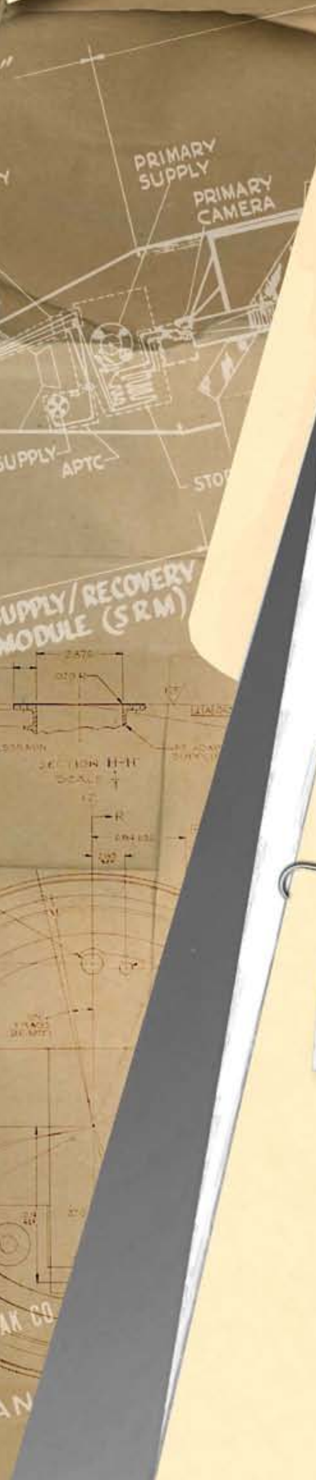
CRITICAL TO US SECURITY:

THE GAMBIT AND HEXAGON SATELLITE RECONNAISSANCE SYSTEMS

CRITICAL TO US SECURITY:
THE GAMBIT AND HEXAGON SATELLITE RECONNAISSANCE SYSTEMS

TABLE OF CONTENTS



CRITICAL TO US SECURITY:

THE GAMBIT AND HEXAGON SATELLITE RECONNAISSANCE SYSTEMS

FOREWORD

I am pleased that the Historical Documentation & Research (HDR) Section of the Center for the Study of National Reconnaissance (CSNR) has produced this early electronic edition of the Critical to U.S. Security: A Compendium of Gambit and Hexagon Satellite Reconnaissance Systems Documents. This will give researchers in the Intelligence Community and academic world an opportunity to preview some of the program documents that the National Reconnaissance Office (NRO) will be declassifying and an opportunity to study the history and background of these two phenomenal film-return satellite reconnaissance programs as reflected in these documents.

I personally have been involved in efforts to declassify the Gambit and Hexagon satellite programs for over a decade. The declassification process has been slow and deliberate because these two systems have represented state-of-the-art capabilities that even in 2011, on the occasion of the NRO's 50th Anniversary, remain impressive. The CSNR conducted a series of assessments of the risks of declassifying program details and consulted with experts across the Intelligence Community. There has been extended dialogue to ensure that the Intelligence Community continues to protect any capabilities, the disclosure of which might adversely impact on current operations. National reconnaissance is a much too valuable national treasure for its secrets to be lost to compromise.

During the past decade, I have come to understand the importance of these programs on a number of levels. First, the then newly established NRO developed these systems relatively early in its history, and that activity helped forge the way for the NRO to develop and operate satellite systems. Second, the systems provided essential data to intelligence users and valuable information to national security policymakers, thereby making the NRO an essential organization for succeeding in the intelligence battles of the Cold War. Third, the systems proved essential for teaching the NRO how to transition from successful programs to new programs that promised even greater capabilities. In short, these programs are cornerstones of the NRO's history and architects of its culture of success.

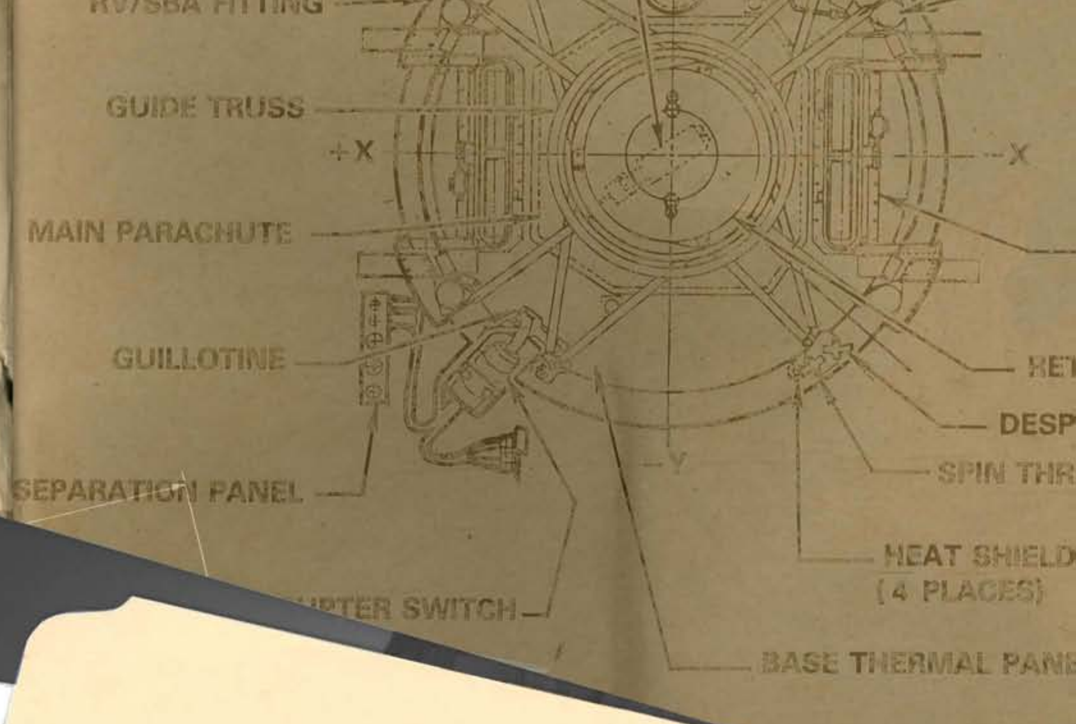
The NRO developed the Gambit and Hexagon satellite photoreconnaissance systems to satisfy intelligence requirements that date back to at least the mid 1950s. Dr. James Outzen, the NRO Historian, selected the documents contained in this initial edition of the compendium to provide the reader with information on the history, capabilities, and technical contributions of these programs.

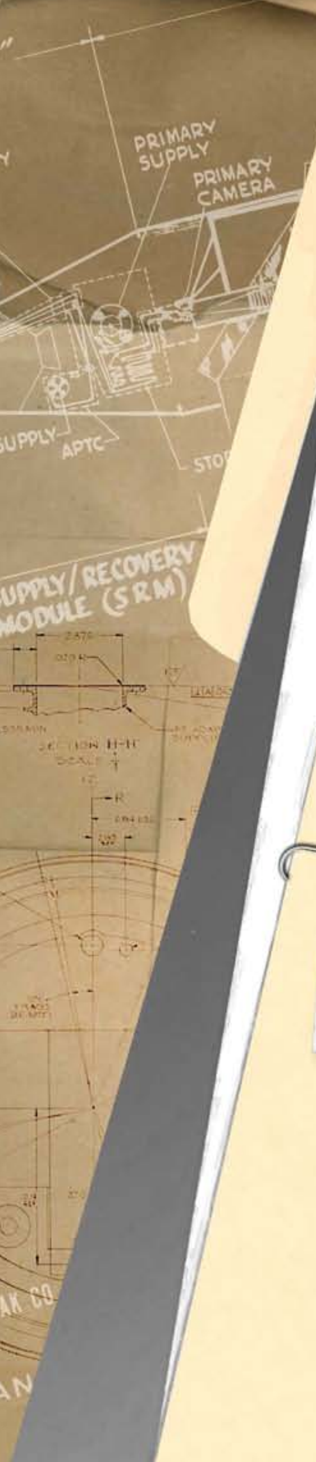
The first section of this volume is a short history of the Gambit and Hexagon programs prepared by the NRO's first historian, Dr. Gerald Haines. Dr. Outzen and I chose this history because Dr. Haines wrote it for the occasion of the declassification of the programs—something we had anticipated years earlier, but only became possible in 2011, the 50th Anniversary of the NRO. The second and third sections of this compendium contain primary source documents on the capabilities and contributions of the Gambit and Hexagon systems.

Based on the intelligence requirements for these programs and the information contained in the compendium, I anticipate the readers of this compendium will gain an appreciation of the roles Gambit and Hexagon played in the NRO's history. I also expect that the compendium will help readers understand the intelligence reasons for developing the programs, the challenges in meeting the intelligence imperatives, and the successes of the programs. The readers should come away from reviewing this volume with insight applicable to their own efforts to assure the United States' success in gathering intelligence by using satellites.

In a later print edition, we plan to include documents on the intelligence requirements for the systems, initiation of each of the systems, controversies surrounding the systems, and recognition of the systems successes. Although not exhaustive, the compendium will provide a hearty introduction to the dynamics surrounding the development, operation, and termination of these important overhead reconnaissance systems. This compendium is an opportunity to have an early look into a formerly highly classified world of national reconnaissance.

Robert A. McDonald, Ph.D.
Director, Center for the Study of National Reconnaissance
Business Plans and Operations
National Reconnaissance Office





CRITICAL TO US SECURITY:
THE GAMBIT AND HEXAGON SATELLITE RECONNAISSANCE SYSTEMS

PREFACE

This compendium of documents related to the Gambit and Hexagon satellite programs was inspired by a practice initiated with the 1995 declassification of the Corona satellite reconnaissance program. A few months after the declassification announcement for the Corona program, the Central Intelligence Agency (CIA) published a similar volume edited by Kevin Ruffner. Like the CIA's Corona compendium, we wanted to include a basic history of the Gambit and Hexagon systems. Dr. Gerald Haines, the NRO's first historian wrote a history of the Gambit and Hexagon systems that was unpublished up to this point. Dr. Haines finished the history in 1997 in anticipation of the declassification of the Gambit and Hexagon programs. We are pleased to publish the history for the first time in conjunction with the 2011 Gambit and Hexagon declassification announcement. To enhance the history, we have also included photographs and graphic illustrations that were used to explain the capabilities of the two systems.

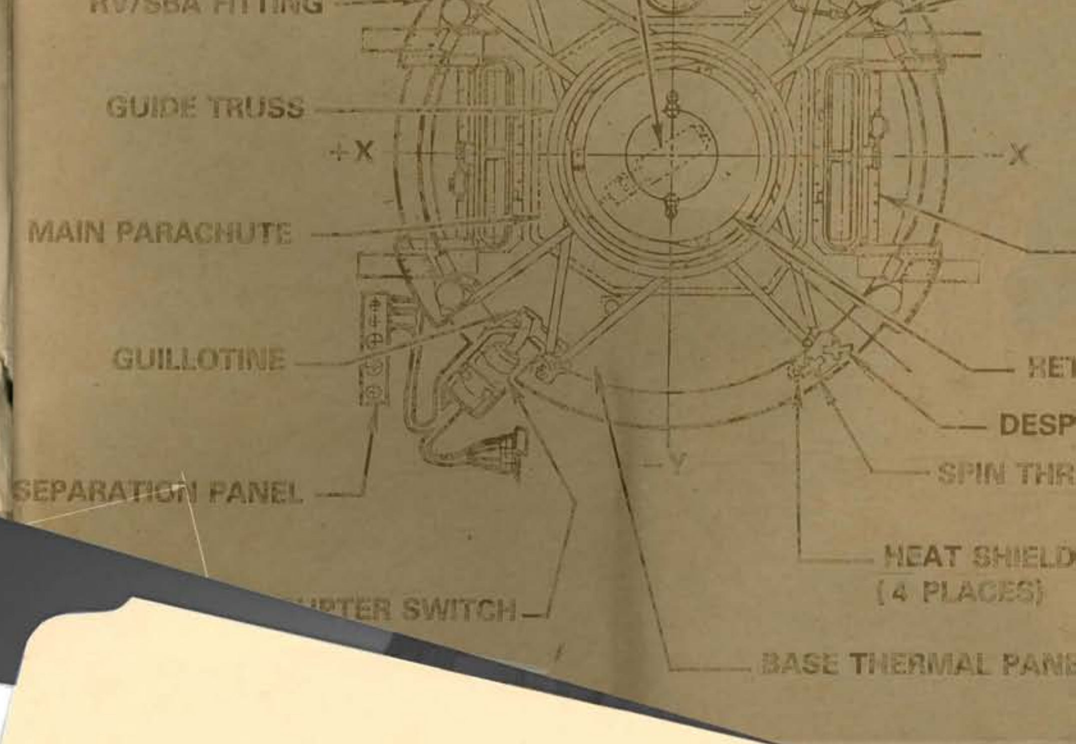
A much more challenging task was to identify documents to include in the compendium in order to explain the development, launch, and operation of the Gambit and Hexagon systems. The difficulty arose from an abundance of documentation for all of the systems. To determine which documents to include, I conducted document reviews at the CIA records center, the NRO records center, and NRO field sites where documentation still resided for the programs. I also reviewed a small number of Hexagon documents complied by the NRO's Public Affairs staff.

From these efforts, I identified some 4,000 pages of documentation for consideration to include in this volume. After this initial selection, I sorted the documents into main themes that characterize the histories of the Gambit and Hexagon systems. Those themes include program requirements, program initiation, system capabilities, technological contributions, controversies surrounding the programs, and recognition of program successes. The challenge then was to select documents representative of these themes. I made the selections that best described important elements relevant to each theme.

Unlike the Corona volume, we are not able to include later Gambit or Hexagon panoramic imagery. This imagery remains classified at this writing, although we hope to have declassified imagery available for this volume when we publish the printed version, expected in early 2012. As an interim step, we are publishing this electronic edition with document sections on system capabilities and technological contributions. The remainder of the documents will be included for other themes in an early 2012 printed edition.

As with any major publication, there are many individuals who are responsible for completing the project. I express appreciation to the NRO records center. Their staff provided outstanding help in locating dozens of boxes of records for me to review. Likewise, I express my appreciation to the staff at the CIA's record center who located many boxes for my review related to the CIA's development of what would become the KH-9 camera system for Hexagon. I express appreciation to the NRO's Public Affairs staff, for sharing documents located through part of their research process. During the summer of 2011, four interns for the Center for the Study of National Reconnaissance (CSNR) provided invaluable assistance with this effort. Steve Glenn and the records declassification staff for the NRO provided incredible support in reviewing several hundred pages of documents for release. Without their efforts, this project would never have been completed The Director of the CSNR, Dr. Robert A. McDonald, provided not only essential support, but valued wisdom in developing this volume. Finally, none of this would have been possible without the editing, layout, and graphic design work by the CSNR support staff.

James Outzen, Ph.D.
Chief, Historical Documentation and Research
Center for the Study of National Reconnaissance



CRITICAL TO US SECURITY:
THE GAMBIT AND HEXAGON SATELLITE RECONNAISSANCE SYSTEMS

INTRODUCTION

After the 1960 success of the Corona program, users of imagery intelligence developed growing appetites for more space based photoreconnaissance. During the more than two and a half decades that followed, the United States operated three additional film-return satellites. They were named Gambit, Gambit-3, and Hexagon.

The introduction of the Gambit system in 1963 provided the United States with the ability to take higher resolution images of specific targets. This complimented Corona's wide area coverage. Gambit allowed the United States to carry out "surveillance," or ongoing tracking of known targets. Corona's wide area coverage allowed the United States to continue to "search" broad areas of the Soviet Union and China in order to locate the targets such as intercontinental ballistic missile sites, nuclear test sites and facilities, and other strategic and tactical land, air, and naval targets. Search and surveillance from space became a key strategic capability for the United States to fight the Cold War.

The National Reconnaissance Office (NRO) developed Gambit-3 to further improve resolution for surveillance of targets identified by Corona imagery or other sources of intelligence. First launched in 1966, Gambit-3 incorporated a number of technological changes to not only improve resolution, but also increase the length of time the system operated, the amount of coverage, and control of the system.

Hexagon was developed to improve resolution of wide-area search imagery captured by the Corona program. Hexagon's developers introduced a primary camera system that produced imagery of high enough resolution to fulfill some search requirements as well. Later Hexagon missions would also include a mapping camera system to aid possible Cold War military operations. The NRO launched the Hexagon system in June 1971, replacing the Corona program that developers originally only expected to last two years. Hexagon would be the last of the nation's four film return imagery systems that, together, provided insight into the U.S. adversaries' military capabilities.

Gambit and Hexagon moved the Intelligence Community closer to meeting the intelligence requirements that prompted the development of space imagery systems. The requirements can be traced back to as early as 1955 for what would become the Air Force's Samos program. First and foremost, the United States needed satellite imagery systems that could provide "instantaneous warning of ballistic missile attack(s)" by the Soviet Union. The requirements also included supporting U.S. war planning, understanding the intentions of possible U.S. adversaries, and determining the military capabilities of those enemies.

The historical record indicates that Corona and Gambit were essential for assessing the Soviet nuclear strike capabilities in the 1960s. The systems worked hand in hand with Corona imagery first identifying nuclear facilities and then Gambit providing detailed information on those facilities. By the end of the 1960s, while U.S. concerns about the size of Soviet nuclear remained, the United States began to focus on curtailing those nuclear capabilities. Gambit and Hexagon would also become essential resources for helping achieve this end.

The United States and the Soviet Union entered the 1970s actively pursuing control of nuclear arms. The Strategic Arms and Limitations Talks (SALT) resulted in an agreement to control development of antiballistic missiles as well as an interim agreement on limitations on nuclear weapons development. By this time, the Hexagon system was operational and replaced Corona for wide area search requirements. Hexagon satellites joined later Gambit satellites in serving as a primary means for verifying Soviet compliance with the agreements reached through the SALT process.

As the systems neared the end of their lifespans in the mid-1980s, they remained a key resource for nuclear arms limitation verification. The systems also served as a means for gaining insight into other intelligence issues that would arise over their lifespans. Together, Gambit and Hexagon yielded intelligence information that assisted the President of the United States, as well as U.S. military, diplomatic, and intelligence officials to make better informed decisions on matters of national security.

Eventually the costs, both in terms of money and time, would lead to the replacement of Gambit and Hexagon by near-real-time imagery systems. Gambit and Hexagon would remain highly regarded for their technological innovations and invaluable contributions to the defense of the United States. The contents of this volume are intended to help the reader understand and appreciate this high regard for the Gambit and Hexagon imagery satellite systems.

James D. Outzen, Ph.D.
Compendium Editor

CRITICAL TO US SECURITY:
THE GAMBIT AND HEXAGON SATELLITE RECONNAISSANCE SYSTEMS

SECTION I: HISTORY

OVERVIEW

Since the early 1960s, U.S. policymakers have come to rely increasingly on photoreconnaissance satellite imagery for timely and accurate intelligence. Photoreconnaissance satellites and the information they provide have become virtually indispensable to the U.S. Intelligence Community and its intelligence assessments. Developed, operated, and managed by the National Reconnaissance Office (NRO), these satellite systems sparked a revolution in intelligence collection. Operating in a crisis atmosphere, the NRO forged a unique working partnership with U.S. private industry partners to design and build these new satellite systems. The NRO/industry partnership drove space reconnaissance technology beyond current limits. It made possible a new generation of photoreconnaissance technologies that resulted in the acquisition of never-before-seen, detailed intelligence data for U.S. officials.

Corona, the first U.S. reconnaissance satellite program ushered in this new era in intelligence. A stop gap film recovery system, Corona focused primarily on the Soviet Union and other denied areas. Corona imagery provided U.S. decisionmakers with vital information on Soviet weapons development, order-of-battle, and its nuclear program. During the 1960s, Corona satellites were this nation's primary search system. Covering wide swaths of the Soviet Union, Corona cameras swept the Soviet land mass for signs of missile development and nuclear testing activity. Although its contribution to U.S. intelligence was "virtually immeasurable," Corona imagery also had limitations. In 1961, for example, it could resolve no object smaller than 10 to 15 ft. U.S. photointerpreters and U.S. planners needed, and demanded, higher resolution imagery for their intelligence estimates relating to Soviet weapons systems and target identifications.

To fill this gap, Director, NRO (DNRO), Joseph Charyk, pushed the development of a high-resolution spotting satellite system, Gambit. Also known as the KH-7, Gambit was to provide resolution better than 2 ft. After overcoming a series of developmental problems, both technical and managerial, the first Gambit satellite flew in July 1963. The returned film product whetted the appetite of U.S. intelligence analysts for more. Although Gambit, a surveillance system, covered far less area than Corona, it produced photography with a much better resolution, for example, objects as small as 6 ft could now be located and observed.

An improved Gambit, known as Gambit-3 or the KH-8, flew in 1967. Capable of stereo photography, it proved highly successful replacing Gambit-1. The Gambit program eventually flew 54 missions over 20 years, concluding in 1984. It provided U.S. officials with unique, highly detailed imagery of sensitive targets, and became a major tool for photo analysts during the Cold War.

Film-recovery payloads culminated with the development of the Hexagon series of satellites. Approved for design and development by the United States Intelligence Board (USIB) in 1964, the Central Intelligence Agency (CIA) designed Hexagon as both a high resolution and wide area coverage system. It was one of the largest and most complex reconnaissance satellites ever built. Known to the American public as "Big Bird," it was 10 ft in diameter and 55 ft in length. It rivaled the National Aeronautics and Space Administration's (NASA's) Space Lab in size. Hexagon featured two panoramic counterrotating optical-bar cameras and four recovery capsules (later Corona and Gambit satellites carried two). Later Hexagons also contained a fifth capsule to return film from a separate mapping camera. Accompanying stellar and terrain cameras in Hexagon made it possible to extract mapping, charting, and geodetic data for the Defense Mapping Agency and other organizations of the Intelligence Community. The NRO launched twenty Hexagon's between June 1971 and April 1986. The only failure to mar this remarkable satellite program occurred on the twentieth and last flight when the launch booster exploded above Vandenberg Air Force Base, California on 18 April 1986.

In the 1980s, the next generation of U.S. photoreconnaissance satellites (which eliminated the need for film return) replaced both Gambit and Hexagon. During their years of operation, however, Gambit and Hexagon proved invaluable to U.S. policymakers. For much of the Cold War, these systems kept watch over the Soviet Union and other communist bloc areas. They proved critical to U.S. security by providing detailed intelligence on U.S. adversaries. Their search and surveillance capabilities also made possible arms limitation negotiations and the verification of nuclear reduction treaties.

This study traces the origins and development of the Gambit and Hexagon programs. It details the technological problems, breakthroughs, and accomplishments encountered as NRO, CIA, Air Force, and private industry engineers, designers, and program managers pushed the cutting edge of space reconnaissance technology. It outlines the evolving close partnership and working relationship between the NRO and industry in pursuing far-reaching scientific and technological goals. This study also describes the bureaucratic battles among the CIA, the NRO, and the Air Force over control and management of these systems. Finally, it places the development of these unique satellite systems squarely in the crisis atmosphere of the Cold War and the constant demands of U.S. officials for more and better pictures. It is a remarkable story.

BACKGROUND

Deeply concerned over Soviet boasts about the success of their missile program and the growing "missile gap," controversy, President Dwight D. Eisenhower, despite reservations, authorized a U-2 penetration flight of the

Soviet Union for 1 May 1960. The Department of State and the CIA strongly supported the decision. The intelligence objective of gathering information on the Soviet missile program was overwhelming in spite of the dangers.

The most experienced U-2 pilot, Francis Gary Powers was selected to fly Operation Grand Slam. According to CIA analysts, this route offered the best chance of photographing suspected locations of Soviet Intercontinental Ballistic Missile (ICBM) sites. Powers' first target was the Tyuratam Missile Test Range; he was then to head for Chelyabinsk, just south of Sverdlovsk. Powers never made it past Sverdlovsk. Four and a half hours into the mission, a Soviet SA-2 Surface-to-Air Missile (SAM) disabled his aircraft 70,500 ft above the Sverdlovsk area. The Soviets had succeeded in downing the United States' most advanced reconnaissance aircraft. When Eisenhower finally admitted U.S. responsibility for the U-2 overflight, he suspended all future U-2 flights over the Soviet Union. The United States was now primarily blind regarding Soviet missile advancements.

At the same time the U-2 was successfully overflying the Soviet Union, 1956 through 1960, and following the dramatic Soviet space successes in 1957 with Sputnik I and Sputnik II, President Eisenhower formally endorsed a stop-gap U.S. satellite program in February 1958. The new Corona project, managed jointly by the same CIA-Air Force team, which had built the U-2, was to produce a satellite imaging reconnaissance system that would take pictures from space and deorbit a capsule with film back to earth. Like the U-2, this was a bold initiative to counter the closed societies of the Sino-Soviet bloc.

A string of twelve successive failures, however, threatened to end the Corona program before it even succeeded in returning a single film capsule from space. As the failures continued to mount, CIA Deputy Director for Plans, Richard Bissell and his Corona team became frustrated. It was not like the development of the U-2 where, if something failed, the pilot, unless it was a fatal error, could usually relate what happened. With satellites, according to Bissell, "they spun out of control, burned up in the atmosphere, crashed, hopelessly lost in the ocean, or exploded. Because the whole system was destroyed on reentry, it was often impossible to retrieve it and do an assessment."

Discouraged, on 10 August 1960, the Corona team launched a diagnostic payload in an attempt to determine what was going wrong. The launch from Vandenberg, AFB, California, was perfect, the Agena rocket sent the spacecraft into the proper orbit, and on its 17th revolution, it successfully returned to earth, the first payload from space.

Buoyed by this success, the CIA/U.S. Air Force team launched a camera-equipped Corona on 18 August. Like the earlier mission, Corona Mission 9009 worked perfectly and deorbited its film payload on Friday, 19 August 1960, exactly 100 days after the Soviets shot down Powers and his U-2. The two recoveries did not make a successful program, however. Of the next four launches, only three went into orbit and one of these suffered a camera failure.

Corona Mission 9013, recovered on 10 December 1960, revealed Soviet construction work on its SS-6 missile sites at Plesetsk and at Yurya. Photoreconnaissance was beginning to pay off. Corona photography obtained in June 1961 also revealed a new Soviet missile project around Leningrad. Some CIA analysts believed this new system was an Antiballistic Missile (ABM) system designed to counter U.S. intermediate-range missiles. The John F. Kennedy administration, anxious over this new development, turned to the CIA and the Corona program for more data. Corona, however, was not able to perform the required task. Even its newest camera, the stereo KH-4, known as Mural, was not good enough to provide technical data on the design of objects as small as a SAM. Moreover, Corona engineers were still grappling with keeping the satellite cameras in focus. According to the Satellite Intelligence Requirements Committee (SIRC), new U.S. satellite systems were needed that could resolve objects as small as 6, 1.5, and 0.3 m. Corona cameras called only for a resolution of 6 m. This was in accordance with its role of performing wide-area, low resolution "search" missions.

CRITICAL TO US SECURITY:
THE GAMBIT AND HEXAGON SATELLITE RECONNAISSANCE SYSTEMS

GAMBIT

ORIGINS OF THE PROGRAM

The NRO Gambit satellite program evolved from the Air Force's larger developmental plans for building reconnaissance satellites—the WS-117L program in the mid-1950s. As originally envisioned, the Air Force sought to create a multifaceted satellite observation system. Little came of these efforts, however, as the Department of Defense (DoD) struggled to eliminate “non-critical” defense expenditures and the Eisenhower administration stressed a “space for peace” theme. Following the Soviet space successes of 1957, however, Defense Secretary Neil H. McElroy authorized the acceleration of WS-117L to proceed “at the maximum rate consistent with good management.”[7]

Upon the urging of his civilian scientific advisors, President Eisenhower in 1958 ordered a small part of the WS-117L program, a satellite with a returnable film capsule, be taken from the Air Force overall program and given to the same team that had built the U-2—the CIA's Richard Bissell and the Air Force's Brig Gen Osmond Ritland—for quick development. Corona was to be a stop-gap measure until the larger Air Force effort produced results.

In the aftermath of the U-2 shoot-down, the suspension of U-2 operations over the Soviet Union in May 1960, and the mounting failures of the Corona and Samos programs, U.S. officials urgently sought new sources of high resolution reconnaissance photography.[8] The imagery was critical to U.S. national security interests.

The U-2 shoot-down triggered a series of top level meetings on the status of the Air Force's Samos programs. The Eisenhower decision to stop all aircraft overflight operations meant the loss of high-resolution observation of the Soviet Union. Even if Corona achieved success, and at this point it had not, there was an immediate need for much better resolution than it could provide. George B. Kistiakowsky, who had succeeded James Killian as President Eisenhower's science advisor, was pessimistic about the Samos programs.

On 26 May 1960, Eisenhower directed Kistiakowsky to set up a group to advise, as quickly as possible, the best way to expand satellite reconnaissance options. Kistiakowsky turned to James Killian, Edwin H. Land, Carl Overhage of Lincoln Laboratories, Richard M. Bissell, Jr., and Air Force Under Secretary Joseph V. Charyk. They all echoed Kistiakowsky's concerns over Samos and suggested a DoD streamlined, super-Corona program. Charyk also argued strongly for keeping the program in the Air Force. If given the chance, Charyk believed he could create a successful covert satellite program within the Air Force.

On 25 August 1960, Eisenhower approved the recommendation of the Kistiakowsky Study Group. Charyk got his wish and Samos became part of a new Air Force organization known as the Air Force Project Office, which subsequently became the Secretary of the Air Force Special Project Office (SAFSP). The new Samos project office in Los Angeles was to be housed in the same building as the new Space System Division. It would have direct access to all Air Force resources: an Atlas booster; an Agena spacecraft; a launching site at Vandenberg AFB; tracking and control services at Sunnyvale, California; and recovery services at Oahu, Hawaii. Brig Gen Robert E. Greer became the first SAFSP director. He had previously been the Air Force's assistant chief of staff for guided missiles. At the same time, under a security strategy called “Raincoat,” Charyk hid the sensitive space program by forbidding any publicity releases on an Air Force space project.

Another factor that affected the Gambit program was the formal establishment of the NRO in September 1961. Now, all national collection requirements went through the NRO and its Satellite Operations Center (SOC) located in the basement of the Pentagon. Joseph Charyk and Richard Bissell, Jr. became the first co-DNROs and Gambit became the first full-scale venture of the new organization. Charyk assigned the Gambit Project to Program A (Air Force) at SAFSP. It proceeded independently from the Corona project and the CIA satellite effort (Program B).

GAMBIT DEVELOPMENT

In March 1960, Eastman Kodak submitted proposals to the Air Force and the CIA for the development of a 77-in (focal length) camera for satellite reconnaissance. Building on its development work for the CIA's Oxcart aircraft program, Kodak suggested that the new high performance catadioptric lens camera might be suitable for satellites.[9]

In June, Kodak proposed a 36-in camera system to provide convergent stereo coverage of Soviet territory. Termed “Blanket,” Kodak claimed the new system could be made operational in a short period of time because it was based on existing technology from the Oxcart program. Kodak officials, Arthur Simmons and Herman Waggershauser, showed the proposal to Edwin H. (Din) Land, one of Eisenhower's scientific advisors. Land enthusiastically brought the proposal to the attention of Air Force Under Secretary Joseph V. Charyk. Charyk, too, was interested. He liked the Kodak proposal, a film-only recovery scheme like Corona with a very high-acuity, long focal-length camera. In discussion with Charyk, Kodak officials confidently projected the feasibility of providing a surveillance camera with 2- to 3-ft around resolution with high-acuity stereo coverage.

A month later, on 20 July, Kodak offered a modified proposal, which integrated the 77-in camera with the stereo features and film recovery techniques embodied in “Blanket.” It termed the new proposal “Sunset Strip” after the popular television series. This was promising technology for new orbital reconnaissance systems.

In September 1960, Charyk met with Greer, Col Paul J. Heran (Chairman of the E-6 Source Selection Board) and Lt Col James Seay (Greer's procurement chief) to review proposed satellite programs. All agreed to proceed with both E-6 (which had the potential of being twice as good as Corona) and the Kodak "Sunset Strip" proposal. Charyk directed that "Sunset Strip" be developed on a cover basis, hidden in the E-6 program. He set initial funding for research and development study funds for the balance of FY 1961. Greer named the new "black" program Gambit. By keeping the physical and environmental limitations of E-6 and Gambit compatible, it seemed possible to develop and test Gambit without any outward indication that such a program existed.

At the same time Charyk moved to hide the Gambit project, he also shielded it from the overall Air Force Samos program, cutting out the Strategic Air Command, the Air Force Ballistic Missile Division, and the Air Force System Command. They all objected strongly to "losing" Samos. Charyk later reflected that it was extremely difficult limiting "need to know" especially when everyone believed they were working on a strategically important program. On the one hand he was telling them that Samos was extremely important and on the other that it would be drastically cut back.

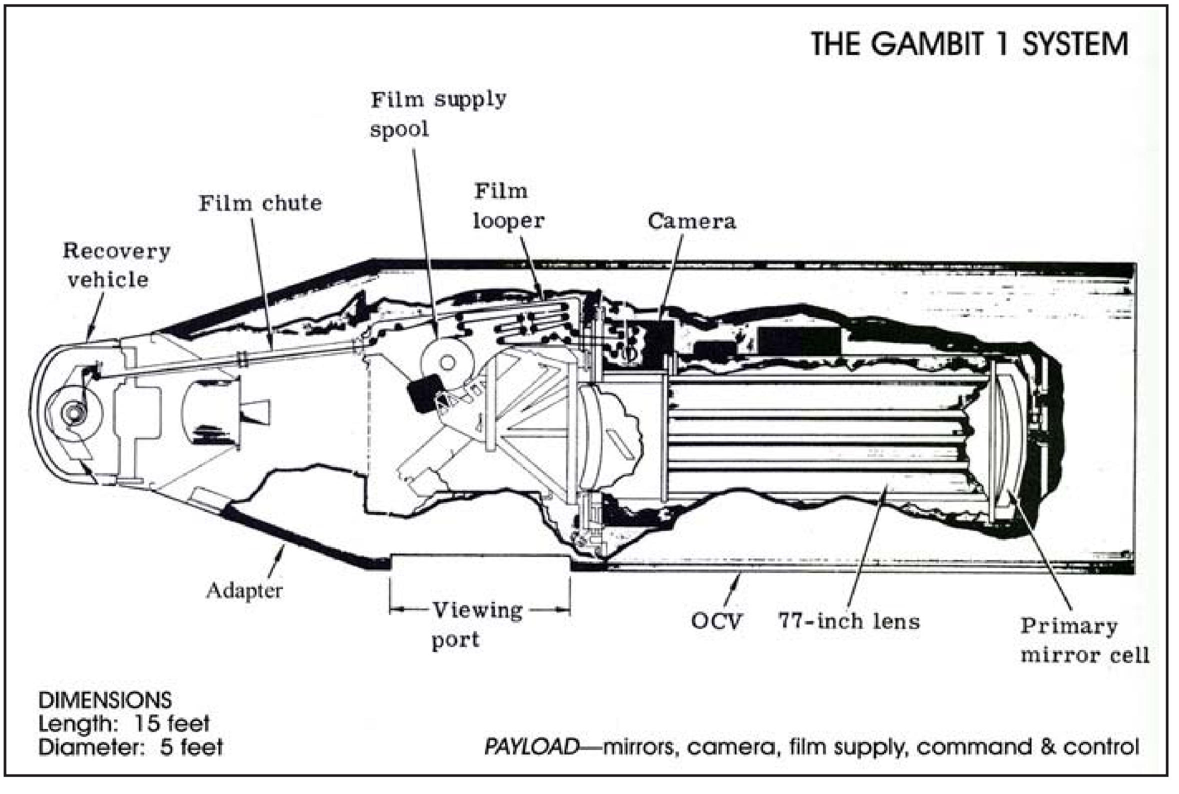
Since the 77-in camera development program was well publicized, Charyk and Greer followed the earlier Corona precedent. They terminated the Kodak study contract for "Sunset Strip" as "no longer required" and simultaneously authorized Kodak to continue the development as a covert effort. As the "Sunset Strip" activity closed and Kodak personnel nominally shifted to other Kodak projects, they actually moved into a new facility in a different building and resumed their work. In establishing the Corona program, Bissell and Ritland followed much the same procedures.[10]

The complex, involved, security procedures for Gambit "cover and deception," in retrospect seem overdone. There were few challenges or threats to the system or the disclosure of Gambit.

GETTING PICTURES

While putting the rather elaborate security system in place, both Charyk and Greer agreed that their real job was to "get pictures," the objective of the national satellite reconnaissance program. Although Charyk initially balked at Eastman Kodak's demand for a 7-percent profit margin on camera development, by January 1961, he and Kodak had reached agreement.

Greer supported Kodak. According to Greer, the fee was not excessive. He based his judgment on the U-2 camera expenses and Kodak's "unique capability." Moreover, the 25 August National Security Council directive ordered the Samos "take to be processed by the same agency that processed U-2 take"—Eastman Kodak. There were no alternatives. General Electric's (GE's) Space Division was to build the orbital-control vehicle. By mid-1961, Gambit had evolved into a 15-ft long, 5 ft in diameter space vehicle.



Gambit-1 configuration

The Gambit payload embodied a Maksutov f/4.0 lens (both reflecting and refracting elements) similar to an astronomical telescope with a 77-in focal length and a clean aperture of 19.5 in. This lens, when flown at a nominal 95 rim altitude was to produce an around resolution, at nadir, from 2 to 3 ft. Gambit was to carry 3,000 ft of 9.5-in diameter, thin-base film through a strip camera, which would provide image-motion compensation by moving the film across the image exposure slit at the same velocity that the projected image moved over the earth. The camera would image a strip on the earth 10.6 nm wide. It possessed the capability of photographing specific targets, which were off the immediate orbital track through oblique pointing. The planned weight of the total photographic system was 1,154 lbs.

The high resolution requirement for Gambit imposed a need for accurate orbit maintenance over a period of several days and for an ability to rotate the camera section about the vehicle's roll axis. The GE Orbital Control Vehicle (OCV) was to be capable of varying the roll attitude from 0 to 45 degrees and of performing 350 roll maneuvers at an average role of one per second. The command system was to receive, accept or reject, and execute both real-time or stored commands.

Samos Nose Cone

The attitude control system was a two-axis gimballed platform on which were mounted infrared horizon scanners and an integrating gyroscope. The horizon sensors measured pitch and roll error; the gyro measured yaw error. Control movements were dependent on several jet-nozzle apertures. A set of four rocket engines, each capable of producing 50 lbs of thrust, would provide orbit maintenance.

The initial Gambit launch vehicle was an Atlas Agena-D. The Atlas used 123 tons of liquid oxygen and refined kerosene (RP-1) to power the booster engines—each generating 154,500 lbs of thrust and a 57,200-lb thrust sustainer engine. The Agena-D upper stage used 13,234 lbs of fuel to power its 16,000-lb thrust engines.

After exposure, the camera’s film was wound up in the Recovery Vehicle (RV). At the end of the mission, the RV was separated from the OCV, spun up on its axis of symmetry by a cold-gas system, and then deboosted from orbit. Parachute deployment was to occur at 55,000 ft. The initial recovery vehicle was intended for land recovery. In fact, in October 1961, Charyk approved the use of the Wendover AFB in Utah for Gambit land recovery operations. At this point, both Kodak and GE appeared to be ahead of schedule in completion of their design concept. By 1 August 1961, a Gambit launch date in January 1963 appeared possible.

Even with progress in the Gambit program, by January 1962, the need for an on-orbit, high-resolution, photographic reconnaissance system was even more critical. The Samos E-5 program had been cancelled after a series of failures and Corona was experiencing operational difficulties. DNRO Charyk, under constant pressure to get quick and effective results from the satellite reconnaissance program, wanted to accelerate the pace of Gambit development and improve its product. In discussions with Greer and Quentin A. Riepe, the program director for Gambit, however, it soon became clear that serious problems remained and any quick fixes would seriously degrade the photography. There was general agreement that the earliest possible date for the initial launch would be May rather than February 1963.

PROBLEMS

The National Security Council (NSC) program directive in 1960 approving Gambit specified the development of a land recovery program. In the climate of the early Corona program, land recovery appeared to be a useful option, less risky, more reliable, and less costly than the ocean recovery used by Corona. Moreover, the projected weight of the Gambit RV would exceed the capability of the C-119 recovery aircraft. By July 1962, however, the reasons for distrusting air-sea recovery methods seemed less valid. The improving capability of the Corona RV and the good performance of the overwater recovery system convinced Greer of the feasibility of using a Corona-like RV on Gambit.

The Gambit RV was then 500 lbs over design weight and most of the overweight derived from complications introduced by the land recovery requirement. Overwater recovery, as developed in the Corona program, seemed to Greer a very simple process when compared to the planned land recovery scheme. In its descent toward the ocean, a Corona reentry vehicle could safely shed all sorts of accessories—hatch covers and ablative cones, for example. They simply fell into the ocean and sank. A land recovery vehicle could shed nothing, lest it became a lethal projectile. Greer asked GE to do a quiet study of "gluing the Discoverer capsule on the front end of Gambit."

Greer was attracted to the concept by the potential of major savings on weight, cost, and launch schedule. More than 600 lbs of orbital weight could be saved by going to an overwater recovery mode. Facility funds for the Wendover range could be cut from the budget. Most importantly, with a modified Corona RV, Gambit could maintain its launch schedule. After listening to the various arguments, including the Gambit program office, which felt that the land recovery approach was still the better option, on 18 September Charyk authorized Greer to begin immediate development of a Corona-type recovery system for Gambit in preparation for a June 1963 first flight date.

The switch to a Corona-type water recovery vehicle markedly simplified the entire Gambit system and probably saved the program. It did not, however, eliminate all problems. While work on the camera payload at Eastman Kodak continued to progress, major problems threatened the launch date schedule. The optics for Gambit were to be larger and lighter than any previously built for space including the primary and stereo mirrors. Using large boules of very pure fused silica glass, engineers joined the sections. The fusion operation was extremely delicate: heated too long or at too high a temperature, the structure became a molten blob, too low a temperature or too short a time prevented the parts from fusing properly. Engineers shipped the large, lightweight blanks to Kodak for figuring and polishing at its special facility.[11]

Frederic Oder, director of Special Projects at Kodak and familiar with the Corona RV from his previous work on WS-117L, favored the use of Corona technology on Gambit. Kodak had originally planned to keep the film path pressurized including the film chute and take-up cassettes. Using his Corona background, Oder urged the adoption of a nonpressurized film path. This simplified the process and allowed the Gambit film load to be accommodated in a Corona-like RV without serious modifications.

Kodak was also having problems attaching or cementing the silica mirrors to their metal case and with the platen drive, which caused the film to move irregularly over the exposure slit. Although the problems were not considered major, they added to existing pressure on delivery time and flight schedules.

The OCV development by GE, in its Valley Forge, Pennsylvania facility, was another story. Repeated failures in such varied experiments as the harnesses, power supplies, batteries, command systems, horizon sensors, rate gyros, environmental doors, and pyro devices, caused major cost overruns and severely threatened delivery schedules.

The prevalence of cost overruns, particularly at GE, the threat of new schedule slippage, and the increasing cost of the Gambit program greatly concerned Charyk. At the same time, pressures continued to increase for hard intelligence on the Soviet Union. The Cuban Missile Crisis of October 1962 added to the sense of urgency.

At a meeting with the President's Foreign Intelligence Advisory Board and the "special group" of the National Security Council, Charyk characterized Gambit as "imperative" and urged that the program be pressed with a "maximum sense of urgency." "No reasonable steps," Charyk argued, "should be omitted to guarantee its success at the earliest possible time." According to Charyk, Gambit offered the most promising approach to discovering whether or not the Soviet Union was actively preparing for war.[12]

Discouraged about the rate of Gambit progress, Charyk suggested to Greer a management change. He wanted an exhaustive technical review of the program to locate any remaining problems. Greer was reluctant to relieve Col Riepe, the original program manager. Nevertheless, on 30 October 1962, Greer replaced Riepe with Col William G. King. King had a long experience with satellite reconnaissance. He had been Samos program director in the late 1950s and was one of the first to recognize the advantages of film recovery techniques over the technically more difficult readout systems. At the time of his appointment to head the Gambit program, he was serving as Greer's special plans officer.[13]

Immediately upon taking over the Gambit program, King discovered that the GE adaptation of the Corona capsule to Gambit was seriously off course. Greer's original intent, confirmed by Charyk, was to "glue on" the Corona recovery vehicle. Elaborate or extensive modification of the capsule was neither intended nor desired. In the course of changing over from land recovery to air-sea recovery, however, Gambit officials had authorized GE to develop a recovery vehicle capable of accepting the original pressurized Gambit take-up cassette and film chute.[14] Responding to the request to convert Gambit to a Corona recovery vehicle, GE scaled up the Corona capsule, making it deeper and increasing its base diameter. The result was a completely new capsule which required an extensive test program. The cost also escalated.

King suggested that the original intent of the Corona modification be reinstated and that the rapidly expanding GE development effort be stopped. Greer, who had originally ordered that changes to the Corona capsule should be minimal, agreed. King imposed an "absolute minimum" change policy in his instructions to GE on adopting the Corona recovery system to Gambit.

At the same time, King was sorting out the technical problems with Gambit, Charyk and Greer decided to strengthen Gambit management further by transferring the program from the Space Systems Division to SAFSP. Such a move would give Gambit the prestige and authority of the office of the Secretary of the Air Force. This set off a fire storm in the Air Force Systems Command (AFSC). General Bernard Schriever, commander of AFSC, had been a major force in establishing the Air Force space program. Schriever believed strongly that all Air Force space activity should be under AFSC management. He made several determined but ultimately unsuccessful attempts to regain "ownership." High priority space programs would from now on report directly to the Office of the Secretary of the Air Force.

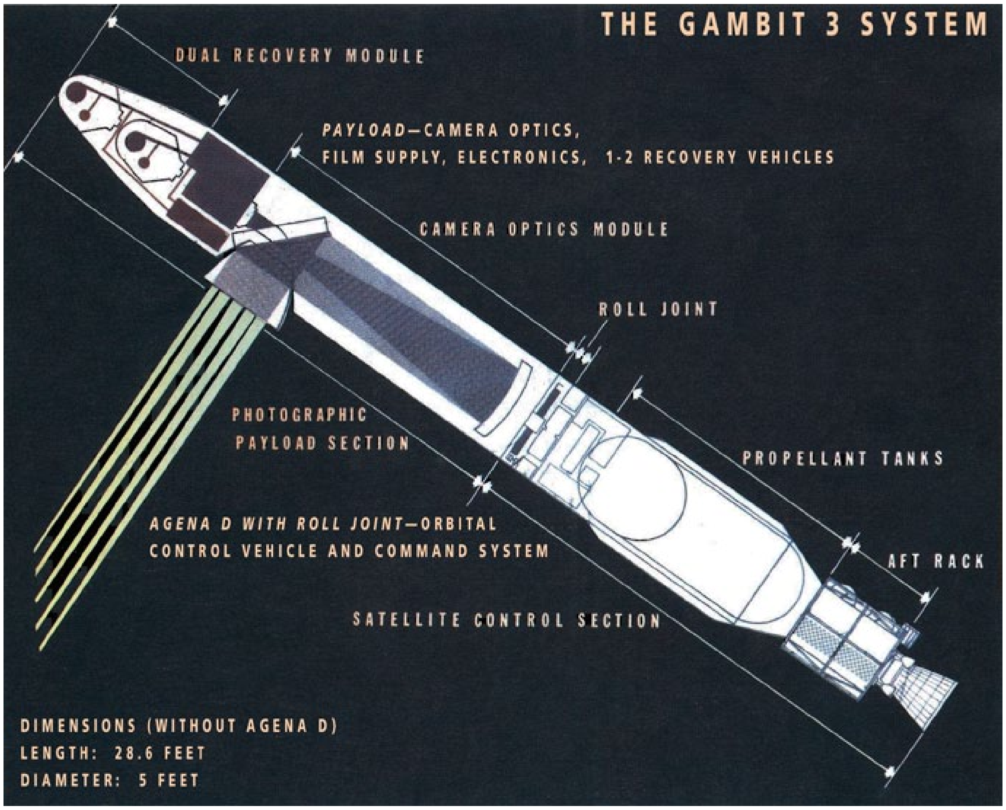
King continued his technical review of the Gambit program by questioning GE's untested OCV and its attitude-control subsystem. In order to improve the probability of early Gambit flight successes, King and Greer suggested that the Agena, at least for the first three flights, remain connected to the OCV. The reliable Agena, while not as precise as the Gambit system, could provide a stabilization and control mechanism to stabilize the Gambit camera long enough to secure operating experience and proof of system feasibility. Flying in this "hitch-up" configuration would not allow the demonstration of Gambit's full capability and it would only permit near-nadir photography, but King and Greer were determined that the first Gambit should return at least "one good picture."

King and Greer also envisioned using a roll-joint coupling (invented for an interim high resolution satellite developed by the CIA, known as Project Lanyard and its KH-6 camera) between the spacecraft (Agena) and the camera system. Should the GE OCV prove unreliable, the introduction of the Lanyard roll-joint could stabilize and control the vehicle.

As was the case with the Corona reentry capsule, the roll-joint technology was unknown to most Gambit people. Because of the high degree of security compartmentation in the reconnaissance Program structure, CIA security officials were reluctant to disclose even the existence of Lanyard to Gambit personnel. Charyk got around this problem by "suggesting" to Greer (Greer actually drafted the suggestion) that he contact Lockheed Corporation about the roll joint as "...he (Charyk) believed a similar idea was once proposed and possibly designed in connection with another space program." Lockheed thus delivered the finished roll joints to the Gambit program as though they were new items with no relationship to any other reconnaissance program.

On 14 December 1962 Greer and King proposed yet another technical innovation. The latest change advocated incorporating "Lifeboat" provisions into Gambit. "Lifeboat" was another Corona originated technique. It involved providing independent reentry command circuitry (including a receiver), a separate magnetometer, and its own stabilization gas supply. All were independent of the main systems. If the primary reentry systems became inoperative, "Lifeboat" could be separately activated.

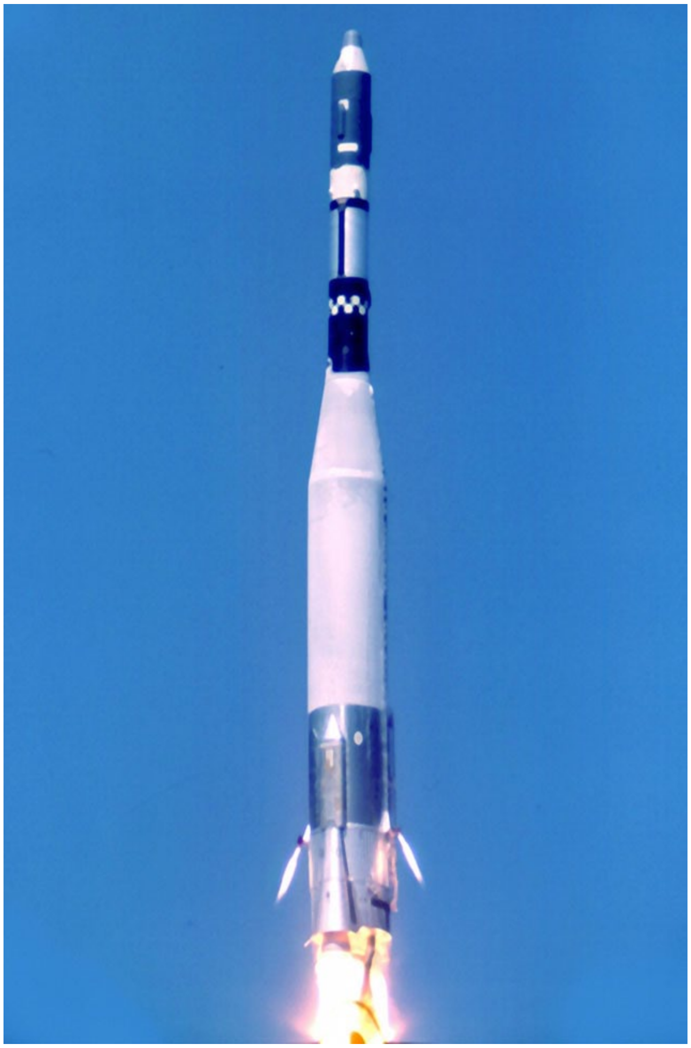
"Lifeboat" had proven its value on several occasions with Corona. Charyk formally approved adding "Lifeboat," "hitchun," and "roll joint" to Gambit on 19 December. "Lifeboat" was to be a permanent part of Gambit, "hitchun" was to be used on just the first four vehicles and then on a flight-by-flight basis. "Roll joint" was to be developed as an operational substitute for the OCV roll system. At the same time, in order to maintain the launch schedule, Greer and King deleted a substantial portion of the test program for Gambit. There was no



Gambit-3 Agena Vehicle

alternative if Gambit was to meet its proposed schedule of June. Both knew the risk, but additional overruns or schedule slippage could put the program in danger of being cancelled.[15] U.S. policymakers demanded useful intelligence images of Soviet targets.

When Charyk resigned as DNRO on 1 March 1963, Brockway McMillan of Bell Telephone Laboratories replaced him. All seemed to be proceeding well with Gambit. By May, Gambit was in its first flight checkout sequence. On the afternoon of 11 May, however, a faulty valve and a deficient fuel loading sequence caused a loss of internal pressure on the Atlas 190D. The booster collapsed on the pad, dumping both the GE orbital vehicle and the Agena on the concrete slab. The GE vehicle was severely damaged, the Agena to a lesser degree. Surprisingly, there was no explosion or fire, although 13,000 gallons of liquid oxygen and a full load of fuel sloshed over the pad. The camera system was damaged beyond repair, a large part of the optics demolished. The Gambit project team worked furiously to repair the damage and keep the pre-flight checkout on schedule. Despite their efforts the original 27 June launch date slipped back to July.[16]



Gambit launch

FIRST LAUNCH

Twenty-two months and 17 days after the National Security Council decision to proceed with a covert high-resolution satellite, Gambit flight vehicle No. 1 lifted off from its Vandenberg launching pad on 12 July 1963 at 1344, Pacific Daylight Time (PDT). For an instant during the launch, most observers experienced the horrified sense that disaster had come again to the NRO/Air Force satellite reconnaissance program. The splashing rocket exhaust of the Atlas knocked out all electrical connections to telemetry and cameras. It gave the impression of a major launch start explosion. Seconds later, however, the Atlas could be seen climbing steadily towards its launch window. Climbout, separation, and orbital injection went smoothly. Greer and King knew, however, it would be another 90 minutes before they would have proof that the bird was in a proper polar orbit. It would take another five orbits before the Gambit payload came to life. After another nine "working" passes, a recovery attempt would be made. There would be another wait as the capsule re-entered the earth's atmosphere, hopefully survived its passage through the upper atmosphere, arrested its descent by parachute, and was recovered.

