground test facilities, for proving out a small, 18-inch ramjet engine at speeds approaching Mach 8, as illustrated in Figure 35. These tests, made in a real environment at the proper Mach numbers, altitudes and dynamic pressures, will help establish the feasibility of hypersonic ramjet engines and contribute to the technology needed for design of future full-scale engines and, ultimately, useful hypersonic aircraft.

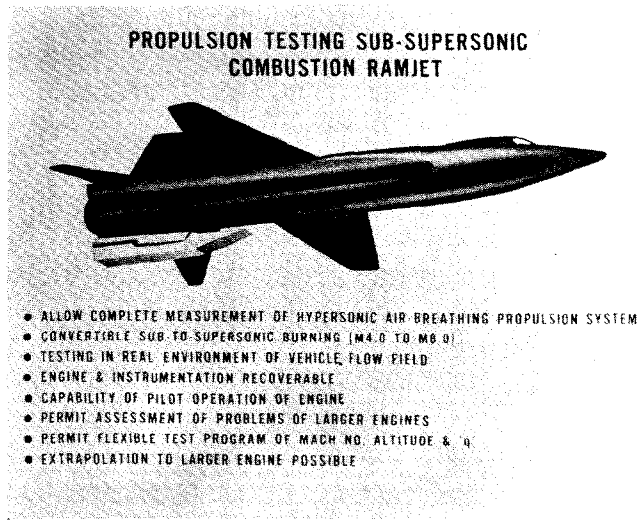


Fig. 35

Another part of the continuing aeronautics program includes the study, design and testing of aerodynamic shapes suitable both for reentry into the Earth's atmosphere at orbital velocities and for landing at subsonic speeds in a conventional manner. These aerodynamic shapes (referred to as lifting reentry bodies) will be applicable to many longer range future developments, such as recoverable orbital transports, hypersonic aircraft and, possible, recoverable boosters.

Figure 36 shows an early configuration whose subsonic flight and landing characteristics are being tested at the NASA Flight Research Center.

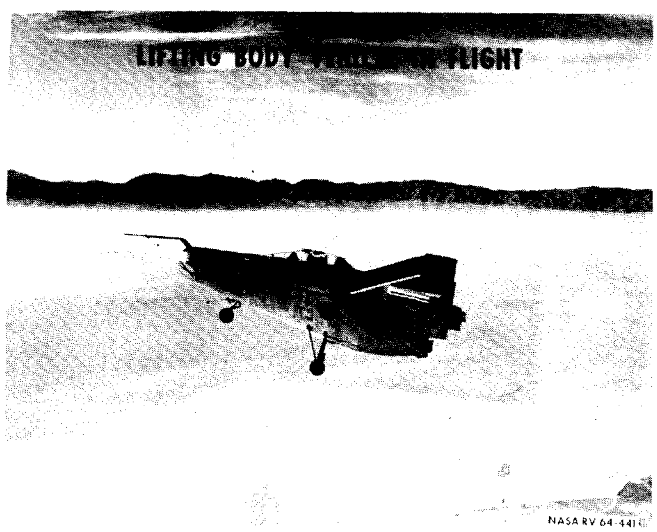


Fig. 36

Special emphasis will be placed on operational problems such as the noise level of supersonic aircraft (including sonic boom), air traffic control, and zero-visibility landing which can establish boundaries limiting the utilization of the aerodynamic, propulsion, and structures advances which aeronautical research can make possible. Close cooperation with the Federal Aviation Agency, the Civil Aeronautics Board, and the military services will be continued.

Satellite Applications

In the area of space applications, NASA's role is that of continuing the advancement of technology needed for the success of operational satellite systems or for support of other NASA missions. In accordance with basic agency policy, operation of meteorological, communication or navigational systems will not be undertaken.

Studies of prospective space application missions show that spacecraft in synchronous (either inclined or geostationary at 22,300 miles) and in 800-mile polar orbits will be particularly useful.

A synchronous meteorological satellite would permit a continuous view of a large area of the Earth, thus eliminating many of the difficulties inherent in taking data between the successive passes of lower altitude satellites. Meteorological satellites in polar orbits are useful where world-wide coverage is needed.

Communication and navigational satellites also take advantage of a fixed position relative to the Earth provided by geostationary orbits. Many problems due to the continuously changing position of lower orbits are eliminated. The complexity, number and cost of antennas may be reduced significantly. Similarly, stationary orbits will be highly desirable for future direct FM or TV broadcast satellites.

To place a satellite in a polar orbit requires more energy than to place it in a low inclination orbit. Even more energy is required to place a satellite at 22,300 miles in a synchronous orbit, and still more in a geostationary orbit. There is, therefore, a need for a small high energy stage on the Atlas/Centaur to provide additional energy for converting inclined transfer orbits to true stationary (synchronous equatorial) orbits. For 10,000-pound applications satellites of the future, Saturn IB/Centaur vehicles will be needed.

The Applications Technology Satellite, illustrated in Figure 37, will be used to develop further the technology of meteorological, communications, and navigation satellites in synchronous orbits. Among these technologies are long-life active and passive stabilization systems, possibly using gravity gradient methods; techniques for accurately erecting and pointing large aperture antennas in space; and the flight test of infra-red and TV sensors for use in meteorological satellites at synchronous altitudes. These satellites will be further used to test advanced components and subsystems applicable to many other satellite systems. These spacecraft can be launched by Atlas/Centaur vehicles.

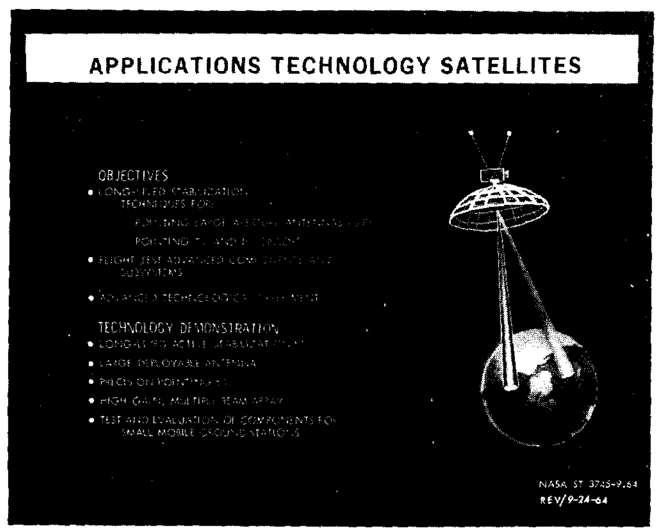


Fig. 37