On the fifth orbital revolution, command controllers turned on the camera for light strip exposures of 20 seconds each. On orbits eight and nine, two stereo pairs, and five, 2-second strips were exposed. A premature exhaustion of Agena stabilization gas then forced the discontinuance of camera operations. With the Agena out of fuel, "Lifeboat" became the only means of recovering the film capsule. On the eighteenth orbit, a ground station commanded "Lifeboat" and Gambit back toward earth. A C-119 aircraft waiting near Hawaii swept the parachuting reentry capsule out of the sky. The first Gambit was a success, but what about the film?

Evaluation of the recovered film, only 198 ft was exposed, indicated an out-of-focus condition for most of the flight caused apparently by uncompensated temperature changes that affected the face of the primary mirror and by faulty image motion compensation settings. Nevertheless, the best resolution was close to 3.5 ft, the average resolution about 10 ft. It was the best photographic return ever obtained from a reconnaissance satellite.

Greer, gratified by the success of the first flight, informed King that he very much wanted "two in a row." The very success of the first flight raised Intelligence Community expectations for subsequent flights.

The second Gambit flight took place on 6 September 1963. All went well. During 51 hours on orbit, the hitched vehicle completed 34 orbits and exposed 1,930 ft of film. On the 34th revolution, the reentry vehicle was detached and successfully recovered by air catch. An analysis of the photographs recovered from the second Gambit showed consistently high quality until the 31st orbit. The resolution achieved during the initial portion of the fight meant the photointerpreters could distinguish such detail as aircraft engine nacelles, small vehicles, and even maintenance equipment. For the first time, a satellite reconnaissance camera had returned detail at levels previously obtained only from reconnaissance aircraft. Only three years after Eisenhower ordered manned reconnaissance flights over the Soviet Union discontinued, U.S. satellites had filled the intelligence gap. First, Corona had returned coverage of areas most U-2s could not reach or safely overfly, and now Gambit had returned detail not greatly inferior to that produced by U-2 cameras. Gambit imagery, however, was limited to 1,930 ft of film from Gambit's second flight. Although Gambit's achievements were remarkable, it did not yet provide recurring coverage of the Soviet Union. Such coverage, at resolutions much better than Corona could provide, was still an urgent national goal.

McMillan, under constant pressure for more pictures, wanted future Gambit missions to concentrate on obtaining the best possible ground resolution over larger numbers of "denied area" targets. McMillan informed Greer, "... the name of the game is specific coverage of specific, known targets with stereo photography of the best possible quality." Greer was increasingly confident Gambit could produce the desired results.

On 25 October 1963, Gambit's third flight produced photography "better and more consistent than that of either of the first two missions." Imagery was the first to show identifiable figures of people on the ground—from a distance of 90 miles. The scene was a football field in Great Falls, Montana. In one photo, a place kicker could be seen putting the football in place while the other players moved into position. In a second photo, the players had lined up, ready for the kickoff.

Despite the superb resolution, however, the first three Gambit flights produced little intelligence. They did, however, whet the appetite of the U.S. Intelligence Community for more and better satellite imagery.

Gambit No. 6, launched on 11 March 1964, seemed to bring the program to maturity. Despite some continuing problems, Gambit No. 6 returned substantial quantities of highly useful intelligence data on targets.

CONTINUING PROBLEMS

The year 1964, however, brought serious problems to the program. From May through October 1964, half of six flights produced no coverage whatsoever. The best resolution degraded to 7 ft. Despite some successes in early 1965, the Gambit program was seriously ill.

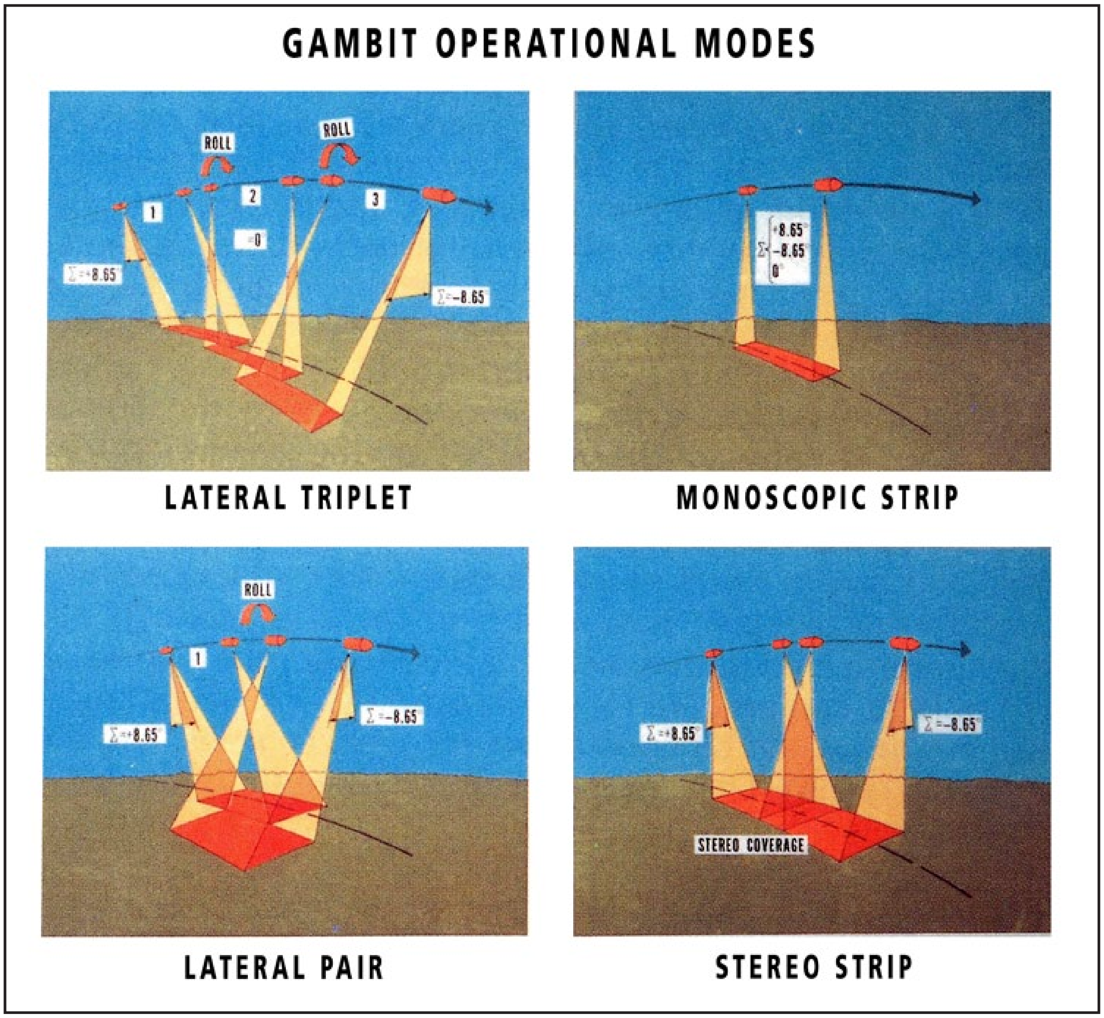
Maj Gen Robert Greer retired on 30 June. He was replaced by Brig Gen John L. Martin who had been chief of the NRO Staff in the Pentagon and deputy to Greer. The summer of 1965 brought key personnel changes as well. Dr. Alexander H. Flax, Assistant Secretary of the Air Force for Research and Development replaced McMillan as DNRO on 1 October. Only Col King continued in place as project director for Gambit.

As Greer's deputy, Martin had a detailed knowledge of Gambit. He had witnessed the agonies of the early Gambit operations and years later recalled the emotion of "watching a bird go dead." "You simply cannot imagine," he said, "the frustration you feel when a healthy-looking Gambit suddenly became a zombie."

Shortly after assuming command, Martin faced the issue of whether or not Gambit No. 20 should hold to its early July flight date. Martin decided to go ahead with the previous schedule. On 12 July Martin witnessed a comprehensive failure, the Atlas booster shut down prematurely and Gambit No. 20 flew a 682-mile arc into the Pacific Ocean. Martin demanded immediate changes. He and King set about tightening quality control and the incentive contracting system. They subjected the Gambit system to new and more stringent test and inspection procedures. Despite their efforts, Gambit No. 21 became the third successive Gambit to experience catastrophic failure when the AC/DC power converter in the OCV failed, resulting in the loss of stability. The Intelligence Community, increasingly dependent on high-resolution photography to determine Soviet ICBM activity expressed its major concern with the gap in detailed coverage of the Soviet program.[17]

Martin, although under pressure to produce detailed imagery, delayed the next scheduled Gambit launch. He turned his attention to GE's OCV, which had, on balance, provided most of the program difficulties. Traveling to GE Philadelphia, he and King mystified GE management by requiring exclusive use of a dining room, ten tables, ten white tablecloths, and ten completed Gambit electronic boxes. With GE management looking on, Martin produced his own screwdriver and removed the cover-plates from the first box. He raised the box above the cloth-covered table and shook it hard. He paused to inventory the native and foreign items which fell on the table. He and King moved from table to table repeating the operation with each box. Martin concluded by stating that someone or someones had to be responsible for the debris on the table. GE management responded by revamping its organization and production and testing procedures. They were determined that GE hardware would become a quality member of the Gambit components family.

GE was not the only errant contractor King and Martin took to task. Lockheed and Kodak were both criticized for shipping unfinished products to Vandenberg and then attempting to complete their work in Vandenberg's Missile Assembly Building (MAE). Determined to guarantee hardware integrity, King even threatened to close the MAB,



Gambit Operational Modes

forcing all contractors to deliver flight-ready hardware to the launch site.

Martin also made an exhaustive study of the incentive contracting in effect for the Gambit program. He was amazed to find that the system of rewards paid more for under-cost, on-time delivery than for high quality performance on orbit. He observed, for example, that such a set of values placed GE in position to collect a healthy bonus for providing the OCV under cost and on time despite the failure rate on orbit. To the contractor, the arrangement stressed the cost factor far more than the performance factor. The result was that GE was motivated to delete as many control and test procedures as possible in order to save money and time in producing the OCV. Taken to its logical extreme, the incentive formula could result in the delivery of a minimum cost vehicle which failed catastrophically, but, nonetheless, earned a premium for the contractors. Martin shifted the focus of the incentive system from cost to performance. Martin's new system placed the emphasis on orbital performance and provided large bonuses for on-orbit success.

Gambit No. 23, launched on 8 November 1965, was the first satellite to have full benefit of the new test and inspection regime. Unfortunately, it too quickly succumbed to flaws and during its 18-revolution lifetime photographed limited targets. The Martin-King plan for improvement in the Gambit program, however, continued unrelenting. It finally paid off. The next 10 flights were all qualified successes. From January to October 1966, the NRO launched Gambit satellites at a rate of about one per month. They routinely returned photographic intelligence of high quality, covering more targets in each flight. “Best resolution” averaged about 2 ft. By the third anniversary of the Gambit flight program, 12 July 1966, Gambit had extended its longevity from one to eight days on orbit; had increased the number of targets and had improved resolution from 3.5 to 2 ft. The last Gambit mission, No. 38 (KH-7), flew on 4 June 1967. It was replaced by the highly successful Gambit-3 Program.[18]

GAMBIT-1 SUMMARY

Gambit was the first operational U.S. satellite system to return high resolution photography consistently. An Atlas-Agena booster combination launched the Gambit into orbit. GE built the orbital control vehicle which housed the camera system. Eastman Kodak developed and manufactured the camera system itself which was originally designed around a lens of 77-in focal length, producing photographs with a ground resolution of 2 to 3 ft. GE built the recovery capsule, which was adapted from the Corona program. The first Gambit was launched in 12 July 1963 and flights continued until 4 June 1967 when Gambit-3 replaced the Gambit-1 system.

THE DEVELOPMENT OF GAMBIT-3[19]

Even before the launch of the first of the Gambit reconnaissance satellites in July 1963, U.S. planners discussed the need for an even greater capability system. Gambit, with its 2- to 3-ft resolution, (three to five times better than anything Corona produced) could produce significant operational and technical details on Soviet weaponry. But, they believed, even greater intelligence on the Soviets could be obtained if the United States developed an imaging system that could return better ground details. Intelligence Community analysts wanted "more."

In the early 1960s, the dominant factor in obtaining higher resolution tended to be focal length and pointing accuracy. Long lens systems created enlarged images of relatively small areas. Eastman Kodak worked on such a system with its Valley program. By August 1963, Valley research and Gambit-1 experience convinced many NRO officials that long focal lengths were feasible for satellite operations. In December 1963, Kodak employees, Charles P. Spoelhof and James H. Mahar, presented their ideas for an advanced Gambit system to DNRO Brockway McMillan and Gen. Robert Greer. Following the presentation, McMillan approved the development of an improved, higher resolution, Gambit program.

The crux of Kodak's proposal was a system that would exploit the pointing accuracy of Gambit-1 with a new camera. Kodak engineers believed that better resolution could be obtained, assuming imagery from an orbital altitude of 90 miles. Spoelhof and Mahar also proposed that the new system incorporate a "factory to pad" concept to provide greater modularity, instead of an orbital control vehicle enveloping the camera system (Gambit-1). They proposed using two modules, one containing the camera and the recovery vehicle, the other housing propulsion and the on-orbit initial subsystems. Kodak also incorporated the Lockheed roll-joint concept between the forward photographic payload/recovery vehicle section and the satellite-control section.

Kodak also planned to use a special, very-low-coefficient-of-thermal-expansion Invar (an iron-nickel alloy) for both the optical barrel and related assemblies, and a new thin-base (1.5 mile) high-resolution film with an exposure index of 6.0. (The film was roughly three times more sensitive than the film then in use on Gambit-1.)

Concerned that the new program might have major problems in producing the larger optics and that the improved film could not be delivered on schedule, DNRO McMillan sponsored a host of alternative technologies. This caution was also evident in the selection of the booster. Although King and Greer favored using the Atlas and Agena booster combination, McMillan wanted an option of using the new Titan-III booster which would provide for a greater payload weight.

King and Greer worked out the remaining major elements of the Gambit-3 concept in January 1964. Their plan called for the entire Gambit-3 program to operate under the purview of the SAFSP. They called for an initial flight in July 1966. The Gambit-1 system would continue until Gambit-3 became operational.

Because of DNRO McMillan's strong interest in the Titan as a possible booster for Gambit-3, Greer and King tasked Lockheed in July 1964 to study Agena compatibility with the Titan-III. In October 1964, on the basis of the Titan III-Agena study carried out by Lockheed, Greer's staff prepared cost estimates for switching from the Atlas-Agena. Consideration for making the change included the desire to use the Titan III family of boosters for other Air Force space missions, the potential versatility and on-orbit weight-growth capability, and the likelihood that a new search system replacing Corona would rely on Titan III boosters. Despite the fact that the Atlas was considered the standard launching vehicle for the Air Force, DNRO McMillan officially approved the switch to Titan in October 1964. Although this increased cost and caused a slippage in the initial launch date, the choice of the Titan, in hindsight, was a major improvement. It allowed future system changes with less consideration of the limited lift capacity of the Atlas.

At Lockheed, the Gambit-3 program came under the direction of the Space Systems Division. The program manager was Harold Huntley who reported directly to James W. Plummer, assistant general manager for Special Programs (Plummer would become DNRO in 1974). While Lockheed's work on the Agena modifications proceeded and never seriously threatened the planned launch date of July 1966, payload development by Eastman Kodak was behind schedule by the fall of 1964. The major problem for Kodak centered on the manufacture and mounting of the two large mirrors of Gambit-3 optics. These optics were larger than those of many earth telescopes, but needed to be much lighter to operate in space. Kodak experienced several failures in attempting to manufacture the mirrors. In addition, the figuring and polishing processes were far more difficult than originally anticipated. Kodak originally estimated that each of the two mirrors would require around 800 hrs of grinding, polishing, testing, and coating to finish. The early mirrors took 3,000 hrs per mirror. Because of mirror-fabrication problems, Kodak was three months behind schedule. Kodak's problem was compounded by its underestimation of the needed engineering manpower. The company experienced a major shortage of technical people, apparently from an overcommitment of resources. Kodak was working simultaneously on Gambit-1, Gambit-3, a lunar camera for NASA, and a proposed new search system that later became the Hexagon program.

The final determination for fabrication fused silica, for the primary aspheric mirror substrate and the return to conventional polishing techniques, pushed the production schedule ahead. By January 1966, there still existed considerable doubt that the high-speed, high resolution film on which Gambit-3 depended would be ready for use in initial flights. If it was not ready, the fall-back film, with an index of 3.6 and a resolution capability of 110 lines per millimeter, as against the 130 lines ASA (American National Standards Institute, formerly known as American Standards Association) 6.0 film would be used. It would build a certain amount of smear but there was no alternative. In fact, the new film did not become available until June 1968.

Given their experience with Gambit-1, Greer and King also introduced another innovative management technique. In contrast to the extensive testing at the launch site that characterized Gambit-1, testing that frequently brought substantial repair work in the Missile Assembly Building, Greer and King initiated a command system for Gambit-3, featuring an automated checkout system that allowed telemetry readout of functions. These readouts directly indicated whether or not various subsystems and components operated within acceptable limits. This automated checkout was normally performed during final assembly at Kodak and Lockheed, the principal manufacturers. The components, therefore, went directly from factory to launch pad.

NRO planners took no chance with the success of the first launch of Gambit-3. By the time of the launch, recovery operations had become rather routine, using Air Force C-130 aircraft and Navy range ships. An NRO agreement with the U.S. Navy provided for the Navy to support these recoveries with two such range ships. As the first Gambit-3 launch approached, the Navy, however, had only one ship on duty station. NRO program officers requested additional Navy support through the Office of the Commander-in-Chief, Pacific Forces (CINCPAC), which controlled all DoD assets in the Pacific. CINCPAC responded that because of the Vietnam conflict, the usual recovery support could not be provided. Col King took the issue to DNRO John McLucas. This was a serious threat to the successful completion of the mission. McLucas took up the matter with the Chief of Naval Operations (CNO), ADM David L. McDonald, who, in turn, sent a flash precedence message to CINPAC ordering the support. CINCPAC signaled back to SAFSP, "We don't know whom you know, but how many battleships do you want and where do you want them delivered?"

GAMBIT-3 BECOMES OPERATIONAL

On 29 July 1966 at 1130 PDT, the first Gambit-3 roared off the launch pad at Vandenberg (the initial launch had been projected nearly three years earlier for 1 July 1966). Two hours later, Sunnyvale reported, "All systems appear normal." The first Gambit-3 performed exceptionally well. The satellite achieved a near-nominal orbit. Its mission lasted five days during which it acquired targets that were successfully "read out."[20]

The overall quality of the imagery from the first Gambit-3 mission was better than that obtained from any Gambit-1 mission. Although the primary optics fell short of the design goal, the intelligence provided by this mission was the highest of any reconnaissance satellite to date.

The fate of Gambit-1 was now sealed, although DNRO Alexander Flax was extremely reluctant to cancel any planned Gambit-1 launches until Gambit-3 actually demonstrated a consistent level of capability. Director of Central Intelligence (DCI) Richard Helms, however, felt strongly that the success of Gambit-3 warranted cutting back Gambit-1 launches. The United States Intelligence Board's (USIB) Committee on Overhead Reconnaissance (COMOR) proposed, after listening to the arguments, that nine Gambit-1s and eight Gambit-3s be approved for the FY 1967 flight schedule. Contemporary launch schedules called for the launch of Gambit-1s at the rate of one per month. The decision to proceed with a mix of Gambit-1 and Gambit-3 was based on the perceived greater cost of the new system (Gambit-3), and the concern that success in all of the scheduled missions would cause the exploitation and analytical elements to be inundated with high resolution imagery. The concern was real.

During the 11-month period, July 1966 to June 1967, the success of Gambit-3 created a new problem for U.S. officials by returning huge quantities of surveillance-quality photography. The sheer volume overwhelmed U.S. photointerpreters. The United States now had three successful satellite systems routinely returning large quantities of imagery: Corona, Gambit-1, and Gambit-3. The Satellite Operations Center (SOC) in the Pentagon was also feeling deluged. It was barely able to cope with Gambit and Corona.

Despite the success, DNRO Flax was less than euphoric. A best resolution fell well short of the planned resolution. He, nevertheless, cancelled the final five Gambit-1 missions on 30 June 1967. Gambit-3 was to be the main surveillance satellite system. Unlike Flax, DCI Helms characterized the take from Gambit-3 in November 1967 as providing "extremely important intelligence." He saw it as a striking success. Flax's more cautious optimism proved prophetic.

By late 1967 the inadequacy of the Gambit-3 camera system remained an unsolved problem. Despite the fact that it was better than that of Gambit-1, it did not obtain the resolution originally specified. Some at NRO believed Gambit-3 would never achieve the resolution for which it had been designed, much less the long coveted resolution desired by photointerpreters. However, improvements were on the way as Kodak continued its work on improving the mirror substitute materials and the high-speed emulsion on its ultra-thin base film. Kodak introduced its new film on the 14th Gambit-3 flight on 5 June 1968. By the 27th flight it exceeded all expectations.[21]

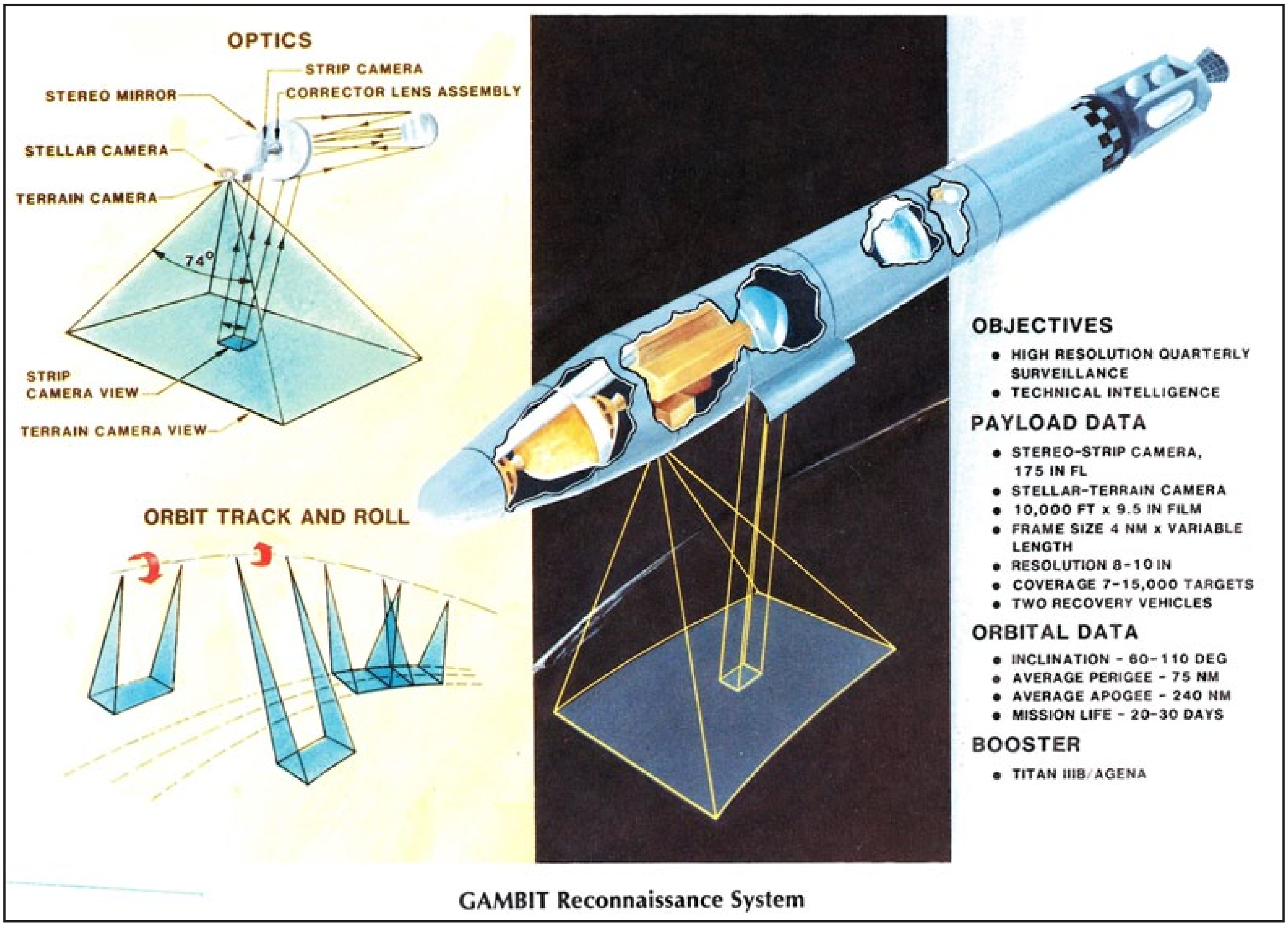
A CHANCE ENCOUNTER

Gambit program officials strongly believed that neither the Soviets, nor anyone else, knew the capability of the Gambit program. In 1969, however, officials held their breath as a Soviet satellite, Cosmos 264, began to make orbital adjustments that U.S. engineers calculated would bring it within 70 miles of Gambit-3. Eventually the two satellites passed within 15 miles of each other as NRO controllers held their breath, wondering if Cosmos was a “killer satellite.”

THE BLOCK II PROGRAM

One of the major innovations in the Gambit-3 program was the introduction of a second recovery vehicle. It eventually became known as the Block II program. Growing national interest during the period of Gambit-3 development in creating a satellite capability of quick reaction to world-wide crisis situations drove concepts for improving Gambit-3. As early as January 1965, DNRO McMillan informed Secretary of Defense, Robert McNamara, of studies underway for providing Gambit-3 with such a capability. The Corona program had demonstrated the feasibility and utility of using two recovery buckets. The premise behind the change was that a long-life, multiple capsule, film return system, could provide urgently required images that would be taken and returned to earth for evaluation, while at the same time continuing the satellite's routine surveillance duties.

Fortunately, owing mostly to McMillan's foresight, the Titan booster used for Gambit-3 had excess lift capability. The addition of a second reentry vehicle and more film capacity, while they greatly increased Gambit-3's weight, did not exceed the Titan lift capacity. Work began on the Block II series of Gambit-3 in late 1966. The double-bucket Gambit was ready by the fall of 1969. The first Block II vehicle (Gambit-3, no. 23) flew on 23 August 1969. After this first successful Block II flight, the program suffered a series of annoying problems, from poor orbits, to failed parachutes, to program malfunctions, which kept it from reaching its full potential.



Gambit system and optics swath

Despite the nagging problems, the resolution of Gambit-3 cameras continued to increase. Operational longevity also increased from 10 days to 27 days. A new lens, under development by Kodak for several years, was finally introduced in 1971. It brought an immediate performance improvement in the camera system. With a different focal length, the new lens permitted Gambit resolution to surpass even the previous best. Target coverage also increased.

A FULLY MATURE SYSTEM

By August 1977 Gambit-3, with 48 vehicles flown, was a fully mature, successful satellite program. During the next seven years, Gambit-3 continued to steadily improve its performance. Time-on-orbit lengthened to three to four months for each flight. Target coverage also increased significantly. By the time of the last Gambit-3 flight in April 1984, Gambit-3 was still producing the high quality imagery, which maintained its preeminence in technical collection.[22]

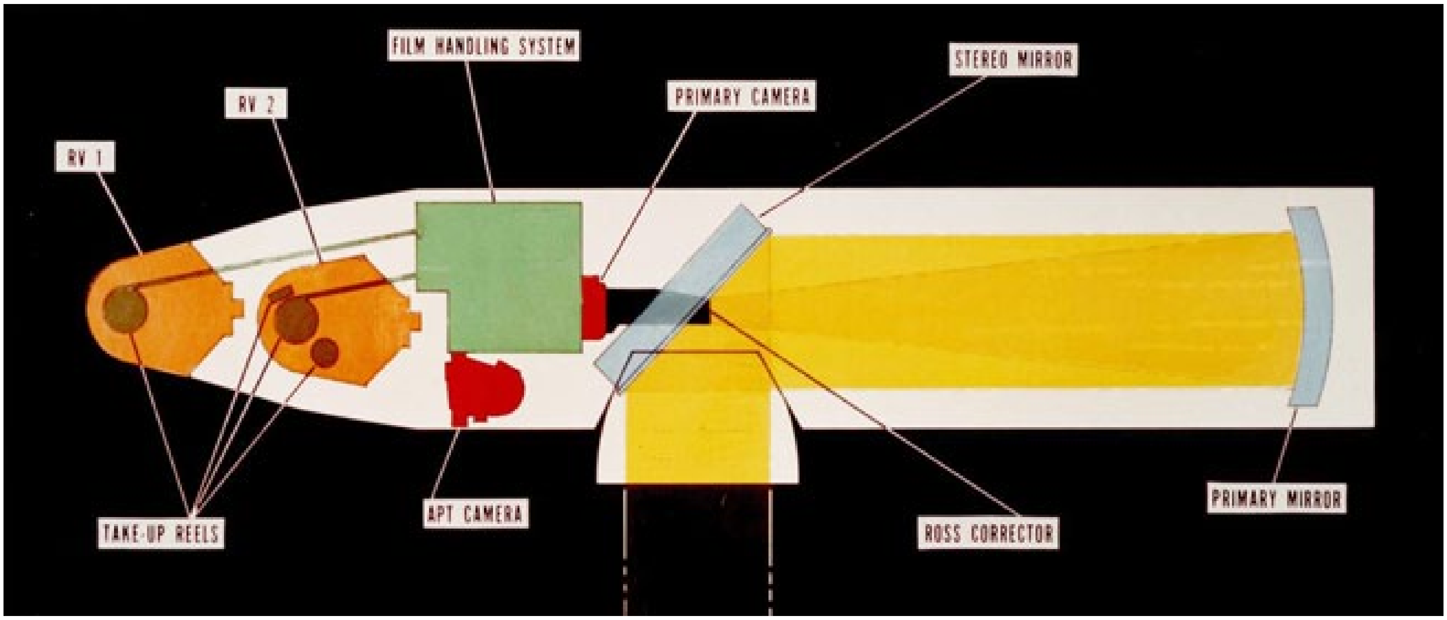
SUMMARY

The Corona program provided U.S. policymakers, for the first time, a capability to monitor military and industrial developments over vast areas of the Soviet Union and other denied areas of the world. Although Corona provided immeasurable contributions to national security, its resolution was not good enough to answer numerous critical intelligence questions regarding Soviet weapons development. Nor could it provide the image quality needed to provide true science and technology analysis. Gambit filled this gap. By the end of the program, Gambit routinely collected high-resolution imagery.

Gambit imagery closely monitored the Soviet Union. Gambit also provided insight on China. This information was vital to U.S. strategic planners, photointerpreters, and U.S. policymakers and defense planners. The Gambit system proved to be an invaluable intelligence collection tool during the Cold War.

In August 1984 President Ronald Reagan emphasized Gambit's contribution to U.S. intelligence in a message to DNRO Pete Aldridge:

> When the Gambit Program commenced we were in the dawn of the space age. Technologies we now take for granted had to be invented, adapted, and refined to meet the Nation's highest intelligence information needs while exploiting the unknown and hostile medium of space. Through the years you and your team have systematically produced improved satellites providing major increases in both quantity and quality of space photography.
>
> The technology of acquiring high quality pictures from space was perfected by the Gambit Program engineers; .... Through the years, intelligence gained from these photographs has been essential to myself, my predecessors, and others involved with international policy decisions. These photographs have greatly assisted our arms monitoring initiatives. They have also provided vital knowledge about Soviet and Communist Bloc scientific and



Gambit photographic payload section

technological military developments, which is of paramount importance in determining our defense posture.

A generation of this Nation's youth has grown up unaware that, in large measure, their security was ensured by the dedicated work of your employees. National security interests prohibit me from rewarding you with public recognition which you so richly deserve. However, rest assured that your accomplishments and contributions are well known and appreciated at the highest levels of our Nation's government.

CRITICAL TO US SECURITY:

THE GAMBIT AND HEXAGON SATELLITE RECONNAISSANCE SYSTEMS

HEXAGON

INTRODUCTION

Gambit was primarily a National Reconnaissance Office (NRO)/Air Force program to develop a high-resolution "spotter-type" satellite. It caused few bureaucratic turf battles and became highly successful. Proposals for and the development of a second-generation search satellite to follow Corona, however, became embroiled in major bureaucratic conflicts between the NRO and the Central Intelligence Agency (CIA).

Despite the bureaucratic in-fighting, the development and operation of the Hexagon photoreconnaissance satellite system provided U.S. policymakers and planners with a unique collection capability. Hexagon's ability to cover thousands of square nautical miles with contiguous, cloud-free, high resolution imagery in a single operation, provided U.S. intelligence users with vast amounts of intelligence information on the Soviet Union and other denied areas. It also collected large-scale contiguous imagery within specific geometric accuracies and unique mapping, charting, and geodesic data. Used in combination with the Gambit program, Hexagon was of paramount importance in confirming or denying Soviet strategic weapons development and deployment. Its ability to detect quickly any new Soviet intercontinental ballistic missile (ICBM) complex or mobile missile placement became invaluable to U.S. negotiators working on arms-limitation treaties and agreements.

ORIGINS

In May 1963, Director of Central Intelligence (DCI) John A. McCone convened a Scientific Advisory Panel under the chairmanship of Edwin Purcell, Nobel laureate and professor of physics at Harvard University, "to determine the future role and posture of the United States Reconnaissance Program." The Purcell Panel recommended a Corona improvement program rather than an entirely new satellite system:

> We believe that an attempt to make a completely new (search) system, which would provide equally wide coverage (as Corona) with a modest improvement in resolution (5-feet, say, instead of 10-feet around resolution) would not be a wise investment of resources.

Not entirely satisfied with the Purcell Panel recommendation, in the fall of 1963, McCone directed his Deputy Director of Science and Technology (DDS&T), Albert D. (Bud) Wheelon, to explore the requirements and possible configuration for a second generation search satellite to replace Corona. One of the major questions confronting Wheelon and his staff was the degree of resolution needed to fulfill the various requirements of the Intelligence Community. Wheelon directed his newly created Systems Analysis Staff, headed by Jackson D. Maxey, to review the types and characteristics of United States Intelligence Board (USIB) targets to determine the kinds of coverage needed. A detailed experiment, which included 25 National Photographic Intelligence Center (NPIC) photointerpreters, concluded that the majority of USIB targets could be properly identified using imagery with a resolution in the 0.6 to 1.2 m (2 to 4 ft) range. Due to the cost of booster rockets, Wheelon concluded that an entirely new camera system with a longer focal length covering a large swath would have to be developed to meet such target requirements.

While Wheelon and Maxey continued to work on their study, Corona's Performance Evaluation Team (PET) also looked at the problem. The PET investigation effort examined the possibility of "scaling up" the Corona camera from the existing 610-mm (24-in) lens to a 1-m (40-in) lens while maintaining the same "acuity." According to the PET report, "scaling up" could improve Corona's resolution without having to design an entirely new camera and satellite.[23]

Director, NRO (DNRO) Brockway McMillan and his NRO staff strongly supported the Purcell Panel and PET recommendations. This sparked a growing debate between the NRO and the CIA over the development of a follow-on system to Corona.[24]

Critical of the NRO position, McCone asked for a meeting with Deputy Defense Secretary, Roswell L. Gilpatric, to discuss the issue. On 22 October 1963, McCone and Gilpatric agreed to form a separate CIA-NRO/Air Force sponsored research group of the nation's leading optical experts to explore the issue of improving satellite photography. Chaired by Sidney Drell of Stanford University, the group met on 13 November 1963 to study image quality. The Drell group findings basically supported the CIA contention that the United States needed a new system, which would provide Corona-type coverage with consistent Gambit-type resolution. At the same time, in order to augment these studies, Wheelon asked for additional reports from Itek and Space Technology Laboratories (STL) of the Thompson Ramo-Wooldridge (TRW) Corporation. All seemed to be in agreement. A new system was needed to meet the growing requirements of the Intelligence Community for high quality imagery and expanded coverage.

PROJECT FULCRUM

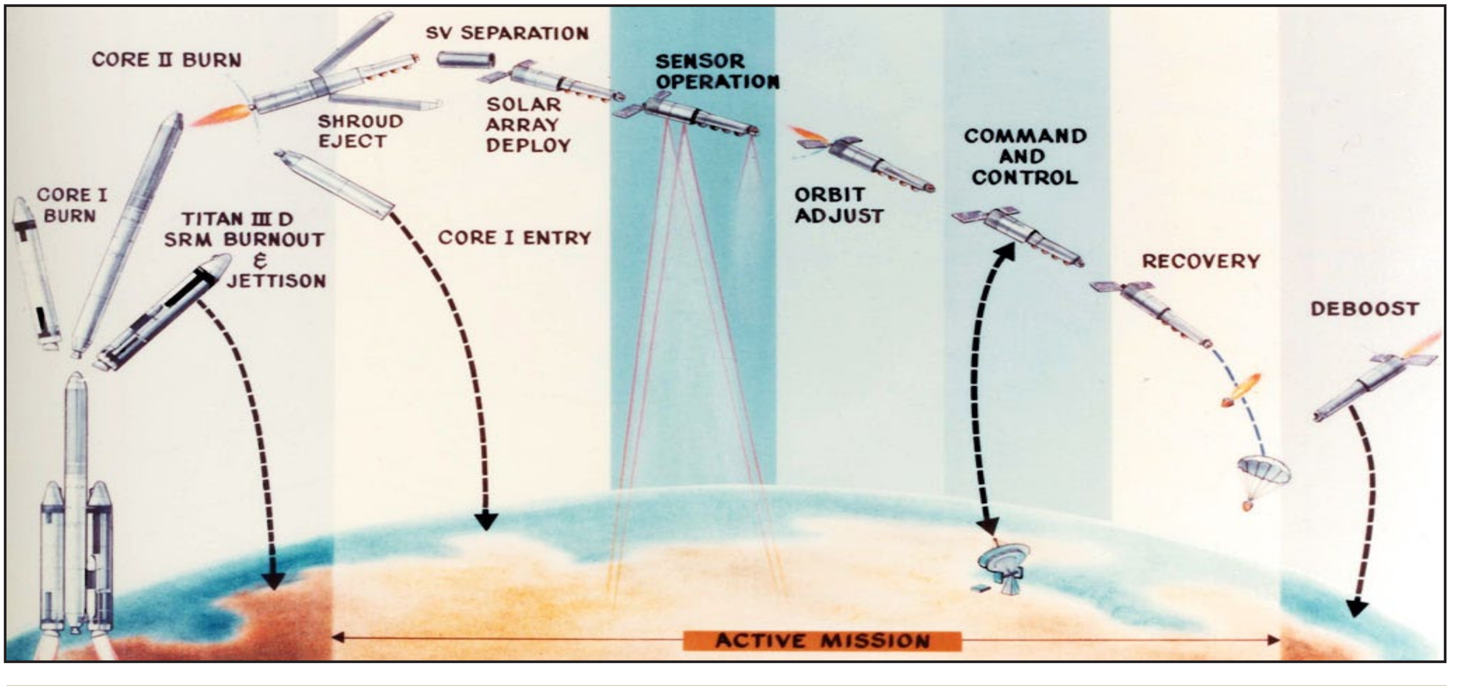
Following up these studies, in May 1964, Wheelon directed Itek and STL to prepare a joint proposal for a satellite system that could replace both Corona and Gambit. The Itek-STL proposal recommended a 2,495-kg (5,500-lb) payload containing two, counter-rotating Itek cameras in an STL three-axis stabilized spacecraft with a simple recovery system. A modified Titan II booster with no second stage would place it directly in orbit. The camera was to be a dual Maksutov reflective system with f/3.0 lenses having a 1.5-m (60-in) focal length employing a corrective lens, beryllium mirror, and eggerate quartz main plate. The cameras would provide a nadir resolution from 0.8 to 1.2 m (2.7 to 4 ft) at an altitude of 185 km (100 miles). In his memorandum recommending NRO/CIA funding for Project Fulcrum, Wheelon suggested the program could be developed within 24 months. He also stressed the cost savings. According Wheelon, by replacing the Corona and Gambit programs, the government could save money by the end of FY 1969.[25]

McMillan was furious. Wheelon and the CIA were contracting for satellite systems and subsystems studies without even informing the NRO, which theoretically had responsibility for all reconnaissance satellite development. Deputy Director, Research and Engineering (DDR&E), Eugene Fubini, sympathetic to McMillan's position, questioned the entire Fulcrum proposal. Fubini reported that the recent Corona missions seemed to confirm the Purcell Panel recommendations that substantial improvement in the Corona camera results could be obtained. Over the strong objections of McMillan and Fubini, DCI McCone asked Gilpatric to direct the DNRO to establish Fulcrum as an NRO development project and assign responsibility for research, development, and operation to the CIA.

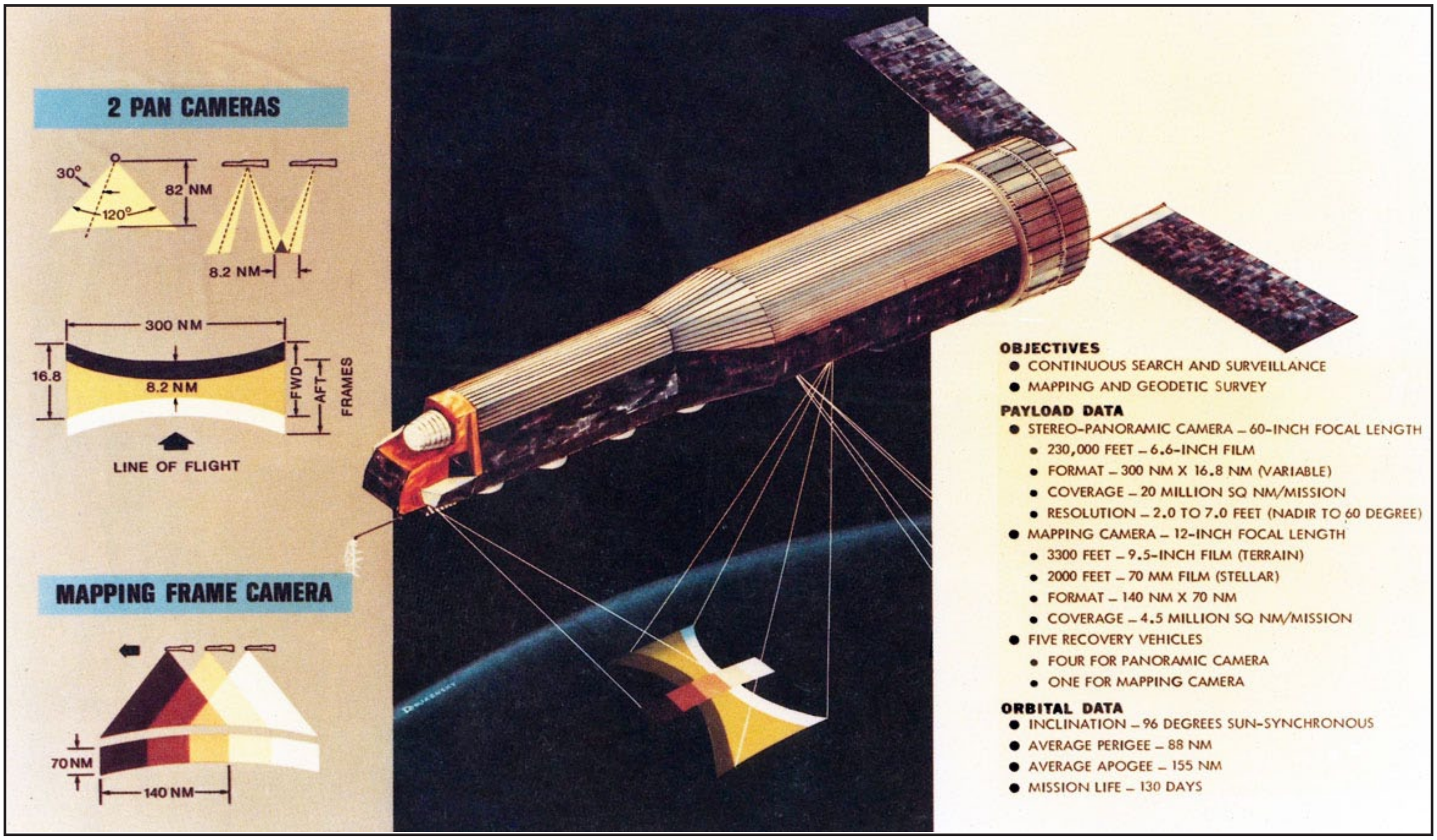
Looking for further support, McCone also asked Polaroid's Edwin H. (Din) Land to convene a panel of experts to consider the technical feasibility of the Fulcrum proposal. The group met on 26 June 1964 and issued its recommendations the same day. Land called the proposed system "extremely attractive," and "praised the ingenuity of the idea." The Land Panel also noted several problem areas but added that the system looked good enough to fund study efforts.

Armed with the Land Panel recommendation, Wheelon, on 2 July 1964, formally presented a plan to McMillan for initiating Fulcrum. After conferring with McMillan, on 8 July, Deputy Secretary of Defense, Cyrus Vance, cautiously suggested that the DNRO complete comparative studies and explore all possible alternatives before committing to the new system. He, nevertheless, authorized the CIA to pursue "design tests necessary to establish the feasibility of the proposed Fulcrum camera concept."

McCone's and Wheelon's plan went far beyond design studies. They wanted to build a strong CIA space system development and management capability. Wheelon and McCone received the backing of the USIB on 27 July 1964. The Board approved the recommendation of its Committee on Overhead Reconnaissance (COMOR) that there was an urgent need for a search and surveillance system capable of Corona coverage and Gambit resolution. This echoed Wheelon's justification for Fulcrum. In August 1964, Wheelon created a Special Projects Group (SPG) within DS&T to handle all CIA satellite reconnaissance programs. He named Jackson D. Maxey Fulcrum Project Manager. (Maxey was one of several senior engineers Wheelon hired from industry.) He also brought in Leslie Dirks as project engineer. In addition, Wheelon proposed to McCone that the CIA sponsor two competitive design efforts for the film-handling system for the Fulcrum camera. At the same time, Wheelon initiated spacecraft and recovery vehicle competitions. Itek won the camera competition. General



Hexagon sequence of events diagram



Hexagon system concept

Electric (GE) became the spacecraft contractor and Avco the reentry vehicle designer. These CIA efforts touched off a bureaucratic donnybrook with the NRO and Department of Defense (DoD) that threatened the very fabric of the U.S. National Reconnaissance Program (NRP).

McMillan and the NRO believed Wheelon and the CIA had exceeded their authority and gone far beyond preliminary design concepts. McMillan took sharp exception to CIA's development of a spacecraft and a Satellite Recovery Vehicle (SRV). Such development, McMillan believed, was contrary to the Third NRP Agreement that gave the NRO specific responsibility for the spacecraft and SRV. McMillan protested that the CIA should limit its activity to developing the sensors carried by the satellites. McMillan requested a suspension of further CIA efforts until the situation could be considered by the ExCom.[26]

Meanwhile, CIA officials learned that DNRO McMillan had authorized Secretary of the Air Force/Special Projects Office (SAFSP) to begin preliminary designs for a photographic payload that would include an optimal search and broad-coverage satellite system. McMillan authorized this SAFSP study in early 1964, even before the CIA's Fulcrum Project. These efforts became known as S-2. Eastman Kodak and Itek completed S-2 preliminary designs by September 1964. Even after the formal approval of the CIA's Fulcrum project, McMillan approved further camera studies at Fairchild Camera and initiated studies for a new orbiting vehicle at both Lockheed and GE in support of S-2.

Relations between the NRO and the CIA continued to deteriorate. Even before Deputy Secretary Vance established a steering group to evaluate the most promising search and/or surveillance satellite and the CIA agreed to participate, cooperation between the CIA and the NRO became virtually nonexistent. When McMillan asked Wheelon to furnish a Fulcrum briefing to the steering group for "the new NRO Search/Surveillance Satellite system," Wheelon refused. He replied that "he would have to await instructions from 'his boss' before agreeing to brief the steering group as requested." Wheelon added that, "his organization was not persuaded that the steering group was a proper or good idea." Given this attitude, the steering group accomplished little.

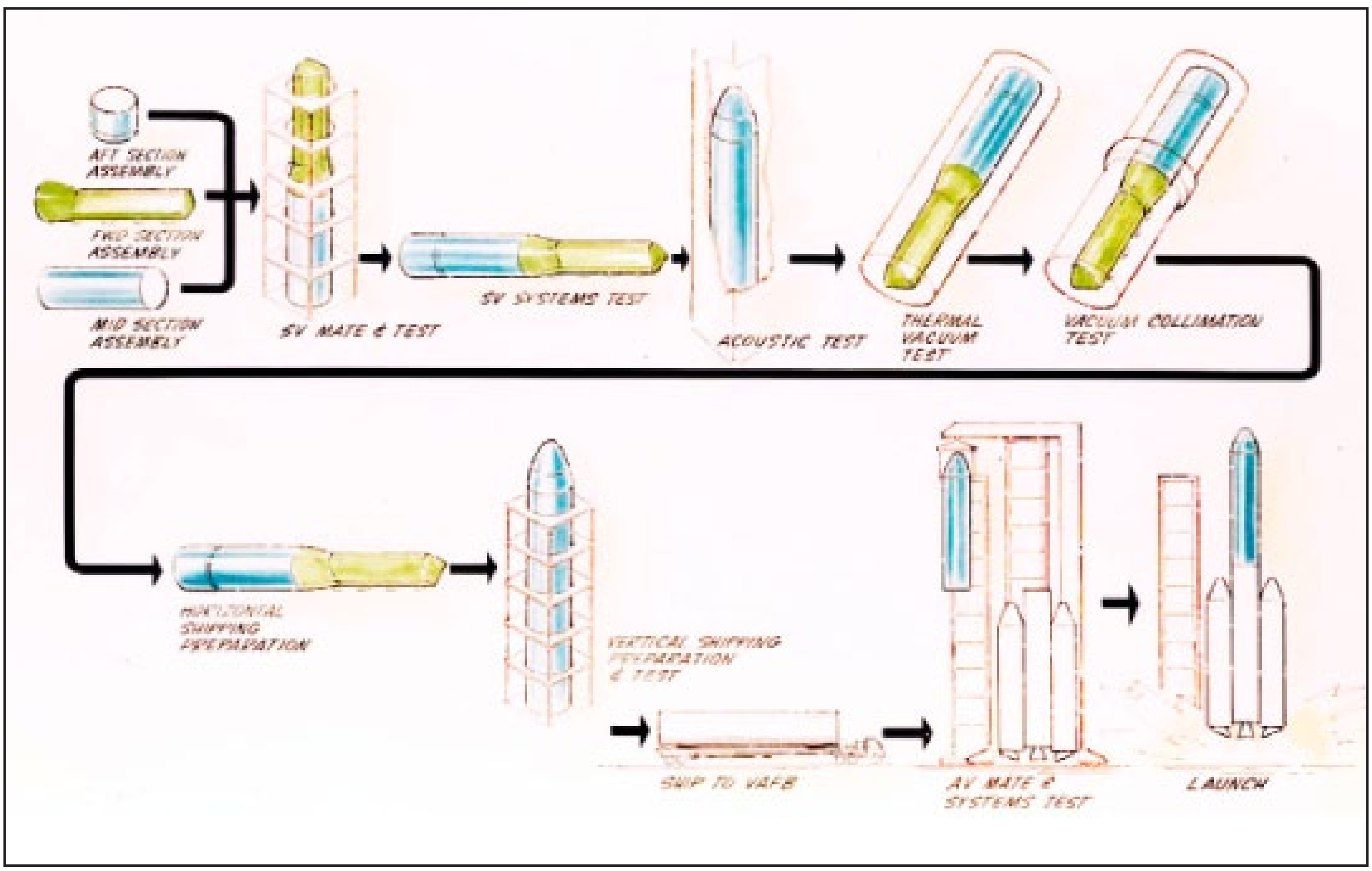
In this fight, McMillan and his NRO staff stood virtually alone in attempting to defend the authorities of the NRO. Secretary of Defense McNamara and most of the DoD were preoccupied with Vietnam. The regular Air Force, or White Air Force, totally ignored space activities. The Air Force Space Systems and Air Staff were still smarting from being excluded from most satellite developments. Even SAFSP took a limited interest. Located in Los Angeles, California, SAFSP officers concerned themselves solely with operations. They saw their role as strictly "birding" (launching and operating satellites). Future systems were not their concern, nor was politics. They saw politics as strictly a function of their “Washington branch.” Moreover, coming from Bell Laboratories, McMillan had few inside connections either in Congress, the White House, or the Department of State.

To get around the DoD's steering group, McCone turned to Din Land and his Panel of experts to evaluate Fulcrum.[27] Convening at Itek headquarters in Boston on 23 February 1965, the panel heard presentations on Fulcrum as well as the other search system studies funded by the NRO (S-2) by Eastman Kodak, Itek, and Fairchild Camera. Itek officials startled CIA officials when they announced to Land that Itek was withdrawing its support from the Fulcrum program because of disagreements with the CIA over systems specifications.[28]

McCone and Wheelon had hoped and expected that the Land Panel findings would be the basis for early approval of Fulcrum by the ExCom.[29] In order to preserve Fulcrum sensor work and the momentum of the project, Wheelon quickly arranged to transfer Itek's government-funded Itek-design plans for the Fulcrum camera system to Perkin-Elmer of Norwalk, Connecticut. Perkin-Elmer had been working on a smaller back-up design for the CIA since June 1964.

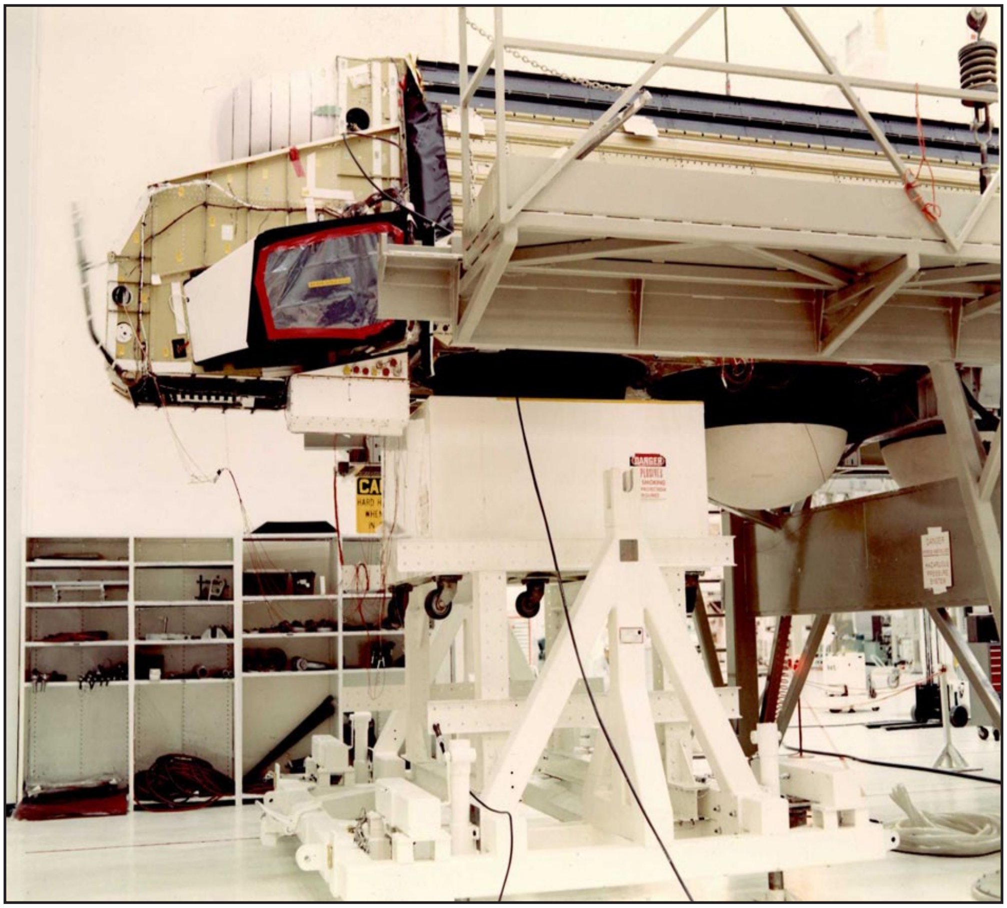
The steadily growing hostility between the NRO and the CIA and the constant battles between Wheelon and McMillan brought the program to a near standstill. On 13 July 1965, in a report to Vance and new DCI VADM William F. Raborn, Jr., McMillan indicated he intended to select the S-2 system for a new search satellite. Upon the advice of Wheelon, Raborn countered by asking Vance to delay any decision pending the Land Panel's report. On 26 July 1965, the Land Panel finally issued its recommendation. It satisfied no one. The Panel recommended that all three camera system studies (the CIA effort at Perkin-Elmer and the NRO S-2 programs at Itek and Kodak) be funded for an additional three months.

At this point work on Fulcrum virtually came to a standstill as DCI Raborn and Deputy Secretary of Defense Vance worked out a new NRP Agreement—the fourth. Signed on 13 August 1965, the new agreement gave the CIA responsibility for developing the optical sensor subsystem of the advanced general-search satellite (Fulcrum) and the engineering development of the spacecraft, reentry vehicles, and booster to the NRO and the Air Force. Both sides hoped this carefully crafted agreement would provide the incoming DNRO, Alexander Flax, with the authorities and leverage to resolve the bitter, divisive debate between the NRO and the CIA over roles and responsibilities for the new satellite system. It did not.



Hexagon factory to launch sequence

McMillan departed the NRO on 30 September 1965, disappointed that the new agreement was less explicit in stating the authorities of the DNRO than the old agreement had been. The new agreement did not please many in the CIA either. Maxey, who headed the Fulcrum effort and was chief of the Special Projects Staff (SPS), resigned because he felt strongly that the new NRP pact was too restrictive on the CIA.[31]



Hexagon SV-5 forward section with mapping camera module

HEXAGON DEVELOPMENT

Flax moved quickly to get the new system on track and mend relations with the CIA. Deputy Director, Central Intelligence (DDCI) Richard Helms also moved to develop a more cooperative relationship between the Agency and DoD. He wrote to Flax that the CIA was consolidating all CIA elements supporting the NRO into an organization headed by Huntington Sheldon, the Director of CIA Reconnaissance, and that all CIA satellite activities would be placed in a new Office of Special Projects (OSP) under John Crowley. Aiding the situation was the fact that Crowley, the new chief, and Flax got along well. Flax, in turn, established a Technical Task Group and a Project Management Task Group to study the various forms of program development and program partnership. Nevertheless, the bickering continued.

Faced with a lack of consensus on the “right” way to do the project, Flax devised his own plan for the management and technical development of Fulcrum. On 22 April 1966, Flax submitted his plan to the ExCom for consideration and approval. Now called the HELIX program, Flax recommended a management approach that would make the CIA OSP responsible for the entire sensor subsystem and SAFSP responsible for the remaining system elements. He proposed making the Director, SAFSP, the project director for the entire system, stating that SAFSP was “the only NRP component possessing the personnel, facilities, operational resources, experience, and technical competence to be designated Special Project Director (SPD) for the new general search and surveillance satellite system.” CIA officials countered that the CIA's in-house technical personnel and its relationship with the contractors built up over the years, gave it the capability of program management commensurate with that of SAFSP.

Despite continuing CIA protests, the ExCom, meeting in executive session on 26 April 1966, approved Flax's HELIX/Hexagon program proposal as submitted.[31] Finally, more than two years after the original Fulcrum planning, the ExCom gave formal authority for developing a new search and surveillance satellite system—Hexagon. Flax's compromises did not resolve all issues between the CIA and the NRO but they did reduce the “turf battles” and allowed development of Hexagon to proceed.

THE SENSOR SUBSYSTEM

The CIA awarded Perkin-Elmer the contract for the design, development, and fabrication of the camera system for Hexagon in October 1966, in a cost-plus-fixed-fee contract. Realizing that the Hexagon contract was the largest single program ever undertaken by Perkin-Elmer, OSP chief, Crowley, traveled to Perkin-Elmer headquarters to urge the company's executives to use a new System Engineering/Technical Support (SETS) System developed by the TRW Corporation.[32] Despite Crowley's concern and special effort to warn Perkin-Elmer of the immense size of the Hexagon project, by the end of 1966, work at Perkin-Elmer was already several weeks behind schedule. Just manning the program was a major problem. Perkin-

Elmer's original proposal called for growth from 150 to 600 people within four months and to 700 by the eighth month. This rate proved impossible to achieve, especially given the long delays in security and clearance approvals. Perkin-Elmer's lack of extensive electronic-design experience and shortage of electronic engineers also created serious problems. In addition, the general Perkin-Elmer management structure was simply inadequate for the magnitude of the Hexagon program. In January 1967, Crowley decided the situation required drastic action. He invited the key Perkin-Elmer managers, including company president, RADM Chester W. Nimitz, Jr., USN (Ret) to CIA headquarters for a management planning session. Crowley told the Perkin-Elmer officials that he was “deeply distressed and vitally concerned” about the lack of progress and even more concerned about Perkin-Elmer's attitude toward deficiencies that had surfaced in both management and technology. Crowley's frank talk resulted in a management overhaul at Perkin-Elmer.

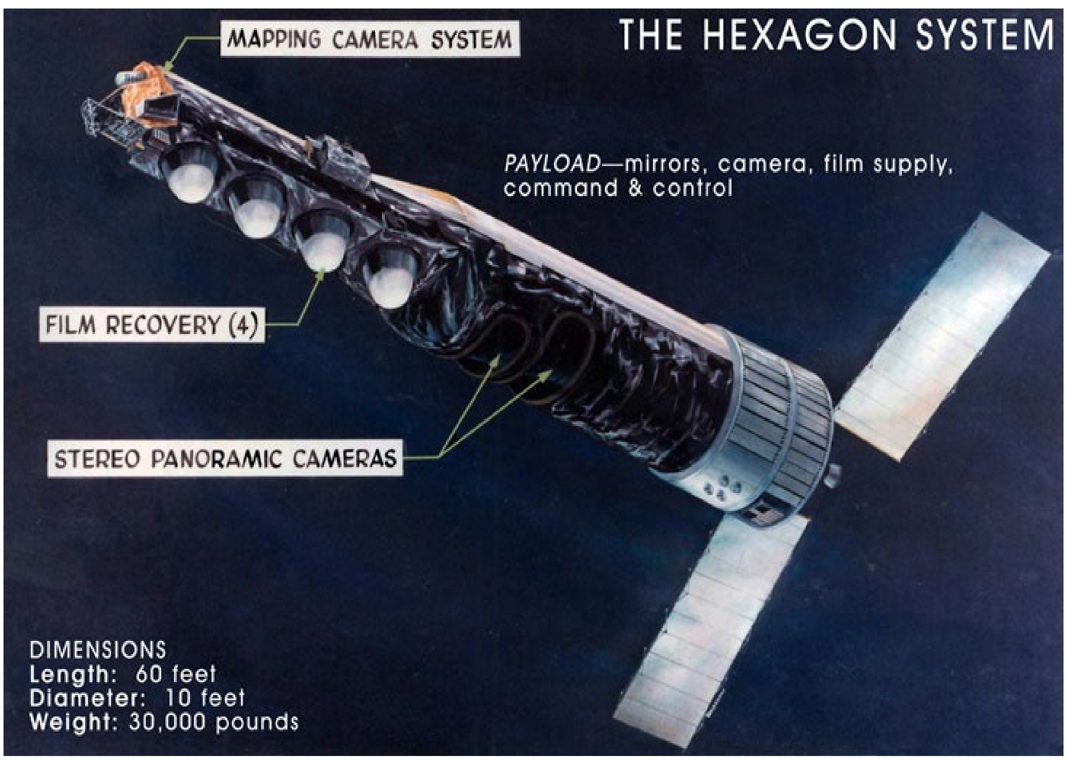
The Hexagon sensor subsystem developed by Perkin-Elmer consisted of a two camera assembly, the film supply, and four take-ups. Located in the Hexagon satellite mid-section, the camera assembly contained a pair of panoramic cameras mounted in a frame. One camera looked forward on the satellite vehicle (camera A, port side) and the other looked aft (camera B, starboard side). Each camera had a 60-in focal length, f/ 3.0 folded Wright optical system. This optical system, which contained both reflection and refracting optical elements, was mounted in an optical bar.

Perkin-Elmer's optical bar involved two, 1-m diameter tubes each containing a 75-cm (30-in) optically flat mirror. This was mounted at a 45-degree angle to reflect the ground images passing beneath the satellite and through a corrector plate into a 91-cm (36-in) concave main mirror at one end of the tube. Images collected in the main mirror were then focused through a hole in the flat mirror and into a compound lens, located behind the flat mirror. The compound lens then projected the images onto the film platen at the opposite end of the optical tube. As the satellite moved through space, each optical bar tube rotated about its longitudinal axis in opposite directions. This provided a panoramic image, up to 120 in wide. Each optical bar was longer than the payload part of Corona. Just to test the tubes, Perkin-Elmer built an entirely new facility at Danbury, Connecticut.

Early on, Perkin Elmer had difficulties with the 91-cm (36-in) main mirror. Initially, the West German firm supplied the mirror blanks, which were quartz optical surfaces fused to ceramic cores. The first blanks exhibited faults in the bonding of the face plates to the cores. These first, fused quartz, blanks were also very heavy and brittle for use in space. CIA and Perkin-Elmer engineers searched for a different material that was lighter weight, with a lower coefficient of expansion.

Beryllium, a relatively rare and lightweight metal, met all their requirements. It was one third as heavy as aluminum, had a very low coefficient of linear expansion, resisted oxidation, and was capable of being polished to a very high degree of reflectance. Its reflectivity extended beyond the visible spectrum into the infrared area, where many other mirrors failed. Unfortunately, beryllium was toxic. Inhalation of beryllium salts caused a reaction similar to chlorine poisoning.

Despite the hazards, Perkin-Elmer undertook a program to develop a beryllium folding mirror for the twin-60 cameras. It soon abandoned the project as too expensive and dangerous. Eventually, Perkin-Elmer decided to use a heavier but less expensive and less dangerous product that had several advantages. It was of lightweight, almost 100 lbs less per mirror blank then fused quartz, and it had a much lower coefficient of expansion. Its cost, however,



Hexagon vehicle on orbit

was 20 percent greater than the German blanks. Hexagon managers reverted to the West German product.

THE MAPPING CAMERA MODULE

In order for imagery to be useful for measurement purposes (measuring distance and determining the size of objects on the ground), satellite altitude and position information needed to be recorded at the exact moment a picture was taken. In the Corona system, this was accomplished by using a stellar-index camera, a separate unit, which took pictures of both the star fields and the ground, thus allowing analysts to determine vehicle altitude and position accurately. This made it possible to prepare maps from Corona imagery. The Defense Mapping Agency also desired a map making capability from Hexagon imagery. In July 1968 Itek became the prime contractor for the stellar-terrain camera and GE for the RV. This was nearly 20 months after Perkin-Elmer won the contract for the main Hexagon cameras. First launch date was projected for April 1970.

The Itek Corporation had far less trouble with the mapping camera module than Perkin-Elmer had with the main camera. Itek developed and built a mapping camera module that contained a stellar-terrain camera with a 12-in f/6.0 metric lens with eight elements. It used 9.5-in film. The stellar camera, which imaged stars above sixth magnitude, had two 10-in f/ 20 systems—one looking out each side of the module. It used 70-mm film. The GE RV was simply an improved version of the vehicle originally developed for the Corona program, modified to accommodate the 9.5-in and 70-mm film take-ups.

THE SATELLITE VEHICLE

It was not until 20 July 1967 that DNRO Flax finally approved a contractor, Lockheed, for the spacecraft. Under the leadership of program manager, Stanley I. Weiss, the general vehicle configuration for Hexagon soon began to emerge. Hexagon would be a satellite vehicle 10 ft in diameter and with an overall length of nearly 47 ft. One section would be devoted to the satellite control unit (the brains of Hexagon), one to the sensor subsystem (the cameras), and a recovery section of four RVs. To grasp the sheer size of Hexagon, the spacecraft weighed five times more than the Corona payload—22,500 lbs compared to 4,280 lbs. It was designed to be well within the lift capabilities of the Titan III-D booster.

The spacecraft design and development experienced few major problems. In early 1971, however, Lockheed itself became involved in a serious financial imbroglio, which nearly brought about the collapse of the company. Rolls-Royce Motors Ltd. of Great Britain was under contract to provide the jet engines for Lockheed's new widebody TriStar airliner. Rolls-Royce’s financial collapse threatened Lockheed's promised delivery of its TriStars to several airlines. This in turn created a cash-flow problem for Lockheed (Lockheed was already claiming heavy losses connected with its Air Force C-5A Galaxy aircraft).

In order not to delay the highly classified work then being performed by Lockheed for Corona and Hexagon, the firm spun off its missiles and space division. It became Lockheed Missiles and Space Company, a wholly owned subsidiary. It was, however, now protected if Lockheed found it necessary to declare bankruptcy. Eventually, the U.S. Government provided a $210 million loan to help Lockheed avoid bankruptcy. It, nevertheless, was a close call for some of the United States' most closely held programs.

Although progress on the various Hexagon components continued, mounting cost overruns and delays brought slippage to the projected launch schedule. By late 1967, Flax and the entire Intelligence Community began to fear that further slips in the Hexagon launch schedule might result in a period during which there would be no photo coverage of the Soviet Union.[33]

Bickering between NRO officials and the CIA continued as well as CIA and SAFSP fighting over the development of on-orbit operational control software for the system. CIA officials wanted to control the satellite from the Satellite Operations Center (SOC) in Washington, sending specific commands to the Satellite Test Center in California for re-transmission to the satellite. This was the system used for the Corona program. SAFSP maintained that the complexity of the new system required that all control of the satellite be done by the Satellite Control Center (SCC) at Sunnyvale, California. In a compromise, Flax finally decided that the SOC in Washington would send a list of requirements with their priorities to the SCC where the actual target selection for a particular revolution would be made, given weather conditions and vehicle health. Although the CIA was not entirely happy with the decision, it was, nevertheless, a semi-victory for the Agency since the CIA now controlled the requirements, which drove the system.

ATTEMPTS TO CANCEL HEXAGON

From the origins of the Hexagon (Fulcrum) program, critics maintained that system requirements could be satisfied less expensively by improving Corona or by using some other less sophisticated system. When the cost of Hexagon at Perkin-Elmer alone rose dramatically in February 1968 and other contractors began showing similar cost increases, the critics intensified their efforts. In 1968, new Deputy Secretary of Defense Paul Nitze questioned the need for Hexagon. Echoing Nitze's concerns and confronted with escalating Vietnam costs, the Bureau of the Budget (BoB) recommended that Hexagon be cancelled in early 1968. Hexagon was the single most expensive item in the 1968 through 1970 NRP. As an alternative to Hexagon, DNRO

Flax, asked the CIA for cost estimates for developing an Improved Corona system. The CIA reported that an improved Corona, without a complete redesign, (with costs estimated to be equal to those of completing Hexagon) could never provide the search resolutions needed for verification of arms limitation agreements (resolutions of 3 ft or better). After reviewing the CIA cost estimates for 20 Improved Corona satellites, an NRO study group recommended to the ExCom that Hexagon be continued. The ExCom agreed and nothing came of the BoB's recommendation.[34]

The Presidential election in November 1968 and the inauguration of Richard M. Nixon as President in January 1969 brought a series of personnel changes and another look at the Hexagon program. Melvin Laird became Secretary of Defense and John L. McLucas, a former DDR&E and head of the Mitre Corporation, replaced Flax as DNRO. In the spring of 1969, the BoB renewed its recommendation to cancel Hexagon.[35]

As Perkin-Elmer began to lay off employees in response to the BoB recommendation, DCI Richard Helms mounted a major effort to have Hexagon reinstated. He called upon Roland Inlow, who had been deeply involved in planning for the Strategic Arms Limitation Treaty (SALT) to study the impact of the loss of Hexagon on arms limitations negotiations. Inlow found that all SALT proposals being made by U.S. officials were predicated on the availability of large-scale search photography from Hexagon satellites. Helms urged Inlow to brief James R. Schlesinger, the BoB's Director for International Relations, on his findings. Inlow did. Helms and Inlow also invited Schlesinger, Vice President Spiro Agnew, and DNRO McLucas for a briefing at NPIC on the Hexagon project. After hearing the briefing, Schlesinger and Agnew recommended to President Nixon that the Hexagon program be reinstated. On 15 June 1969, the BoB reversed its decision and reinstituted Project Hexagon. Full-scale work resumed on the camera system at Perkin-Elmer, but the cost continued to escalate.

Hexagon SV on Titan III D booster

ONE MORE CHALLENGE FOR PERKIN-ELMER

One of the most difficult engineering problems confronting Perkin-Elmer and CIA engineers was the challenge of moving film at very high velocities over many rollers and around sharp bends to deliver it to the focal-plane platen and then transfer it to the take-up reels in the film buckets. The high speeds and shiny surfaces created many problems, including the familiar Van de Graaff effect which had plagued Corona. Another problem was the heat generated by the friction of the film as it rubbed over rubber rollers or on shiny metallic bearing surfaces. In prototype models, the film heated up, became gummy, and stuck to these surfaces.

Perkin-Elmer engineers, headed by Rod Scott, attacked the film transport problem by adapting a unique air-bag (a gas-cushioned bearing surface) approach Scott had designed for the Oxcart (SR-71) cameras. This method permitted moving the film through the spacecraft without it touching either rubber or metal until it reached the focal-plane platen, and then not again until it reached the take-up reel. The 168-mm film, traveling at 6.6 m (21.6 ft) per second, left the supply spool, entered the film channel, traveled nearly 4 m to the focal-plane platen, stopped to accent images from the optical-bar lenses, and moved along another 6 m to the take-up reel. In between the film-supply reel and the platen and between the platen and the take-up reel, the film was allowed to go slack in a buffer chamber known as a “looper” so that the torque of starting and stopping would not stretch or tear it.

LAUNCH

Despite the setbacks, all appeared ready for a first launch on 15 June 1971. One final glitch appeared when Lockheed attempted to move the flight vehicle from Sunnyvale to Vandenberg Air Force Base for launch preparation. The State of California restricted use of the vehicle transporter (a mammoth vehicle some 14 ft high, 14 ft wide, and 70 ft long) to daylight, weekday, and non-rush hours. It was 28 May, the start of the Memorial Day weekend. The satellite could not be moved to Vandenberg until after the holiday.

The Hexagon spacecraft itself was as big as a locomotive and 16.7 m (55 ft) long, almost as large as NASA's Spacelab, and weighed several metric tons. It contained two giant, rotating optical-bar tubes, each with a 91-cm mirror and a camera. There were also four Satellite Recovery Vehicles (SRVs) for returning film to earth and a 208,000-ft film supply. At 1141 Pacific Daylight Time (PDT) 15 June 1971, the first Hexagon, sitting atop a Titan III-D missile, roared over the launch pad. The Lompoc, California Record reported the launch and nicknamed the satellite “Big Bird.”

On 20 June 1971, during orbital revolution 82, the first film bucket separated from the satellite and reentered the earth's atmosphere in the Hawaiian recovery area. Recovery teams sighted the capsule and its badly damaged parachute. It hit the ocean but the recovery teams got to it before it sank. The film was immediately flown to Eastman Kodak in Rochester, New York for processing. An NPIC representative at Eastman Kodak remarked after reviewing the film, “My God, we never dreamed there would be this much, this good! We'll have to revamp our entire operation to handle the stuff.”

Hexagon launch

The second film bucket was brought back to earth on 26 June and recovery teams successfully snatched it in midair. Both the first two buckets provided extensive coverage of Soviet missile sites and other sensitive targets. The U.S. Intelligence Community greeted the product enthusiastically. Unfortunately, when the third RV deorbited on 10 July, its main parachute failed completely and the bucket made a high-speed impact into the Pacific Ocean. It sank in several thousand meters of water before the recovery team could reach it. A recovery team snatched the fourth film bucket without incident on 16 July.

Approximately 75 percent of the photography in the three recovered film buckets was free of clouds, a considerable improvement over earlier satellite photography. This was due to a revolutionary new system named the Hexagon Targeting Program (HTP). The HTP effort was a computer-based method for determining, prior to launch, the accessibility on the intended targets for each mission as well as the likelihood of their being cloud-free. The major features of the HTP included: the use of World Aeronautical Chart (WAC) divisions known as World Aeronautical Grid (WAG) cells, which were a uniform 12 by 18 nm, computer routines for forecasting cloud cover, and maintaining a

WAC cell climatological history. Eventually, HTP became part of a much larger NRO effort known as TUNITY. It was used in coordination with the Air Force's advanced Defense Meteorological Satellite Program and increased the efficiency of Hexagon cameras to 90 percent.

During its 52-day mission (31 days active phase) this first Hexagon conducted 430 photo operations and produced an average ground resolution of 3.5 ft and a best resolution of 2.3 ft. It used 175,601 ft (1,350 lbs) of film. Of this 123,601 ft (930 lbs) was recovered. In comparison, the first successful Corona recovery (August 1960) carried 20 lbs of film. Later, Corona flights carried 40 lbs, the two-capsule version, 80 lbs. In the Gambit program, Gambit-1 carried 45 lbs of film and 3,000 ft of film. Gambit-3 carried multiple types of film with differing weights that ranged in length from 7,500 to 10,000 ft of film. It also included two film return capsules, increasing the duration of Gambit-3 missions.

The first Hexagon mission was an outstanding success. For example, the first return capsule contained coverage of more than two thirds of Soviet missile sites alone. The first mission was not without complications, however. Batteries on the first Hexagon overheated, reducing camera operations. Additionally, only the fourth return capsule was free of parachute malfunctions. The first and second capsules were captured despite limited parachute malfunctions. The third return capsule’s parachute failed completely and the capsule hit the ocean surface with such force that flotation devices also failed. The capsule quickly sank to the ocean floor, nearly 3 miles below the surface, before surface ships could retrieve the capsule.

The second Hexagon mission, no. 1202, was originally scheduled to launch three months after the return of the final capsule from the first Hexagon mission. The problems with batteries and parachute malfunctions resulted in a longer delay, and the second mission was launched on 20 January 1972. The first two return capsules were retrieved uneventfully. A film tracking malfunction of the aft camera left only the forward camera available for the final two capsules. Both were retrieved uneventfully in February, 1972.

The third Hexagon mission, no. 1203, was launched 7 July 1972. A modified parachute design for the return capsule was incorporated into this mission as well as some additional modifications based on the previous two Hexagon missions. Similar to the second mission, both of the first two return capsules were de-orbited and retrieved without difficulty. During imaging operations for the third capsule, an altitude control problem developed as well as film tracking problems again with the aft camera. Both problems limited successful imagery operations for the third and fourth return capsules, despite their successful retrieval.

The fourth Hexagon mission, no. 1204, launched on 10 October 1972, involved an extraordinary effort by CIA and NRO officials to test color film and analyze camera focus. This exercise deployed targets throughout the Southwest United States to evaluate Hexagon camera operations with color film. A 28-man team cleared sites and erected and dismantled various configurations along the ground trace of the Hexagon satellite so they were photographable as the Hexagon passed overhead. Known as ground-truthing, CIA and NRO engineers used the photographs of these targets to analyze the focus accuracy of the Hexagon optical system. NRO and CIA officials considered this 68-day mission highly successful.

Hexagon re-entry chute

The fifth Hexagon flight, mission no. 1205, launched on 9 March 1973, was the first to carry the separate Mapping Camera System. Both the stellar and the terrain cameras functioned well during the mission. Defense Mapping Agency analysts rated the results “outstanding.” Numerous small man-made features were easily detected and often identifiable; a baseball diamond, a small aircraft on a taxiway, individual homes with driveways and automobiles. This was quite remarkable for a 12-in focal-length lens at a 92-mile altitude. The stellar photography also provided adequate star images in both magnitude and quality.

A CHANGE IN MANAGEMENT

When President Nixon approved the CIA proposal for a follow-on imaging system as the next photo reconnaissance system in September 1971, Carl Duckett, DDS&T, and other CIA officials, began to look for ways to ensure that the new program was properly staffed. They asked DNRO John McLucas to consolidate all aspects of the Hexagon program under Program A (SAFSP) so that Program B (CIA) could concentrate on the new revolutionary system. McLucas agreed and transferred Program B responsibilities for Hexagon to Program A. The transfer went smoothly and on 1 July 1973, Gen David D. Bradburn, Director SAFSP, formally assumed all responsibility for management of the Hexagon system, wiring the CIA "we will do our very best to continue the proud record." The CIA's Office of Special Projects was now free to focus on the next generation of imagery satellites.

The Hexagon program continued to fly with ever-improving results after the transfer. Unfortunately, the Hexagon program ended on 18 April 1986. A catastrophic Titan 34D failure, nine seconds after lift-off, terminated the 20th and final Hexagon mission. Nevertheless, during its 13 year-life, Hexagon proved to be an invaluable intelligence collection tool.

SUMMARY

Despite numerous delays and large cost over-runs, Hexagon met 70 to 80 percent of all the U.S. Intelligence Community's surveillance requirements. Considering that the Soviet Union encompassed an area of almost 7 million square nautical miles, the mature Hexagon system would image about 80 percent of this area, cloud-free, on a typical mission. During its lifetime, Hexagon played a key role in monitoring Soviet research and development, production, and deployment of strategic offensive and defensive weapons systems. It made possible the first SALT in 1972. Hexagon's broad area coverage capability provided U.S. officials a high degree of confidence, that the United States could detect any new Soviet installations or activities early in the construction phase. The ability of Hexagon to furnish high quality imagery of military installations also allowed U.S. intelligence analysts to develop and maintain very accurate, order-of-battle information on Soviet and Chinese forces.[36] Entire Soviet military districts, for example, could, at times, be imaged on a single mission. These images provided current and accurate force-structure assessments. Hexagon's broad area coverage provided the U.S. analysts opportunities to monitor large-scale Soviet military exercises. In March 1979, for example, when the Soviets staged a major military exercise in Mongolia, in response to the Chinese attack on Vietnam, Hexagon captured the Soviet mobilization.

Hexagon was also tasked to provide coverage of Soviet and Chinese nuclear test sites; often providing complete coverage of these test sites often in a single image. This allowed U.S. officials to closely monitor test preparations and assemble data on the tests themselves. Hexagon also played a key contributing role in U.S. economic forecasts and projections regarding the Soviet economy. During its lifetime, Hexagon provided economic intelligence on Soviet heavy metal production, oil and natural gas exploitation, nuclear production, and conventional electrical power capacity. It also photographed Soviet grain-growing regions allowing accurate U.S. predictions on Soviet grain production.

In addition to its coverage of the Soviet Union and China, Hexagon produced more detailed knowledge of third world development than any system before or since. Moreover, the Defense Mapping Agency and other government agencies that produced maps and charts were almost solely dependent on Hexagon for mapping source materials. Not a bad job for an over-sized "Big Bird."

CRITICAL TO US SECURITY:
THE GAMBIT AND HEXAGON SATELLITE RECONNAISSANCE SYSTEMS

CONCLUSION

During the heart of the Cold War, the National Reconnaissance Office (NRO), with its Central Intelligence Agency (CIA) and Air Force components and their industry partners, designed, developed, built, and operated the Gambit and Hexagon photoreconnaissance satellite systems. The growing reality of a Soviet nuclear arsenal, the development of Soviet nuclear-tipped intercontinental ballistic missiles (ICBMs), and a vigorous Soviet nuclear weapons program, combined with an increasingly complex and divisive Vietnam conflict, created a global crisis atmosphere for U.S. policymakers during the 1960s and 1970s. A sense of extraordinary urgency swept over Washington as U.S. officials searched for intelligence on the Soviet Union and its allies.

This crisis atmosphere drove the NRO effort to develop the next generation of search and surveillance satellites and to provide U.S. decisionmakers with ever more detailed imagery. Building on the pioneer efforts and accomplishments of the Corona program, U.S. designers, engineers, scientists, and managers pushed photoreconnaissance and space flight technologies to their limit in order to meet the demand for more and better photographs from space of Soviet activities.
Most program officials felt the security of the United States depended upon their success.

The years of Gambit and Hexagon program development were marked by great vision, repeated disappointment and failure, and finally by extraordinary triumphs. Gambit, an NRO/Air Force/private industry effort strove to capture clear details of Soviet weapons activity. Under constant pressure to achieve results quickly and operating almost totally in a “black” environment, the Gambit program suffered from excessive compartmentation and secrecy. Corona program development, with its successes and failures, for example, remained virtually unknown to Gambit officials. This resulted in duplication of effort and long delays in design and testing time. Only the introduction of Corona technologies such as the stabilizing Agena second stage “hitchup,” the state-of-the-art roll-joint, the Lockheed developed “Lifeboat,” and Corona recovery techniques saved the early Gambit program from cancellation and catastrophic failure. Frustrated time and again with system problems, the Gambit team finally reached its goal of routinely providing U.S. intelligence analysts with high resolution imagery. It was a giant step from the fuzzy, 20- to 30-ft resolution imagery provided by the early Corona cameras. This imagery was even better than manned reconnaissance photography. It amazed U.S. photointerpreters.

Overcoming technical uncertainty, Gambit scientists and engineers not only brought a revolution to space photography but they made major improvements in satellite command and control systems, time on orbit, and target coverage. Its impact on U.S. intelligence capabilities was enormous. Combined with the imagery data from Corona and Hexagon, Gambit provided the U.S. Intelligence Community with over 90 percent of its hard data on the Soviet Union. For the first time, using Gambit imagery, U.S. officials had detailed factual information and accurate mensuration data to actually develop engineering drawings on Soviet weapons capabilities. This helped U.S. officials save billions of dollars in U.S. weapons development alone. President Lyndon Johnson expressed his appreciation for these satellites when in early 1967, he informed a meeting of American educators that these satellites “justified spending ten times what the nation had already spent on space.” “Because of this reconnaissance,” the President confided to the group, “I know how many missiles the enemy has.” President Johnson also knew, because of Gambit, the approximate capabilities and state of readiness of Soviet ICBMs.

Hexagon, like Gambit, was a daring technological challenge. An NRO/CIA/industry program, Hexagon became the ultimate film-return photoreconnaissance satellite system. It, like Gambit, suffered hard times during its development stages. Not only were there technological problems to overcome—camera and film design, reflective and refractive mirror construction, and film movement—but Hexagon also suffered from constant bureaucratic struggles over who would control the program. The often bitter debates between the NRO and the CIA caused major delays in design and development time. This resulted in serious launch slippages and major cost overruns. Originally proposed as a cost-saving system to replace Corona and Gambit, Hexagon became the most expensive system yet built. Nevertheless, Hexagon proved to be an extraordinary success. It had the capability of providing stereoscopic, cloud-free photography over 80 to 90 percent of the Sino-Soviet landmass on each mission. In addition, Hexagon had the unique ability to satisfy surveillance and mapping, charting, and geodetic data requirements. Hexagon imagery, by providing continuous direct evidence of Soviet activities, helped eliminate the surprise element for U.S. officials and increased the Intelligence Community's and U.S. policymakers confidence in the overall intelligence product. It provided the hard data for analysis. It also provided assurance to U.S. leaders negotiating arms limitation agreements with the Soviets.

Gambit and Hexagon proved to be of paramount importance to U.S. policymakers. With these systems, U.S. officials had detailed information on Soviet strategic weapons development and deployment. Any new Soviet ICBM complex or development, such as mobile missile deployment, was quickly detected. Soviet construction of antiballistic (ABM) sites, nuclear submarines, aircraft, and naval vessels, and Soviet ballistic missile launchings were all carefully monitored by Gambit and Hexagon. Conceived and built under a crisis situation, these systems stretched space technologies and ultimately performed well beyond their initial expectations. They were truly, “Critical to U.S. Security.”

CRITICAL TO US SECURITY:
THE GAMBIT AND HEXAGON SATELLITE RECONNAISSANCE SYSTEMS

NOTES

1. Traditionally, photointerpreters divided reconnaissance photography into two categories. One was “search.” It was dedicated to finding something. Corona was a search system. Its cameras were designed to photograph large contiguous areas in a single frame of film. The second observation function was “surveillance.” Once it was determined there was something of interest there, the surveillance system provided detailed information on the particular target.

2. For a review of the missile gap controversy see Roy E. Licklides, “The Missile Gap Controversy,” *Political Science Quarterly* 85 (1970): 600-615. For a detailed review of the U-2 program see Gregory W. Pedlow and Ronald E. Welzenbach, *The Central Intelligence Agency and Overhead Reconnaissance: The U-2 and Oxcart Programs 1954-1974* (CIA, 1992) (S). In August 1957, the Soviets launched a long-range ballistic missile. On 4 October 1957, they rocked U.S. policymakers by orbiting Sputnik I (the first artificial earth satellite; it weighed 84 kg or 185 pounds) and in November 1957 the Soviet Union announced the launching of another earth satellite weighing 900 kg or 1,980 pounds. See Gerald K. Haines, *The National Reconnaissance Office, Its Origins, Creation, and Early Years* (NRO, 1997), pp. 12-13, Cargill Hall “Post-War Strategic Reconnaissance and the Genesis of Project Corona,” and Robert A. McDonald, ed., *Corona: Between the Sun and the Earth, The First NRO Reconnaissance Eye in Space* (American Society for Photogrammetry and Remote Sensing, 1997), pp. 25-58. No U-2 operations were to be carried out after 1 May because the President did not want anything to disrupt the Paris Summit scheduled to begin 16 May 1960.

3. For a discussion of the shoot-down and the aftermath of the U-2 downing, see Pedlow and Welzenbach, pp. 177-187. The Soviets prepared an elaborate show trial for Powers which began on 17 August 1960. The Soviets sentenced him to 10 years in prison. On 10 February 1962, the Soviet exchanged Powers for captured Soviet spy Rudolf Abel.

4. Corona was to be a stop-gap effort until the much larger and complex Air Force W117L Samos Satellite became operational. See Hall, pp. 42-51; Haines, pp. 14-15; and McDonald, pp. 61-74. At the same time, Eisenhower approved plans for the CIA to develop a follow-on plane for the U-2.

5. Richard M. Bissell, Jr., with Jonathan E. Lewis and Frances T. Pudlo, *Reflections of a Cold Warrior: From Yalta to the Bay of Pigs*, (New Haven: Yale University Press, 1996) p. 137.

6. The Air Force had the task of developing a high-resolution “spotting” satellite.

7. In early 1958 President Eisenhower set up a Satellite Intelligence Requirements Committee (SIRC) within the Intelligence Advisory Committee (IAC) to establish requirements for satellite reconnaissance. In July 1960, the United States Intelligence Board (USIB) (The IAC was the predecessor body to the USIB.) merged the Ad Hoc Requirements Committee (ARC), originally established by Richard Bissell as an intragovernmental unit to oversee the tasking requirements for the U-2, with SIRC to form a new unit, the Committee on Overhead Reconnaissance (COMOR). William M. Leary, ed., *The Central Intelligence Agency, History and Documents* (Birmingham, Alabama: University of Alabama Press, 1984).

8. Samos originally had two planned photographic capabilities E-1 and E-2. These involved the on-orbit exposure and processing of film, translation of that imagery into an electrical signal by means of a flying-spot scanner, and transmission of the signal to earth for recomposition as a picture. E-3 was the designator for a system which substituted photosensitive electrostatic tape for film; E-4 was used to identify a proposed mapping/geodetic photographic system; E-5 was a recoverable satellite with a large recovery vehicle; and E-6 was a recoverable-film search system with several times the capability of Corona. E-1, E-2, and E-3 were readout systems, E-5 and E-6 were film-recovery systems. Only E1, E-2, and E-6 ever flew.

9. Oxcart was the next generation of manned reconnaissance aircraft. Although originally developed to overfly the Soviet Union, it never did. Improvements in Soviet radar and the SAM missile made such overflights impossible. The Air Force version of Oxcart was known as the SR-71 or Blackbird.

10. Kevin C.Ruffner, ed., *Corona: America's First Satellite Program*, (Washington, DC: CIA History Staff, 1995).

11. Kodak set up a special unit to deal with Gambit. Dr. Frank Hicks directed the program at Kodak. He reported to the director of Special Projects, Dr. Frederic C. E. Oder. The Special Projects organization reported to Arthur Simmons, director of research and engineering of the Apparatus and Optical Division. The Gambit project received the highest priority within Kodak because of its national priority. Earlier, as an Air Force officer, Oder was the original WS-117L project officer and was witting of the entire Corona effort.

12. Most of the Samos program's photo-oriented reconnaissance had been canceled and the E-6 program was experiencing grave technical problems—four failures in four tries.

13. Greer’s instruction to King emphasized these goals: 1) stay within budget; 2) stay on schedule; and 3) obtain one good picture.

14. Because of rigid compartmentation of programs, only Col Riepe in the Gambit program office had a working knowledge of the Corona program. Lacking any indication that unpressurized operation was possible, (The Corona

experience with unpressurized operation had been employed successfully for two years.) Gambit officials assumed that the pressurization of the film cassette would have to be continued in the new recovery capsule.

15. The CIA program Lanyard at this point had some prospect of filling the proposed Gambit role.

16. Charyk resigned to become president of the newly formed Communications Satellite (Comsat) Corporation.

17. Corona operation continued reasonably successfully during the summer of 1965, only one major mission failure in three flights, but Corona did not return the detail that intelligence analysts needed to interpret Soviet force status.

18. See later discussion of Gambit-3.

19. When first considered, Gambit-3 was informally referred to as Advanced Gambit, and G3, or G-Cubed. G-3 eventually became the accepted designator for the successor program, although upon the completion of the original Gambit program and the start of Gambit-3 operations that suffix was dropped and it became simply the Gambit program. For the sake of clarity, this study will continue to distinguish between the two systems using Gambit-1 for the first program and Gambit-3 for the follow-on.

20. The dominant cause for differences between targets programmed and targets readout in the entire Gambit-3 program was cloud cover. The introduction of weather satellites helped, but the problem persisted as long as cloud cover data was delayed.

21. The dominant cause for differences between targets programmed and targets readout in the entire Gambit-3 program was cloud cover. The introduction of weather satellites helped, but the problem persisted as long as cloud cover data was delayed.

22. The development of near-real time imagery systems made the Gambit-3 film return system obsolete.

23. 0ne way of obtaining greater resolution is to use a longer focal-length lens. The other is to improve “acuity” of the existing system by enlarging and enhancing the imagery. In the beginning of the Corona program there were finite limitations on the size of the lens because of the weight restraints of the booster vehicle. The optimum focal length was a 610 mm refracting lens. Throughout the 14-year Corona program, the focal length of the system never changed—it was 610 mm for the KH-1, KH-2, KH3, KH-4, KH-4A, and KH-4B cameras. Any increase in the focal length would have required a spacecraft with a larger diameter and greater payload capacity. It would have meant abandoning the heavy refracting-type lenses and developing reflecting-type systems that used mirrors and smaller lens cells. Given the limitations of the launch vehicles, the Corona team concentrated on improving the acuity of the 610 mm system.

24. McMillan was at odds with McCone and Wheelon over a host of NRO/CIA issues. He wrote to Secretary of Defense, Robert McNamara, on 12 December 1963, that “the final price of peace with the CIA ‘considering the temperament of its leaders’ was at least to give the CIA *carte blanche* for development of a new search system.” McMillan believed that unless something like this was done, or the CIA management changed, there would be continued obstruction to the NRO and its activity.

25. Wheelon estimated that a single Fulcrum launch could return as much film as the Corona and Gambit programs and cost less.

26. The ExCom was made up of the DCI, John McCone, the Secretary of Defense Robert McNamara, and the President's Scientific Advisor.

27. The Panel consisted of Land, chairman, Dr. Sidney Drell, Dr. Donald Ling, Dr. James Baker, Dr. Allen Puckett, Dr. Edwin Purcell, and Dr. Joseph Shea.

28. CIA and Itek squabbled over the angle through which the camera system would scan. The CIA demanded a 120-degree scan. Itek officials felt this angle was too large and would seriously prejudice the Fulcrum design.

29. In fact, the Land Panel had made no recommendation on the new camera system by the time McCone resigned as DCI in April 1965. President Lyndon Johnson replaced McCone with Vice Admiral William F. Raborn, Jr.

30. Wheelon recruited a new Fulcrum program chief and John J. Crowley as Chief SPS. Crowley was, at the time, heading the Corona project.

31. The ExCom consisted of DCI Raborn, Deputy Secretary of Defense Vance and Presidential Scientific Advisor, Dr. Donald Horning.

32. Total Perkin-Elmer employment in the Norwalk, Connecticut, area was 2,800 (1,350 of these in the Optical Group, of which 150 were involved with Hexagon).

33. The number of Corona vehicles was now severely limited. There were only 11 left in the barn. They could only be stretched out so far.

34. The CIA reported that even an Improved Corona could never provide search resolutions much better than 4.5 ft. The Budget Bureau questioned whether a 1.5 ft difference in resolution could possibly be worth the major cost it estimated it would take to complete the Hexagon program. The decision was already made, however.

35. The Bureau of the Budget was simply dismayed at the size of the satellite programs underway in the CIA, Air Force, and NRO.

36. The high quality of Hexagon imagery is often overlooked because the Gambit program, which produced imagery of the very highest quality, overlapped Hexagon. Nevertheless, Hexagon was capable of meeting most Intelligence Community requirements.

CRITICAL TO US SECURITY:
THE GAMBIT AND HEXAGON SATELLITE RECONNAISSANCE SYSTEMS

SECTION II: CAPABILITIES DOCUMENTS

We have selected the documents for this section to highlight the capabilities of the newly declassified Gambit, Gambit-3, and Hexagon systems. The documents describe the individual camera systems and were developed to help producers and consumers of imagery intelligence understand the camera systems' capabilities.

We included the National Photographic Interpretation Center's KH-7 Camera System Part I because this document presents general technical information for early exploitation of photography from KH-7. The document provides details on the strip, stellar, and index cameras that composed the integrated KH-7 camera system and flew on the Gambit system. The document highlights measurement capabilities as well.

The NRO and NPIC collaborated on a very similar document for Gambit-3. The KH-8B Camera System contains detailed information on the main strip camera as well as the cameras used to position the satellite—the terrain and stellar cameras. A comparison of the KH-7 and KH-8 camera system books reveal the significant advances that were made with the operation of the Gambit-3 system.

We opted to include the NRO's Project Hexagon Overview because it contains a very thorough description of Hexagon acquisition, operations, and search capability. The document contains descriptive diagrams explaining functions of Hexagon camera systems and is one of the single best documents we found in our review for explaining the overall Hexagon system.

LIST OF CAPBILITIES DOCUMENTS

1. Technical Document: *KH-7 Camera System (Part I)*, National Photographic Interpretation Center, July 1963.

2. Technical Document: *The KH-8B Camera System (Third Edition)*, National Reconnaissance Office and National Photographic Interpretation Center, October 1970.

3. Briefing Book: *Project Hexagon Overview*, National Reconnaissance Office, 25 January 1978.

Copy 28
19 Pages

~~TOP SECRET~~
SPECIAL HANDLING REQUIRED

ST15797-63KH
NPIC/TP-18/63
July 1963

TECHNICAL PUBLICATION

KH-7 CAMERA SYSTEM

PART I

CIA

DIA

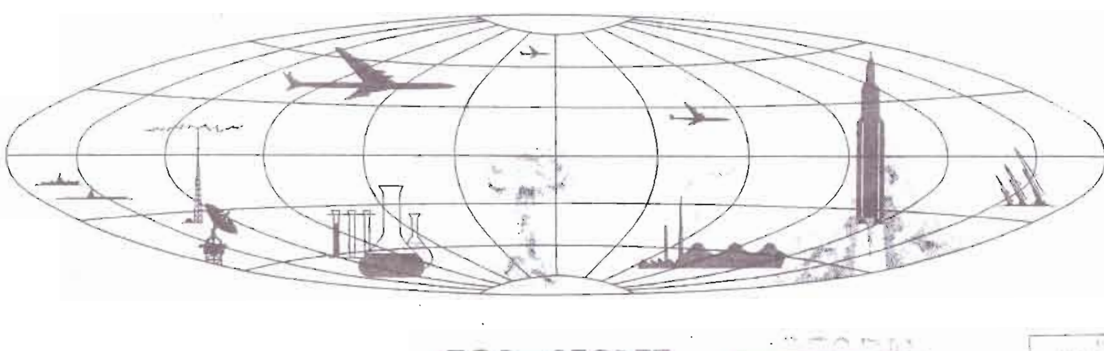
18.1

Handle Via TALENT - KEYHOLE Control Only

WARNING

This document contains classified information affecting the national security of the United States within the meaning of the espionage laws U. S. Code Title 18, Sections 793 and 794. The law prohibits its transmission or the revelation of its contents in any manner to an unauthorized person, as well as its use in any manner prejudicial to the safety or interest of the United States or for the benefit of any foreign government to the detriment of the United States. It is to be seen only by personnel especially indoctrinated and authorized to receive TALENT-KEYHOLE information. Its security must be maintained in accordance with KEYHOLE and TALENT regulations.

NATIONAL PHOTOGRAPHIC INTERPRETATION CENTER



~~TOP SECRET~~
SPECIAL HANDLING REQUIRED

TECHNICAL PUBLICATION

KH-7 CAMERA SYSTEM

PART I

NPIC/TP-18/63

July 1963

NATIONAL PHOTOGRAPHIC INTERPRETATION CENTER

PREFACE

This publication presents general technical imormation for the early exploitation of photography obtained by the KH-7 camera system. The scales, tables, charts, and graphs presented are for the photo-interpreter's use in determining approximate sizes, scales, and relative orientation of objects or images and is not meant to take the place of the more precise mensuration parameters.

Technical information with complete mathematical analysis for reduction of quantitative data will be published as Part II of this manual.

The following data will be made available for each mission on a timely basis:

1. Camera Data: Operational focal length, lens distortions, ramp informations, film velocity, image motion data, film type, filters, exposures, slit width, and expected resolution.
2. Stellar/Index Unit Data: Calibrated focal lengths, distortions, grid intersections, exposures, etc.
3. Orbital Data: A one second orbital ephemeris for each second of camera operation, including velocity, altitude, geographic position, time of operation, etc.
4. Vehicle Attitude: Pitch, roll, and yaw, and rates of each when available.

INTRODUCTION

The KH-7 camera system consists of a single strip camera, a stellar camera, and an index camera.

The strip camera utilized in the KH-7 system will provide relatively large-scale, high-acuity photography of selected target areas in either monoscopic or stereo modes. It is designed to provide the photo-interpreter with an image considerably larger and with better ground resolution than that provided by the present KH-4 surveillance system. The strip camera can roll about its longitudinal axis to either side of the ground track in increments of 0.709 degrees to a maximum of plus or minus 44 degrees 40 minutes. This allows centering of the target area in the format of the strip frame. Also the camera is yawed around its vertical axis to eliminate coriolis force.

The strip camera consists of a rotating mirror, a 77-inch focal length folded lens system, and a cylindrical platen. (See Figure 1 for details.) The camera system may be operated in several modes: monoscopic strip, stereoscopic superimposed strips, or lateral pairs of strips. Any of these modes are available in any of the roll positions. (See Table No 1.)

Table No 1. Roll Positions Available In Degrees (Left or Right)

0 Vertical	11.344	22.688	34.032
0.709	12.053	23.397	34.741
1.418	12.762	24.106	35.450
2.127	13.471	24.815	36.159
2.836	14.180	25.524	36.868
3.545	14.889	26.233	37.577
4.254	15.598	26.942	38.286
4.963	16.307	27.651	38.995
5.672	17.016	28.361	39.704
6.381	17.725	29.069	40.413
7.090	18.434	29.778	41.122
7.799	19.143	30.487	41.831
8.508	19.852	31.196	42.540
9.217	20.561	31.905	43.249
9.926	21.270	32.614	43.958
10.635	21.979	33.323	44.667

The film width is 9.460 inches with variable length to each strip depending on operation parameters. This system will produce an image at a nominal scale of about 1:90,000, and the nominal strip will be about 12 nautical miles (nm) in width.

The lens film resolution will be approximately 2.5 feet with proper camera operation.

Two time tracks are recorded on the film with a binary time word recorded on each track every .8 second.

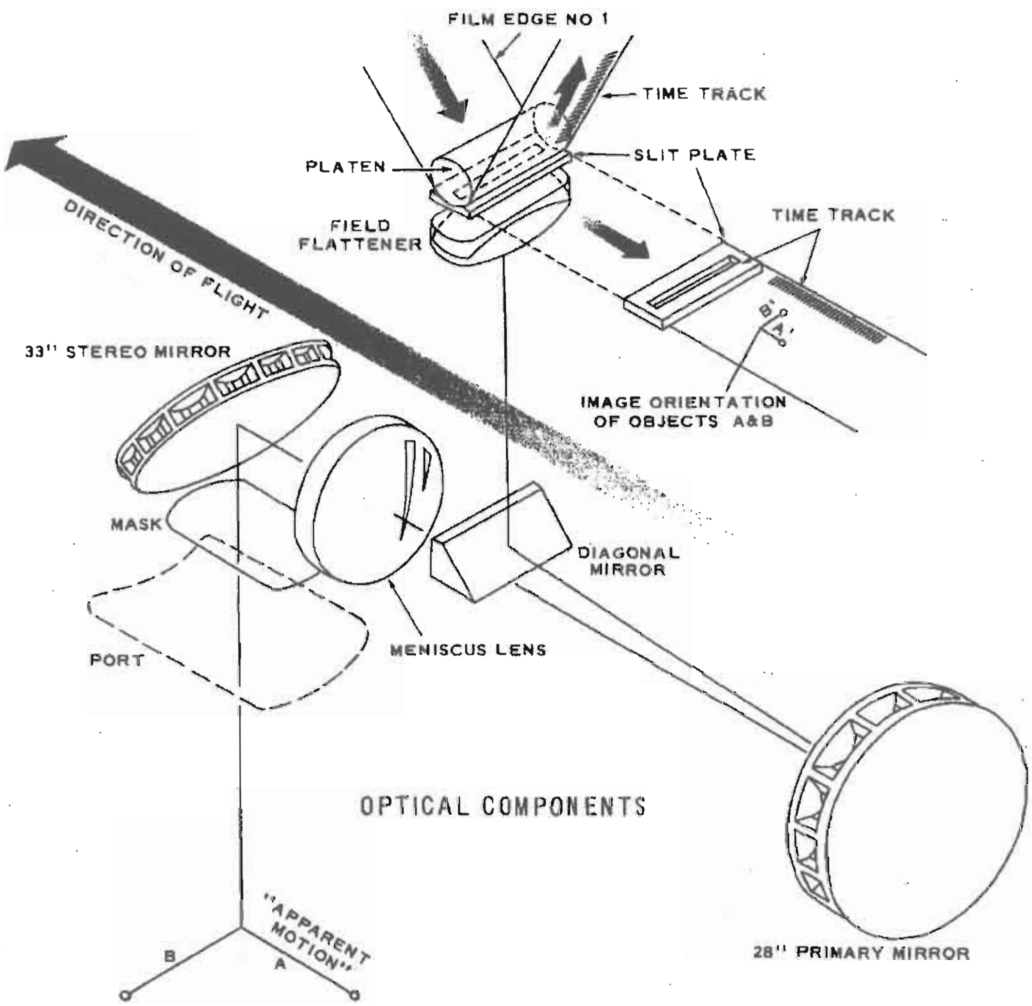
Yaw slits are exposed on both sides of the film as an aid in attitude analysis.

THE STRIP CAMERA

DESCRIPTION OF THE STRIP CAMERA

The strip camera is a 77-inch focal length folded lens system consisting of a primary rotating mirror, a meniscus lens, a stationary primary mirror, a diagonal mirror, field flatteners, a slit plate, and a rotating platen.

The rotating mirror moves to forward and aft positions to produce 30 degree convergent photography for the stereo and lateral pair operating modes. In the mono strip mode the mirror is stationary at 45 degrees from the axis of the lens system. This is a narrow angle lens system since the angle of coverage is only 6.4 degrees with a half angle of 3.2 degrees across ground track. The primary mirror and diagonal mirror focus the image through the slit onto the rotating platen.



NPIC H-3530 (7/63)

FIGURE 1. KH-7 CAMERA LENS SCHEMATIC.

The speed of the rotating platen is the controlling factor in production of sharp, distortion-free images and therefore is of utmost importance to the intelligence community. (See "Discussion of Strip Camera".) This cylindrical platen moves at variable speeds and carries the film past the image forming slit at a speed compatible with the movement of ground images past the slit. When operating at the proper speed, this platen will enable the camera to produce sharp images with high resolution. (See Table No 2.)

A pair of fiducial lines will be on the film, one on each edge, rather than fiducial marks. These lines will be the same distance apart at all times, since they are being exposed at the same time that the image is exposed, and will be one controlling factor in mensuration and determination of coverage and size of objects. In addition to these two

Table No 2. Lengths of Film Strips in Inches With Varying Film Speeds and Lengths of Operations

Film Speed Inches Per Second										
2.022	4.04	6.07	8.09	10.11	13.35	18.20	24.87	50.55	101.10	207.05
2.132	4.26	6.40	8.52	10.66	14.07	19.19	26.22	53.30	106.60	218.32
2.242	4.48	6.73	8.97	11.21	14.80	20.18	27.58	56.05	112.10	229.58
2.352	4.70	7.06	9.41	11.76	15.52	21.17	28.93	58.80	117.60	240.85
2.462	4.92	7.39	9.85	12.31	16.25	22.16	30.29	61.55	123.10	252.11
2.572	5.14	7.72	10.29	12.86	16.98	23.15	31.64	64.30	128.60	263.38
2.682	5.36	8.05	10.73	13.41	17.70	24.14	33.00	67.05	134.10	274.64
2.793	5.59	8.38	11.17	13.97	18.43	25.13	34.35	69.83	139.65	286.00
2.903	5.81	8.71	11.61	14.52	19.15	26.12	35.70	72.58	145.15	297.27
3.013	6.03	9.04	12.05	15.07	19.88	27.11	37.06	75.33	150.65	308.53
3.123	6.25	9.37	12.49	15.62	20.61	28.10	38.41	78.08	156.15	319.80
3.233	6.47	9.70	12.93	16.17	21.33	29.09	39.76	80.83	161.65	331.06
3.343	6.69	10.03	13.37	16.72	22.06	30.08	41.12	83.58	167.15	342.22
3.453	6.91	10.36	13.82	17.27	22.79	31.08	42.48	86.33	172.65	353.59
3.564	7.13	10.69	14.26	17.82	23.52	32.07	43.83	89.10	178.15	364.95
3.674	7.35	11.02	14.70	18.37	24.25	33.06	45.19	91.85	183.70	376.22
3.784	7.57	11.35	15.14	18.92	24.98	34.06	46.54	94.60	189.20	387.48
Length of Operation in Seconds	2.0	3.0	4.0	5.0	6.6	9.0	12.3	25.0	50.0	102.4

lines, there will be four yaw slits, two on each edge of the film. Each pair of slits is offset from the image slit, one on either side, so that the same image is exposed at two different times. By analyzing the image displacement from slit to slit, roll and yaw can be determined.

STRIP CAMERA FEATURES

Lens: Meniscus Maksutov, Concave-Convex Type.

Rotating Mirror: Plano Surface Mirror 33 Inch Diameter.

Focal Length: 77 Inches.

Slit Plate: Three Slit Widths Available (not changeable during operation).

Primary Mirror: 1st Surface Spherical Mirror (focusing mirror).

Diagonal Mirror: Rectangular Flat Mirror.

Field Flattener: Two Lens Elements (Chromatic Aberration Corrector).

Film Load: 3,000 Feet, 9.460 Inch Width.

Format Size: 8.718 Inches (variable length).

DISCUSSION OF STRIP CAMERA

A strip camera is primarily a motion recording device which stabilizes an image in the focal plane by moving the film past a stationary slit at the same speed as the image moves past the slit. When these two motions are in synchronization, a high resolution image is recorded on the film. Since the film speed and image speed are difficult to establish in an orbiting vehicle, a discussion of variations caused by changes in speed is necessary.

Assuming a stable vehicle, the camera can be operated at near the proper speed, and images formed are very close to precise scale; however, as the speed of the film image combination varies away from the synchronous position, distortion will occur along the line of flight. This distortion or smearing of images is a direct result of film-image speeds, and with the speed available in the KH-7 camera system, smear of 130% is possible along the flight path.

Smear is not the only type distortion apparent in strip photography since a mismatch of film-image speed can also cause compression of images along the flight path. If film speed is too fast for the image, elongation occurs, and if the film speed is too slow for the image, compression occurs.

Any change of film speed will cause elongation or compression of images along the flight path, and because of this, it is very difficult to determine sizes of objects in that direction. A high order of elongation or compression is readily apparent to the trained eye; however, a small order of elongation or compression will make distortion of the size and shape of objects difficult to detect. If the speed of the film changes during exposure, a differential distortion pattern will result in trapezoidal shapes of rectangular objects and curving lines that should be straight.

Since the speed of the film is applicable in only one direction, there is no distortion across the film with a stable vehicle, and all distortions caused by incorrect film speed are in the longitudinal direction of the film (parallel to flight path). Since the vehicle is not a stable platform, it is possible to have distortions caused by vehicle motion in the pitch, roll and yaw planes. There are two separate motions, static and dynamic conditions, in each of the planes. The static condition is when the vehicle is rolled, pitched, or yawed from its nominal position and remains in this position throughout the exposure. The dynamic condition is when the vehicle is pitching, rolling, or yawing during the exposure. For the static condition, pitch and roll are altitude sensitive because any change in vehicle attitude in these planes will alter the image speed at the center of the lens; since image speed is the one that controls film speed, distortions will occur in the direction parallel to the flight path. In the dynamic condition where movement is occuring during exposure, the motion is translated to the images being recorded, and distortions will occur in either direction, parallel to the flight path or perpendicular to it.

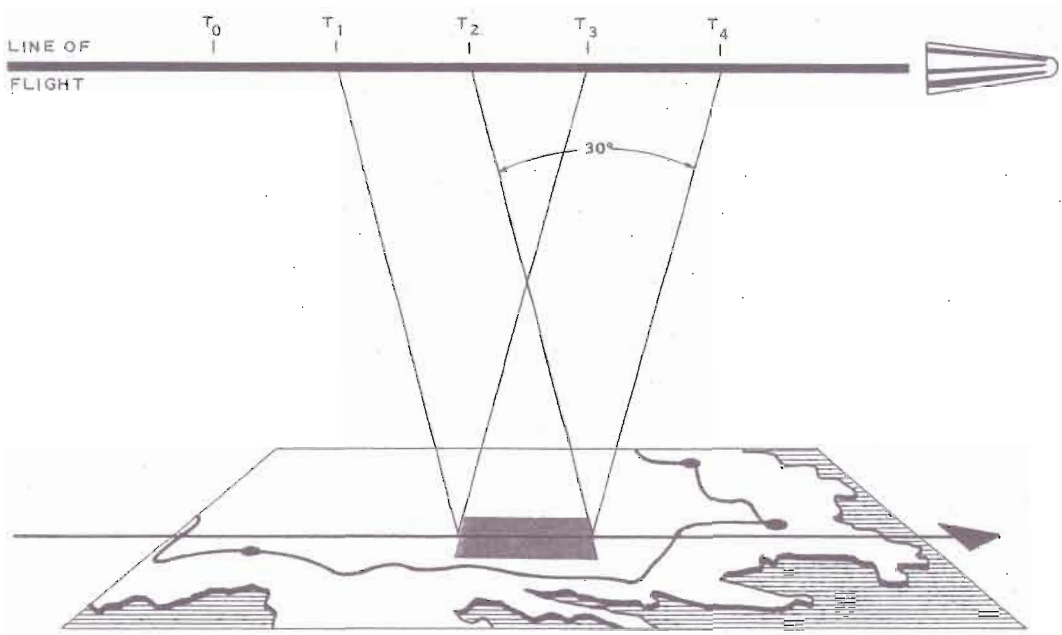
Yaw is not altitude sensitive, but the rotational motion in the dynamic condition is translated to the image the same as the pitch and roll motions are. Under static yaw conditions only small amounts of distortions are evident unless the yaw is excessive.

All of the distortions or smear of images discussed may occur at the same time and on the same exposure; therefore, determination of the exact cause of image distortion is not possible. Part II of this manual will discuss the mathematical approach to the problem of determination of image size and shape with multiple image motion problems.

OPERATING MODES

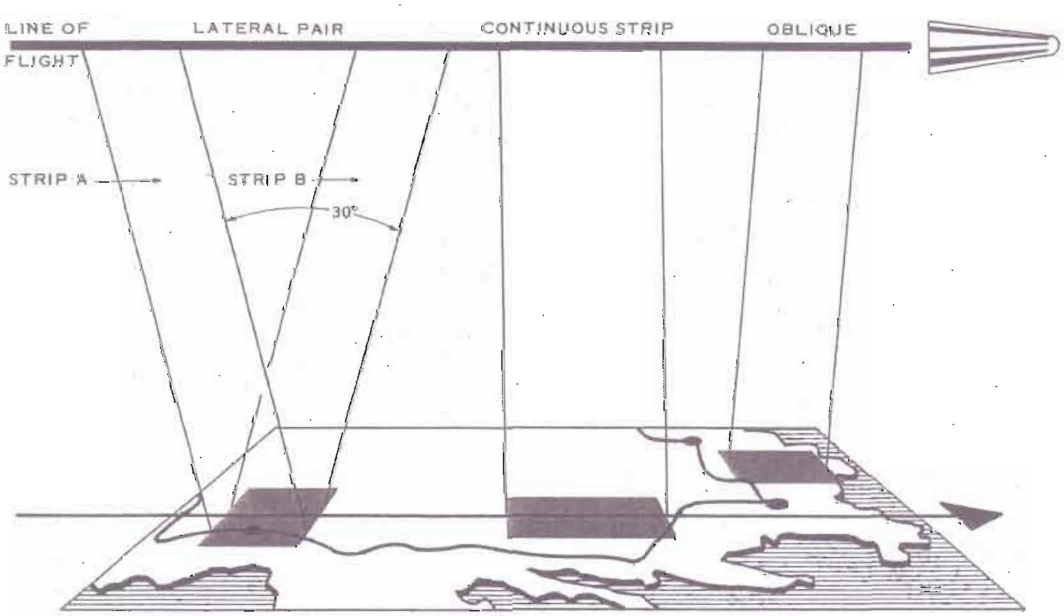
The KH-7 camera system can produce single strips of photography over a wide range of sizes from a minimum of 4 to a maximum of 387 inches in length; however, normal operations will fall in a much narrower range of 13 to 46 inches in length. (See Table No 2.) The film speeds available are from 2.022 inches per second up to 3.784 inches per second in 64 separate speeds; this allows operation in various portions of the orbit to produce distortion-free photography. (See "Discussion of Strip Cameras".)

When operating in either the stereo mode or in the lateral pair mode, the lengths of strips are controlled by speed of the vehicle and its altitude. The stereo pairs are programmed to produce 100% forward lap, and the lateral pairs are programmed to produce parallel strips with minimum side lap. (See Figures 2 and 3.) In the stereo mode, the rotating mirror is moved to the forward-looking position (15 degrees from the vertical along the flight path or parallel to the flight path); a strip of photography is ex-



NPIC H-3531 (7/63)

FIGURE 2. STEREO OPERATION SCHEMATIC.



NPIC H-3532 (7/63)

FIGURE 3. OPERATING MODES KH-7 CAMERA SYSTEM.

posed; then the mirror is rotated to its aft position (15 degrees), and the second exposure is made. Some roll is required to produce 100% stereo coverage due to coriolis; therefore, the vehicle rolls to the correct position between exposures. For the lateral pairs, the same 15 degree forward and aft positions are occupied, but the roll position is changed between frames to produce parallel photographs, rather than stereo.

The camera will produce photography over a wide range of coverage area by producing strip, pair, or stereo coverage any place within the 89 degree angular roll coverage available. Any mode may be operated in any roll position, and therefore, a high accuracy pointing camera is available. (See Figures 4 and 5.)

FORMAT AND TITLING

The KH-7 camera format provides a photographic strip of variable length, with a scene width of 8.514 inches as measured between the fiducial lines and excluding the yaw slits. This represents the usable image width. The scene width, if yaw slits are included, is 8.718 inches. (See Figure 6.)

At nominal altitude, the ground coverage width is approximately 12.25 nm. It is not anticipated that altitudes will vary to the extent that width of ground coverage will be less than 10 nm or appreciably more than 20 nm under normal oribtal conditions. (Refer to Table No 3 for altitude/coverage computations.)

The maximum obtainable strip length is approximately 32 feet if film speed and operational time are set to their limits. Strip length, therefore, will vary as film speed and length of camera operation are varied. A total of 64 speed steps are available, from a minimum of 2.022 inches to a maximum of 3.784 inches per second. The length of camera operation may range from 2 seconds to 102.4 seconds. Refer to Table No 2 for the pertinent data. The end of each frame will be denoted by an overexposed section of film, with a small area of distorted imagery caused by film speed acceleration and deceleration in this area. (See Figure 2.) The titling is imprinted in 10-point type on the film edge opposite the edge that contains the time track and is right-reading with the emulsion ~~up~~ down on film positives. Titles are started 1.5 inches in from the leading edge of the photographic format and are repeated to provide two complete title blocks within every 18 linear inches of film. Explanation of the title increments follows, in order of appearance:

1. Pass Direction Designator ("A" or "D", as appropriate)
2. Pass Number
3. Engineering Pass Designator ("E"), if applicable
4. Frame Number - The sequence begins with 001 on each photographic pass
5. Mission Number
6. Day-Month-Year (The day is the Z Date of each frame, and the components in this increment are separated by spaces)
7. Security Classification
8. Special Designations (Codeword)

FOCUS

The KH-7 camera system is designed to minimize spontaneous changes in focal length (FL = 77 inches) generated by mechanical or thermal factors beyond the system's control. However, it is recognized that slight shifts in excess of acceptable tolerances may be induced in the image plane by environmental conditions during launch or orbit. Consequently, a focus control assembly is provided for determination

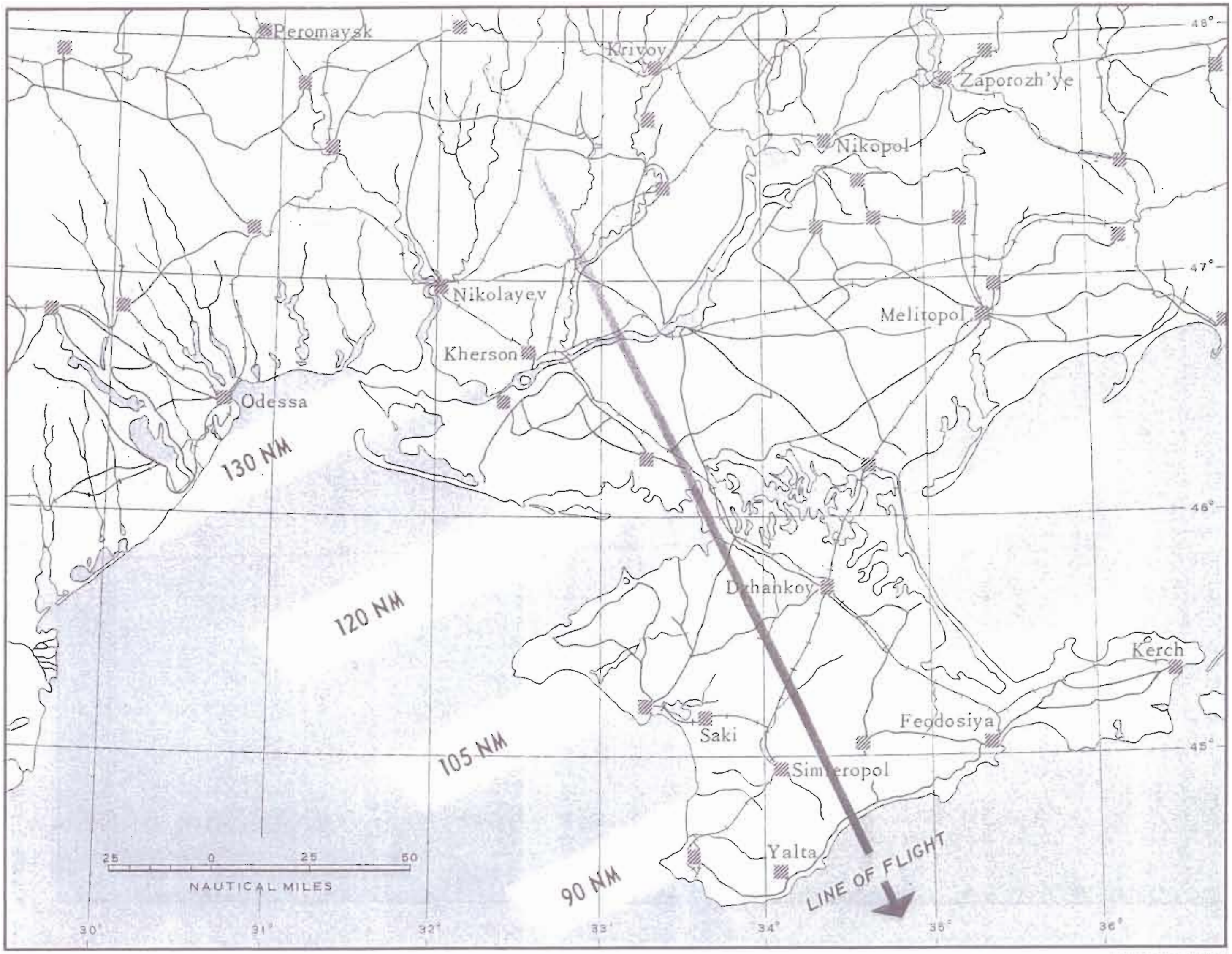


FIGURE 4. POSSIBLE SEARCH AREA FOR VARIOUS ALTITUDES OF KH-7 PROVIDED BY ROLL CAPABILITY.

~~TOP SECRET~~
SPECIAL HANDLING REQUIRED

Handle Via
TALENT-KEYHOLE
Control Only

~~TOP SECRET~~
SPECIAL HANDLING REQUIRED

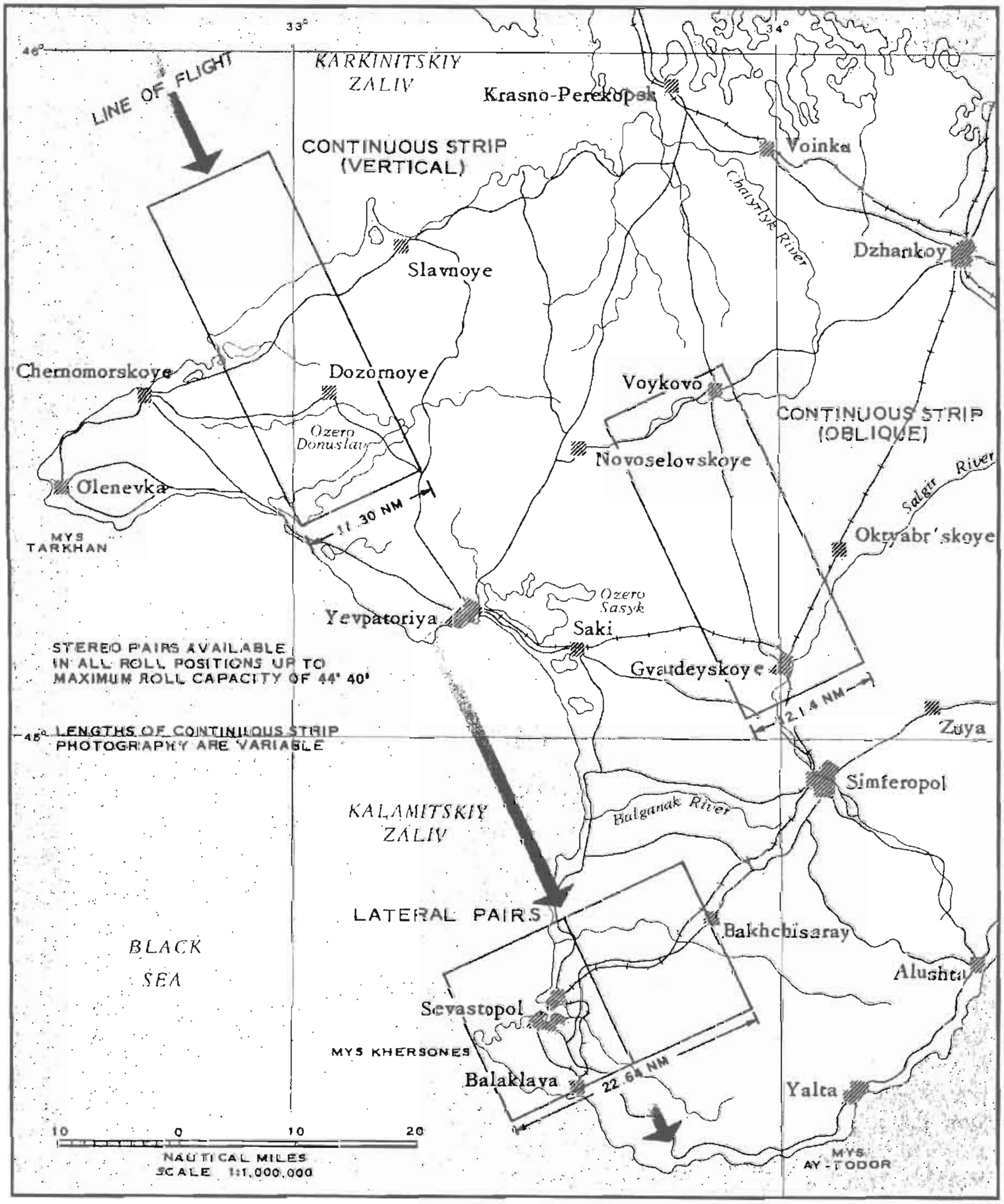


FIGURE 5. TYPICAL EXAMPLES OF CONTINOUS STRIP AND LATERAL PAIR FRAME COVERAGE AT NOMINAL 95 NM ALTITUDE.

Table No 3. Vertical Coverage Table

ALTITUDE NAUTICAL MILES	ALTITUDE FEET	WIDTH COVERAGE NAUTICAL MILES	SCALES	WIDTH COVERAGE IN FEET
90	547,200	10.06	85,275	61,186
90.46	550,000	10.12	85,712	61,500
95	577,600	10.62	90,013	64,586
98.68	600,000	11.03	93,504	67,090
100	608,000	11.18	94,750	67,984
100.33	610,000	11.22	95,062	68,200
102.80	625,000	11.50	97,400	69,886
104.44	635,000	11.68	98,958	71,004
105	638,400	11.74	99,488	71,384
106.91	650,000	11.95	101,296	72,680
110	668,800	12.30	104,225	74,784
111.84	680,000	12.51	105,970	76,036
113.49	690,000	12.69	107,530	77,154
115	699,200	12.86	108,965	78,182
115.13	700,000	12.89	109,088	78,372
116.78	710,000	13.06	110,646	79,390
118.42	720,000	13.24	112,205	80,508
120	729,600	13.42	113,700	81,582
120.89	735,000	13.51	114,540	82,186
123.35	750,000	13.80	116,880	83,864
125	760,000	13.98	118,438	84,980
125.82	765,000	14.07	119,218	85,540
127.46	775,000	14.25	120,776	86,660
129.93	790,000	14.53	123,115	88,340
130	790,400	14.54	123,175	88,380
131.58	800,000	14.71	124,672	89,454
135	820,800	15.10	127,913	91,780
139.80	850,000	15.63	132,464	95,044
140	851,200	15.65	132,651	95,180
143.91	875,000	16.09	136,360	97,840
145	881,600	16.21	137,389	98,578
148.02	900,000	16.55	140,256	100,636
150	912,000	16.77	142,216	101,978
152.13	925,000	17.01	144,152	103,430
155	942,400	17.33	146,864	105,376
156.25	950,000	17.48	148,048	106,226
160	972,800	17.89	151,601	108,776
160.36	975,000	17.93	151,944	109,020
164.47	1,000,000	18.40	155,840	111,818
165	1,003,200	18.45	156,340	112,176
168.58	1,025,000	18.85	159,736	114,612
170	1,033,600	19.00	161,076	115,574
172.69	1,050,000	19.31	163,632	117,408
175	1,064,000	19.57	165,814	118,974
176.81	1,075,000	19.77	167,528	120,204
180	1,094,400	20.13	170,551	122,372
180.92	1,100,000	20.25	171,424	123,000

of the optimal lens-image plane--film-surface plane relationship. The range of focus adjustment is ± 0.010 inches.

In general terms, the focus control assembly evaluates the conditions of focus. When departure from the limits of best focus is detected, the focus output signals (generated by the detector) indicate that an adjustment of focus is required. The focus drive motor, upon command, then shifts the film platen a controlled distance, returning the plane of best focus to coincidence with the film surface plane.

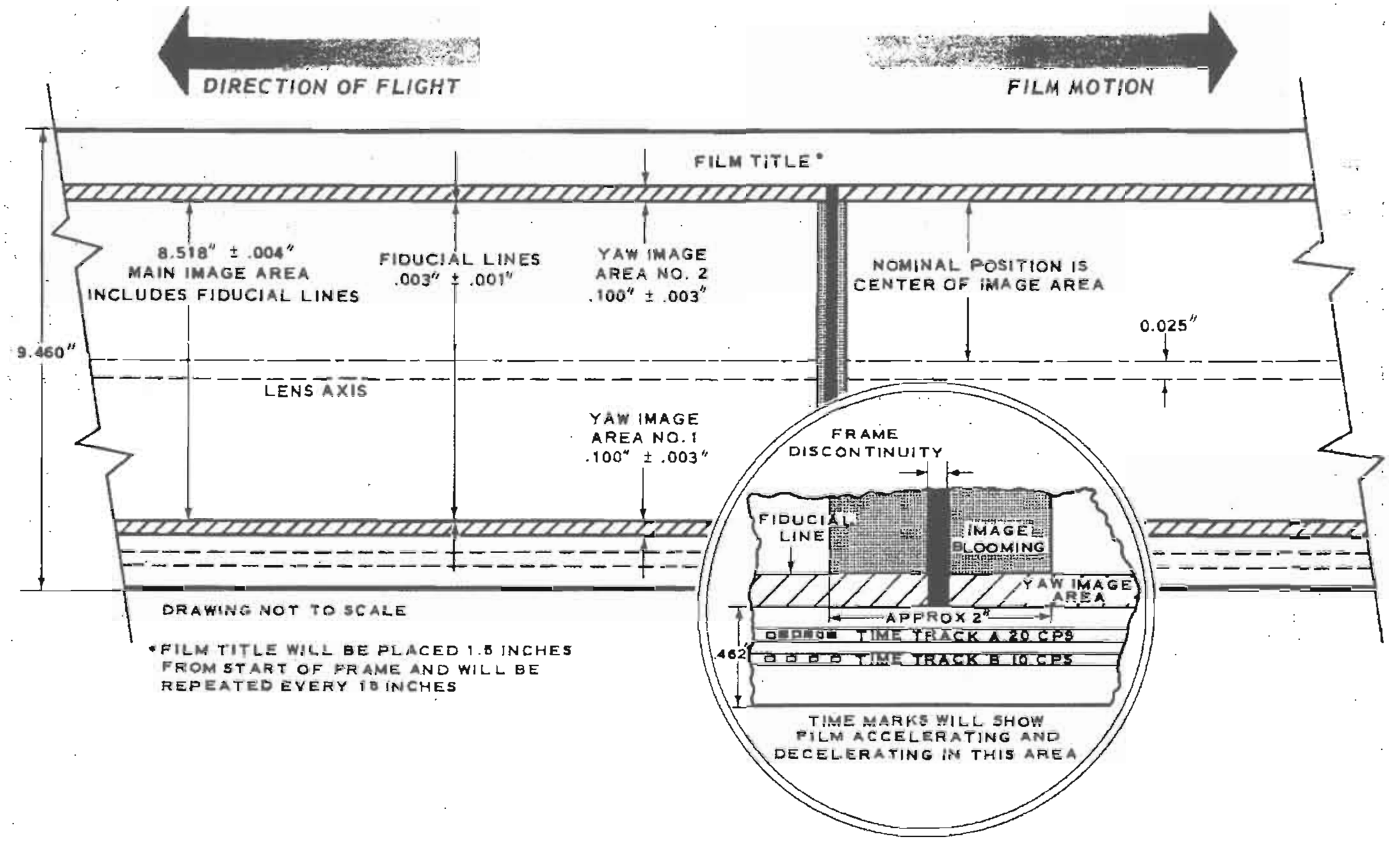


FIGURE 6. KH-7 FILM FORMAT.

NPIC H-3535 (REV 8/63)

TIME MARKS

A time track will be exposed on the film from which correlative data may be extracted. This time track is composed of two separate time tracks, one operating at 10 cycles per second (cps) and one operating at 20 cps. Binary time is recorded in both time tracks for redundancy checks, with the index marks for each track appearing at different intervals (50 milliseconds apart for the 20 cps track and 100 milliseconds apart for the 10 cps track). (See Inset, Figure 6.)

The binary time word is recorded in 23 bits to an accuracy of .1 second and is repeated every .8 second.

The size and variability of this time word and time track precludes early and easy access to the information. The variability of the time track and time word are controlled by the speed of the film moving past the slit; since this is a variable speed, the recording of the time track is variable also. (See "Discussion of Strip Cameras".) The size of the time track is so small that it is difficult to distinguish individual data bits at less than 10-time magnification, and a 25- or 30-time magnification is necessary to adequately read the time track.

STELLAR/INDEX CAMERA

The stellar/index camera system to be employed in the KH-7 system is the same one used in previous KH-4 and KH-6 systems. (See Figure 7.) These S/I units may be operated at varying intervals to produce adequate exposures for attitude determination during the main strip camera operation. A greater film supply than has been available in the KH-4 S/I units will allow more flexibility in the number of exposures and therefore attitude determination.

STELLAR CAMERA

The stellar camera produces photography of the stellar field over a format area 0.9375 inches diameter. A reseau grid is superimposed on the image plane to produce four fiducial marks at certain intersections of the grid and also to produce a grid on the exposure. The orientation of the reseau grid will vary from mission to mission. Calibration data for the camera and its reseau grid will be supplied with other camera data for each mission.

Frame correlation marks will appear on random frames for correlations of stellar frame and index frame.

Only the frame number will be titled on each frame. Frames will be numbered consecutively throughout the mission. Titling information consisting of mission number, date, classification, codeword, and a chart correlating frames to passes will be affixed to the head leader.

Stellar Camera Data

Lens: Cannon f/1.9.

Focal Length: 85 mm.

Cone Angle: 16 degrees.

Shutter Speed: 0.5 second to 6 seconds.

Filter: None.

Film Load: Variable 35 mm by 75 to 250 feet.

Format Size: 0.9375 inches diameter.

Reseau Grid: 2.5 mm calibrated grid.

In the roll positions available, the stellar camera will be photographing a changing star field since the entire package is rolled to these positions. In the case of a negative roll condition, the stellar unit will be pointing at or near the earth's surface; therefore, attitude may not always be available from this source.

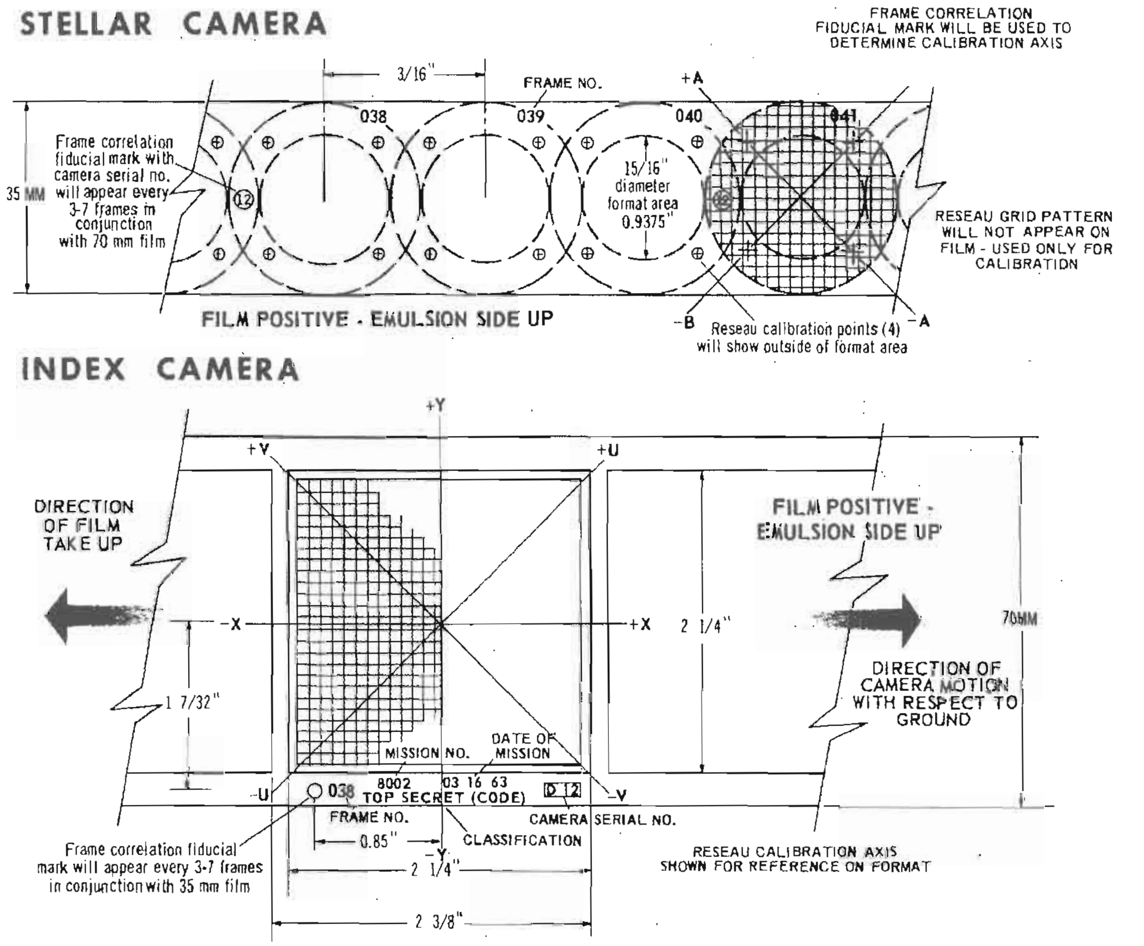


FIGURE 7. STELLAR AND INDEX CAMERA FORMAT AND TITLING.

NPIC H-3538 (7/63)

INDEX CAMERA

The index camera used is the same as the one in use on other systems, and has a format size of 2.25 inches square with a 2.5 mm reseau grid superimposed on the image. Calibration will be provided for each index camera, and the camera serial number will be recorded on each frame. A frame correlation mark, on a random frame basis, will be imaged for correlation of the stellar camera on one edge of the frame. Titling data will include the frame number, mission number, date, classification, and codeword. Frames will be numbered consecutively throughout the mission, and a chart correlating frames to passes will be attached to the leader.

INDEX CAMERA DATA

Lens: Zeiss Biogon f/4.5.

Focal Length: 38 mm.

Field Angle: 72 x 72 degrees.

Shutter Speeds: 1/125 second, 1/250 second & 1/500 seconds.

Filter: Wratten 21.

Film Load: 70 mm by 125 to 500 feet.

Format Size: 2.25 inches square.

Reseau: 2.5 mm calibrated grid.

Scale: Approximately 1:4,400,000.

The index camera will photograph the portion of the earth directly in line with the roll position of the vehicle since the index camera will be rolled the same amount as the main camera system. This will preclude yaw analysis and stereo coverage between frames taken at different roll positions.

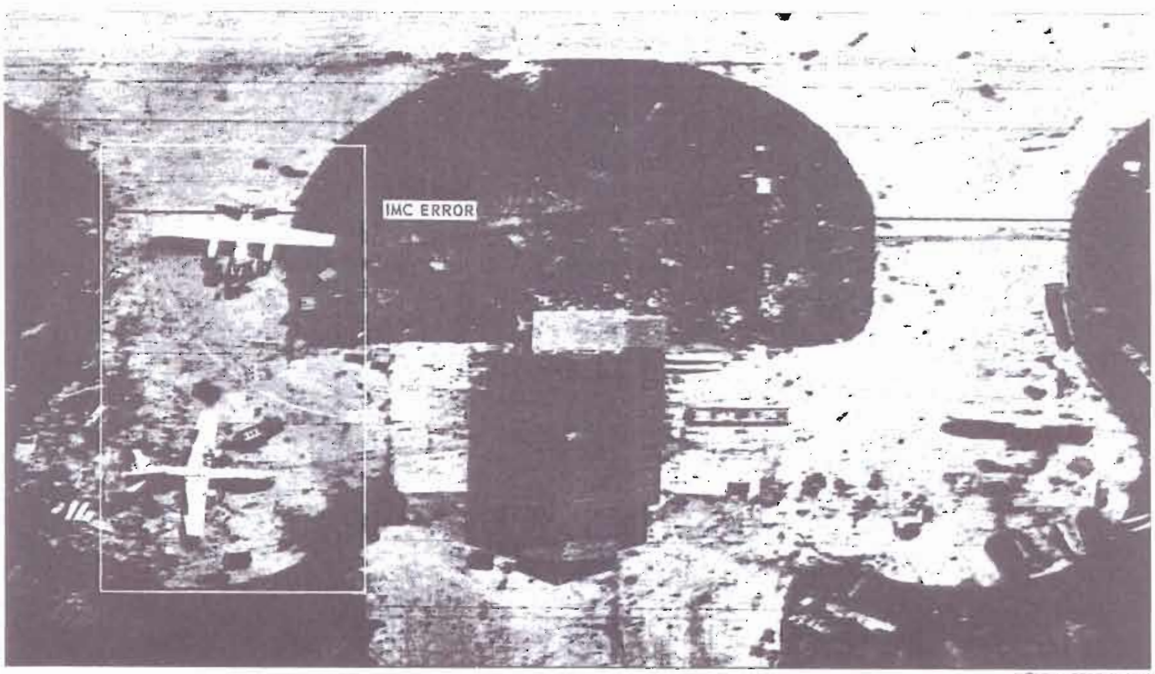
GLOSSARY

The possible degradation of photography by image smearing is inherent in any aerial photographic system. (See Figures 8, 9, and 10.) Hence, one of the major requirements of a system is the capability of reducing or compensating for the various smear-inducing factors. The following are technical terms most commonly encountered with relation to this problem:

IMAGE SMEAR: The degradation or distortion of terrestrial images, usually evidenced by edge-smearing in a direction parallel to the line of flight or approximately perpendicular to it, depending on the factors involved. Elongation or compression of images results, and circular objects may be recorded as elliptical forms.

ALONG-TRACK SMEAR: Image smear parallel to the forward motion or flight path of the camera vehicle.

CROSS-TRACK SMEAR: Image smear perpendicular to the forward motion or flight path of the camera vehicle.



NPIC H-3537 (7/63)

FIGURE 8. DISTORTION IN STRIP PHOTOGRAPHY.

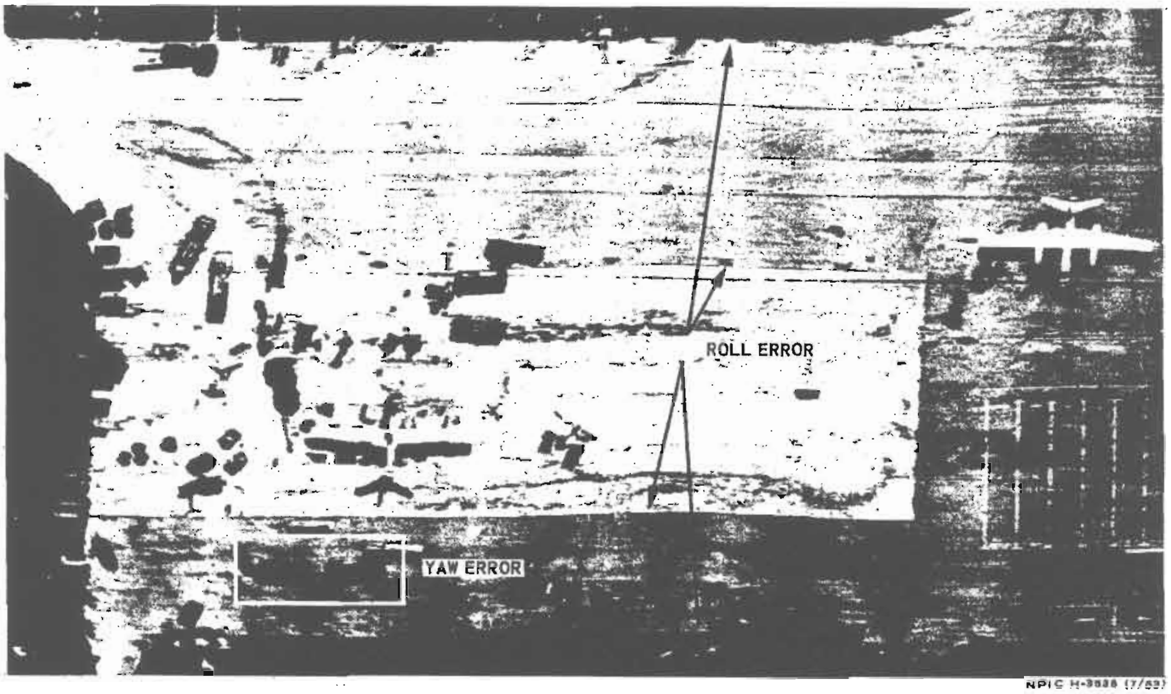


FIGURE 9. DISTORTION IN STRIP PHOTOGRAPHY.

FILM SPEED: The rate at which the film is advanced in the camera as a means of compensation for the relative motion between terrestrial images and the camera. If too slow, images of ground objects will be compressed; if too fast, images will be elongated.

PITCH: Movement of the vehicle about its lateral axis. Pitch deviations may be negative or positive with relation to the nominal reference angle and alter the camera altitude over ground objects.

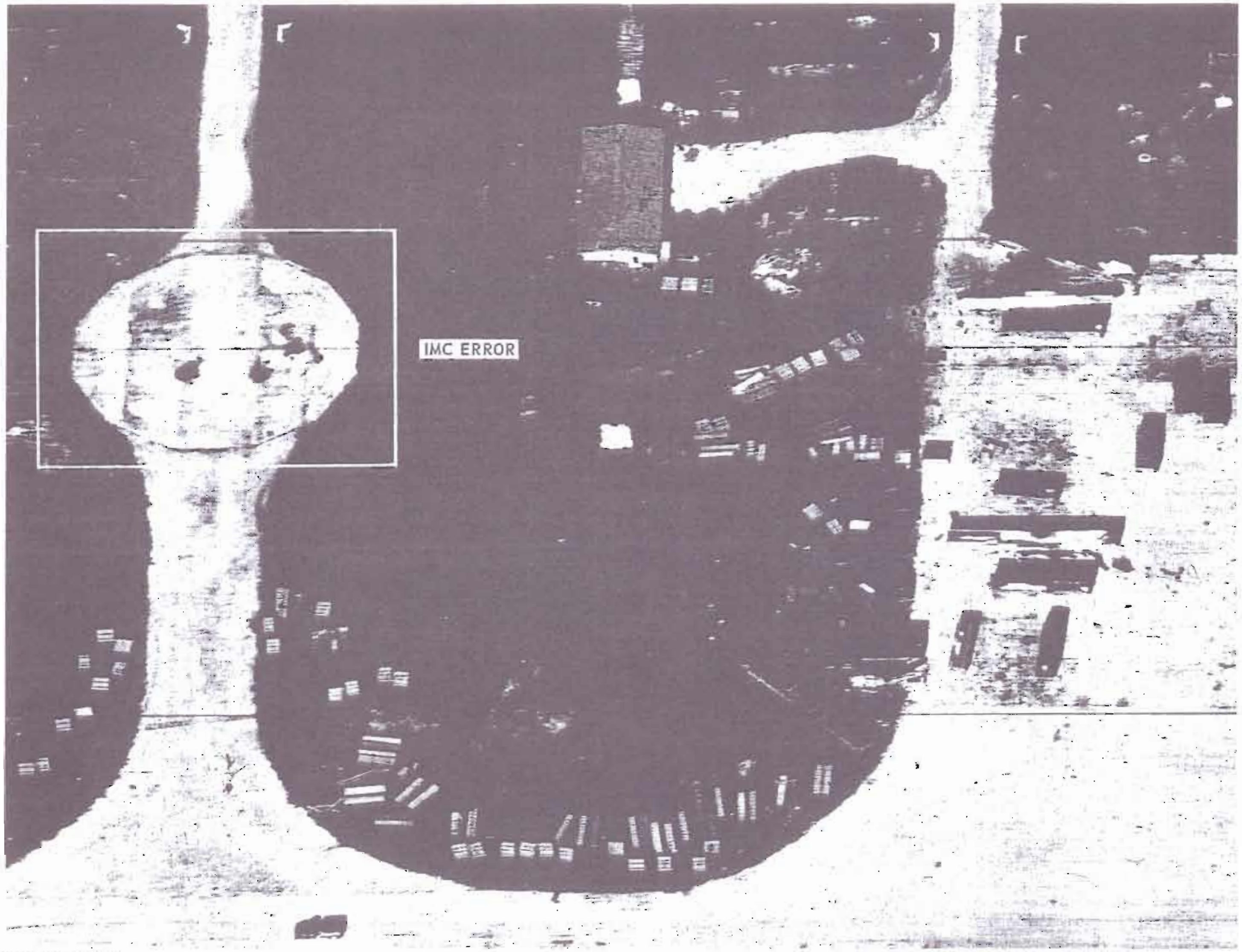
PITCH RATE: Motion during exposure, not to be confused with pitch, per se. However, pitch rate is similarly altitude-sensitive and therefore causes along-track image smearing.

ROLL: Movement of the vehicle about its longitudinal axis. This results in a change in attitude that alters the height of the camera over ground images; hence, it is an along-track error. However, note carefully the distinction between roll and roll rate with relation to image smear effect.

ROLL RATE: Motion during exposure. Since the actual movement leading to roll change in vehicle attitude is perpendicular to the line of flight, it is so recorded by the film, resulting in cross-track image smears.

YAW: Rotation from the line of flight of the longitudinal axis of the vehicle about its vertical axis.

YAW RATE: Motion during exposure. Since yaw and yaw rate are not altitude-sensitive, the resultant displacement of ground imagery is solely in a lateral direction and induces cross-track smearing.



NPIC H-3539 (7/63)

FIGURE 10. DISTORTION IN STRIP PHOTOGRAPHY.

~~TOP SECRET~~

Handle Via TALENT - KEYHOLE Control Only

SDA-A-2 TCS-20292/70

Copy 159

29 pages

(18.1)

NRO

National Reconnaissance Office

DATA BOOK

THE KH-8B CAMERA SYSTEM

THIRD EDITION

PUBLISHED BY
NATIONAL PHOTOGRAPHIC INTERPRETATION CENTER
OCTOBER 1970

Group I Excluded from Automatic
Downgrading and Declassification

~~TOP SECRET~~

Handle Via TALENT - KEYHOLE Control Only

PREFACE

This data book has been prepared by the National Reconnaissance Office with the assistance of the National Photographic Interpretation Center to facilitate the use of the photography from the KH-8B camera system. This book revises and updates previous releases concerning this system.

Third Edition

October 1970

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

INTRODUCTION

The KH-8B camera system (Figure 1) consists of four cameras and two recovery buckets. Various improvements are designed to increase the primary camera resolution by about 30% and increase the lifetime of the vehicle by an additional 6 days over the next 10 missions (starting with 27). The Primary camera is designed to produce high-resolution, large-scale photography of selected target areas.

A separate unit, the Astro-Position Terrain Camera (APTC), contains the other 3 cameras, one 75mm focal length terrain frame camera and dual 90mm focal length stellar cameras. The terrain camera is designed to point in the direction of the principal ray of the main camera. It provides mapping coverage and images for relative orientation. The stellar cameras are pointed 180 degrees apart, one to the port (left) side of the vehicle and one to the starboard (right) side. These provide at least one reduceable stellar frame with each main camera frame. The APTC will also be improved by providing a larger film load.

MAIN CAMERA

Strip Cameras

A strip camera is a device which stabilizes an image in the focal plane of the camera by moving film past a stationary slit at the same speed that the image is moving past the slit. When these two motions are synchronized, an unsmeared image is recorded on the film.

If these motions are not synchronized, the images are distorted by either compression or elongation in the direction of film movement.

Mensuration techniques allow for these variations in film speed and permit determination of changes in film speed with a high degree of accuracy.

When the camera is operating normally, the film speed should be within 0.6 mm/sec of the speed desired, except during looper action and start up transients. Image distortion will also occur if the film speed drive malfunctions or is commanded to operate at the wrong speed. However, this compression or elongation will not be discernible to the photointerpreter, and proper mensuration techniques still permit accurate mensuration of images on the film.

Optics

The optical part of the main camera consists of a flat stereo mirror, an aspheric mirror used as a converging lens, a corrector lens assembly, a slit, and a platen.

Film Drive

The film-drive mechanism is designed to maintain highly accurate and consistent film speeds throughout camera operation and through the following range of possible image motion: altitude from 65 to 135 nautical miles (nm) and obliquity angles from 0 to 45 degrees.

The film load can be either 10,000 feet of black and white 1414 ultra-thin-base (UTB) film; 7,500 feet of SO-242 UTB color film; or a combination of both film types which results in a variable film load. The film-drive mechanism prevents motion, except rotation of the platen, during normal exposure.

Accurate determinations of film speed can be made by measuring the time-track recordings on the edge of the film. These aid greatly in determining the mensuration capability for missions (See Recorded Data, p. 9).

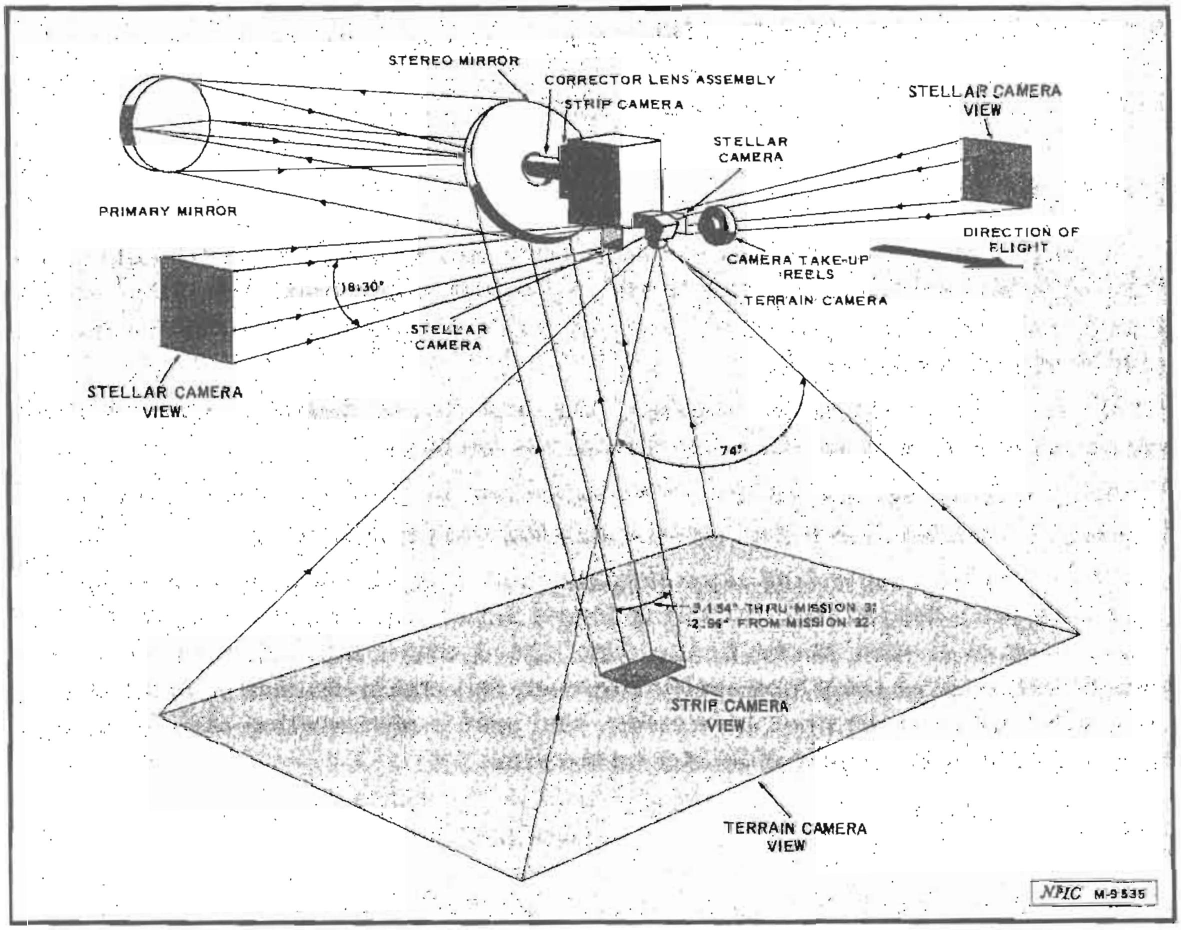


FIGURE 1. KH-8B CAMERA SYSTEM

Exposure

Film speed, slit size, and sun angle determine the exposure of images on the film. Since the film speed is determined by the speed of images in the focal plane, variation in film speed cannot be used for exposure control. Several slits have been supplied so that exposure can be controlled from sun angles of from 2 to 90 degrees and throughout the range of film speeds available (Figure 3).

Faster film speeds shorten and wider slits lengthen the exposure time. The film speed is determined by the image speed, and then the sun angle (and predicted snow cover) are viewed to find the best possible exposure. With these two parameters determined, the slit with the nearest exposure time for this combination can then be programmed.

Exposure may be determined by this formula:

$$T = W/VF$$

Where:

T = Exposure time in seconds

W = Slit width in inches

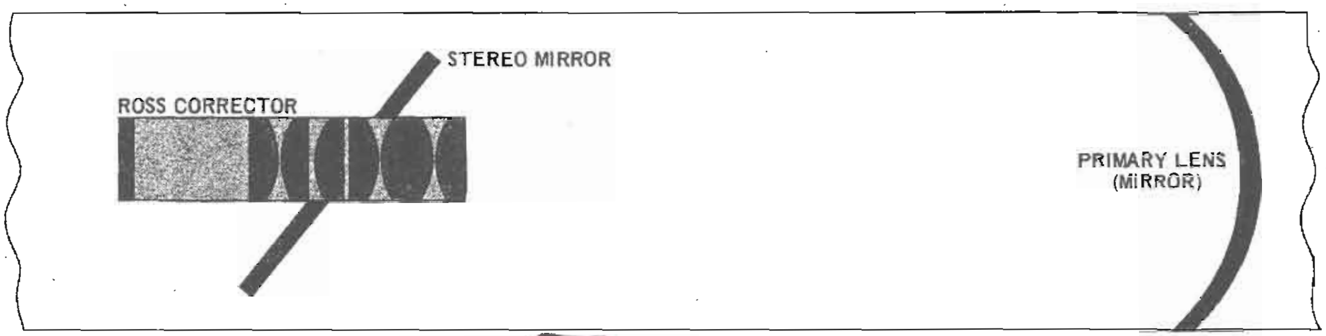
VF = Film velocity in inches per second

Unpredicted snow cover, desert scenes, and heavily wooded areas present special exposure problems. Consequently, some frames on each mission will not have the best possible exposure. These individual frames can be enhanced through printing techniques.

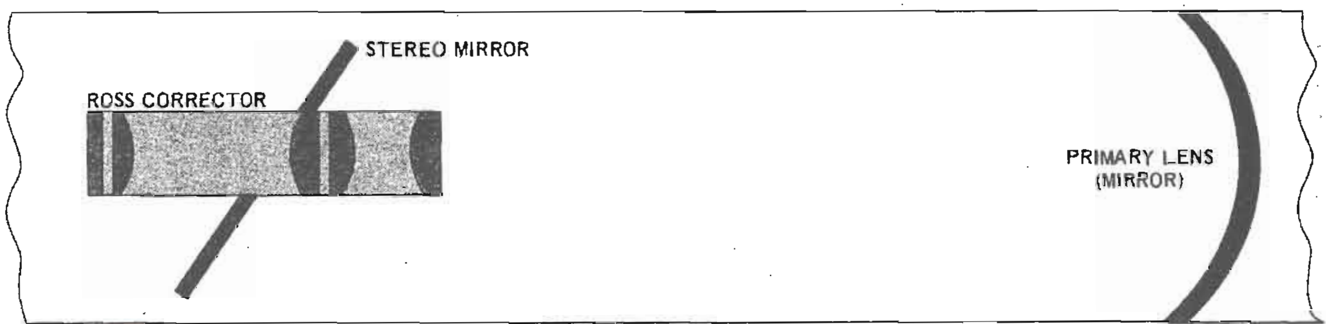
Control

The vehicle control system is designed to allow accurate pointing of a main camera system to the area of interest. The stereo mirror is rotated in the pitch plane of the vehicle to give the necessary angular relationship for stereoscopic coverage. The mirror can be stopped in any one of 3 positions. The effective lines of sight are 8.65 degrees forward from the vertical, vertical, and 8.65 degrees aft. Normal stereo is obtained in the forward and aft positions, but may be acquired in other modes.

The mirror is crabbed in the roll plane to compensate for the Earth's rotation.



KH-8[redacted]FOCAL LENGTH 4301-4331, DESIGN GOAL:[redacted]AT 72 NM



KH-8B[redacted]FOCAL LENGTH 4332-4341, DESIGN GOAL:[redacted]AT 72 NM

NPIC M-9536

FIGURE 2. KH-8B LENS IMPROVEMENT PROGRAM

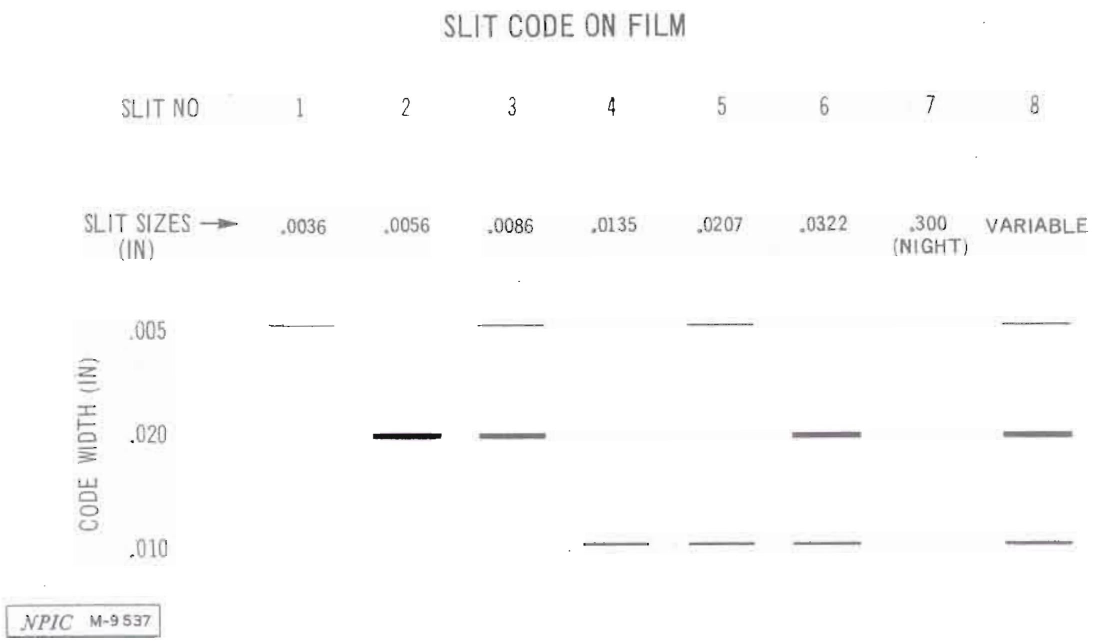


FIGURE 3. SLIT CODE ON FILM

Modes of Operation

The main camera can be used in various ways to provide the best views and selection of targets. These include:

Stereo: Fwd-aft, fwd-vertical, vertical-aft, fwd-vertical with aft mono, fwd-aft with vertical mono, fwd mono with vertical-aft.

Stereo: Double stereo fwd-aft of target with fwd-aft of second target interspersed.

Mono: Forward, vertical, aft, lateral pair, lateral triplet, end to end, and strip.

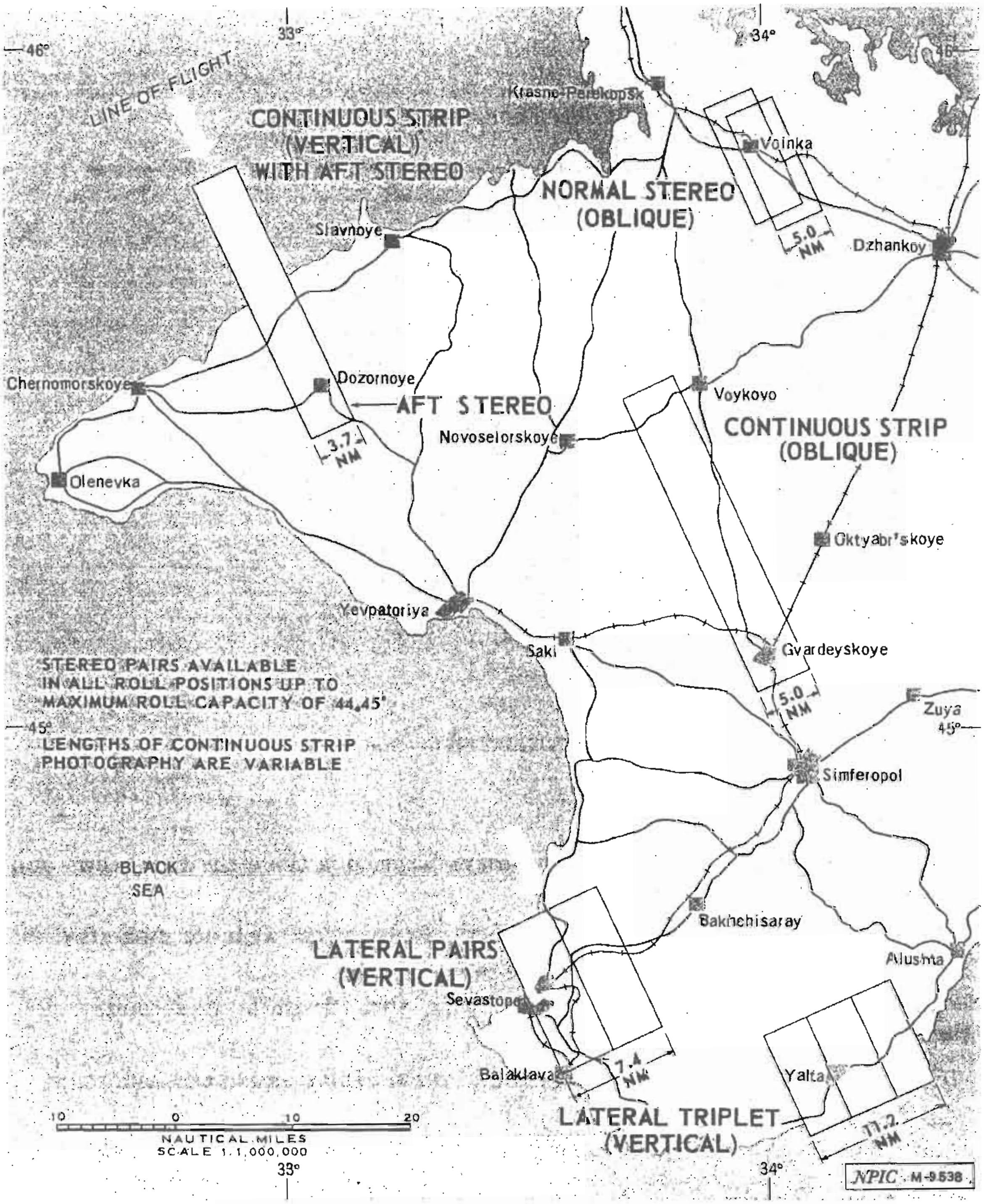


FIGURE 4. FRAME COVERAGE WITH 160" FOCAL LENGTH LENS

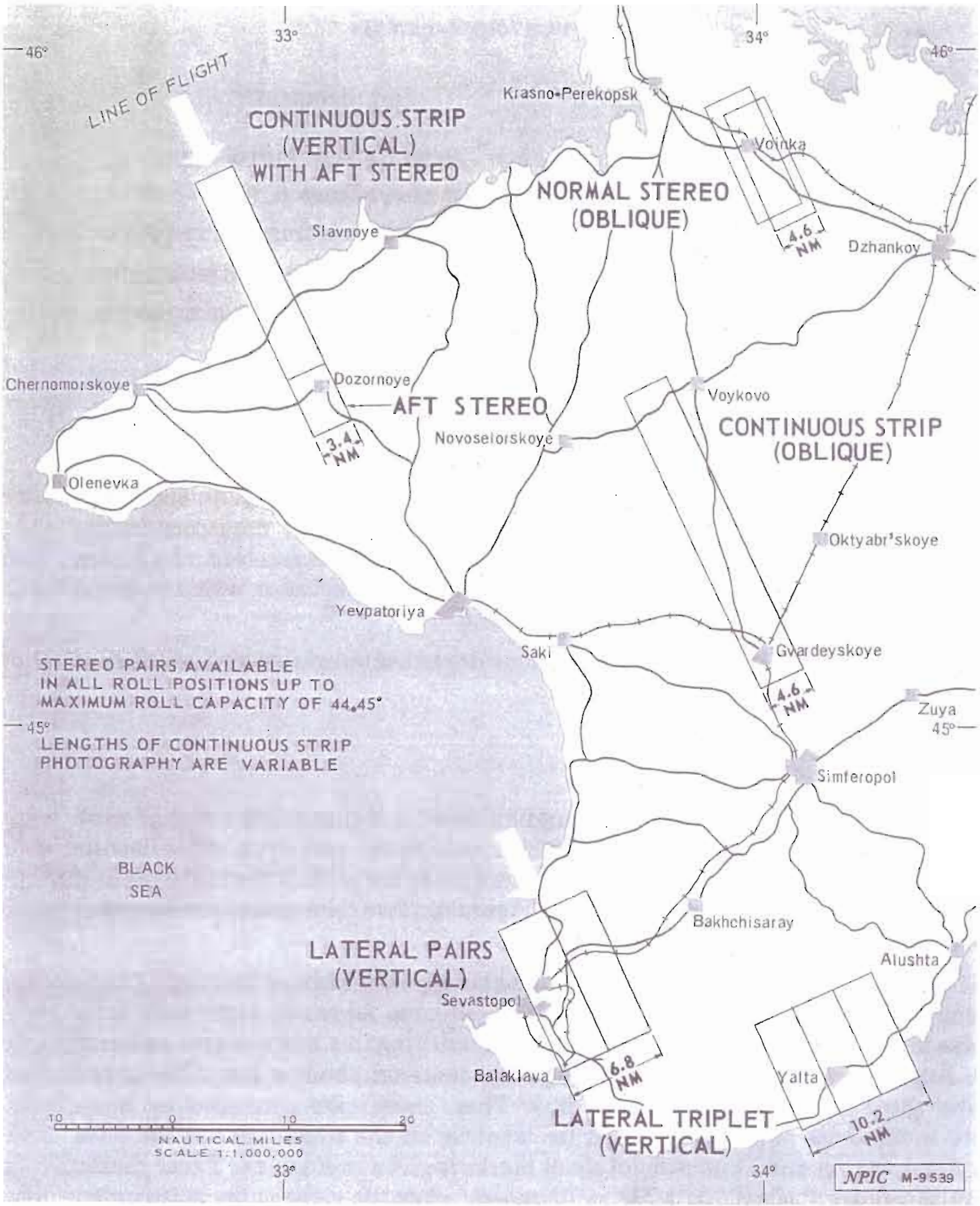


FIGURE 5. FRAME COVERAGE WITH 175.6" FOCAL LENGTH LENS

Table 1. Main Camera Improvements

Mission	Improvement
27	Low coefficient stereo mirror
29-31 (only)	Minus red filter coated on lens
32	Focal length increase from [redacted]
32	Flatter field & color corrected lens
26-32	Approach lower end of altitude range

Start-up Times and Film Coast

This system utilizes film moving on the platen face to record imagery; and, since this is a dynamic motion, a 0.25-second start-up transient time is necessary for the film to gain the proper speed. Also, when the command to stop is received, the platen and film coast to a stationary position. This coasting distance varies with the speed of the platen, but it is between 0.3 and 1.35 inches.

These two areas of the film may record some degraded imagery which should not be used for interpretation mensuration.

Format

The main camera records the image and all data on a film roll 9.5 inches wide (Figures 6 and 7). The image area is 8.810 inches wide with a yaw slit 0.100 inch wide on both sides of the film. The yaw slits record images at the ends of the main slit and provide some checks on vehicle motion (see Figure 6). Two data tracks are recorded outside the yaw slit on one side of the film.

The end-of-frame markers are recorded on the opposite edge of the film. At the beginning of each exposure or frame, the film will have remained stationary for a period far in excess of any normal exposure time, resulting in a burn-in area or burn-in line. A pair of frame-line position marks are centered about a line 2.25 inches preceding the burn-in area or burn-in line. These marks are produced by lamp exposure in the area normally reserved for labeling on the edge opposite the data tracks. The location and dimension of these marks is given in Figure 4. These marks are simultaneously flashed 700 ± 50 milliseconds after the camera is commanded off.

Titling Information

Titling information is on the base side of the original negative along the edge opposite the time track. It includes:

	SAMPLE
a. Revolution number (Pass)	196
b. Frame number	27
c. Mission - bucket number.	4332-2
d. Date of actual photography	Jan 4, 1970
e. Classification	TOP SECRET RUFF
f. Index number	+33

This information is repeated on long frames within each 18 inches of film. The frame numbers remain constant within each frame, but the index numbers advance sequentially with each title. Frames are numbered sequentially within each pass, beginning with 001. Index numbers on each pass also begin with 001.

Recorded Data

The data tracks are located near the left-hand edge of the primary film (see Figure 6). These data tracks record as photographic code marks such pertinent data as vehicle time, time of terrain camera shutter actuation and roll position.

A time label is recorded on data track A at 200 millisecond intervals. Each positive bit in the time code causes a lamp to produce a 1-millisecond exposure. The first bit in the code is always positive (binary one) and serves as synchronization pulse. The synchronization pulse is followed by a 22 bit time word with least significant bit first. For example, Figure 8 reads:

binary	1	010	010	111	111	111	100	100	10
octal		2	2	7	7	7	1	0	1

or, reading from most to least significant bit, 10177722.

A slit identifier code is also recorded on the same edge of the frame as the time track. This recording identifies the slit that is being used by continuously recording a code in three channels on the film edge (Figure 3).

Data track B is a 500 pulse-per-second timing signal containing the complement time label of data track A and the terrain camera shutter actuation indicator.

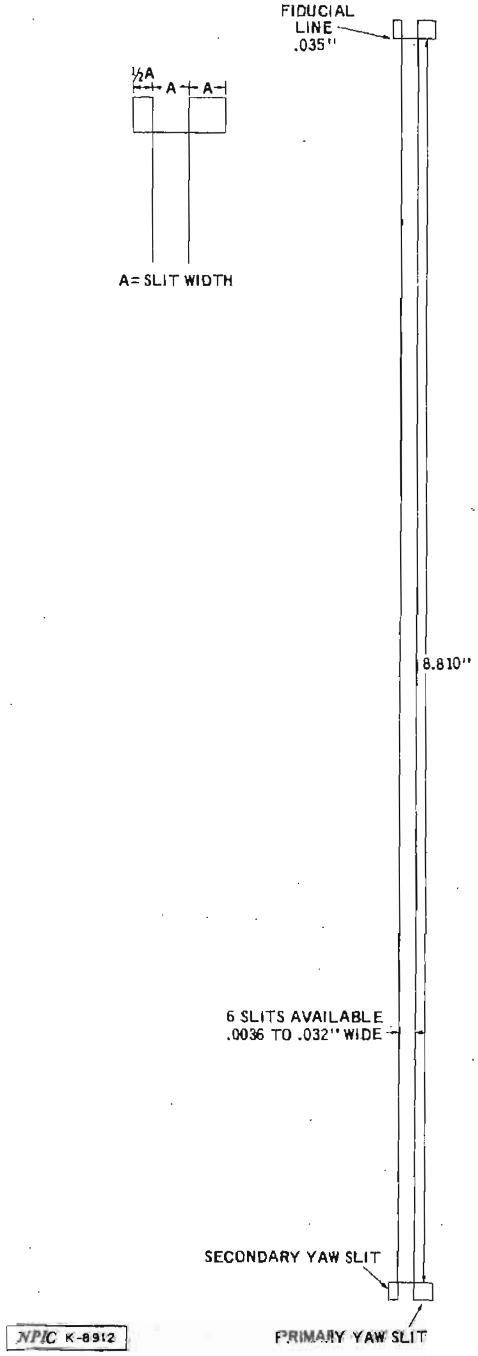
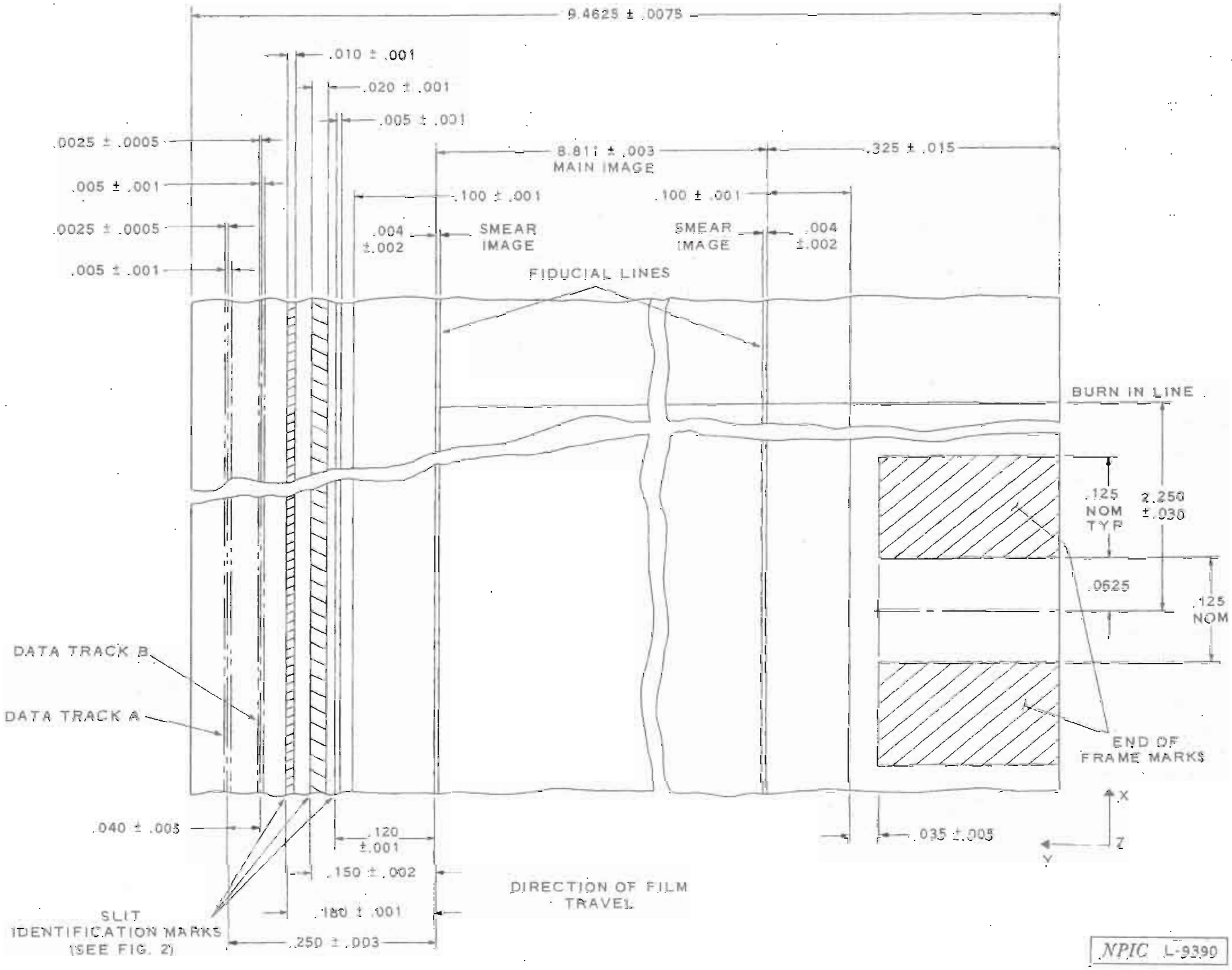


FIGURE 6. PRIMARY CAMERA SLIT

TOP SECRET



NPIC L-9390

FIGURE 7. PRIMARY CAMERA FILM FORMAT, FILM NEGATIVE EMULSION SIDE DOWN

TOP SECRET

TCS-20292/70

In addition to the data recorded in the camera system, there are other sources of information available such as telemetry, command lists, calibration manuals, computer sources, and the mission correlation data (MCD), an outline of which is given below.

Mission Correlation Data

A. Data Output at Beginning of each Run

1. Earth constants
2. Vehicle Payload Constants:

    a. Primary:

        (1) Slit calibrations
        (2) Focal length
        (3) Field angles
        (4) Mirror pitch angles (calibrated)
        (5) Skew angle

    b. APTC:

        (1) Focal lengths (3 cameras)
        (2) Field angles (3 cameras)
        (3) Calibration angles (3 cameras)

B. Data Output at the Beginning of Each Rev Which Has Camera Operations

1. Start of new rev indicators:

    a. Rev & mission number
    b. GMT date of new rev
    c. GMT time & longitude of ascending node

2. Ephemeris Data:

    a. Vehicle inertial position (X, Y, Z)
    b. Vehicle inertial velocity (XD, YD, ZD)
    c. Vehicle inertial acceleration (XDD, YDD, ZDD)

C. Data Output for Primary Camera Operations

1. Event data:

    a. Rev number
    b. Frame number
    c. Duration of event (camera exposure time)
    d. Mode:

(1) One-half of a stereo pair
(2) Strip
(3) One-half of a lateral pair
(4) F = mirror fwd
(5) V = mirror vertical
(6) A = mirror aft

e. Aperture designator (slit size)
f. Cone angle (angle between nadir and principal ray)
g. Camera roll
h. Film velocity (theoretical & commanded) in inches/second
i. Camera crab angle
j. Effective shutter speed
k. Intrack-crosstrack scale
l. Frame altitude
m. Skew angle
n. Frame length in inches

2. Target Data:

a. Programmed (Target ID)
b. Actual target ID, priority and X and Y coordinates on frame for target location
c. Marginal targets
d. Frame corners latitude and longitude

3. Ephemeris and Positioning Data:

a. System time referenced to GMT
b. Geodetic position of vehicle nadir
c. Geodetic position of intersection of camera principal ray with the earth.
d. Vehicle altitude
e. Inertial velocity & azimuth of vehicle
f. Flight path angle of vehicle
g. Sun elevation & azimuth
h. V/H (Velocity/Height) ratio in radians/second
i. Payload clock time (OCTAL)

4. Programmed blank frame event & corresponding data:

D. <u>APTC Camera Data</u>

1. Dependent operation
2. Independent operation

3. Frame number
4. Time of exposure GMT & OCTAL
5. Shutter speed
6. Geodetic Latitude & Longitude of Principal Ray
7. Altitude & radial distance
8. Inertial velocity & azimuth
9. Right ascension
10. Camera roll
11. Velocity/height ratio
12. Right ascension & declination
13. Solar azimuth & elevation
14. Flight path angle
15. Swing angle

E. Film Summary Data

1. Primary Camera Data:

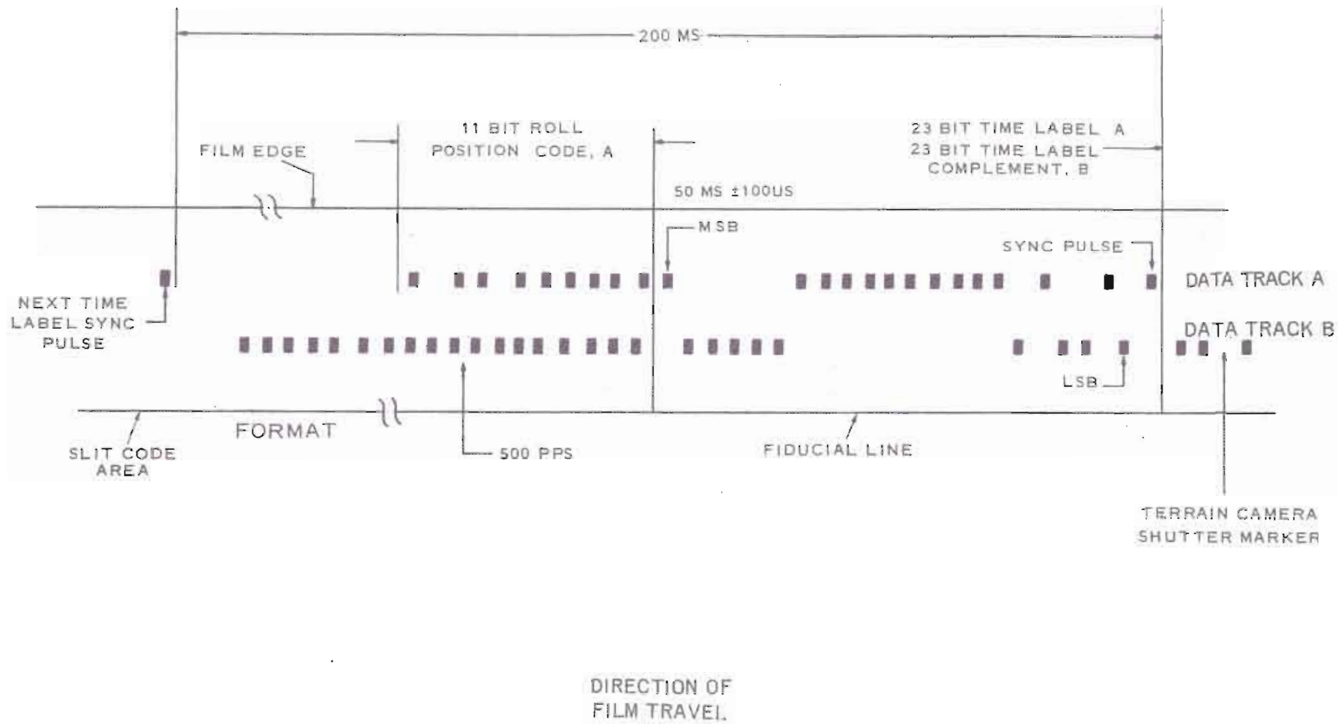
    (a) Rev number
    (b) Exposed frames & footage
    (c) Unexposed frames & footage
    (d) R&D exposed frames & footage
    (e) Total footage for rev
    (f) Total footage for mission

2. APTC:

    a. Independent & dependent frames
    b. Blank frames
    c. Rev and mission total footages

ASTRO-POSITION TERRAIN CAMERA

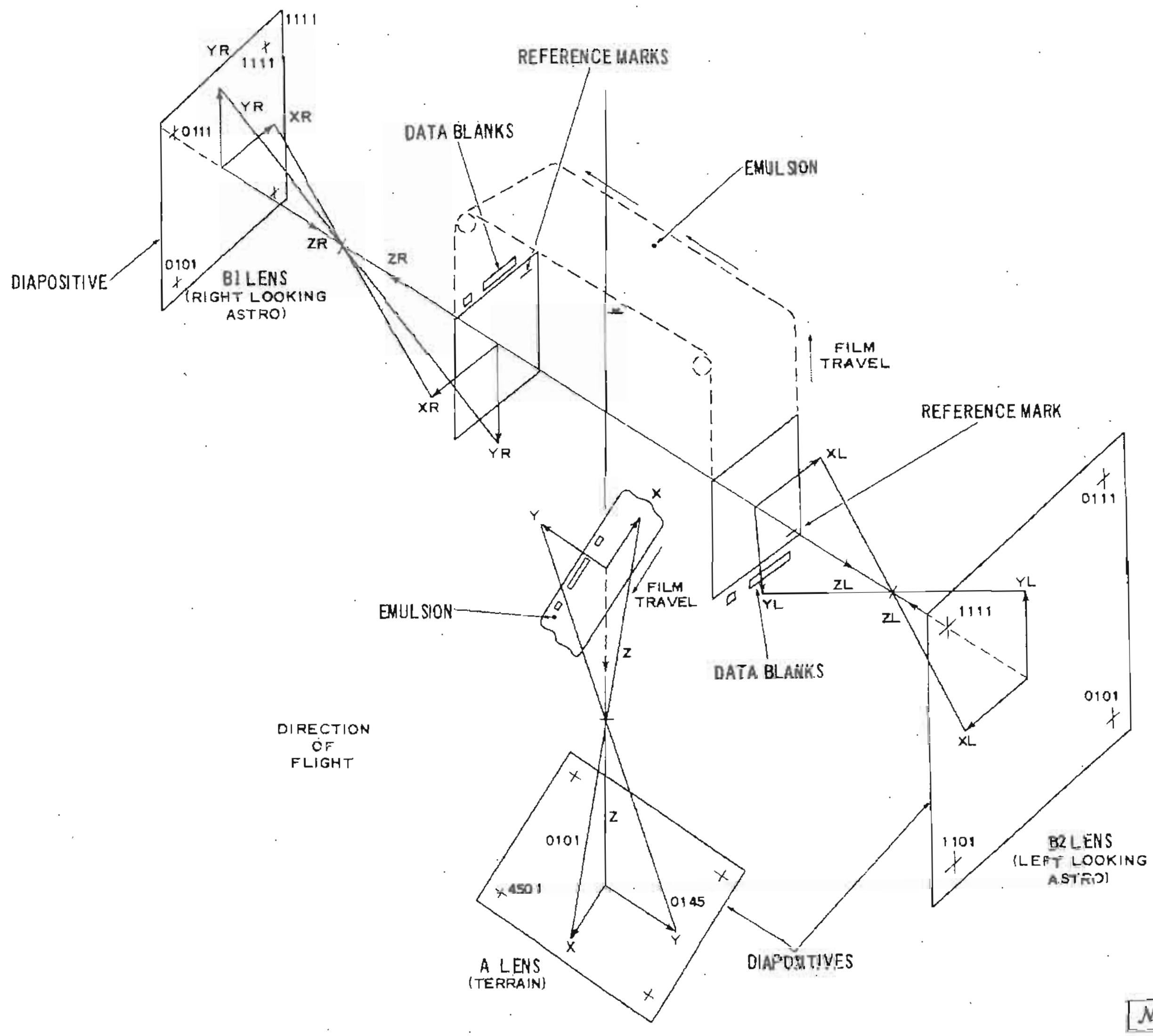
The Astro-Position Terrain Camera (APTC) system is used to produce: 1) terrain photographs for image correlation, mapping, geodetic, and relative orientation purposes, and 2) stellar photographs for attitude determinations and rate computations (Figures 9, 10, and 11).



NPIC M-9540

FIGURE 8. PRIMARY FILM DATA TRACKS, NEGATIVE EMULSION DOWN

Handle Via
TALENT-KEYHOLE
Control System Only



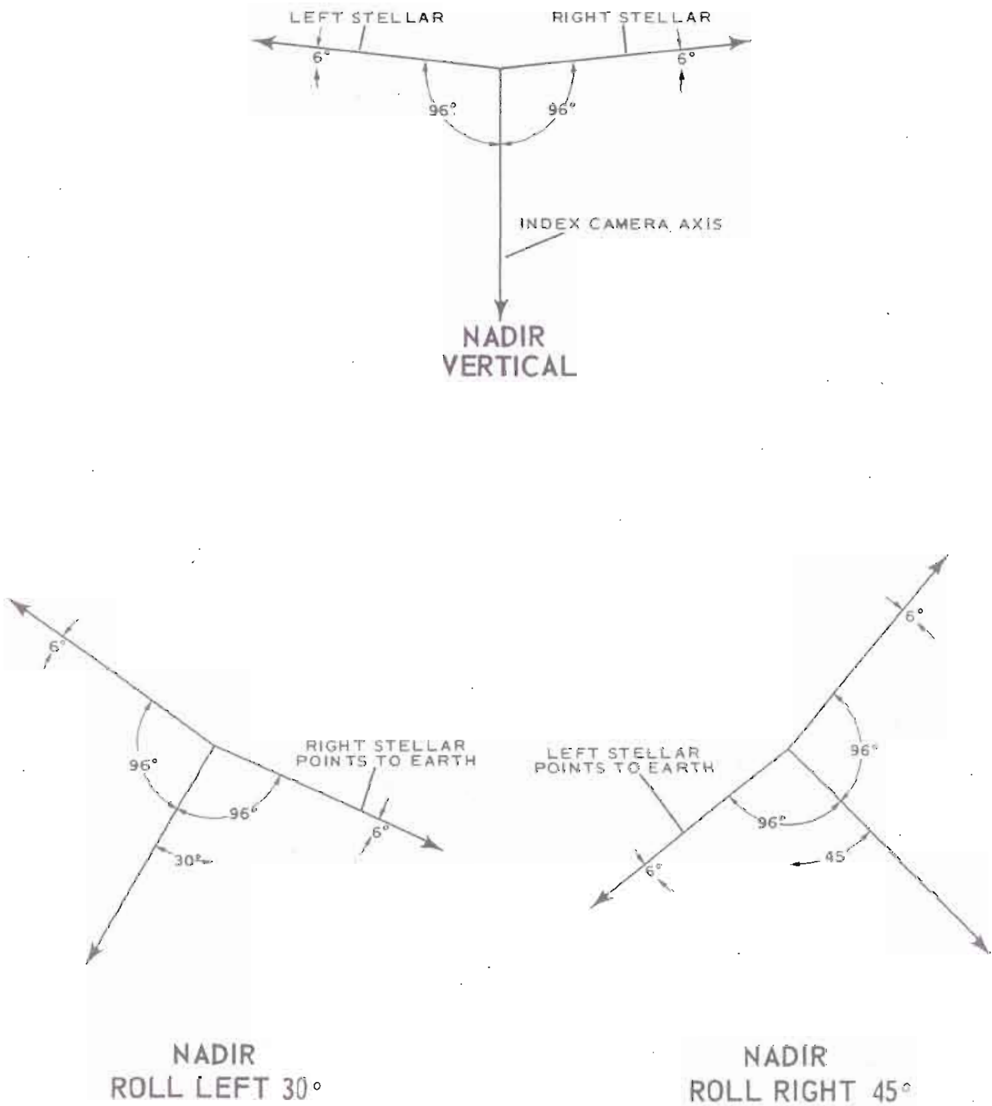
NPIC M-9541

FIGURE 9. THE ASTRO-POSITION TERRAIN CAMERA COORDINATE SYSTEM

TOP SECRET

Handle Via
TALENT-KEYHOLE
Control System Only

TCS-20292/70



NPIC M-9542

FIGURE 10. APTC ORIENTATION

Terrain Camera

The terrain camera is an f/5.0 frame camera with a 75 mm focal length. The camera uses an Aptcagon lens with a 74-degree field angle and produces frames 4.5 x 4.5 inches on 5-inch film. The camera contains sufficient ultra-thin-base (UTB) 5-inch film to photograph approximately 3,190 frames per mission. The film load will be increased with Mission 4330 to match the new APC capacity of 4,150 frames per mission.

The primary purpose of the terrain camera is to provide input to relative orientation computations for an accurate determination of the attitudes of the main frame. The terrain camera and the stellar cameras are accurately calibrated. The terrain camera is also used independently for mapping and geodetic purposes to obtain photography of poorly mapped or controlled areas of the world.

Titling Information

The titling information for the terrain camera is placed on the base side of original negatives. The information is along the edge of the film, opposite the binary time word. It includes:

Pass number

Frame number

Mission number

Date of photography

Classification

Pass numbers are titled in the blank frame at the beginning and end of each pass. Frames are numbered sequentially throughout each pass, beginning with 001. The terrain format is shown in Figure 12.

Data

Table 3. Terrain Camera Data

Focal length	75mm
f number	5.0
Half field angle	47 deg diagonal
Full field angle	94 deg
Film format	4.5 x 4.5 in
Film type	1414
Exposure	1/200 sec, 1/300 sec, and 1/500 sec (changeable on orbit)
Film supply	3,190 to 4,150 frames
Reseau	2.5-mm grid

Stellar Camera

The stellar cameras, pointed out opposite sides of the vehicle, are used to match main camera frames with useable stellar frames. These cameras point with the main camera. Therefore when the main camera rolls the APTC rolls to the same place. Since high roll angles would cause a single stellar camera to be pointing at the ground half the time, two stellar cameras are required to get full coverage. They are mounted to point six degrees above the horizontal line through the vehicle to eliminate albedo light. Therefore, in the vertical and near vertical positions, two useable photographs will be taken.

The stellar cameras are f/2.0 cameras with a 90-mm focal length, a 25.6-degree field angle, and a 29 x 29mm square film format (Figure 13).

A 2.5-mm reseau grid superimposed on the format of both the stellar and terrain cameras aids in calibration and data reduction.

The stellar cameras produce two exposures with each index frame, and, since these two cameras are physically separated, the same left and right exposures are two frames apart on the film.

The exposure time selected for the stellar cameras is 0.4 seconds. However, if this should prove inadequate, it can be changed to .8, 1.2, 1.6, or 2.0 seconds as necessary on future missions.

Titling Information

The original negative on the stellar camera is not titled except for the beginning and end of each pass. The duplicate negatives are titled on the base side, the duplicate positives are titled on the emulsion side.

The information carried on the duplicate negatives and duplicate positives includes the frame number (in sequence) and the left or right designator. The sequence of photographs in each stellar pass is as follows: 1 left, blank, 2 left, 1 right, 3 left, 2 right, 4 left, 3 right, etc. The leader contains the mission number and classification. The stellar format is shown in Figure 13.

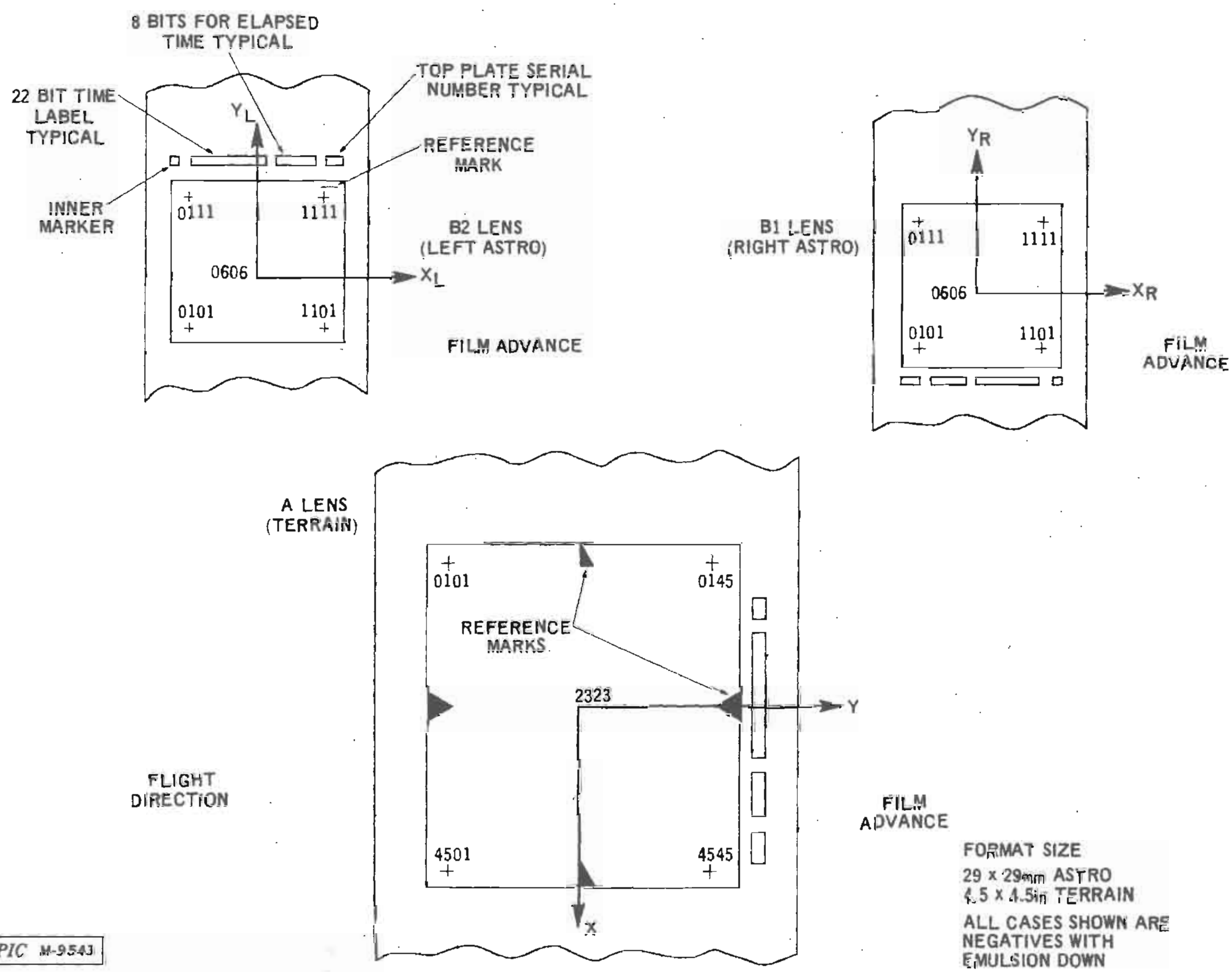


FIGURE 11. APTC FILM FORMAT AND IDENTIFICATION OF RESEAU INTERSECTIONS

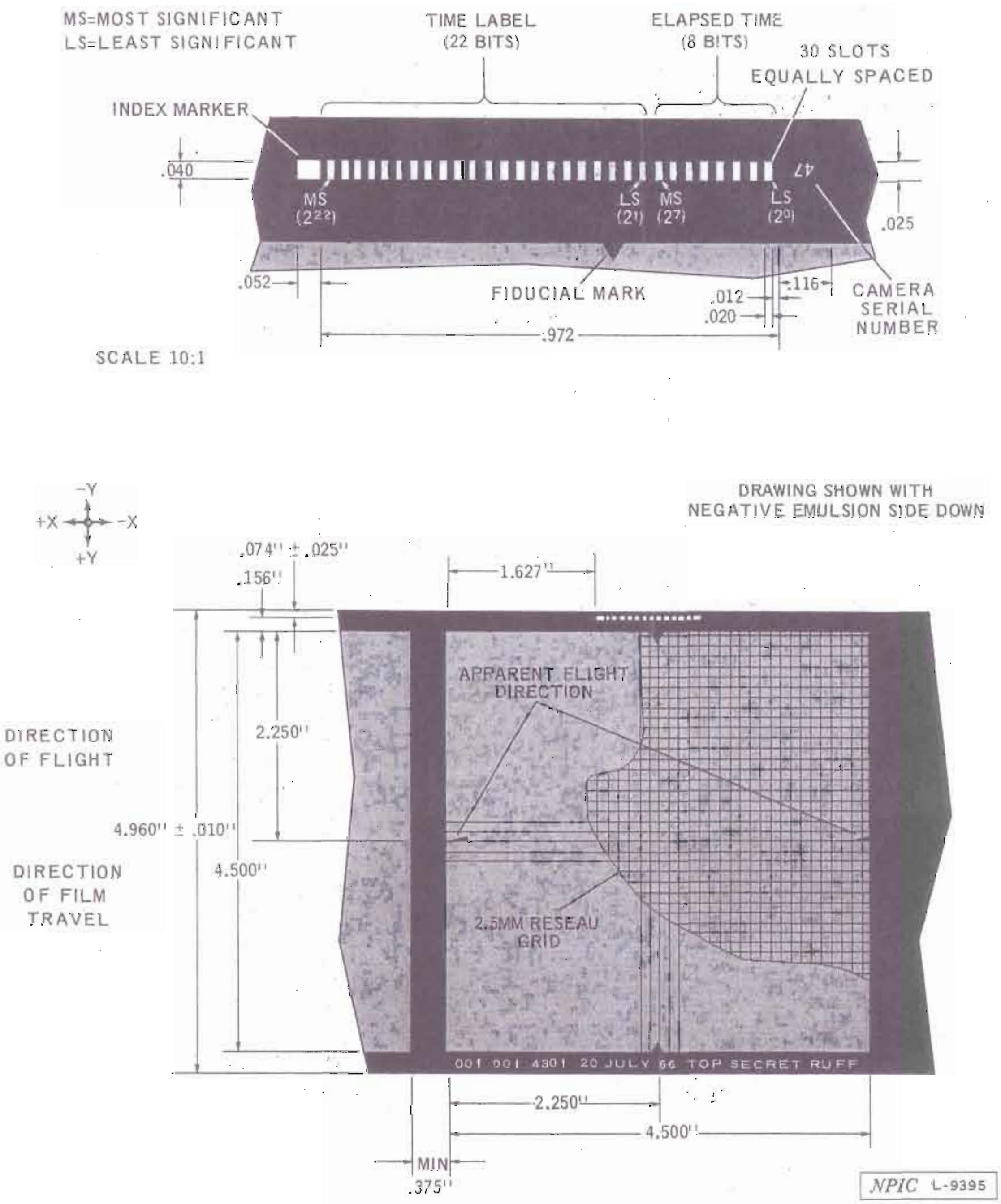


FIGURE 12. TERRAIN CAMERA FORMAT

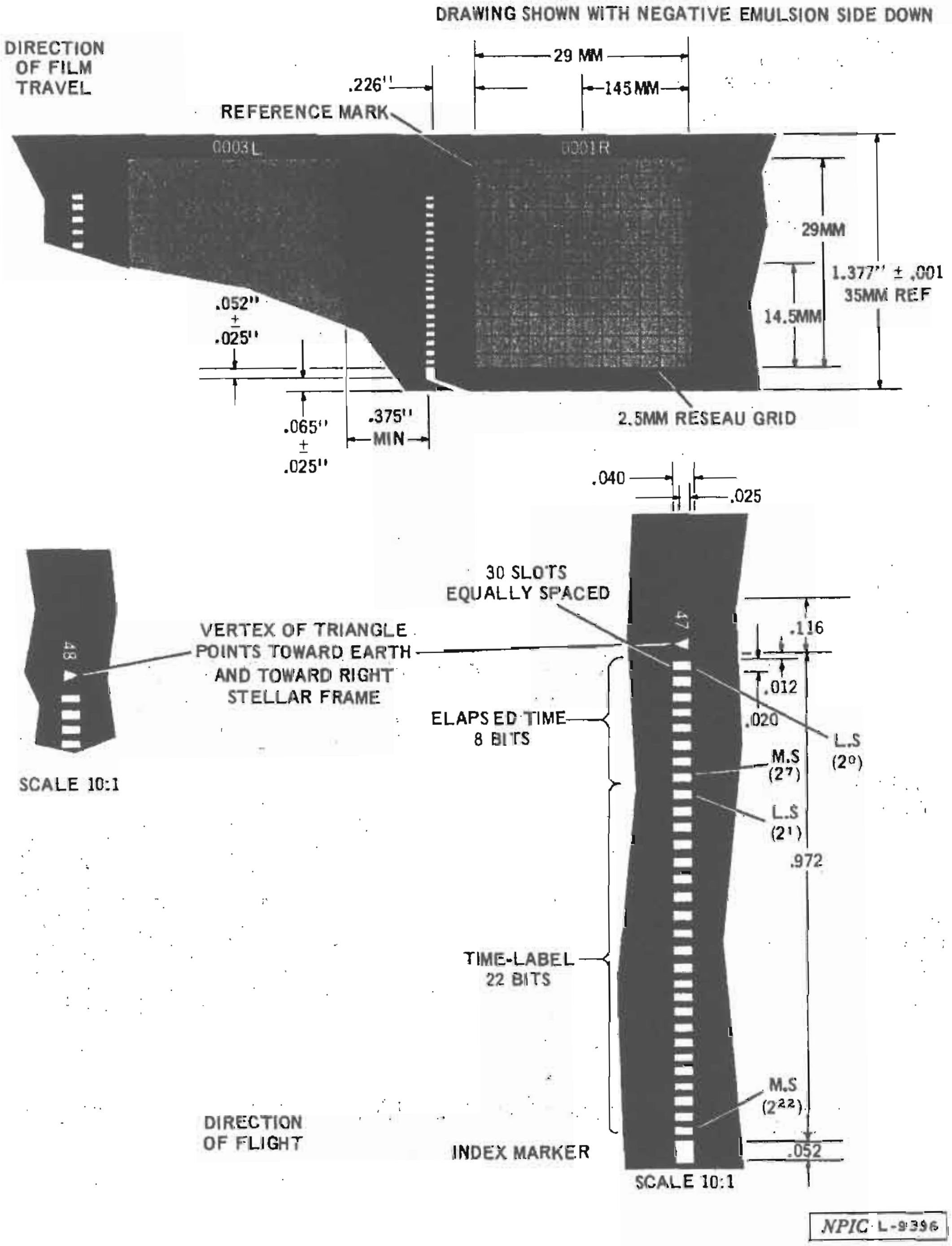


FIGURE 13. STELLAR CAMERA FORMAT

Data

Table 4. Stellar Camera Data

Focal length	90 mm
f number	2.0
Half angle	12.8 deg diagonal
Full angle	25.6 deg
Film format	29 x 29 mm
Film type	3401
Exposure	0.4 sec (standard), changeable at factory up to 2.0 sec
Film supply	3,190 and 4,150 frames
Reseau	2.5-mm grid

APTC Operation

The APTC can operate in either a dependent mode with the main camera or in an independent mode for mapping or geodetic purposes.

The independent mode is utilized exclusively for coverage of areas of the world that have inadequate maps or inadequate geodetic bases. The dependent mode is used to match the main camera frames with reduceable stellar frames. For strip photographs of long duration, one reduceable frame will be cycled each 10 seconds of operation.

Both the terrain camera and the stellar cameras record the time of exposure to an accuracy of .001 second in a 30-bit binary time word in the space outside the frame. The stellar cameras record the time word across the format and the terrain camera records along the format. Both units record a camera number or designator at the ends of the time words. The lower 8 bits are used to designate the milliseconds of elapsed time and the higher 22 bits record the actual clock time to .1 seconds.

The stellars are presently inhibited in the near-vertical positions since attitude is not necessary in the lower roll positions. The inhibited portion of the flight is at approximately 16 degrees obliquity.

GLOSSARY

The possible degradation of photography by image smearing is inherent in any aerial photographic system. Hence, one of the major requirements of a system is the capability of reducing or compensating for the various smear-inducing factors. The following are technical terms most commonly encountered with relation to this problem.

IMAGE SMEAR: The degradation or distortion of terrestrial images, usually evidenced by edge-smearing in a direction either parallel to the line of flight or approximately perpendicular to it, depending upon the factors involved. Elongation or compression of images results, and circular objects may be recorded as elliptical forms.

ALONG-TRACK SMEAR: Image smear parallel to the forward motion or flight path of the vehicle.

ACROSS-TRACK SMEAR: Image smear perpendicular to the forward motion or flight path of the vehicle.

FILM SPEED: The rate at which the film is advanced in the camera as a means of compensation for the relative motion between terrestrial images and the camera. If the film is too slow, images of ground objects will be compressed; if it is too fast, images will be elongated.

PITCH: Rotation of the vehicle about its lateral axis. Pitch deviations may be negative or positive with relation to the nominal reference angle, and may alter the camera's effective attitude over ground objects.

PITCH RATE: Motion about the lateral axis--not to be confused with pitch, per se. Pitch rate causes along-track image smearing.

ROLL: Rotation of the vehicle about its longitudinal axis. This results in a change in attitude that alters the slant range of the camera to ground images; hence, it is an along-track error. However, note carefully the distinction between roll and roll rate with relation to image-smear effect.

ROLL RATE:	Motion about the longitudinal axis. Since roll change is perpendicular to the line of flight, it is so recorded by film, resulting in across-track image smears.
YAW:	Rotation from the line of flight of the longitudinal axis of the vehicle about its vertical axis. The resultant displacement of ground imagery is solely in a lateral direction and induces cross-track smearing.
YAW RATE:	Motion about the verticle axis. Smearing caused by yaw rate is negligible.

7-0221-78
BIF003W/2-093942-77
25 January 1978
Cy 6

HEXAGON

CLASSIFIED BY BYEMAN 1 EXEMPT FROM GENERAL DECLASSIFICATION SCHEDULE OF E.O. 11652, EXEMPTION CATEGORY: 5B, (2) AUTOMATICALLY DECLASSIFIED ON:IMPOSSIBLE TO DETERMINE

NATIONAL SECURITY INFORMATION
UNAUTHORIZED DISCLOSURE SUBJECT TO CRIMINAL SANCTIONS

WARNING NOTICE
SENSITIVE INTELLIGENCE SOURCES AND METHODS INVOLVED

HANDLE VIA BYEMAN CONTROL SYSTEM ONLY

BIF003W/2-093942-77
HEXAGON CY 6
31 DECEMBER 1977
72 SHEETS

PROJECT HEXAGON OVERVIEW

CLASSIFIED BY BYEMAN 1 EXEMPT FROM GENERAL DECLASSIFICATION SCHEDULE OF E.O. 11652, EXEMPTION CATEGORY 5B, (2) AUTOMATICALLY DECLASSIFIED ON:IMPOSSIBLE TO DETERMINE

NATIONAL SECURITY INFORMATION
UNAUTHORIZED DISCLOSURE SUBJECT TO CRIMINAL SANCTIONS

WARNING NOTICE
SENSITIVE INTELLIGENCE SOURCES AND METHODS INVOLVED

HANDLE VIA BYEMAN CONTROL SYSTEM ONLY

HEXAGON VEHICLE ON ORBIT

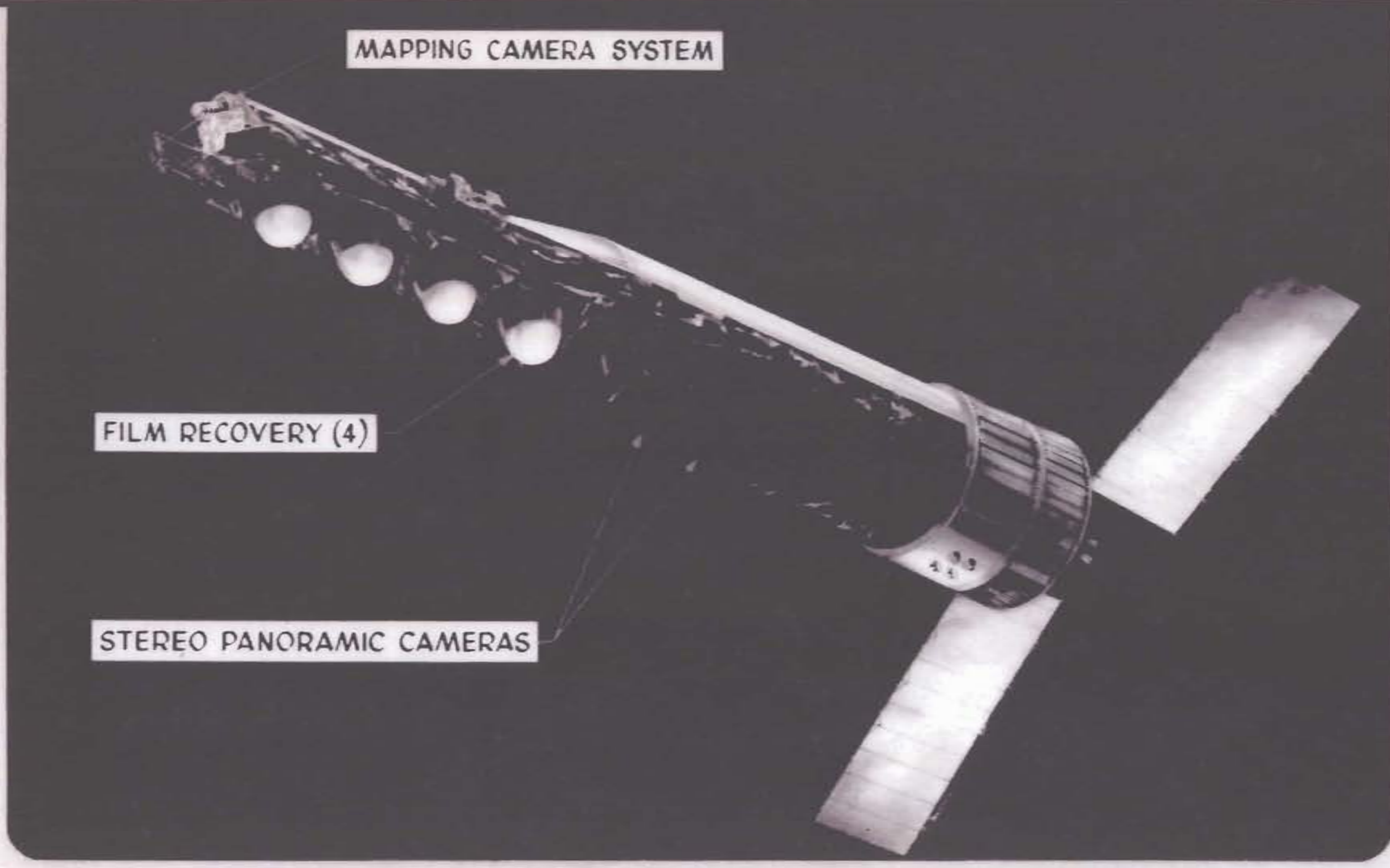
The Hexagon vehicle performs world-wide search and surveillance missions with two cameras that provide stereo panoramic photography. The film is recovered as each of four (4) large reentry vehicles (Mark 8) is filled. Each reentry vehicle is ejected from the Hexagon vehicle and is caught by USAF JC130 aircraft near the Hawaiian Islands. The film is then flown to Eastman Kodak at Rochester, N. Y., to be despooled, processed, and then copied for the using agencies.

The Hexagon vehicle also performs mapping and geodesy missions with stellar and terrain frame cameras. The film is retrieved via the small (Mark V) reentry vehicle mounted on the Hexagon vehicle nose. Accurate Hexagon vehicle location for the mapping mission is determined with the Doppler Beacon System and in the future via the Navigational Package.

The Hexagon vehicle flies in a near polar orbit (97 deg inclination) at a typical perigee/apogee of 88/155 NM, respectively. Mission durations of up to 180 days have been flown. In addition to the stereo panoramic cameras and the Mapping Camera System, the Hexagon vehicle [redacted]

~~TOP SECRET~~/H

HEXAGON VEHICLE ON ORBIT



SATELLITE VEHICLE (SV) CONFIGURATION

The SV configuration incorporates overall mission success considerations as well as weight minimization and structural efficiency. Film supply, cameras, and RVs are arranged in line for film path simplicity; the two-camera assembly is relatively close to the attitude control system in the Aft Section to enhance pointing accuracy. Aft Section electronic/electric equipment, mounted on trays in a modular fashion, is accessible through removable panels during the factory and pad spans. Access is provided to the RVs, two camera assembly, and film supply for necessary servicing. Propulsion/control force elements are grouped in a module for testing efficiency and brazed plumbing is used to assure the integrity of the propellant system through handling, launch, and flight.

In the factory the SV is brought to flight readiness by acoustic and thermal vacuum testing of the assembled vehicle; vehicle instrumentation is designed for such system level testing with RF command and data links.

The SV is shipped flight-ready to the launch base, with validation prior to launch. When required, equipment is replaced on a module/box basis to preserve factory verifications.

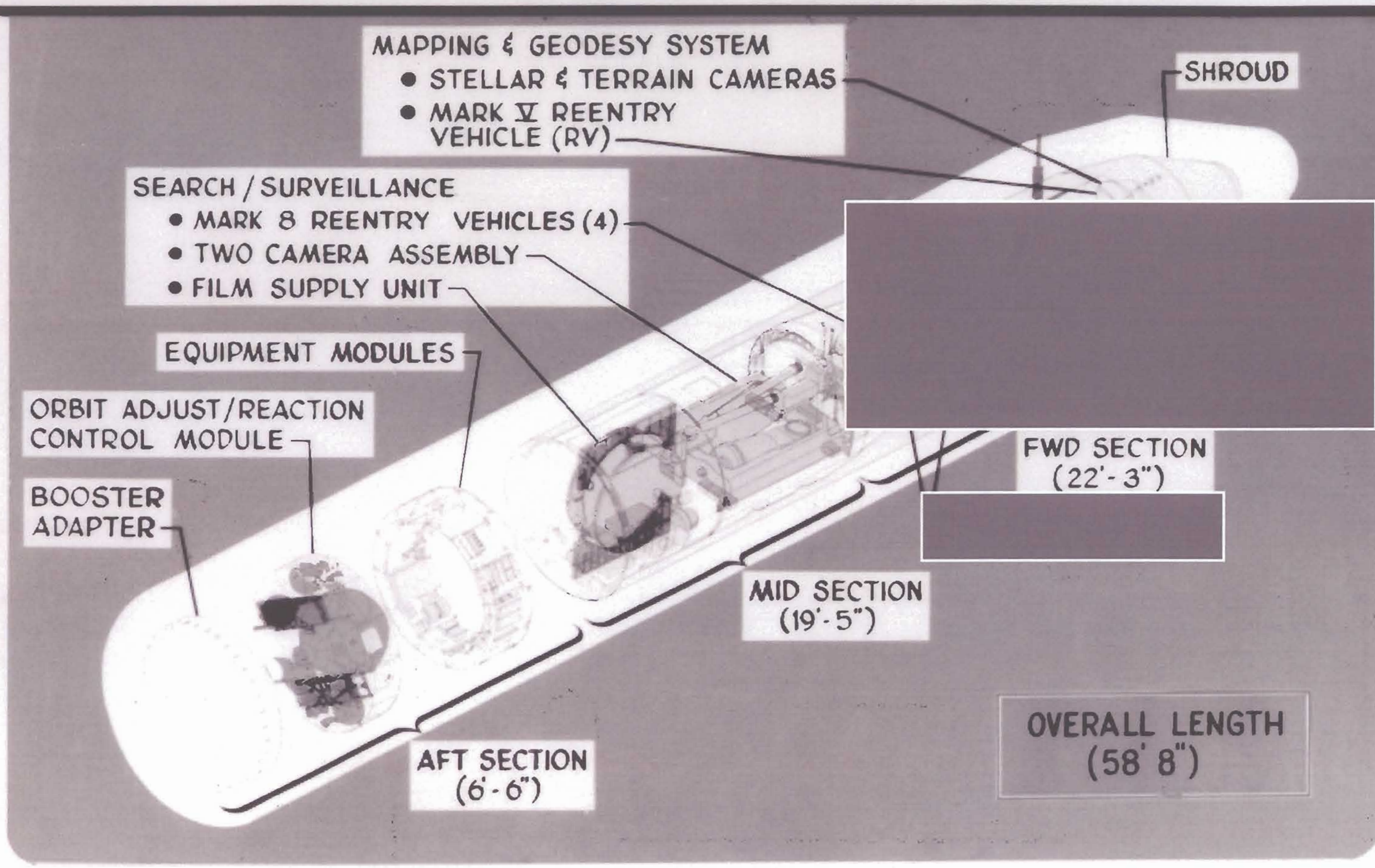
Provision has been made for alignment of critical elements during assembly and for verifying the alignment of the Attitude Reference Module with the two-camera assembly at the launch pad.

The SV configuration permits modification to meet specific mission requirements. The Mapping Camera System, [redacted] can be omitted, and propellant and RVs can be off-loaded at the base.

The overall length in orbit of the SV illustrated is 52 feet. At launch, with shroud and booster adapter, the length is 58.75 feet. The shroud, which protects all but the Aft Section, is 52 feet long. The solar arrays, when deployed, extend 17 feet outboard on each side of the vehicle. Injection weight for the SV illustrated is approximately 24,000 pounds.

~~TOP SECRET~~/H

SATELLITE VEHICLE CONFIGURATION



ASSOCIATE CONTRACTORS

Project HEXAGON is a team effort consisting of nine major contractors throughout the United States. These contractors provide a coordinated effort by using Interface Control Documents as binding technical agreement on responsibilities and performance of their respective equipments. The project HEXAGON team consists of:

Search/Surveillance (Stereo Panoramic)

- Two Camera Assembly – Perkin-Elmer, Danbury
- Film supply and take-up units – Perkin-Elmer, Danbury
- Shroud, Mid and Forward Section structure – Lockheed, Sunnyvale
- Reentry vehicles (Mark 8) – McDonnell Douglas, St. Louis
- Film – Eastman Kodak, Rochester

Mapping and Geodesy System

- Stellar and terrain cameras – Itek, Burlington
- Reentry vehicle (Mark V) – General Electric, Philadelphia
- Structure – Lockheed, Sunnyvale
- Film – Eastman Kodak, Rochester

Satellite Control Section

- Telemetry, power, and pyros – Lockheed, Sunnyvale
- Command system – General Electric, Utica
- Attitude control and orbit adjust – Lockheed, Sunnyvale
- Structure and booster adapter – Lockheed, Sunnyvale

Booster Vehicle – Titan IIID

- Stage O solid propellant – United Technologies Chemical System Division, Sunnyvale
- Stage I and II liquid propellant – Martin Marietta Corporation, Denver

The photographs were taken via the search and surveillance camera and magnified 40 times.

ASSOCIATE CONTRACTORS

[redacted]

OPERATIONS

AEROSPACE VEHICLE

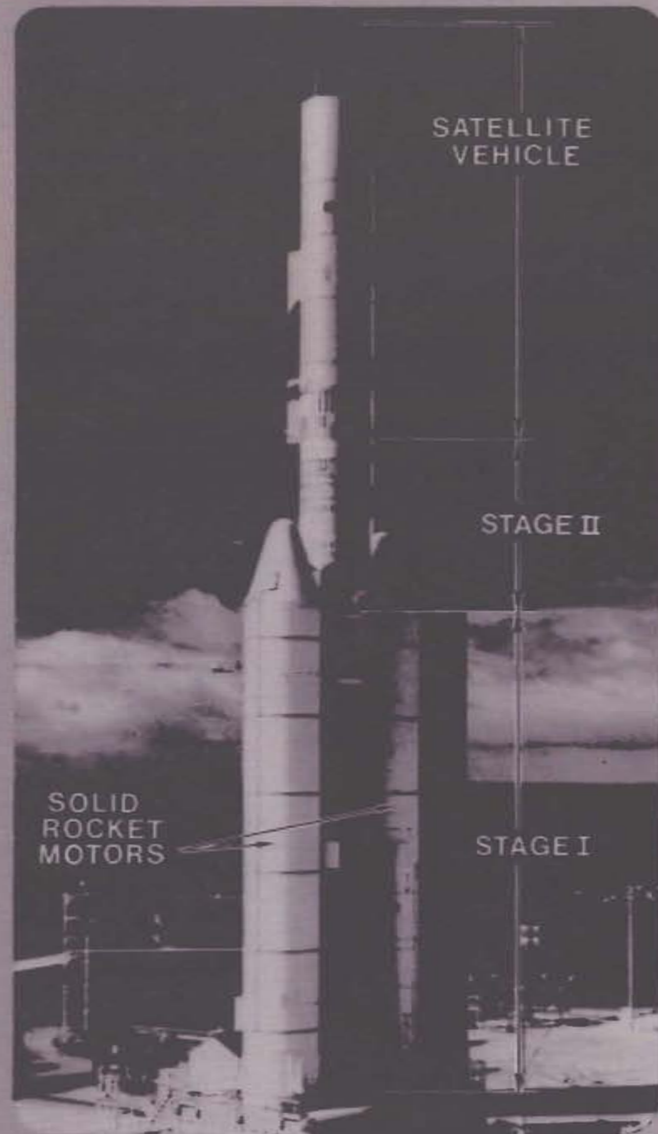
The HEXAGON Satellite Vehicle is launched by the Titan IIID Booster Vehicle. When mated together, the entire assembly is termed the Aerospace Vehicle.

The Aerospace Vehicle is launched from Space Launch Complex -4 East, Vandenberg Air Force Base. The Solid Rocket Motor, Stage I and Stage II are stacked at the launch site and functionally tested. The complete SV including the shroud is mated to the booster vehicle fourteen (14) days prior to launch. The Aerospace Vehicle is then functionally checked and all propellants and gases are loaded.

The booster vehicle can place 24,800 pounds into an 82 x 144 nm (perigee x apogee) orbit with an inclination (~ 97 degrees) that provides the nearly sun synchronous condition needed for long life missions.

AEROSPACE VEHICLE

-1.4 MILLION POUNDS LIFT-OFF WEIGHT
-LAUNCH HEIGHT: 160 FT
-VANDENBERG AIR FORCE BASE LAUNCH SITE
BOOSTER VEHICLE - TITAN III D
-STAGE O SOLID ROCKET MOTOR
2.3 MILLION LBS INITIAL THRUST
INITIAL WEIGHT: 1.01 MILLION LBS
-STAGE I
TWO A[redacted] ENGINES
0.53 [redacted] THRUST
INITIAL [redacted] LBS
-STAGE II
ONE A[redacted]
0.1 [redacted]
INITIAL [redacted] MILLION LBS
SATE[redacted]
-27,000 LB LAUNCH WEIGHT
-2,800 LB SHROUD EJECTED DURING ASCENT



TITAN IIID BOOSTER VEHICLE

The Titan IIID booster vehicle is a three-stage booster consisting of the standard liquid core for Stages I and II plus two solid rocket motors (SRMs) as Stage 0.

Each SRM is 10 feet in diameter and 85 feet long. It consists of five identical interchangeable segments, a six-degree canted nozzle, a gas generator type igniter, staging rockets, and an externally mounted thrust vector control (TVC) injectant tank. The TVC provides steering during Stage 0 burn by injecting nitrogen tetroxide (N_20_4) through 24 proportional valves around the SRM nozzle. Jettison is provided by pyrotechnic separation of the interconnecting structure between each SRM and the Titan core vehicle, followed by ignition of four solid staging rockets at each end of each SRM.

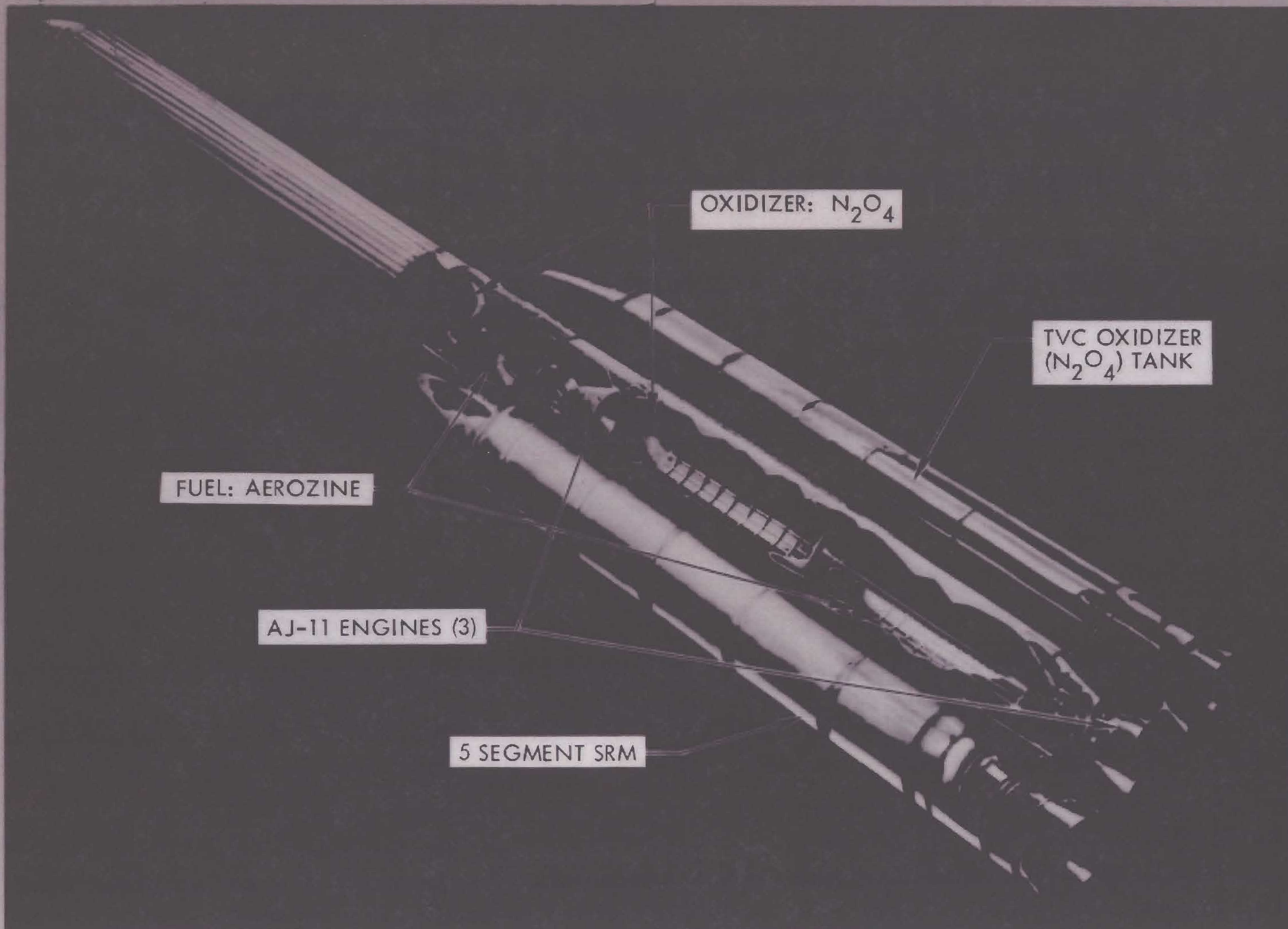
Stage I liquid core is 10 feet in diameter and 71.5 feet long. It is aluminum skin-stringer construction with propellant tanks arranged in tandem. The two turbo pump feed Aerojet LR87-AJ-11 engines burn a 50-50 blend of hydrazine/UDMH (Aerozine) as the fuel and nitrogen textroxide as the oxidizer. Each engine subassembly contains a regeneratively cooled gimballed thrust chamber combined with an ablative skirt extension giving a 15:1 expansion ratio.

The Stage II propulsion system is similar to that of Stage I. It is also 10 ft in diameter but only 31 feet long. The single engine thrust chamber is also regeneratively cooled and has an ablative skirt extension that provides an overall expansion ratio of 49:1.

The flight control system stabilizes the vehicle from launch to SV separation in response to (1) attitude data, (2) rate data, (3) command data – issued by flight control computer and/or the radio guidance system via ground tracking station.

Electrical power for the flight control system, instrumentation, flight safety, and electrical sequencing system is provided via silver-zinc primary batteries.

TITAN IIID BOOSTER VEHICLE



OPERATIONAL EVENTS

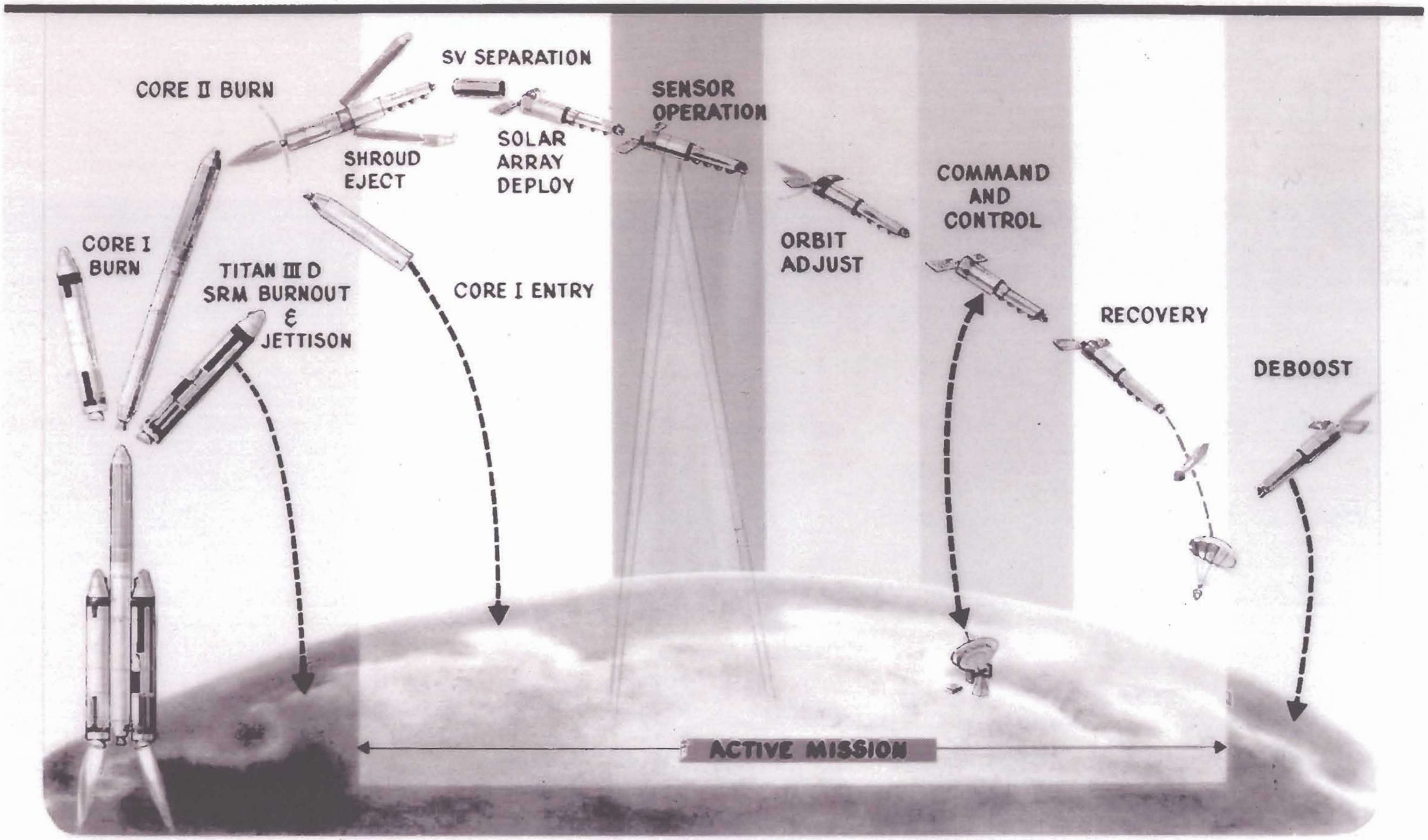
The major operational events are launch, orbit maintenance/payload operations, and RV recovery/SV deboost. Sequence of launch events:

0.0 sec	SRM Ignition
0.2	Lift-off
40.0	Transonic passage
54.0	Maximum dynamic pressure
113.9	Core I start burn
125.3	SRM separation
262.0	Core I shutdown and Core II start burn
262.7	Core I separation
276.0	Shroud separation
460.6	Core II shutdown
472.6	Core II separation (injection)

The solar arrays are deployed after SV stabilization on Rev 1 with payload operations starting on Rev 5. Orbit adjusts to correct period, altitude and perigee location occur every two to four days. All control of the SV and telemetry data is processed through the Air Force Satellite Control Facilities and associated remote tracking stations.

The SV is pitched down to a specified angle for each RV ejection. The SV is deboosted for ocean impact after the last RV is ejected.

OPERATIONAL EVENTS



USAF TRACKING NETWORK

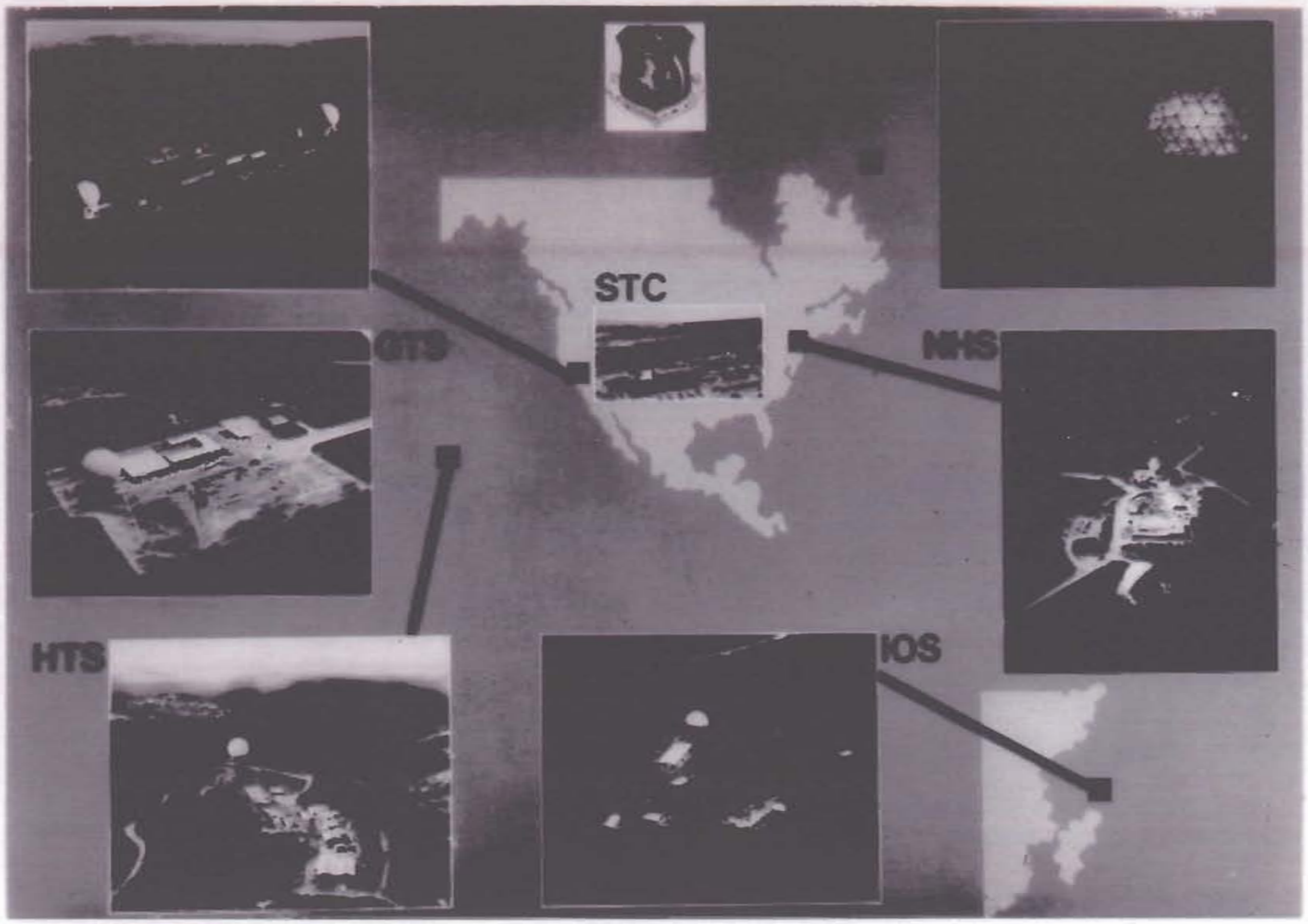
The Sunnyvale Satellite Test Center (STC), part of the SAMSO Satellite Control Facilities, is organized to provide operational control of on-orbit satellites and does this function for project HEXAGON. The center directs the tracking and commanding of these satellites through a net of remote tracking stations (RTS). The STC also coordinates the aerial and surface recovery operations for reentry vehicles (RV). Launch activities are a coordinated effort between the Vandenberg AFB Test Wing and the STC.

Servicing the HEXAGON vehicle requires skin and beacon tracking, recording and displaying telemetry data, and commanding that often needs more than one RTS each revolution. Because the STC supports several programs, the Mission Control Center (MCC) within the STC is used to direct the effort of each tracking station in support of each program. The SV real time telemetry data incoming to the RTS are processed and displayed in real time via 1200 bit lines or relay satellites to the STC. The SV real time and recorded data are recorded at the RTS for later playback to the STC. Complete RTS recorded tapes are flown to the STC as permanent records. Display and analysis of these data provides SV health and status information to the Technical Advisor (TA) staff on a continuous basis throughout the mission. The TA staff, located at the STC, includes operational specialist teams for each major contractor.

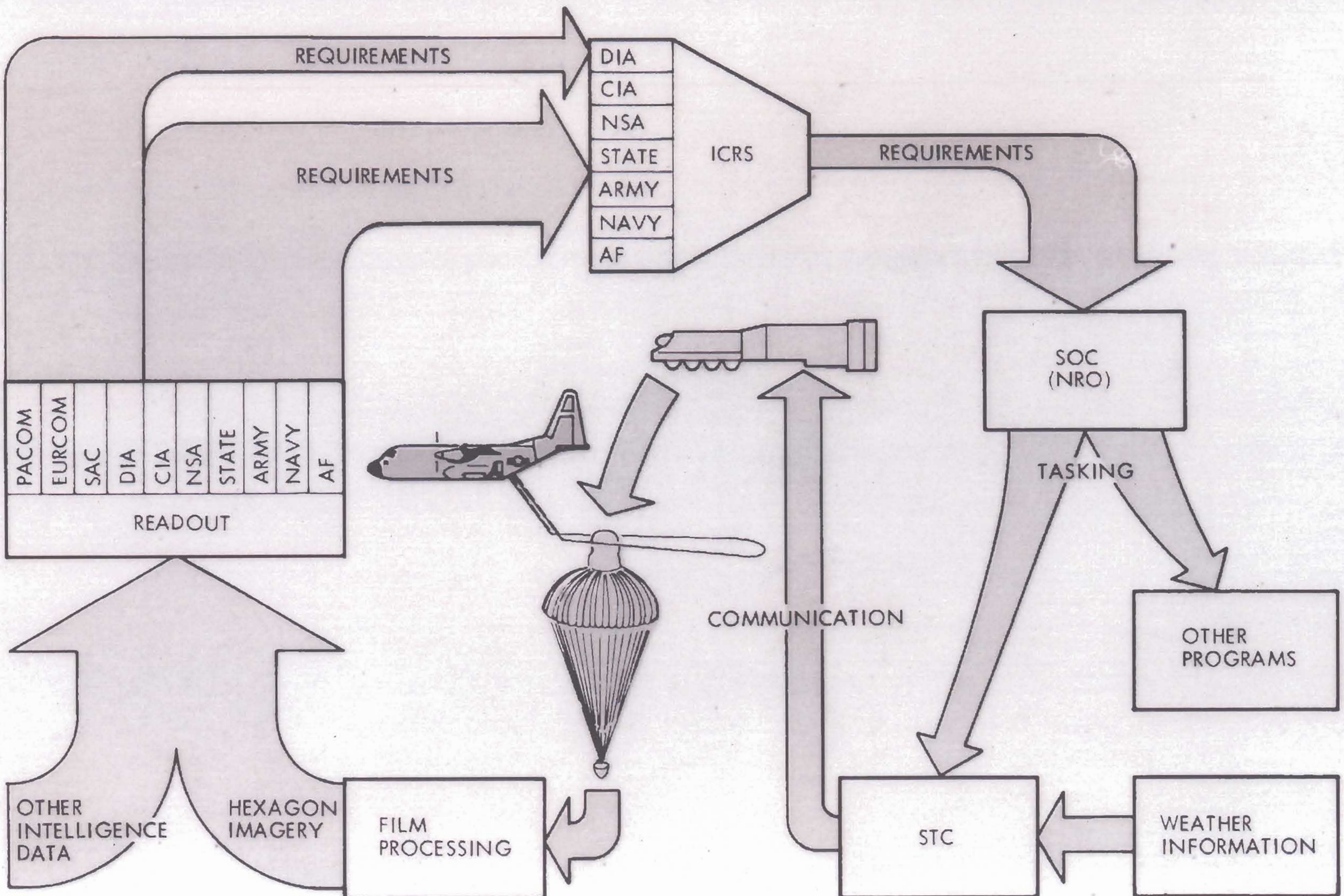
The remote tracking stations acronyms and locations are as follows:

- Vandenberg Tracking Station (VTS) or COOK at Vandenberg Air Force Base, California
- Guam Tracking Station (GTS) or GUAM on Guam Island
- Hawaii Tracking Station (HTS) or HULA at Kaena Point on the island of Oahu
- Indian Ocean Station (IOS) or INDI in Seychelles Island group on Mahe' Island
- New Hampshire Station (NHS) or BOSS near New Boston, New Hampshire
- Thule Tracking Station (TTS) or POGO at Thule Air Force Base, Greenland

USAF TRACKING NETWORK



HEXAGON INTELLIGENCE TASKING LOOP



SEARCH/SURVEILLANCE CAMERAS

SEARCH/SURVEILLANCE CAMERAS

The search/surveillance cameras provide high-resolution stereoscopic coverage of selected areas on the earth's surface by using two independently controllable panoramic cameras. The system provides a target resolution of 2.7 ft or better at nadir when operating at primary mission orbital altitudes with an apparent target contrast of 2:1, sun angles greater than 30 degrees and using *S0-208 film.

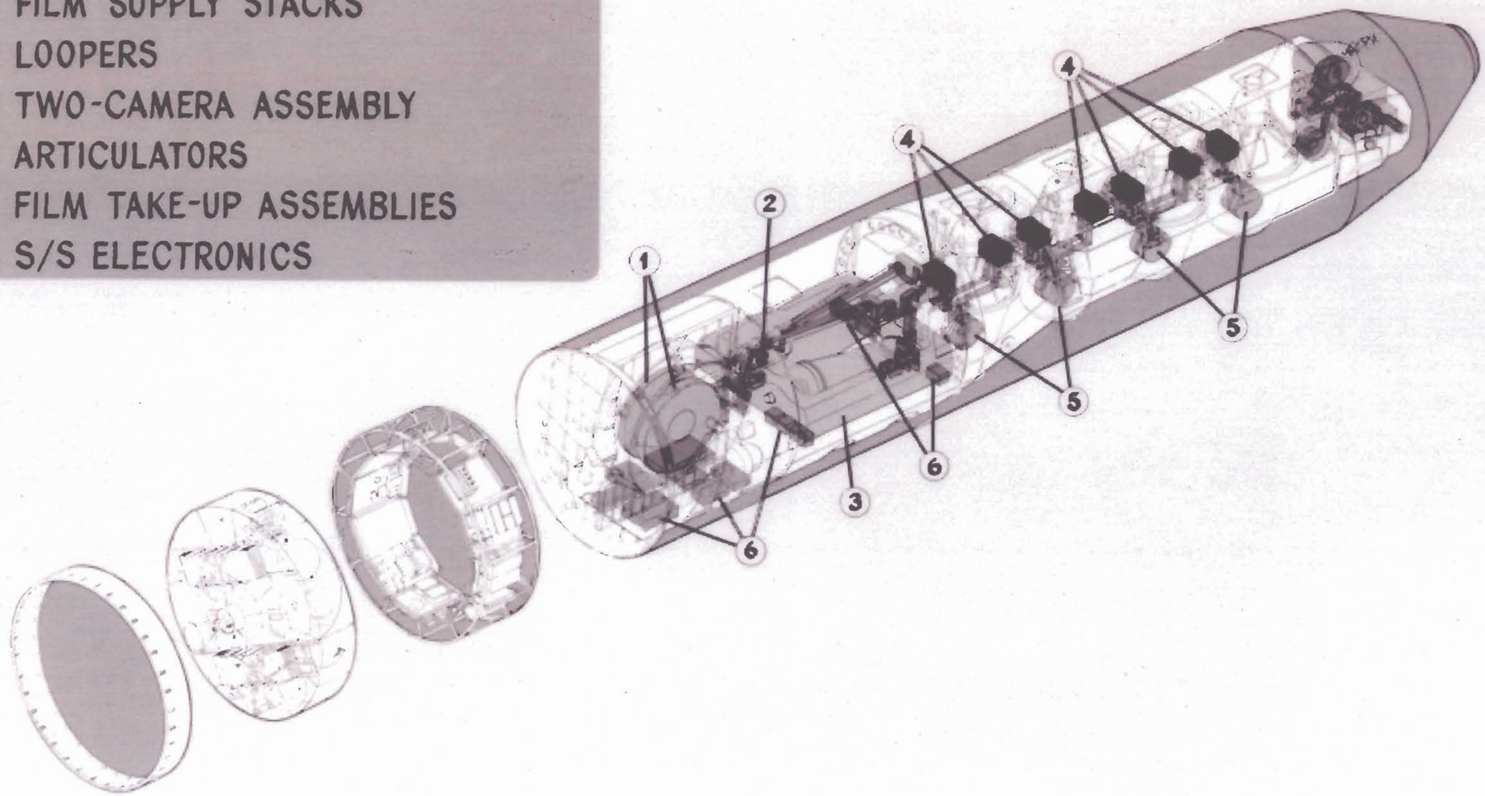
The search/surveillance system has been designed with the following characteristics:

Optics	60-in. focal length, f/3 Folded Wright (Modified Schmidt) System
Film	6.6-in. wide film – Type 1414 or S0-208 (B & W), S0255 (Color), and S0130 (Infrared)
Film Load	123,000 ft Type 1414 or 144,000 ft S0-208 per camera (1950 lb total)
Film Resolution (2:1 Contrast)	Center of format ≥ 155 l/mm, elsewhere in format ≥ 94 l/mm
Field Angle	±2.85 Degrees
Scan Modes	30, 60, 90, and 120 degrees
Center of Scan	0, ±15, ±30, and ±45 degrees
Maximum Scan Angle	±60 degrees
Stereo Convergence Angle	20 degrees
Frame format (120 degree scan)	6-in. by 125-in.
Film Velocity	200 in./sec (maximum) at focal plane
Image Motion Compensation Range	0.018 rad/sec to 0.054 rad/sec for Vx/H ±0.0033 rad/sec for Vy/H
Weight (less film)	5375 pounds

*S0-208 is a thinner base equivalent to Type 1414 film used extensively for the first 13 missions.

SEARCH/SURVEILLANCE CAMERAS

1. FILM SUPPLY STACKS
2. LOOPERS
3. TWO-CAMERA ASSEMBLY
4. ARTICULATORS
5. FILM TAKE-UP ASSEMBLIES
6. S/S ELECTRONICS



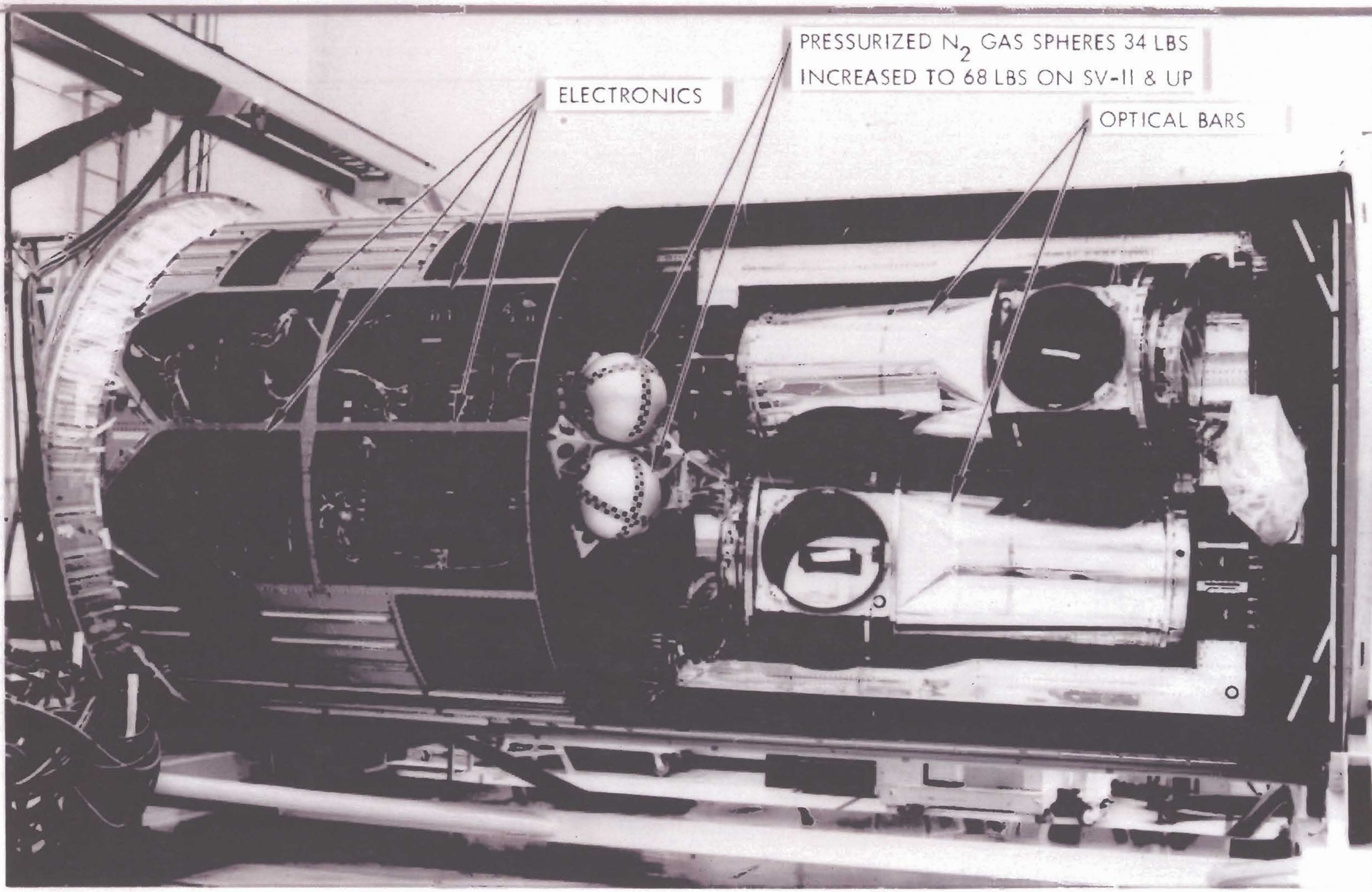
TWO CAMERA ASSEMBLY

The Mid Section has been rotated to show the side that looks toward the earth with the two Camera Assembly (TCA) exposed. In flight, a black fiberglass baffle and a multilayer insulation covers the gas spheres and optical bars except for view ports. Doors cover the electronics and then multilayer insulation blankets are installed. Not shown are the film take-up reentry vehicles in the Forward Section.

The two optical bars rotate in opposite directions indicated by the arrows adjacent to the lenses. The light is conducted along a folded path to the film platen where the film motion is matched to the image motion by the commands generated in the electronics.

Normally both optical bars are commanded on simultaneously to reduce vehicle roll torques. However, each camera can be commanded individually, and either may be operated alone, if desired.

TWO CAMERA ASSEMBLY



SYSTEM FILM PATH

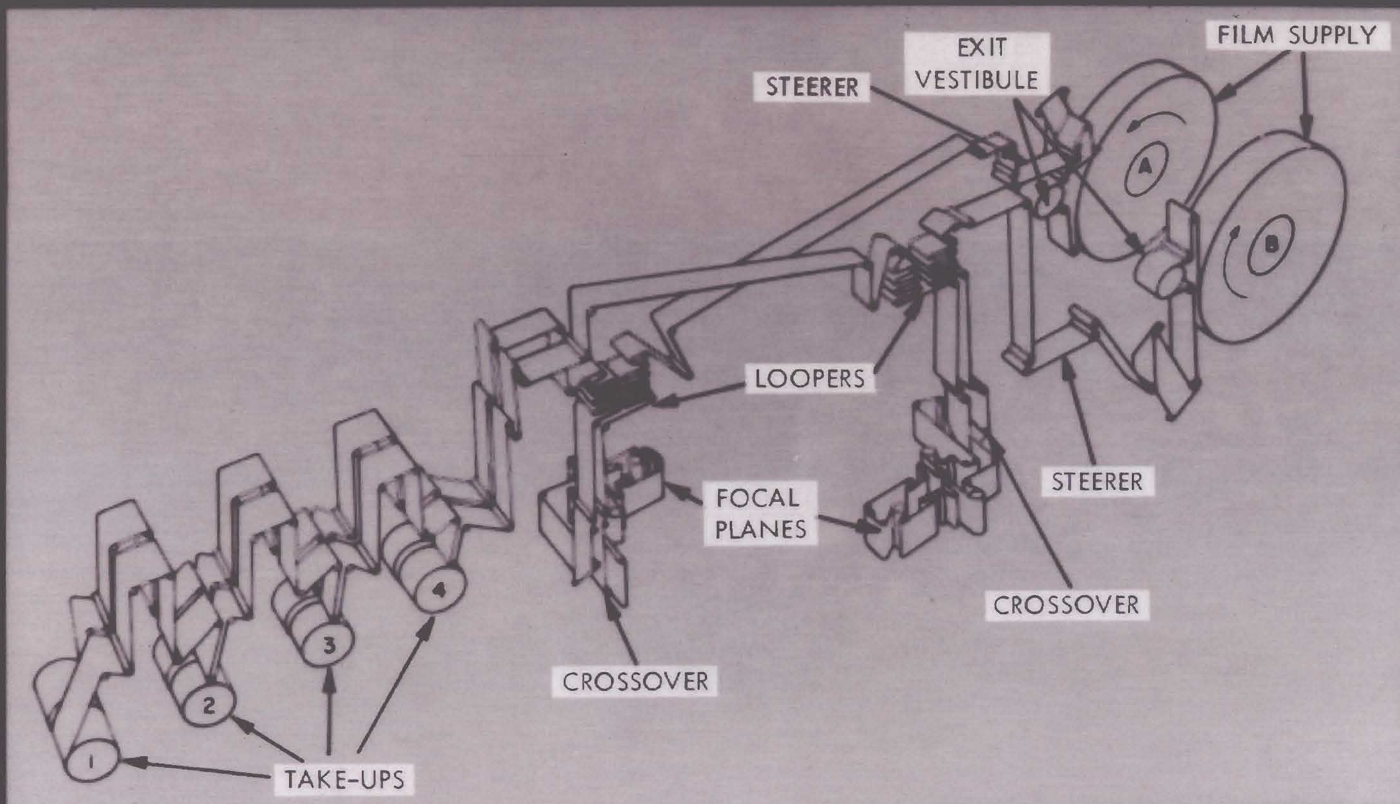
The coarse film transport includes all components that operate at nominally constant speed during photography and recycle, as well as the looper carriage which operates at the recycle frequency. The supply and take-up control system maintains a steady flow of film into and out of the loopers at precisely the average rate at which film moves through the platen. The loopers serve as an interface between the coarse and fine film transport system. Total film in the looper is constant but relative lengths in supply and take-up sides vary with looper carriage position.

The control of film tracking is by active and passive articulators. The film path of the forward camera functionally includes component assemblies in the following order:

a. Supply "B"
b. Seal Door/Exit Vestibule
c. Articulator Steerer
d. Looper
e. Crossover
f. Input Drive Capstan
g. Platen
h. Metering Capstan
i. Output Drive Capstan
j. Crossover
k. Looper
l. Articulator Steerer
m. Take-up 4
n. Articulator
o. Takeup 3
p. Articulator
q. Takeup 2
r. Articulator
s. Takeup 1

The film supply spools rotate in opposite directions, and the respective take-up spools rotate opposite to the supply spools in order to reduce vehicle torques. The start-up disturbances are minimized by accelerating the film path to the required coarse velocity before photographic operations are begun.

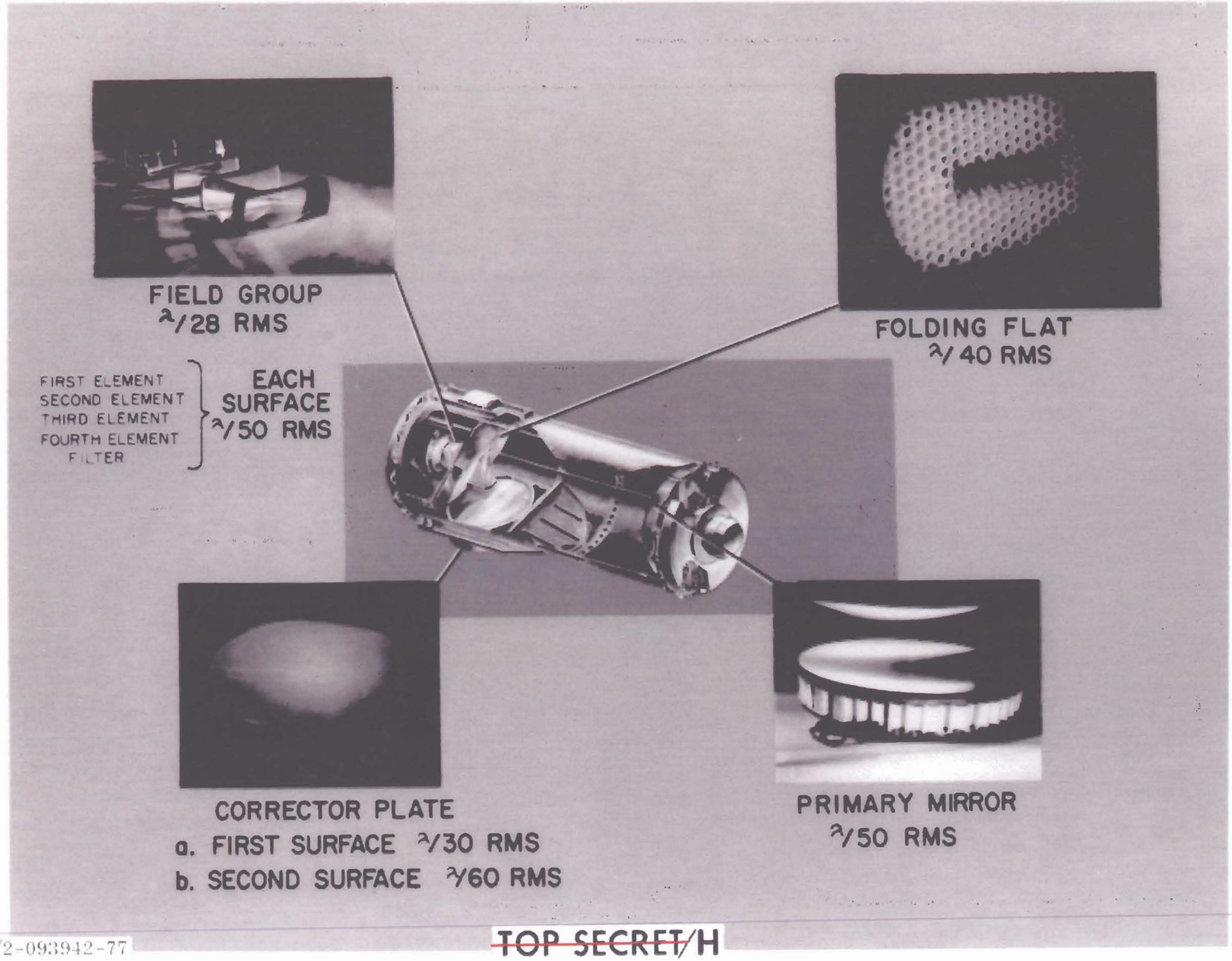
SYSTEM FILM PATH



OPTICAL BAR ASSEMBLY

The two cameras mounted in a frame make up a two-camera assembly with each camera having a folded Wright optical system mounted in a rotating optical bar. Structurally the bar consists of two rigid end bulkheads separated by a cylindrical tube with housings and hollow shafts at each end on which bearings are mounted. The platen end bulkhead is the member to which the optical components are referenced. The optics consist of the corrector plate as the aperture, a folding flat mirror, a concave primary mirror and a field group of refracting elements and a filter. The optics wavefront errors spec values are shown as a fraction of the wavelength. All values are root mean square (RMS).

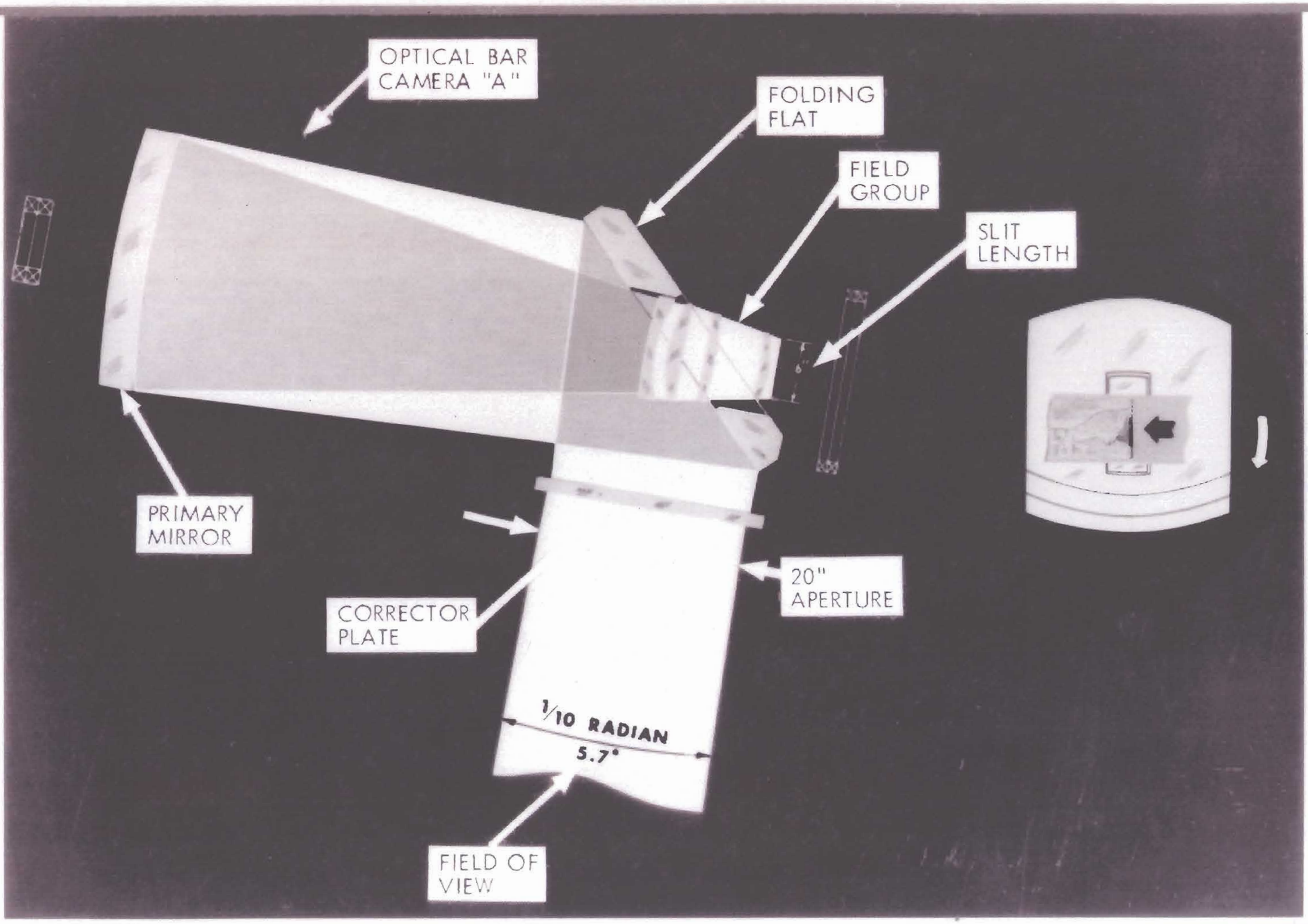
OPTICAL BAR ASSEMBLY



OPTICAL PATH

The optics for each camera are mounted in an optical bar (OB). The system is a f/3 folded Wright. The aperture is formed by an aspheric corrector plate that corrects for spherical aberration. Light entering the aperture is folded 90° by the folding flat and reflected onto the primary mirror at the far end of the OB. The primary mirror focuses the light back through the field group mounted in a center hole in the folding flat. The field group includes four refracting elements and a filter. The refracting elements provide correction for the field curvature and residual chromatic aberration characteristics of optical systems using a concave primary mirror.

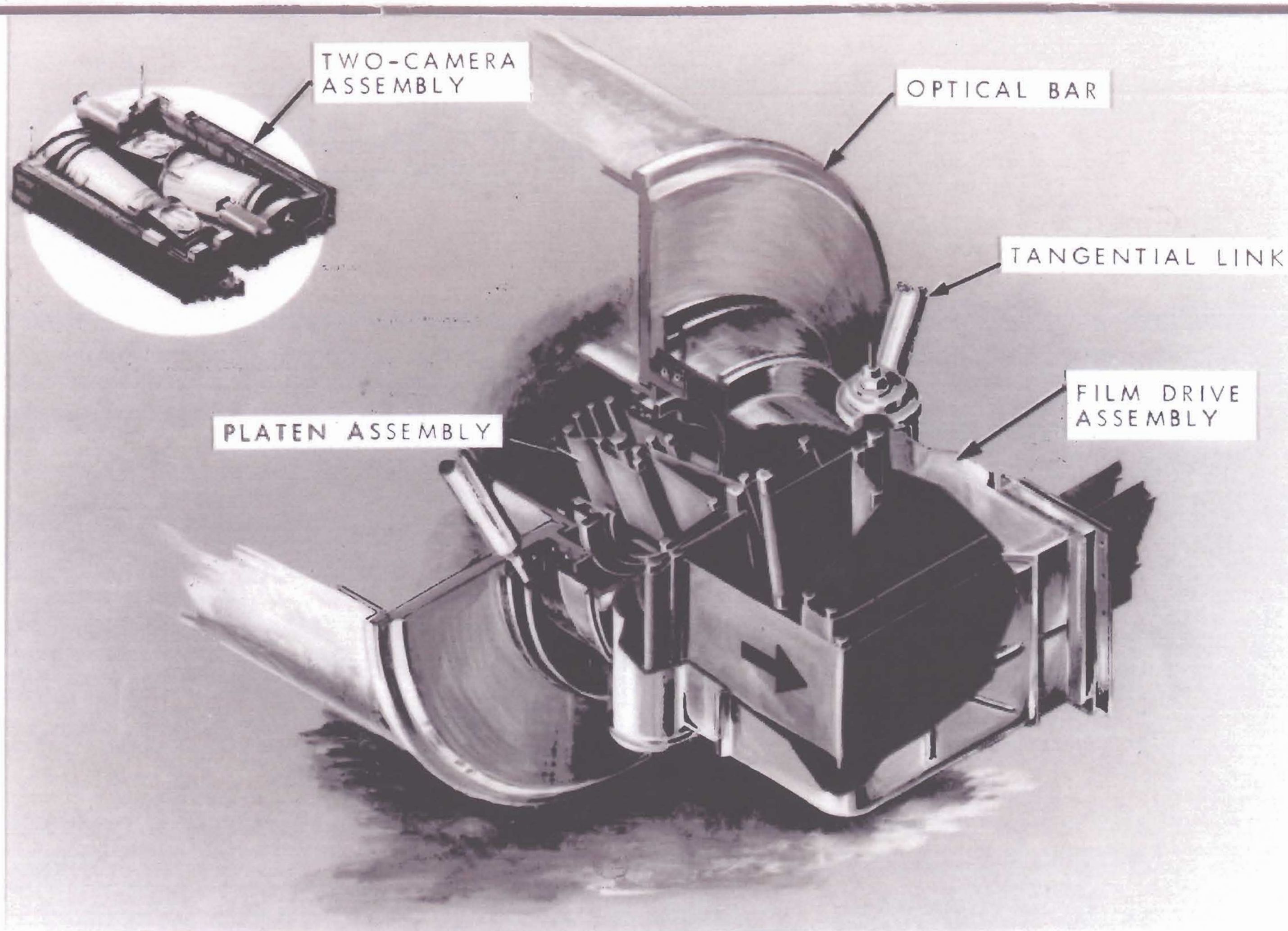
OPTICAL PATH



PLATEN AND FILM DRIVE

The platen is mounted at the focal plane end of the optical bar (OB). The platen assembly is mounted on the OB's inner housing to support the film in the camera focal plane, and to rotate on its own bearings independently of the OB. While the OB is rotating continuously on its end bearings, the platen assembly is free to oscillate through its 130-degree operational arc. The fine film drive assembly encloses the outer end of the platen assembly and is stationary. A twister assembly, included in the fine film drive assembly, accommodates the twisting of the film path at the interface between the stationary film drive assembly and the oscillating platen assembly. The twister assembly consists of a twin air-bar assembly and a housing that incorporates a manifold through which nitrogen gas is supplied to the bars. The use of air bars in the twister, rather than rollers, permits the film to translate along the length of the bars without damage as the film path twists.

PLATEN AND FILM DRIVE



PNEUMATICS SYSTEM

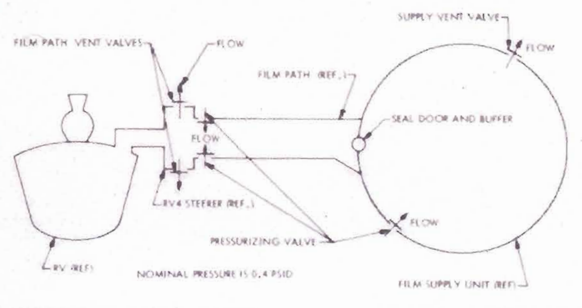
Dry nitrogen gas is supplied to the film path air bars at specified flow rates and pressures. Air bars are located in the twister, TCA cross-over, and the supply cross-overs. These bars are D-shaped in cross-section and hollow with small holes in their curved portion through which nitrogen is forced by the pneumatic system. This provides a practically frictionless bearing for the film, permitting both lateral film movement and film transport across the bar. The nitrogen supply is two spherical tanks with a combined storage capacity of 68 pounds of which 62 pounds are usable.

Pressure enclosures seal the entire film path including the film supply and the take-ups, maintaining the required relative humidity for film moisture content stabilization. The film path gaseous environment includes the 50 pounds of water in the film as outgassing water vapor plus the 62 pounds of nitrogen coming through the orifices of the gas bars. During non-operating periods the film supply unit is isolated from the rest of the film path by a commandable seal door to minimize leakage and moisture loss.

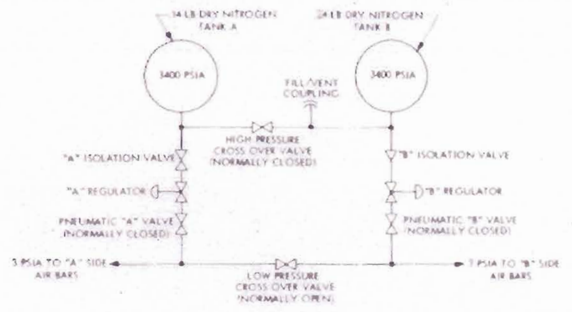
In test and during ascent the sealed film path accommodates atmospheric pressure changes through relief and pressurizing valves. When film is being transported, a lower pressure relief setting in the film path compared to that in the supply allows a system pressure bleed-off through vents on the forward steerer enclosure.

The pneumatics supply module is a self-contained unit consisting of high pressure storage spheres, regulators, and valves. The system is designed with individual paths from a supply sphere to a camera with cross-overs at the high pressure and low pressure portions of the system. The high pressure cross-over valve between the nitrogen tanks is normally closed. It is used to transfer gas from one tank to the other. To isolate a flow path, on external command or in response to a feedback signal of over-pressure downstream of the regulator, a solenoid latching valve in the high pressure portion is closed. Normally, a uniform simultaneous flow through both sides is maintained by the open low pressure cross-over valve, which is commanded closed only because of any failure requiring isolation. The shut-off valves in the low pressure paths are commandable, controlling on/off requirements of gas flow.

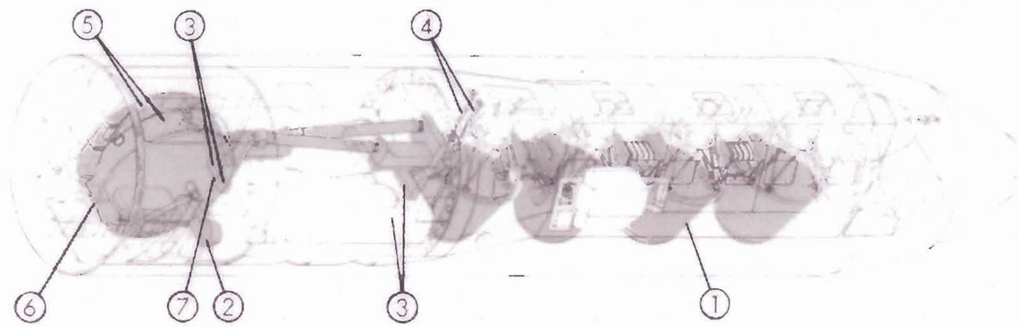
PNEUMATICS SYSTEM



FILM PATH VENTING SCHEMATIC



PNEUMATICS SUPPLY MODULE



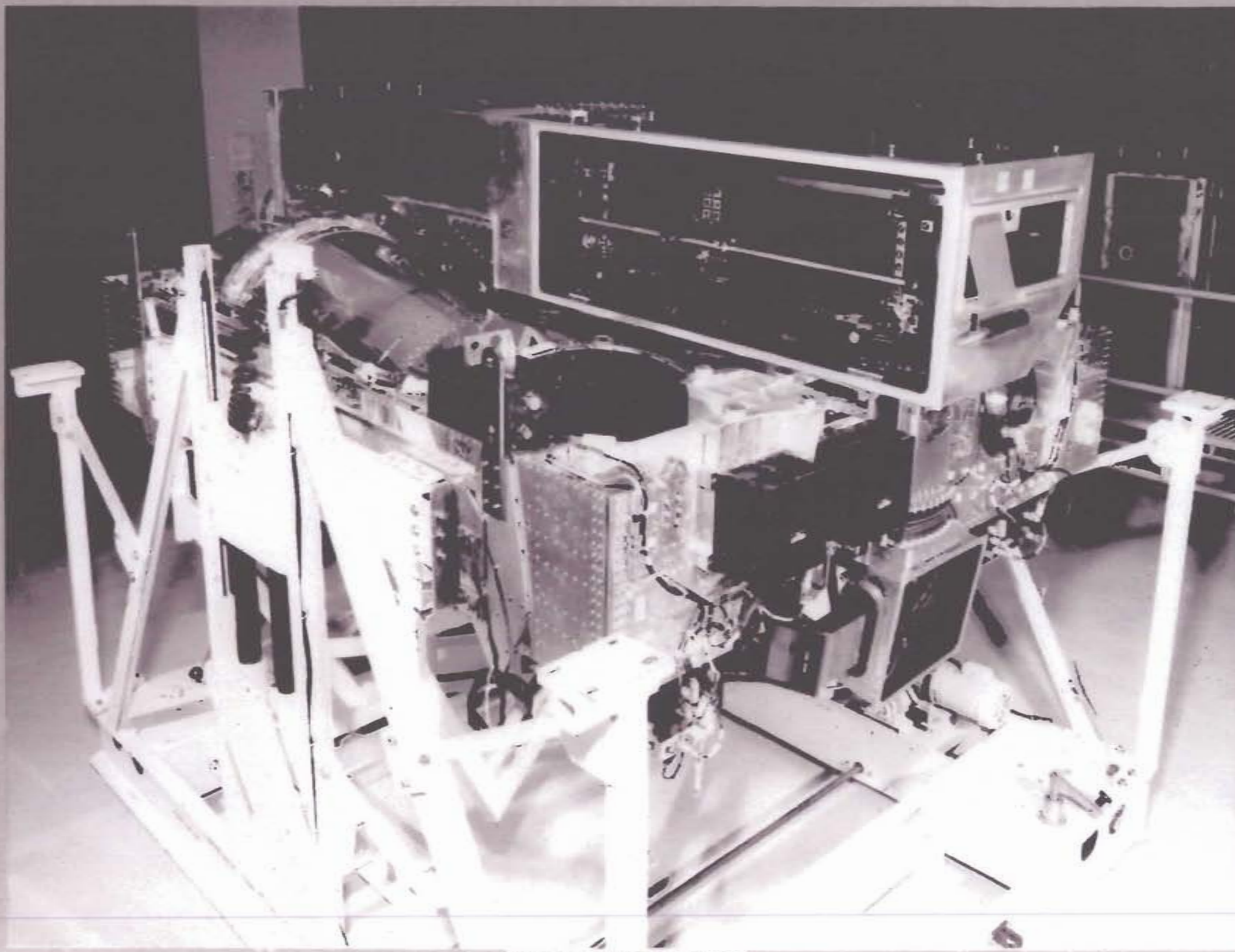
PRESSURIZED REGIONS - SHADED

1. REENTRY VEHICLES
2. PNEUMATIC SUPPLY MODULE
3. AIR BAR PAIRS
4. FILM PATH VENT VALVES
5. SUPPLY VENT VALVES
6. PRESSURIZING VALVE
7. SUPPLY SEAL DOOR

LARGE LOOPER

The accompanying illustration shows a Two Camera Assembly (TCA) incorporating the large looper which will become operational with SV-17. The increased film capacity (45 feet versus the 13 feet on the original design) enables the platen to be fed film at the desired rate during the time the coarse transport system is accelerating and to be stopped while the coarse film transport system is decelerating. Film management is greatly simplified since all the film is used in sequence. The present delay in the start of photography until the coarse film transport has accelerated to the average rate and the rewind of unexposed film passed through the platen is eliminated. This removes rewind as a possible source of contamination or as a wastage of film when rewind could not be accomplished between nested operations. Because this major change is being accomplished in-line, full provisions are retained to operate the coarse transport system in the original mode.

LARGE LOOPER



MARK 8 REENTRY VEHICLE

When the take-ups in the RV are filled, the next in-line RV is enabled and the full RV is ejected from the optimized pitched down SV at a 3 ft/second rate. The spin-up to 10 radians per second is accomplished via hot gas generator to stabilize the RV during the retro rocket motor burn. The retro rocket provides a 1623 pound thrust to slow the RV for reentry. The despin system then slows the spin rate to 1.4 radians per second, which provides the needed stability during the coast period and still permits the aerodynamic torques to align the RV angle-of-attack with the flight path early in the reentry period. The drogue parachute is deployed upon closure of an acceleration switch at approximately 60,000 ft altitude. The drogue parachute is released and main parachute deployed upon closure of a barometric pressure switch at about 50,000 feet.

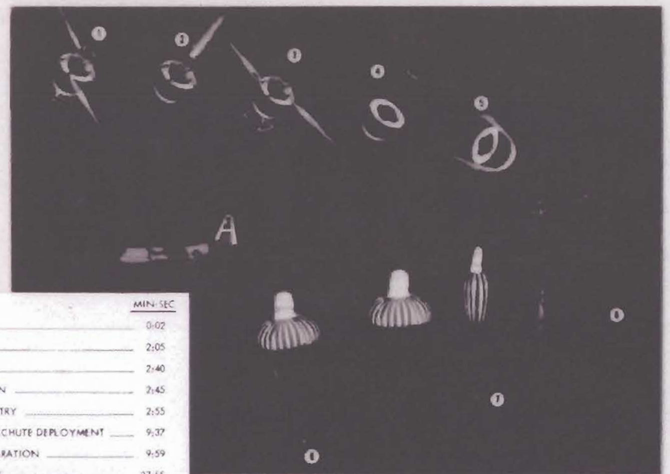
At 15,000 feet, the rate of descent is from 1200 to 1650 feet per minute, which is suitable for aerial recovery by USAF JC130 aircraft.

Each RV has a base diameter of 57-1/2 inches and is 85 inches from the heatshield nose to the retro motor nozzle. Maximum total weight of the RV and film is 1695 pounds. This consists of 956 pounds of RV and equipment, 239 pounds for film take-ups, and 500 pounds of film.

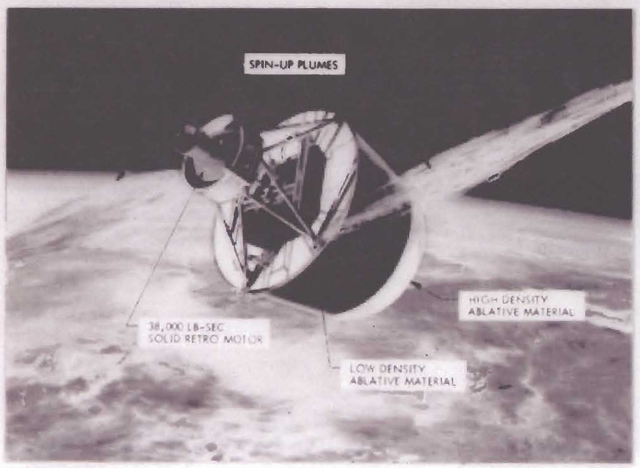
The heatshield when removed shows the gold tape covered canister which is part of a passive on-orbit thermal control system which, together with electrical heaters, maintains the desired canister temperature. The propulsion truss assembly and SV attachment fittings are shown.

MARK 8 REENTRY VEHICLE

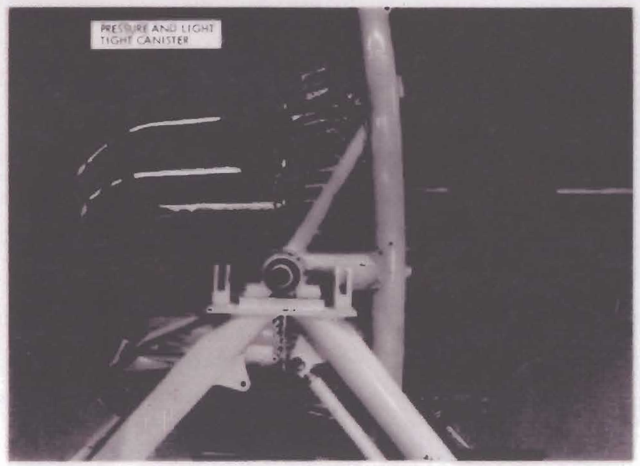
RECOVERY SEQUENCE



		MIN:SEC
1	SPIN-UP	0:02
2	RETROGRADE	2:05
3	SPIN-DOWN	2:40
4	TRUSS SEPARATION	2:45
5	ATMOSPHERIC ENTRY	2:55
6	DROGUE & MAIN CHUTE DEPLOYMENT	9:37
7	HEAT SHIELD SEPARATION	9:59
8	AERIAL RECOVERY	27:55



SPIN-UP EVENT



RV WITHOUT HEAT SHIELD

DATA RECOVERY OPERATIONS

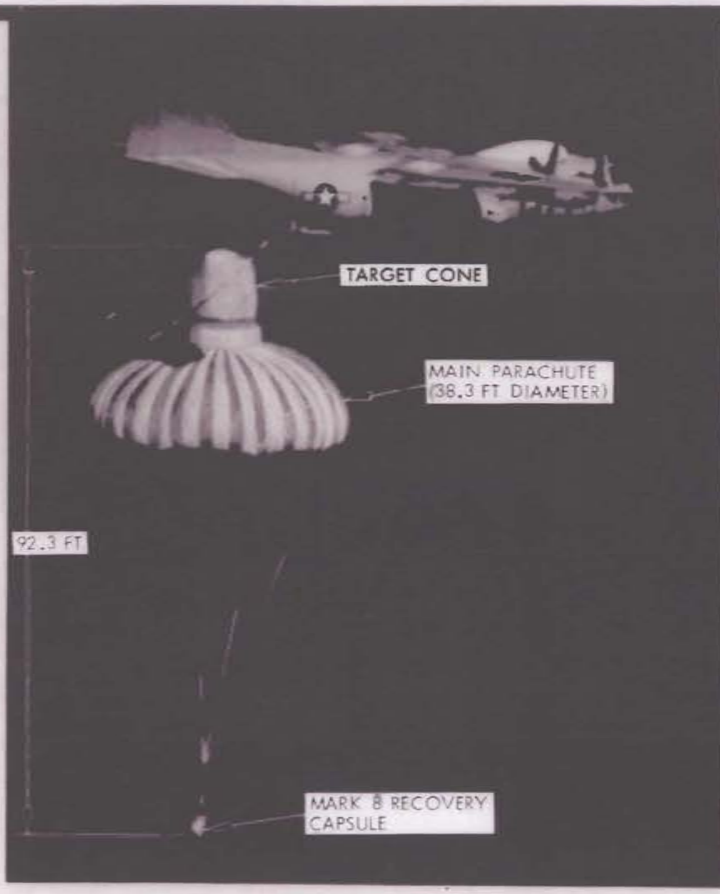
The target cone is 10 feet in diameter and 15 feet high. It contains the nylon load lines which are engaged by hooks on the retrieval line loops deployed by the retrieval aircraft.

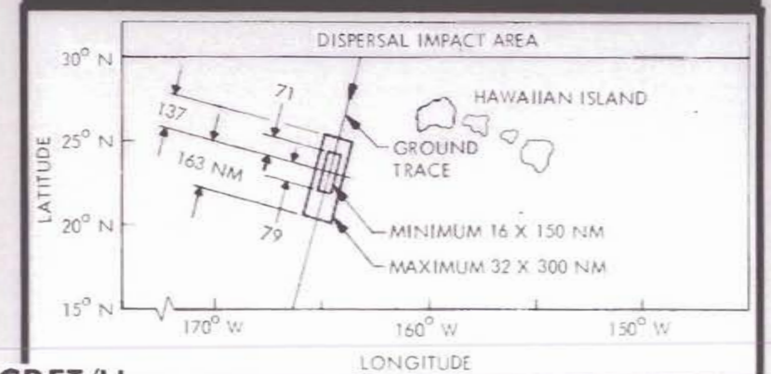
The minimum dispersal impact area applies to all normal film load with the maximum dispersal area applicable to a maximum unbalanced film load. In an emergency, recoveries may be required outside this designated area toward Midway Island or the California Coast.

If aerial retrieval is not accomplished, water recovery becomes a backup phase. When sea water contacts a sensor, a relay closes the film canister vent valve and transfers vehicle power to the water recovery beacon. A salt water corrosion plug will sink the recovery capsule in 48 to 60 hours after water impact. This allows a reasonable time for location and pickup by Air Force and Navy forces.

If the RV significantly overshoots the specified impact point, it will be destroyed. This is accomplished by ejecting the heatshield and deploying the drogue chute if aero drag has not produced 0.003 g by a given time after RV separation. This results in the RV burning up when the atmosphere is encountered. This provision has not been utilized on the HEXAGON program to date.

DATA RECOVERY OPERATIONS





MARK 8 EQUIPMENT

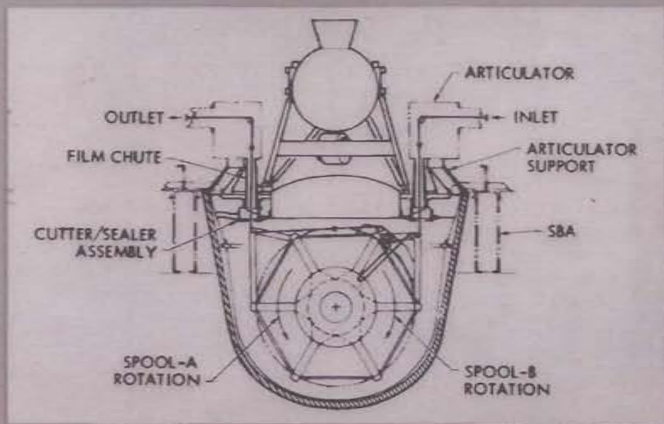
The film is shown passing through the RV. Transfer of film to this RV consists of transferring take-up power, wrapping film on this take-up, cutting and sealing the film path on the exit side, followed by cutting and sealing the inlet film path on the forward RV.

The RV base ablative cover consists of panels of ultra low density material. The base panel structures are of fiberglass honeycomb sandwich construction. A laminate of graphite blankets over glass fiber blankets covers the main parachute compartment. The circuit interrupter switch and wire bundles are mechanically separated near the ablative surface by a guillotine prior to physical separation of the RV from the SV.

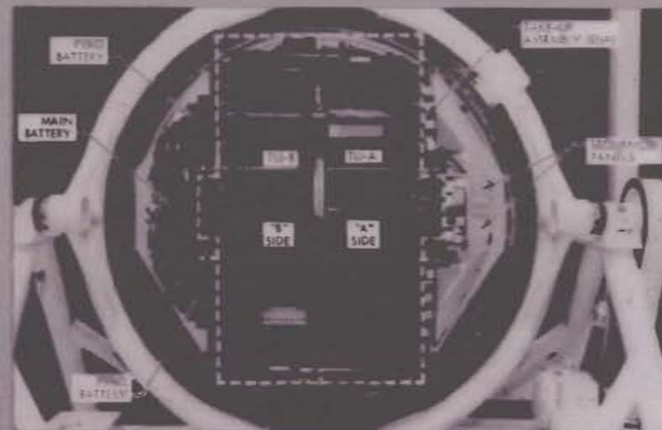
The bottom view shows the film on take-up A and B. The take-up drive motor and control electronics are contained mainly within the take-up hub. The canister is shown removed for access to the take-up and the RV equipment. This access greatly enhances film tracking alignments and testing during SV factory testing.

The RV assembly shows the structural frames within the RV which provide mechanical support for the take-up assembly and RV equipment. Of the encapsulated volume inside the RV, 18 ft^3 is for the take-up assembly and 13 ft^3 is used by the RV equipment. The film stack diameter can be up to 35 inches. RV power distribution and event sequence control is provided by relays. Time delay relays are used to control sequence timing. Instrumentation is provided for monitoring the deorbit-reentry events and temperature. This data is processed through the PCM commutator to the tracking and telemetry transmitter.

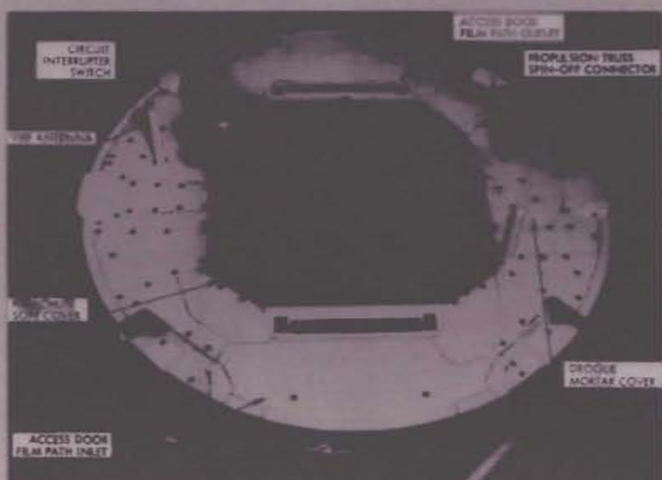
MARK 8 RV EQUIPMENT



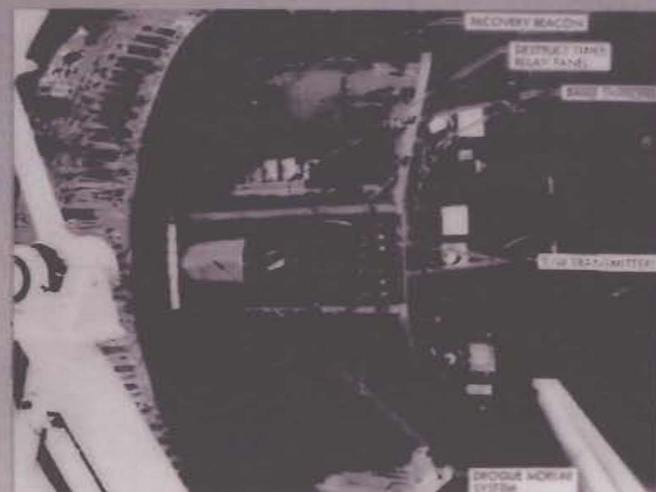
FILM THROUGH RV



FILM ON RV TAKE UPS



RV BASE ABLATIVE COVER



RV ASSEMBLY

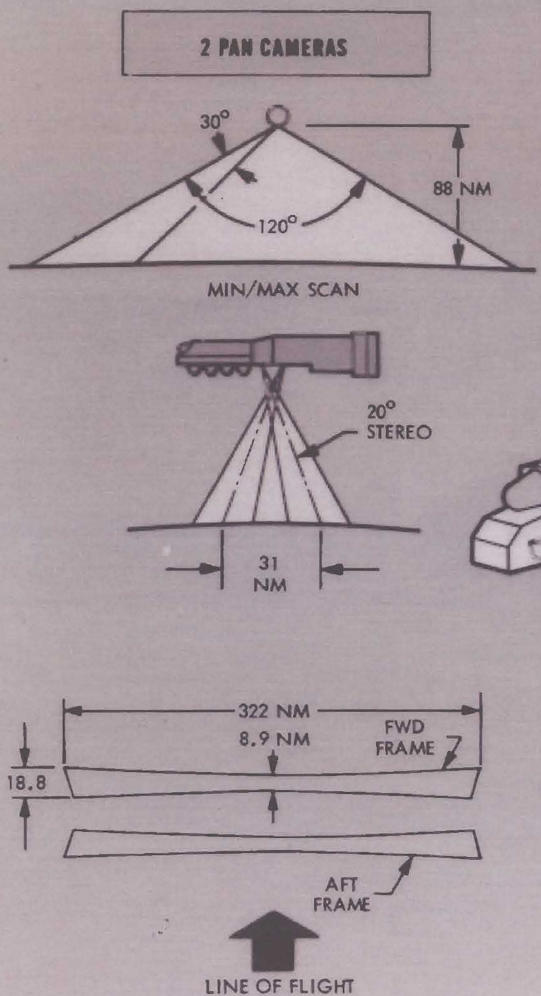
SEARCH CAPABILITY

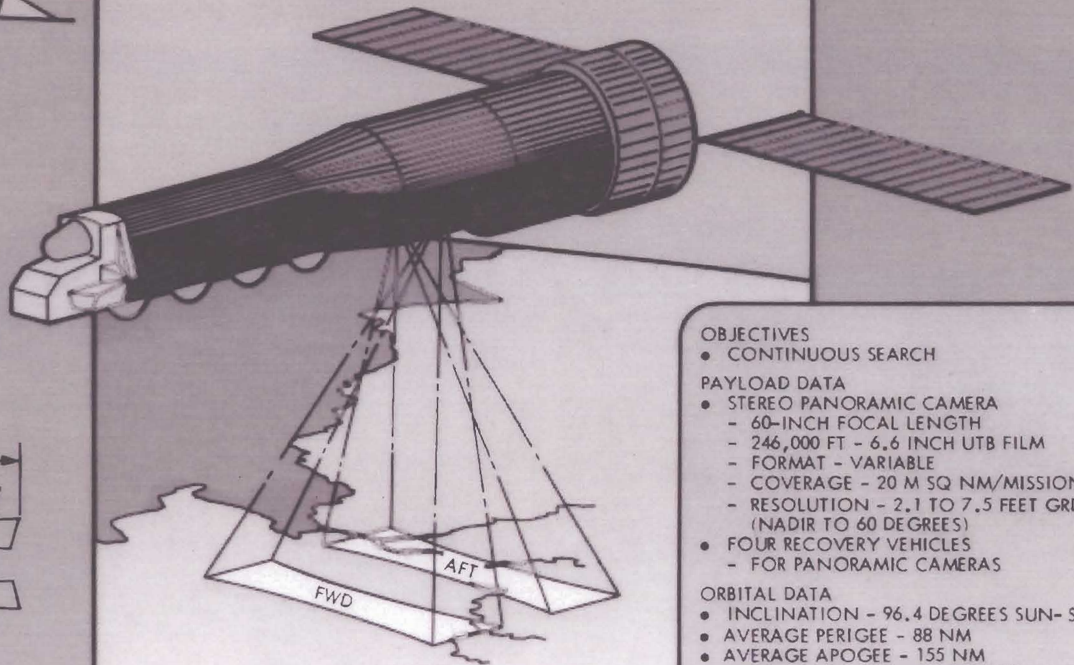
SEARCH/SURVEILLANCE OPERATIONS

Scanning is accomplished by continuous rotation of the optical bars at a rate to produce a nominal three percent frame-to-frame overlap allowance at nadir. The minimum scan sector is 30 degrees, the maximum 120 degrees. To achieve stereoscopic coverage the port camera (camera-A) looks forward 10 degrees and the starboard camera (camera-B) looks aft 10 degrees. At 88 nm altitude the interval of the forward to the aft frame is 31 nm. Since camera-B lags camera-A with respect to ground cover at nadir, the shutter of camera-B is inhibited for the first three frames and camera-A for the last three frames of each operation. Either camera can be operated separately in a mono mode.

The ground format varies with altitude, scan sector, and scan center. With the optical bars counter-rotating the ground formats for the two camera are not the same. The area of coverage per mission also varies with the average scan sector of acquisitions. At ±45 degrees average scan with the maximum supply of 1414 black and white film, gross stereo coverage of 20 million square nautical miles (M sq. nm) can be achieved at an average acquisition altitude of 88 nm with the current film transport system. At an average scan of ±30 degrees, this coverage would be reduced to 16 M sq. nm.

SEARCH/SURVEILLANCE OPERATIONS





OBJECTIVES
- CONTINUOUS SEARCH

PAYLOAD DATA
- STEREO PANORAMIC CAMERA
  - 60-INCH FOCAL LENGTH
  - 246,000 FT - 6.6 INCH UTB FILM
  - FORMAT - VARIABLE
  - COVERAGE - 20 M SQ NM/MISSION STEREO
  - RESOLUTION - 2.1 TO 7.5 FEET GRD (NADIR TO 60 DEGREES)
- FOUR RECOVERY VEHICLES
  - FOR PANORAMIC CAMERAS

ORBITAL DATA
- INCLINATION - 96.4 DEGREES SUN-SYNCHRONOUS
- AVERAGE PERIGEE - 88 NM
- AVERAGE APOGEE - 155 NM
- MISSION LIFE - UP TO 180 DAYS

~~TOP SECRET~~/H

PENTAGON

[redacted]

~~TOP SECRET~~/H

SAMSO IN LOS ANGELES

[redacted]

THE CAPITOL

Conditions for this photograph are: Mission 1212-3, op 723, frame 002 forward, 002 aft, -24^{o} scan, 15 October 1976, stereo, 20X magnification of the Capital, Washington, D. C.

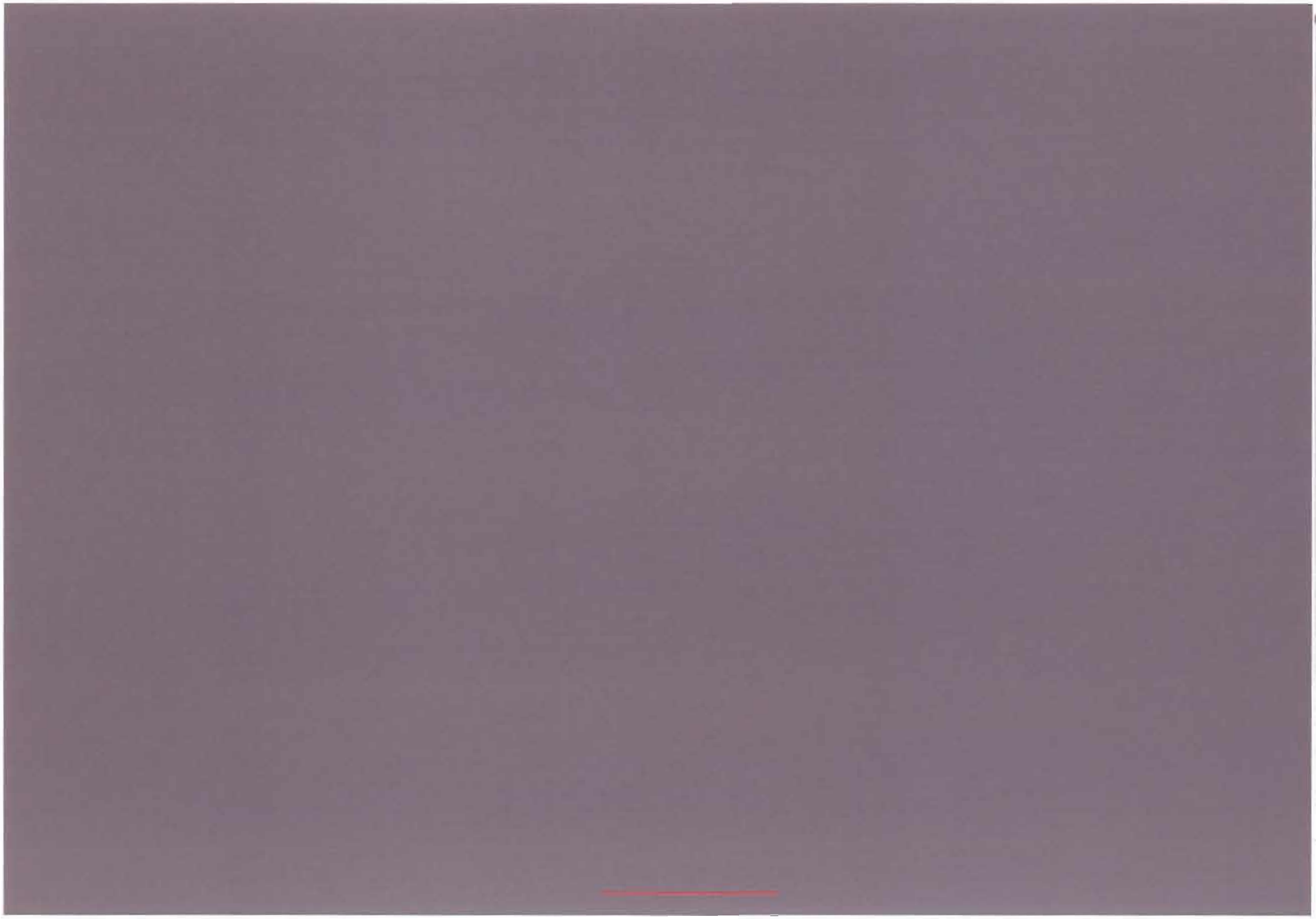
The ability of the HEXAGON camera to photograph targets in stereo greatly increase its capability as an intelligence gathering tool. All subjects reveal more information in three dimensions because they assume all the spatial dimension we are used to seeing. This allows determination of structure height, seeing the real shape of unusual objects and separation of items from confusing background.

The item at (A) is the press box for the last presidential inauguration. It was still under construction. The relief of the trees at (B) shows how cover for troops and vehicles can be interpreted and targets located.

During the time between exposures, vehicles (C) moved to new locations. The scale of the photograph and time interval are known so their speed can be calculated.

Stereo imagery generally increases the information content of a target area and provides for a more complete and accurate intelligence reporting.

THE CAPITOL



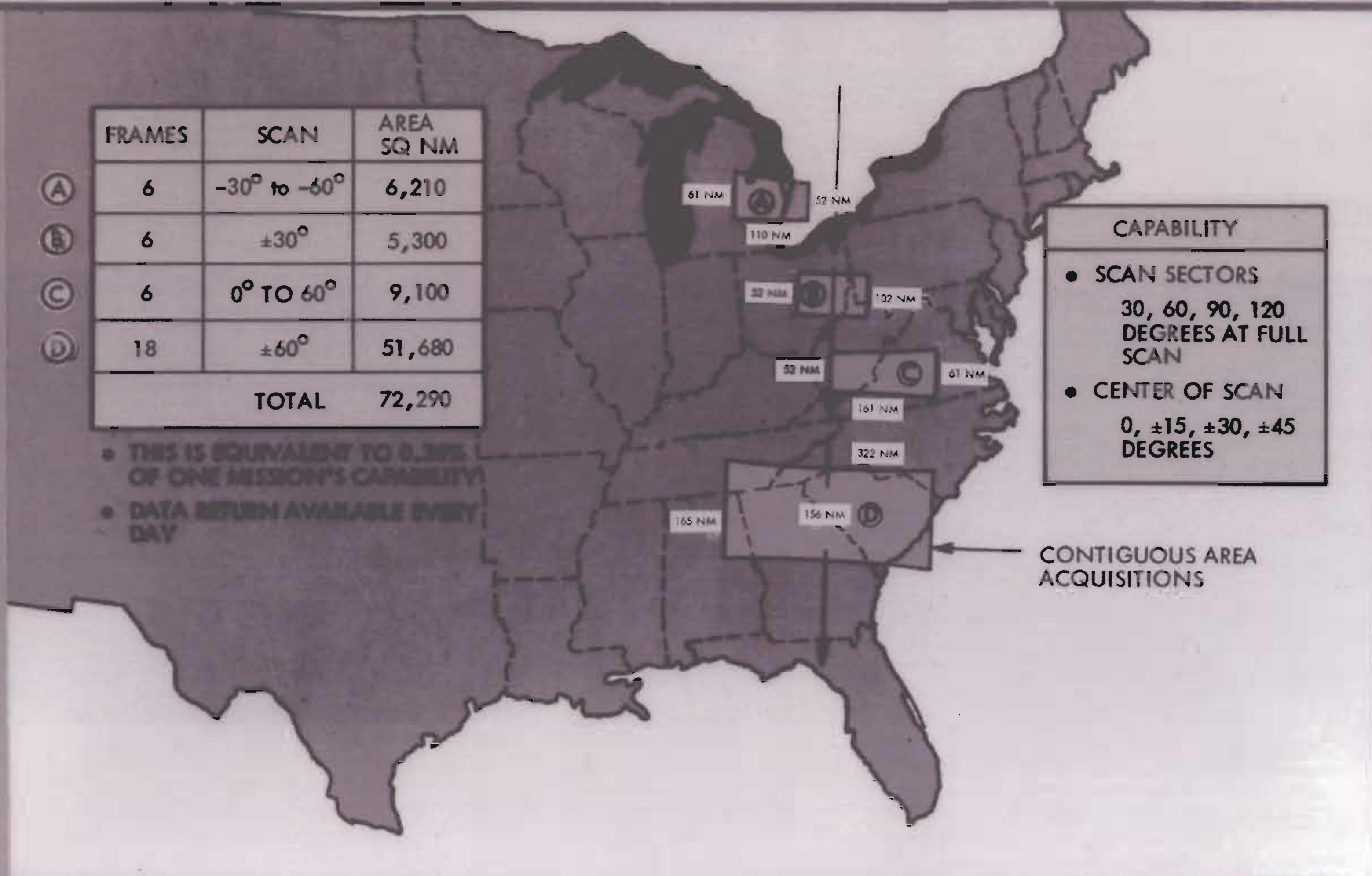
PANORAMIC SYSTEM FLEXIBILITY

HEXAGON has considerable flexibility in area search because of the selectability of scan sectors, scan centers, mono/stereo modes, and the number of frames for contiguous area acquisition. Using the United States as a familiar target objective, the four operations shown in the accompanying illustration range from a ±30 degree scan sector with 6 frames totaling 5300 sq nm mono to a ±60 degree scan sector with 18 frames totaling 51,680 sq nm mono. The example illustrates acquisitions along the flight path and on either side of it in a variety of modes, all during a single orbit rev. Acquisitions could be either mono or stereo operations.

Data return at Hawaii is available in [redacted] from this particular pass if timeliness is a factor. In its capability to perform world-wide search, data return of any acquisition is achievable within a one-day period.

TOP SECRET/H

PANORAMIC SYSTEM FLEXIBILITY



	FRAMES	SCAN	AREA SQ NM
Ⓐ	6	-30° to -60°	6,210
Ⓑ	6	±30°	5,300
Ⓒ	6	0° TO 60°	9,100
Ⓓ	18	±60°	51,680
		TOTAL	72,290

- THIS IS EQUIVALENT TO 0.38% OF ONE MISSION'S CAPABILITY
- DATA RETURN AVAILABLE EVERY DAY

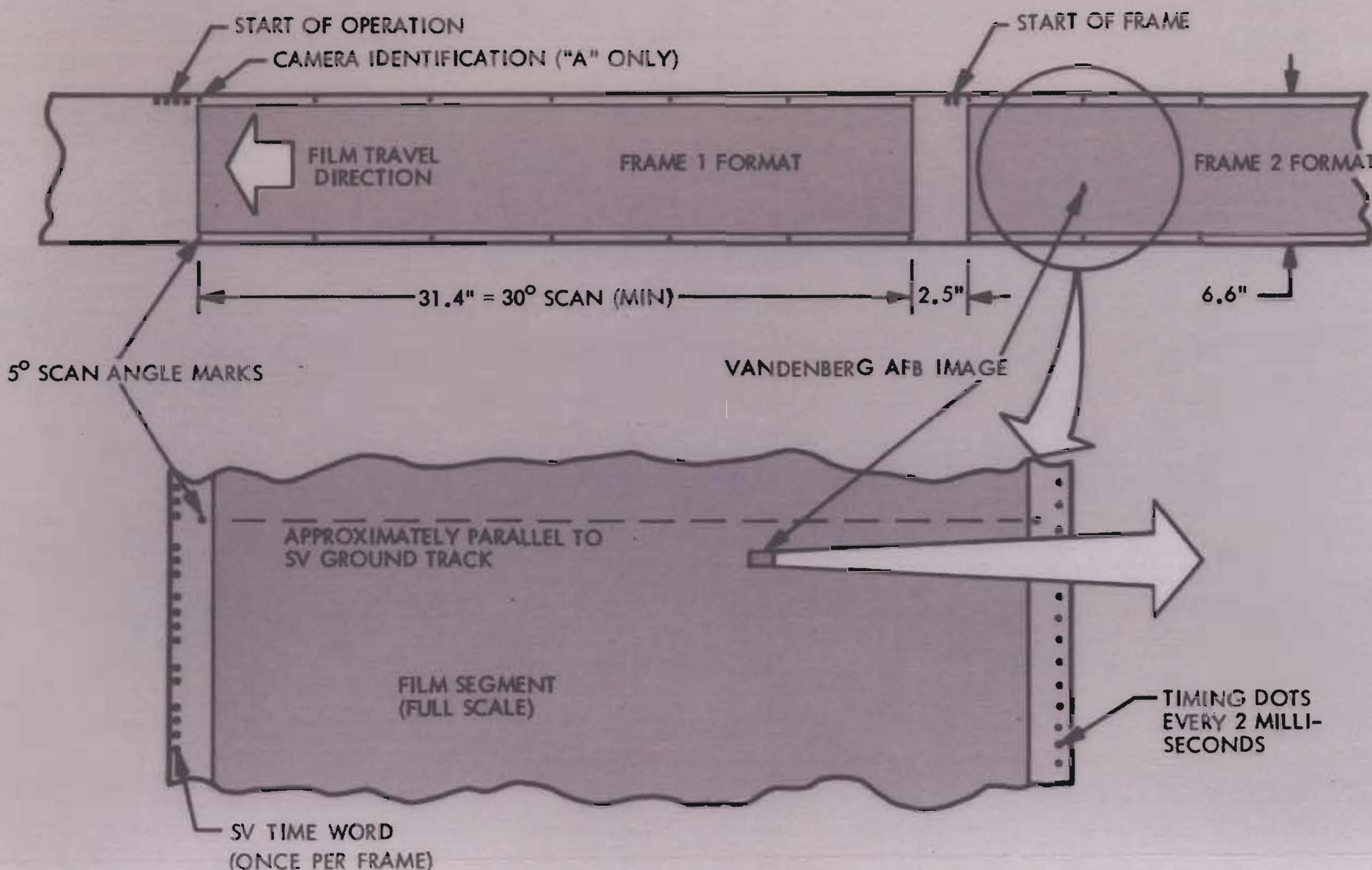
CAPABILITY

- SCAN SECTORS

  30, 60, 90, 120 DEGREES AT FULL SCAN
- CENTER OF SCAN

  0, ±15, ±30, ±45 DEGREES

CONTIGUOUS WIDE AREA COVERAGE



CONTIGUOUS WIDE AREA COVERAGE

[redacted]

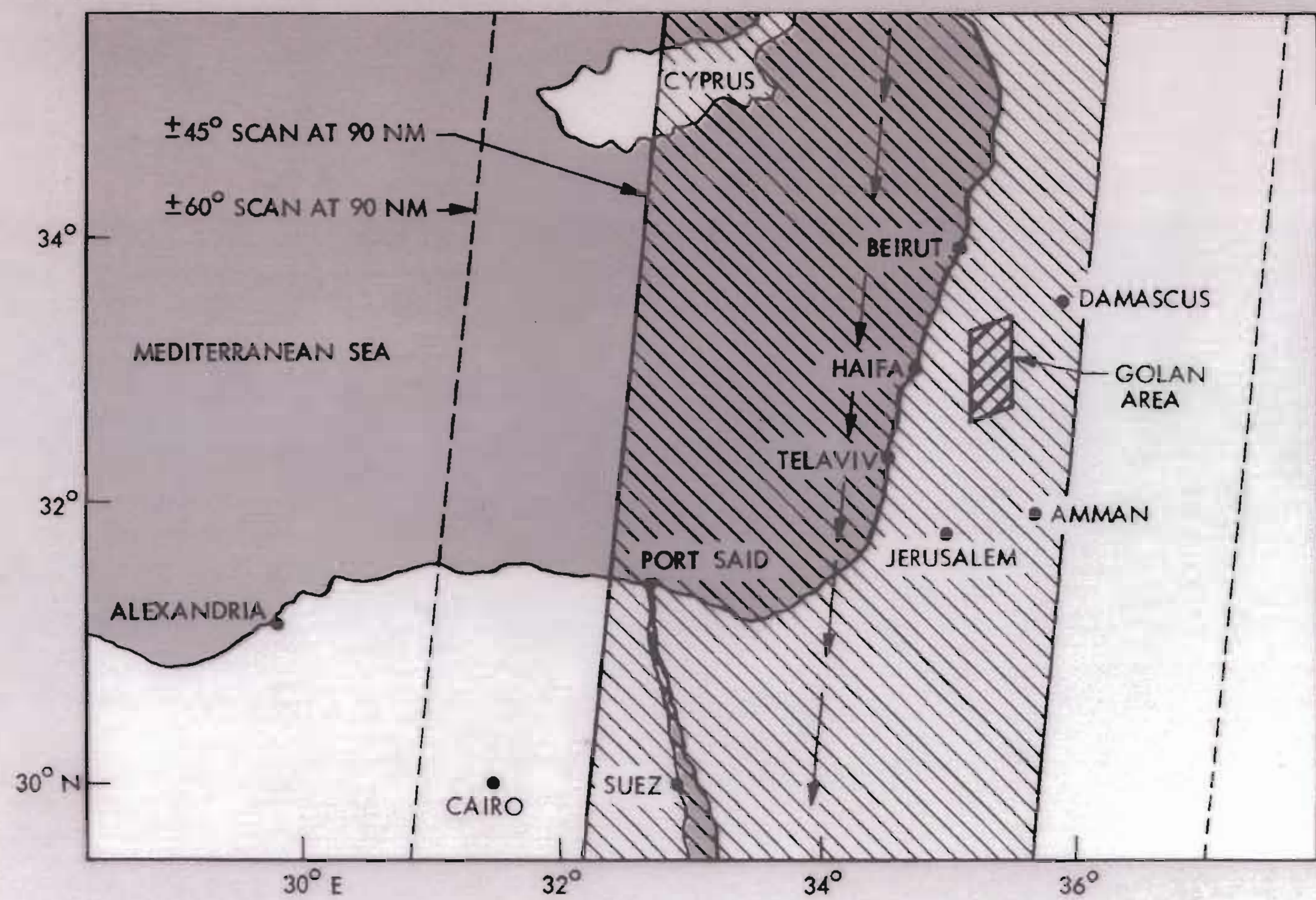
VANDENBERG AFB (HEXAGON LAUNCH SITE ON RIGHT)
VIA MISSION 1209-1 AT 40 TIMES MAGNIFICATION

THE KEY UNIQUE FEATURE OF HEXAGON IS ITS ABILITY TO CAPTURE LARGE AREAS ON FILM WITHIN A FEW MINUTES. A "FREEZING" OF THE ENTIRE AREA ALLOWS FOR IDENTIFICATION AND ENLARGEMENT OF ANY POINT OF POSSIBLE INTEREST AS ILLUSTRATED ABOVE. THIS IS A VALUABLE CAPABILITY WHEN CONDUCTING SEARCH FOR SPECIFIC TARGETS OF UNCERTAIN LOCATIONS.

MID EAST COVERAGE

A typical area search acquisition by HEXAGON is the coverage of the Eastern Mediterranean. This is a single two-minute stereo operation. At 90 nm altitude and a cross track scan of ±45 degrees, the primary areas of interest in Western Syria, Lebanon, Israel, Western Jordan, part of the Sinai Peninsula, and part of Cyprus are acquired as a contiguous area. At ±60 degrees scan, the additional width permits a greater tolerance in the longitudinal position of the flight path in addition to a wider area searched. In an extreme crisis, through the control of the orbit, a daily report of the acquisition of these areas is achievable.

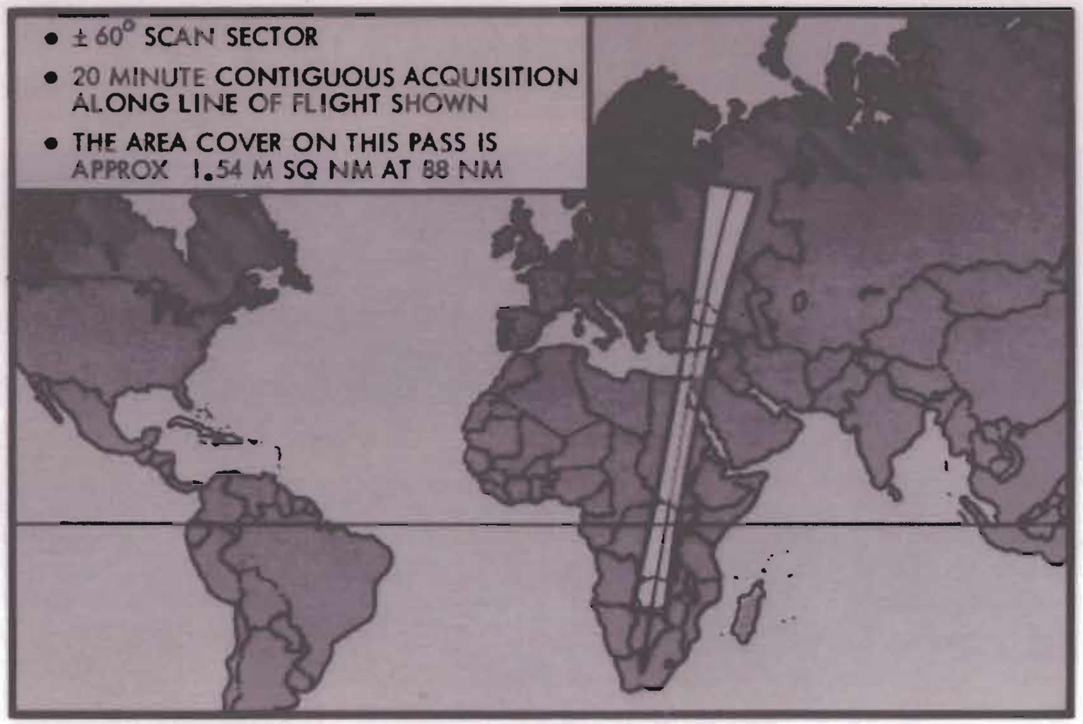
MID EAST COVERAGE



BROAD AREA ACQUISITION

The HEXAGON system can provide broad area acquisition with a contiguous area acquisition of considerable magnitude along the line of flight using any of the selectable scan sector and scan center combinations. The maximum 120 degree swath width is illustrated for a 20 minute contiguous operation acquiring a 4800 nm long area, 322 nm wide, extending from Western Russia, through the Eastern Mediterranean, down into Southern Africa. The total area approximates 1.54 M sq nm with an average altitude of 88 nm.

BROAD AREA ACQUISITION



COVERAGE ACHIEVEMENTS

The magnitude of the total world-wide imagery accomplished by HEXAGON can be compared with a familiar geographic area equivalent. As examples, the cloud-free total worldwide imagery of the fourth mission is equivalent to sixty acquisitions of Texas, or mission three equivalent to eight times the United States. The total area of Communist and free-world is 52.2 million square nautical miles which could be covered within two to three missions. The reduced coverage on mission 1201 was due to the loss of RV-3.

The percent of cloud-free acquisitions are dependent on several factors. The geographic locations of selected targets, the time of year, the time of day, and satellite weather information determine basic weather expectancy. The probability of cloud-free acquisitions is improved by longer missions, permitting more selectivity of operations within longer intervals of time between RV returns. The need to acquire certain high priority targets on every access reduces the probability of cloud-free acquisitions. The cloud-free unique imagery from mission 1212 consisted of: USSR [redacted] square nautical miles, Eastern Europe [redacted] China [redacted] other [redacted] and Middle East [redacted] Egypt, Syria, Jordan, Iraq, Lebanon and Israel) for a total of [redacted] square nautical miles.

The unique COMIREX targets shown in the table for each mission were read out by NPIC out of a total COMIREX target population that has ranged from about [redacted] in the earlier missions to about [redacted] on the most recent missions.

COVERAGE ACHIEVEMENTS

MISSION NUMBER	AREA COVERAGE (MILLION SQUARE NAUTICAL MILES) — WORLD-WIDE — TOTAL IMAGERY	WORLD-WIDE — PERCENT CLOUD FREE	COMMUNIST COUNTRIES AND MIDDLE EAST — TOTAL IMAGERY	COMMUNIST COUNTRIES AND MIDDLE EAST — CLOUD-FREE — GROSS	COMMUNIST COUNTRIES AND MIDDLE EAST — CLOUD-FREE — UNIQUE	UNIQUE COMIREX TARGETS IMAGED
1201	15.9	[redacted]	11.2	[redacted]	[redacted]	[redacted]
1202	21.1	[redacted]	16.1	[redacted]	[redacted]	[redacted]
1203	26.4	[redacted]	22.5	[redacted]	[redacted]	[redacted]
1204	18.8	[redacted]	14.2	[redacted]	[redacted]	[redacted]
1205	17.5	[redacted]	12.7	[redacted]	[redacted]	[redacted]
1206	18.9	[redacted]	15.1	[redacted]	[redacted]	[redacted]
1207	18.0	[redacted]	13.9	[redacted]	[redacted]	[redacted]
1208	16.6	[redacted]	13.0	[redacted]	[redacted]	[redacted]
1209	18.6	[redacted]	14.1	[redacted]	[redacted]	[redacted]
1210	17.4	[redacted]	13.6	[redacted]	[redacted]	[redacted]
1211	23.1	[redacted]	17.6	[redacted]	[redacted]	[redacted]
1212	17.9	[redacted]	12.6	[redacted]	[redacted]	[redacted]
1213	14.2 (1)	[redacted]				

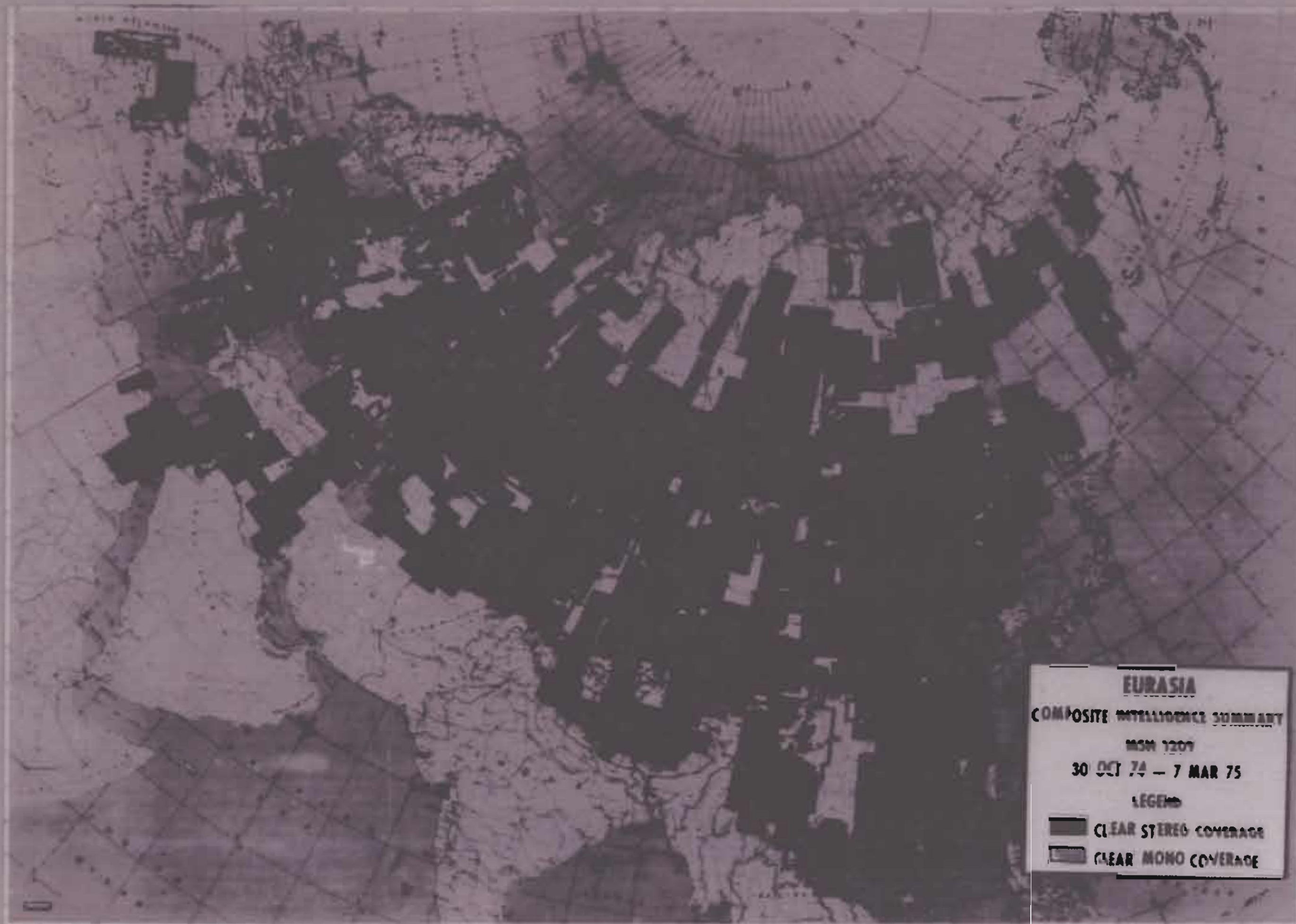
(1) THROUGH RV #3

SEARCH GLOBAL COVERAGE

This is a representative coverage of the Europe, Asia, and surrounding countries. The enclosed block or cell areas taken but not cloud-free are also shown. High priority targets were taken several times to ensure a cloud-free take and to note ground activity changes throughout the four-month life of Mission 1209.

These geographic areas of interest total 10.9 million square nautical miles and consist of: USSR 6.87, Eastern Europe 0.4, China 2.82, other Communist countries 0.56, and Middle East 0.25. The free-world area, including the United States, comprises a total of 41.3 million square nautical miles.

SEARCH GLOBAL COVERAGE

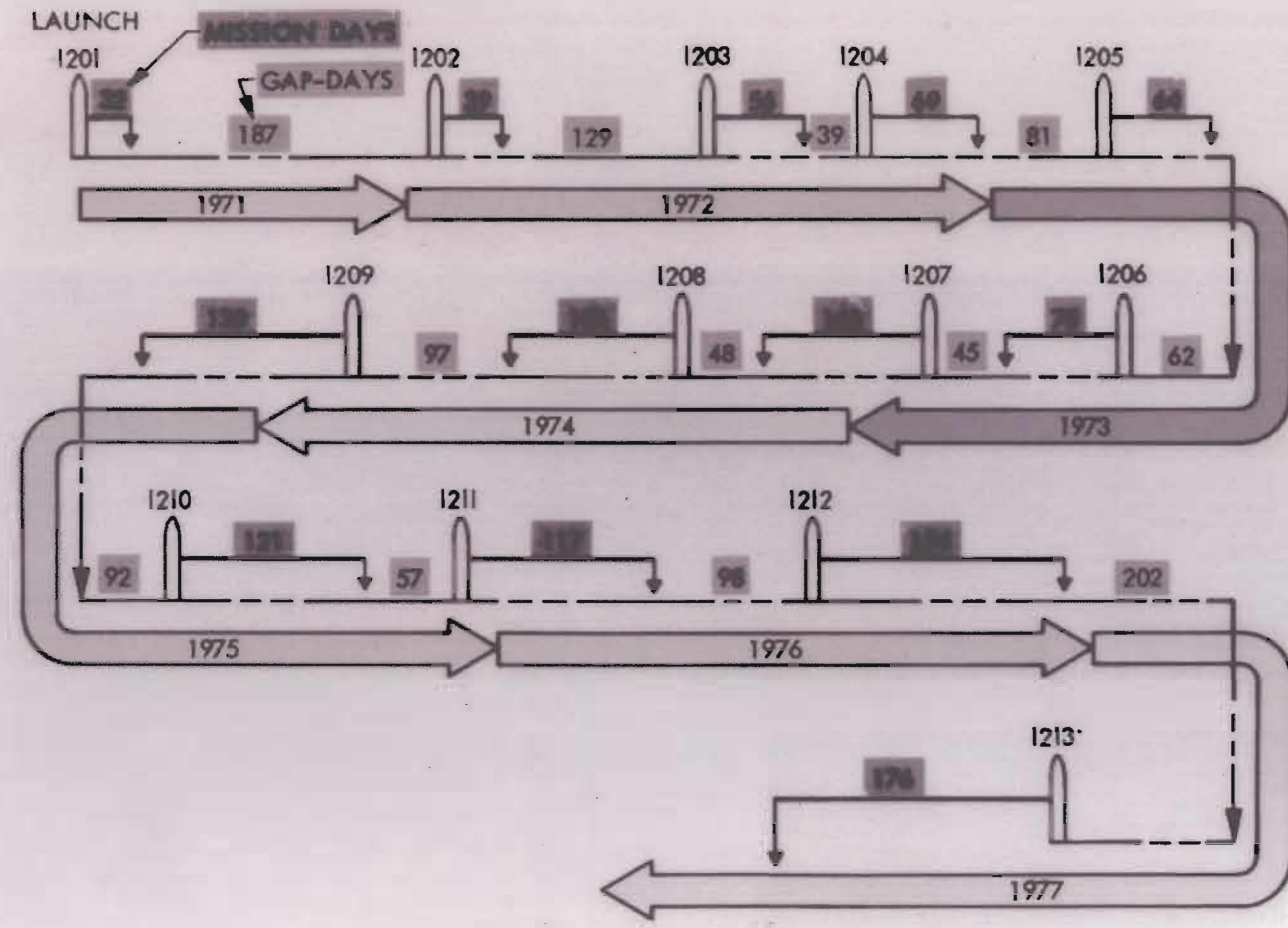


COVERAGE HISTORY

The initial contract for HEXAGON was to fly each vehicle for thirty days every 60 days for a 50% search coverage. The highly successful on-orbit performance, higher altitude, and design improvements of HEXAGON has allowed longer mission durations. This has resulted in extending search and surveillance operations up to 176 days.

The gap in continuity (RV #4 recovery to next vehicle launch) of HEXAGON coverage has varied widely. These gaps for the 13 flights to date have ranged from a low of 39 days to a high of more than 200 days. Under the accomplished schedule of the 13 launches, operational coverage with the acquisition and subsequent return of imagery data was available approximately half the time.

COVERAGE HISTORY



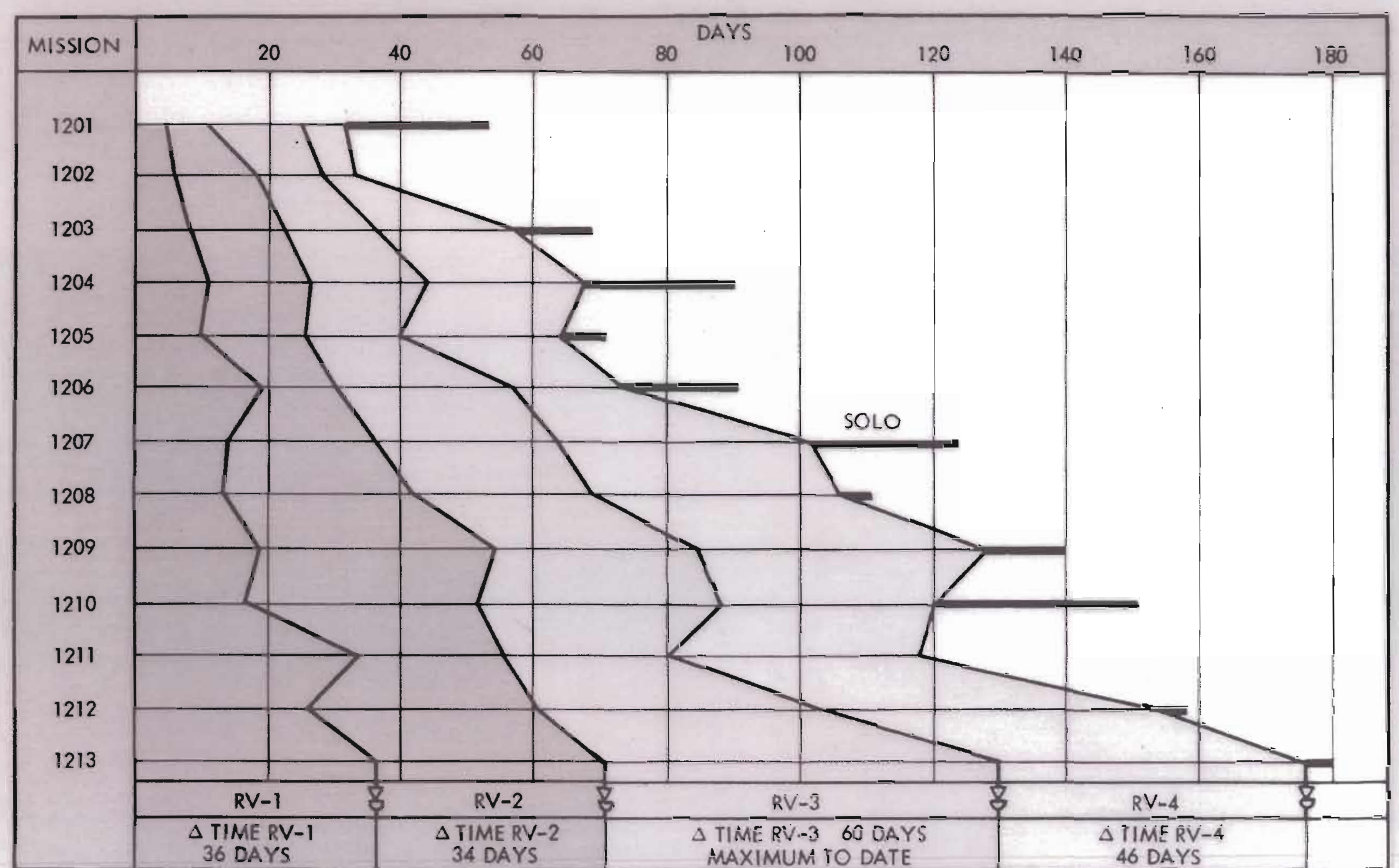
INCREASING DURATION BETWEEN RECOVERIES

Since the first launch on 15 June 1971 the increasing mission life (from 32 to 176 days) has resulted in an increasing number of operating days between recoveries. Starting with a low of 5 days, it has increased to intervals of 36, 34, 60, and 46 days on the thirteenth flight. On each of 11 flights, the shortest operating days per RV preceded the recovery of RV-1. On each of eight flights the longest time period preceded RV-4 recovery. Future increases in mission life to utilize the potential of the SV will produce on the average as many as 60 days of operations preceding the recovery of each RV.

Under crisis condition it is [redacted]possible to make a non-full RV recovery after the critical target is photographed; however, this option has not been selected to date.

Solo operations have been used to exploit the SV capabilities without risk to RV recovery. Solo tests have been instrumental in successfully increasing mission durations.

INCREASING DURATION BETWEEN RECOVERIES



SO-255 COLOR FILM

Conditions for this photo are: Mission 1208-4, OP 733, Frame 006, Aft, Scan Angle -2^{o}, 15 July 1974, 40X magnification of San Francisco, California.

Color photography contributes an additional dimension to search and surveillance photography. It removes the image from the abstraction of black-and-white and places it in a context we understand more readily.

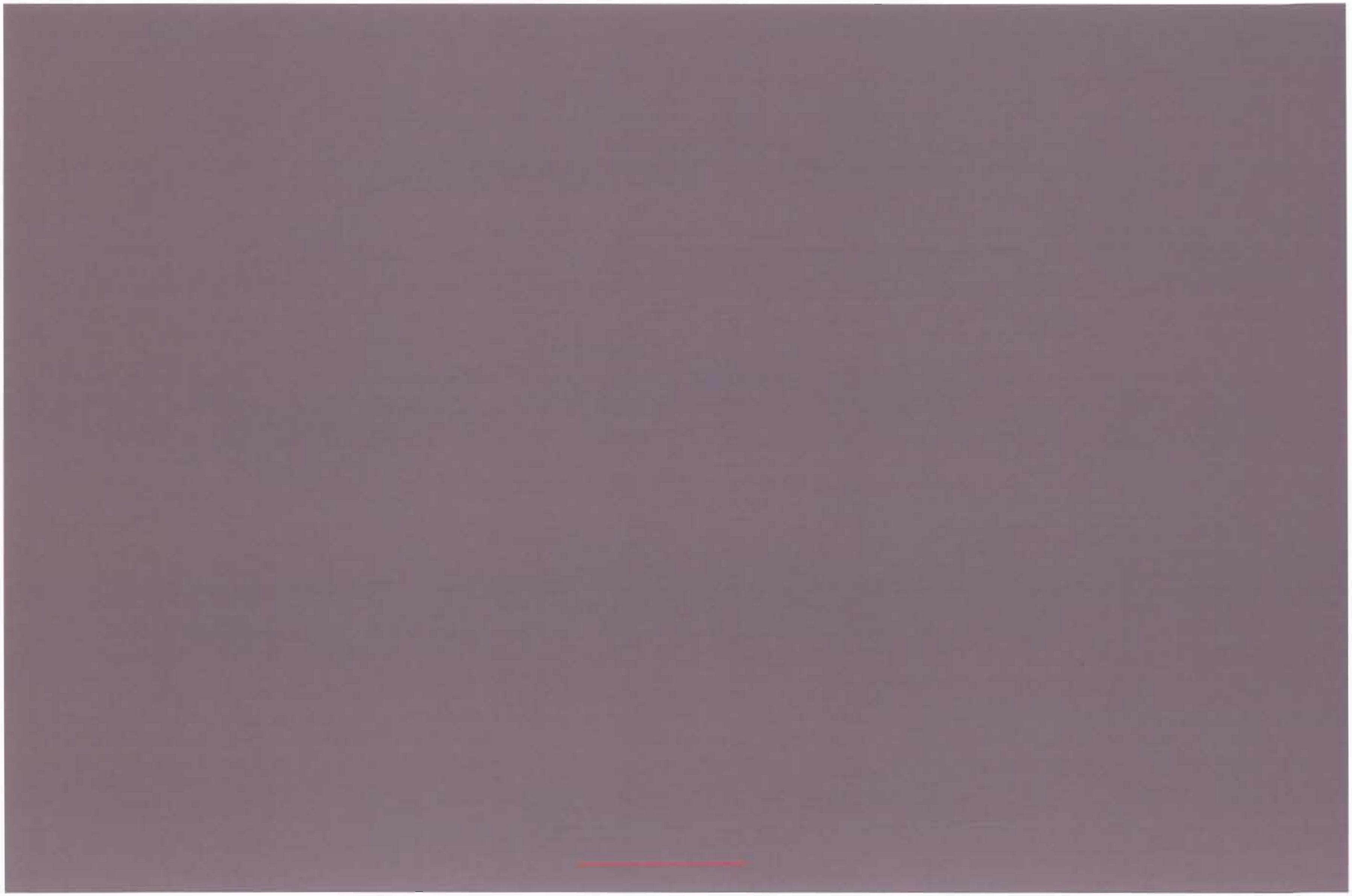
We see the world as a collection of shapes with size, texture, and color. A photograph lacking color is lacking one element in relation to reality.

This scene is photographed in natural color and many items are readily identifiable because of color cues. The school buses at (A) could be interpreted as such in black-and-white by their proximity to the school complex. However, the distinctive yellow hue that we associate with school buses signals their use immediately.

The blue color traditionally found in swimming pools is easily located in several residential areas (B). Black and white coverage would require a detailed search because their geometric shapes would be lost among the buildings. The competition pool at (C) shows varying depth by the transition from lighter to darker blue as the water deepens. This same signature is seen at (D) indicating an expensive, in-ground pool. Numerous other items will be apparent to the viewer because of its association with object color in everyday experience.

Military, industrial, and transportation items also have distinctive color coding signatures and are separated from the enormous amount of photo detail in the same manner as the items cited above.

SO-255 COLOR FILM



SO-130 INFRARED COLOR FILM

Conditions for this photo are: Mission 1213-3, OP 713, Frame 006, aft, scan angle 0^{o}, Oct 14, 1976, 5X magnification near Santa Fe, New Mexico.

Infrared color films were originally designed as a camouflage detection film. They have the capability of separating man-made, hidden objects from natural vegetation because of special characteristics of infrared radiation. Resolution is quite low compared to the black-and-white films used as the primary payload.

Vegetation containing living chlorophyl reflects a large percentage of the infra-red component of natural sunlight. Plants under stress (having insufficient water, diseased, etc.) will have a breakdown in their chlorophyl structure and consequently reflect less infrared. This type of color film shows infrared reflectance as a magenta colored image. Healthy vegetation will appear as bright magenta and will change in either color or brightness as the plants degrade.

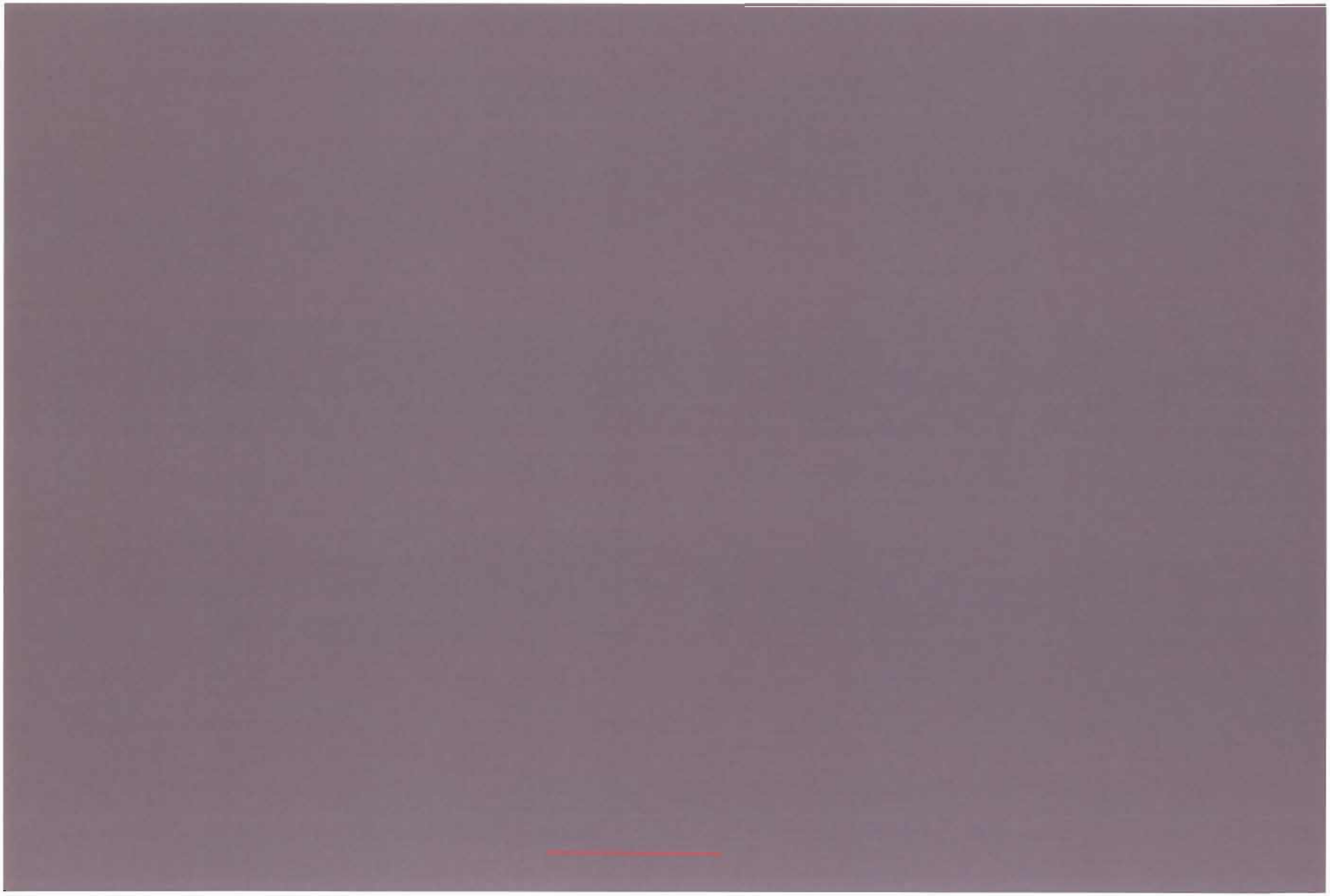
As a result of this characteristic, SO-130 is an ideal film for monitoring crop vigor and potential yield giving very basic intelligence data on the food supply and import/export requirements of a country.

In the accompanying photo varying degrees of vegetation vigor and distribution are indicated. The plantings at (A) are well advanced and show local irregularities in water supply and/or soil capability. Pasture land is seen as healthy at (B) and fallow fields are obvious at (C). The natural ground cover for the area is indicated as arid area, low chlorophyl cover by the response indicated by (D).

There are also notable color differences in the ponds that cross the format diagonally. As suspended sediments increase in volume, the color shifts toward the light blue and into the green portion of the spectrum. This is an indicator of the erosion and retention of valuable soils. Though marginally useful as a comouflage detection film at this scale, SO-130 is outstanding as a crop monitoring tool.

~~TOP SECRET~~/H

SO-130 INFRARED COLOR FILM



FILM TYPES FLOWN

CONVENTIONAL BLACK AND WHITE FILMS ARE:

- 1414 – The standard fine grain high resolution B & W film flown on HEXAGON Missions through Mission 1213. This film has an extended red sensitivity, is approximately 2 mils thick (0.5 mil emulsion coated on a 1.5 mil base), and has an Aerial Film Speed (AFS) of 15.0.
- SO-208 – This film is identical to 1414 except that it is coated on an ultra-thin 1.2 mil base. This will allow approximately 20,000 additional feet of film to be utilized in the HEXAGON system and is the standard material for missions 1214 and up.

HIGHER RESOLUTION BLACK AND WHITE FILMS ARE:

- SO-124 – A panchromatic B & W film flown experimentally on Mission 1210. This film has higher low-contrast resolution than the conventional B & W films. It is coated on a 1.5 mil base and has an AFS of 6.0 requiring longer exposure times than the conventional B & W films.
- SO-460 – This film is essentially identical to SO-124 except that it is coated on the ultra-thin 1.2 mil base. The AFS is 6.0.
- SO-464 – This film is essentially SO-460 with the yellow AH dye removed. This results in an increase of emulsion speed to an AFS of 10.0. This emulsion is also coated on the ultra-thin 1.2 mil base.
- Aerial 15 – This is one of the new "Mono Dispersed Cubic" emulsions sometimes also referred to as "J" coatings. These emulsions exhibit extremely fine grain, high resolution, and very slow emulsion speeds. This film has an AFS of 6.6 and is coated on the ultra-thin 1.2 mil base.

COLOR FILMS ARE:

- SO-255 – This is a conventionally sensitized, fine grain, high-definition color reversal film. The emulsion is coated on a 1.5 mil base with the film having an AFS of 9.5.
- SO-130 – This is a "False Color" infrared sensitive color reversal film on a 1.5 mil base with an AFS of 7.5. This film is used extensively for economic intelligence evaluation.

FILM TYPES FLOWN

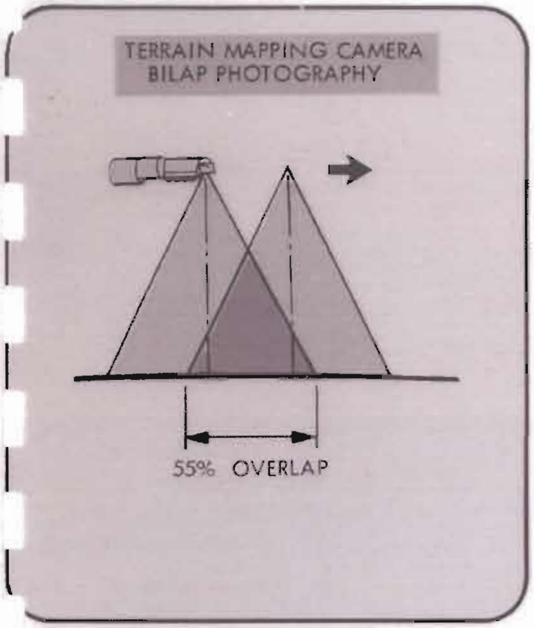
MISSION	FILM TYPES 1414	SO-255	SO-130	SO-208	SO-124	SO-460	SO-464	AERIAL 15
	Film Footage - Feet							
1201	172,640							
1202	156,115							
1203	185,325							
1204	208,454	10,000						
1205	216,010	2,000						
1206	191,017	21,000	500					
1207	207,832	4,984	500					
1208	210,069	2,588	3,000					
1209	217,338	8,150	3,400					
1210	210,156	9,150	3,150		3,750			
1211	153,942	4,500	4,500	4,500				
1212	231,450	4,500	4,500					
1213	198,536	3,500	5,500	20,000		7,000	8,000	2,000
TOTALS	2,558,884	70,372	25,050	24,500	3,750	7,000	8,000	2,000

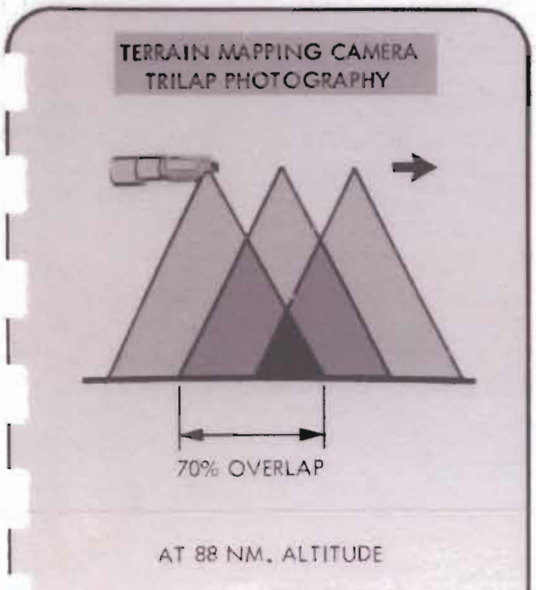
MAPPING SYSTEM

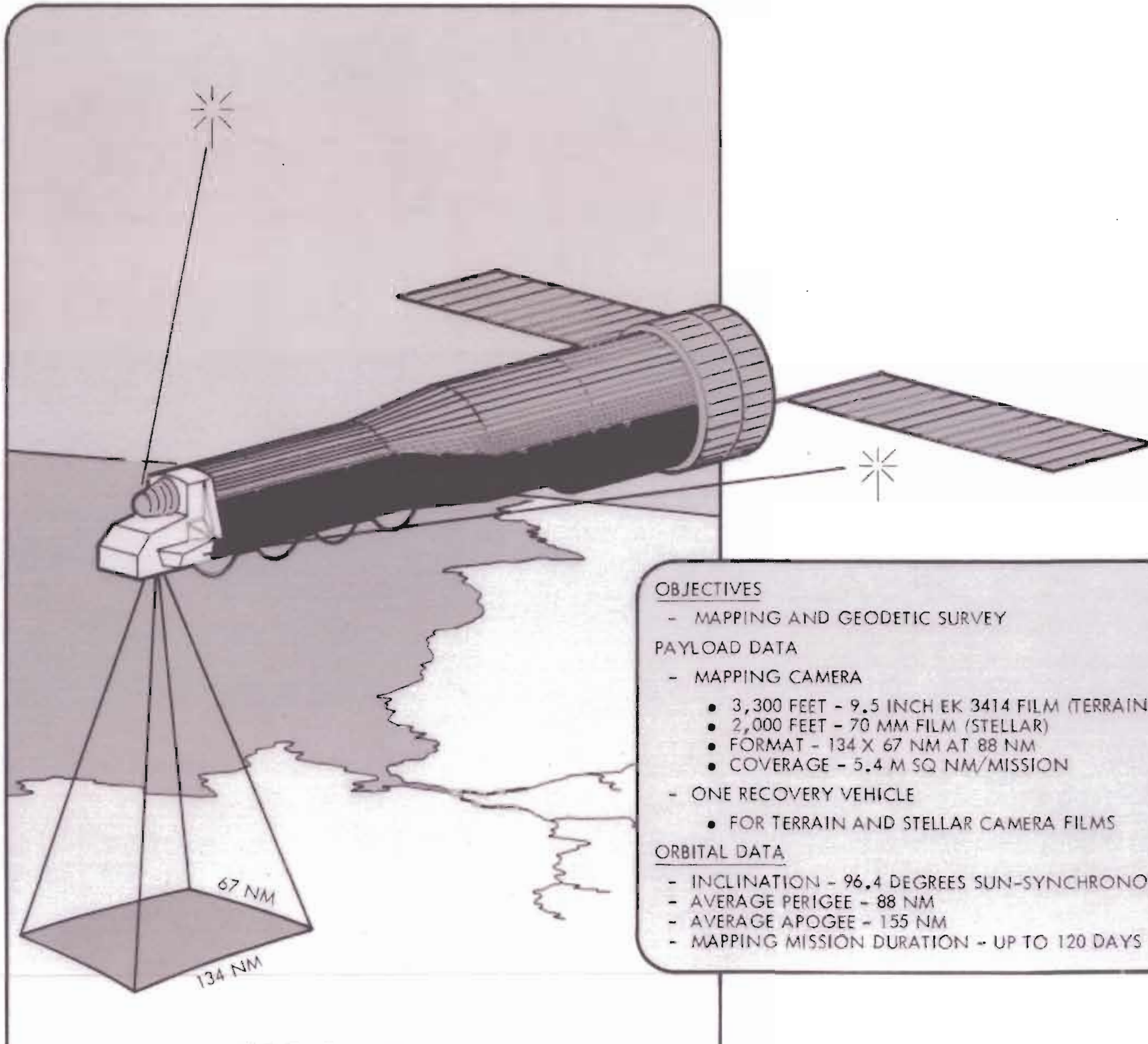
MAPPING CAMERA OPERATION

The mapping camera system (MCS) is utilized to provide cartographic control for compilation of 1:50,000 scale maps. Photogrametric data is achieved by simultaneously acquiring overlapping terrain and star field photographs through three precisely calibrated lens systems. Control points are established by measurements of prominent imagery on overlapping pairs of terrain photography. Measurements of star image locations on stellar frames provide an accurate orientation of the terrain camera axis in space at the time of each photograph. Stereo photography, necessary for vertical measurements of terrain imagery, is acquired in two stereo modes providing 70% or 55% overlap. A third mode is used to provide mono photography with 10% overlap. The high resolution and wide coverage (70 X 140 nm) of the terrain camera provide a useful tool in searching for primary targets of interest and earth survey objectives. On completion of the MCS mission, the terrain and stellar films are returned in a single Mark V recovery vehicle. The doppler beacon system and NAVPAC system provides ephemeral information which accurately establishes camera/vehicle position in space. These data are needed to support mensuration of MCS imagery.

MAPPING CAMERA OPERATIONS







OBJECTIVES

- MAPPING AND GEODETIC SURVEY

PAYLOAD DATA

- MAPPING CAMERA
  - 3,300 FEET - 9.5 INCH EK 3414 FILM (TERRAIN)
  - 2,000 FEET - 70 MM FILM (STELLAR)
  - FORMAT - 134 X 67 NM AT 88 NM
  - COVERAGE - 5.4 M SQ NM/MISSION
- ONE RECOVERY VEHICLE
  - FOR TERRAIN AND STELLAR CAMERA FILMS

ORBITAL DATA

- INCLINATION - 96.4 DEGREES SUN-SYNCHRONOUS
- AVERAGE PERIGEE - 88 NM
- AVERAGE APOGEE - 155 NM
- MAPPING MISSION DURATION - UP TO 120 DAYS

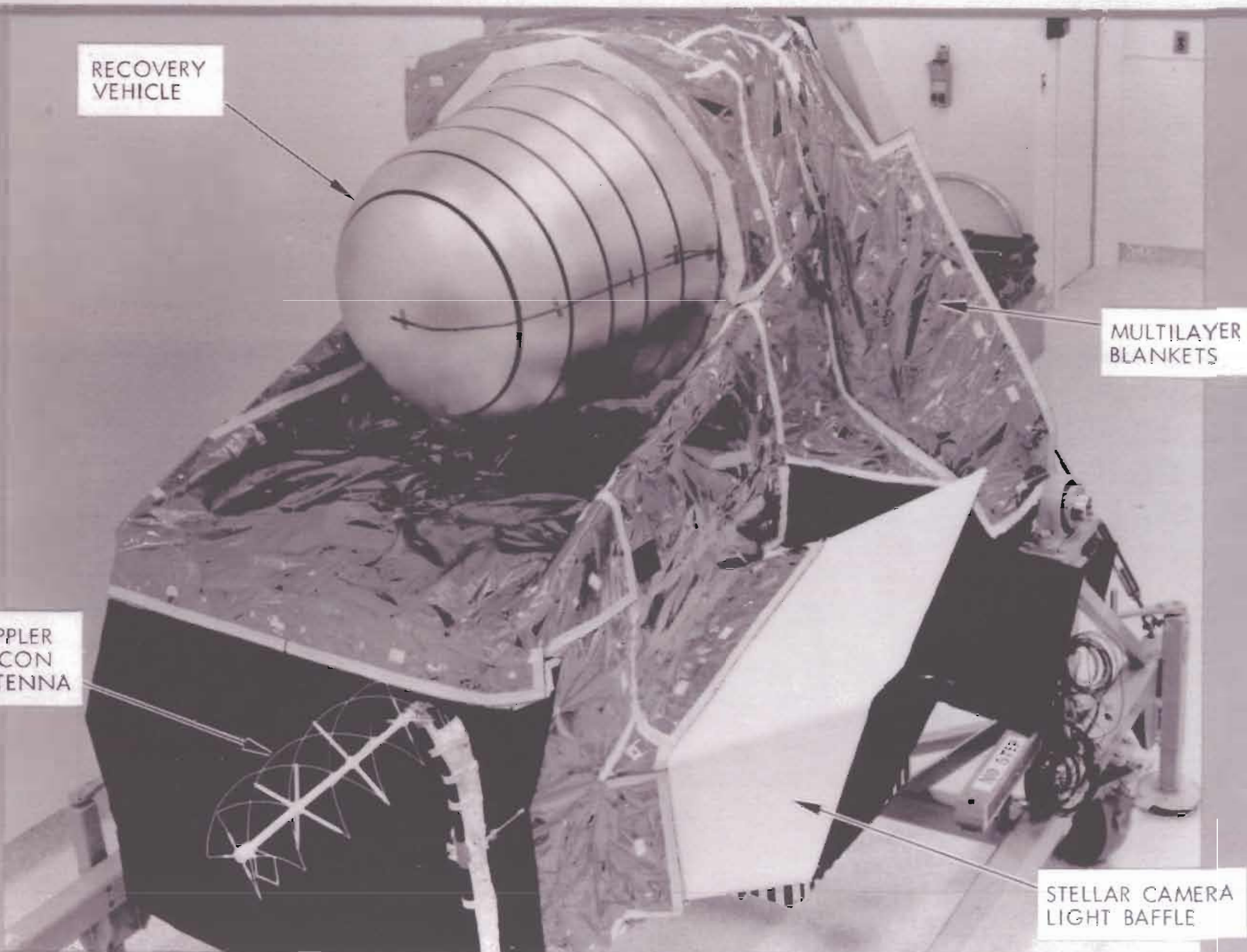
MAPPING CAMERA SYSTEM

The Mapping Camera System (MCS) structure supports and positions the individual subsystems with respect to each other and within the space constraints of the SV shroud. The loads are transmitted to six structural attach points on the vehicle bulkhead. Pitch and yaw alignment of the structure to the SV attitude reference module is achieved by shimming the attach points.

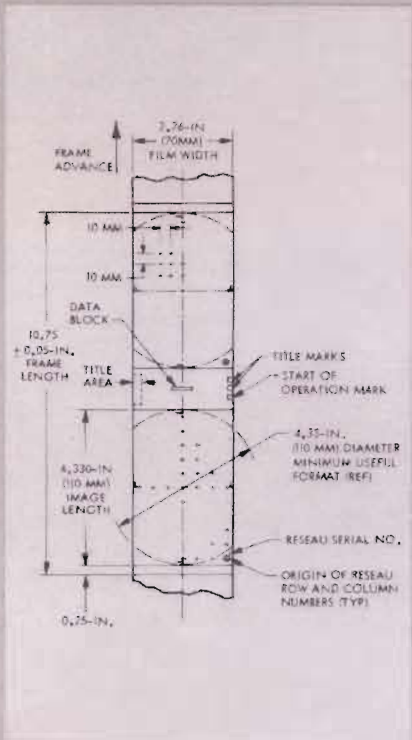
Temperature control is achieved by passive means (paint, tape, multilayer blankets and thin metal sheets, i.e., cocoons) for all but the precise temperature requirements of the lens system, which employs heaters for their accurate control.

Electrical interfaces between the SV and the MCS are at the bulkhead. All command, telemetry, timing and power are provided by the SV.

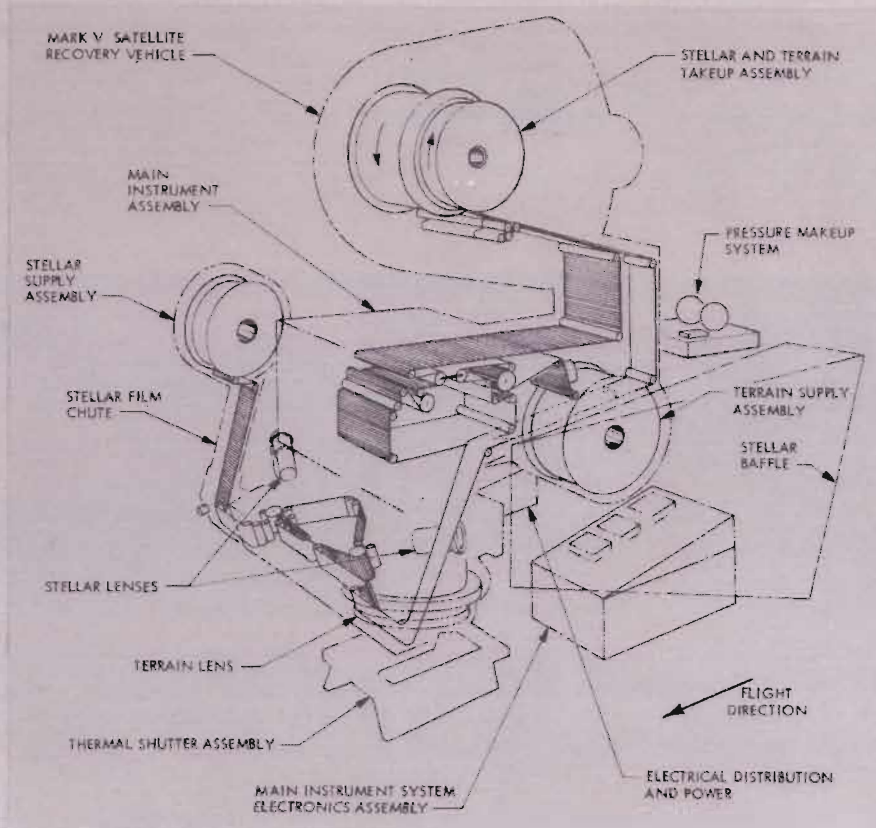
MAPPING CAMERA SYSTEM

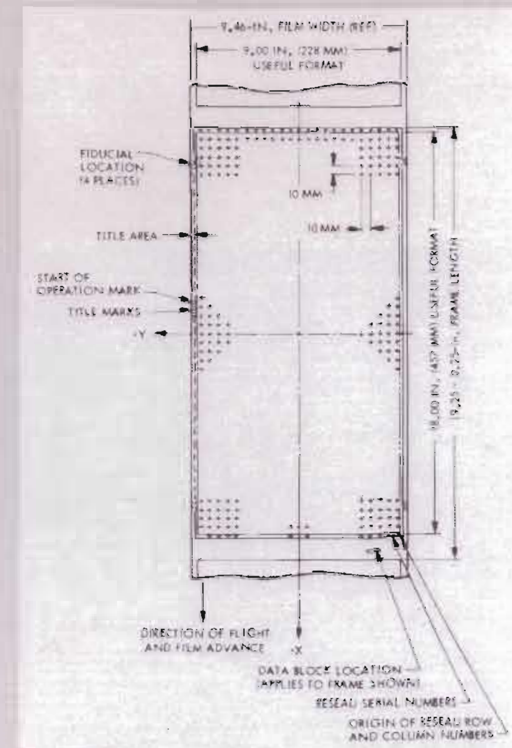


MAPPING CAMERA DESCRIPTION



STELLAR FORMAT

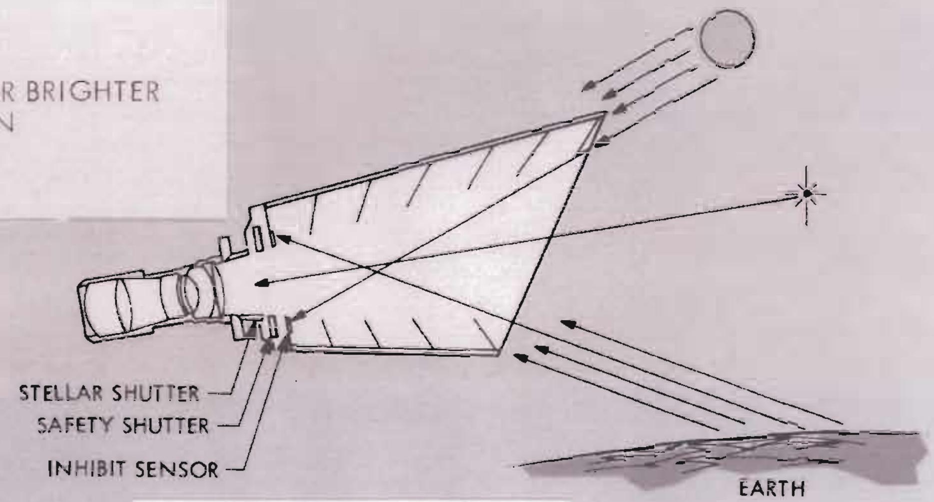




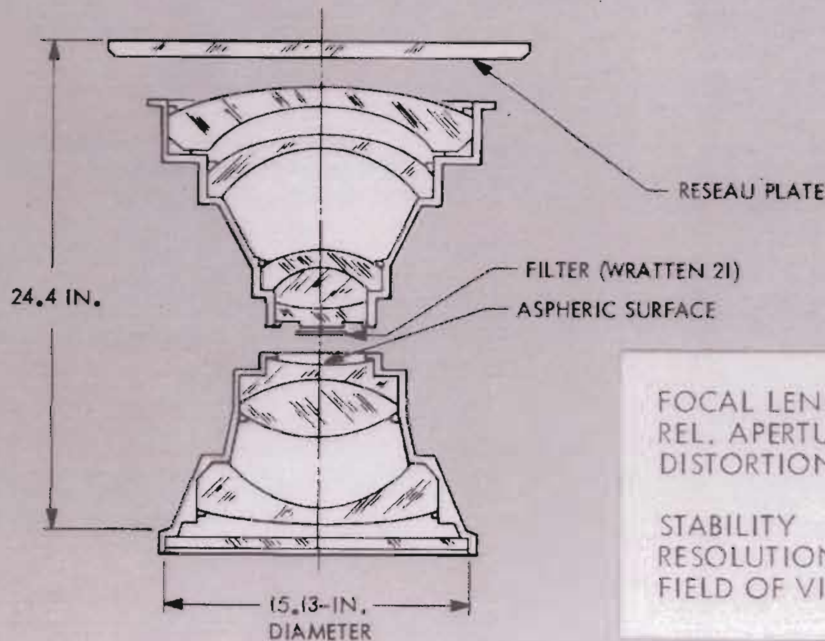
TERRAIN FORMAT

MAPPING CAMERA LENSES

LENS FOCAL LENGTH	10.0 INCHES
RELATIVE APERTURE	f/2.0
SENSITIVITY	6th MAGNITUDE STARS OR BRIGHTER
BORESIGHT STABILITY	2 ARC-SEC IN OPERATION
FIELD OF VIEW	16 BY 25 DEGREES



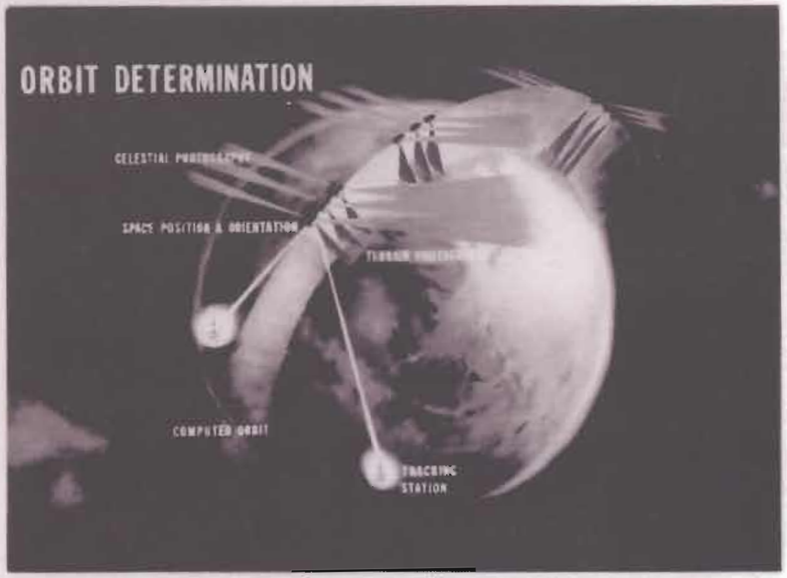
STELLAR LENS AND BAFFLE



TERRAIN LENS

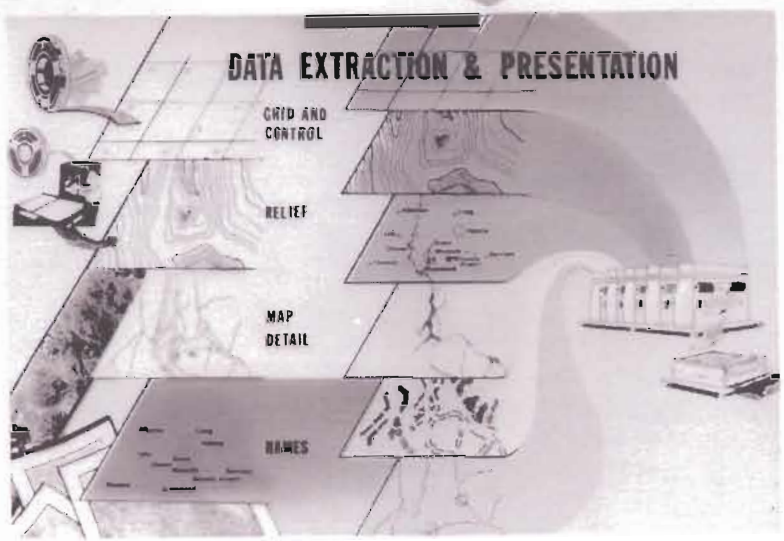
FOCAL LENGTH	12.0 IN.
REL. APERTURE	f/6, T/14
DISTORTION	100 MICRONS MAX RADIAL 20 MICRONS MAX TANGENTIAL
STABILITY	2 MICRONS IN OPERATION
RESOLUTION	95 L/MM AWAR (VEM ON 3414 FILM)
FIELD OF VIEW	38 BY 72 DEGREES

MAPPING PROCESS



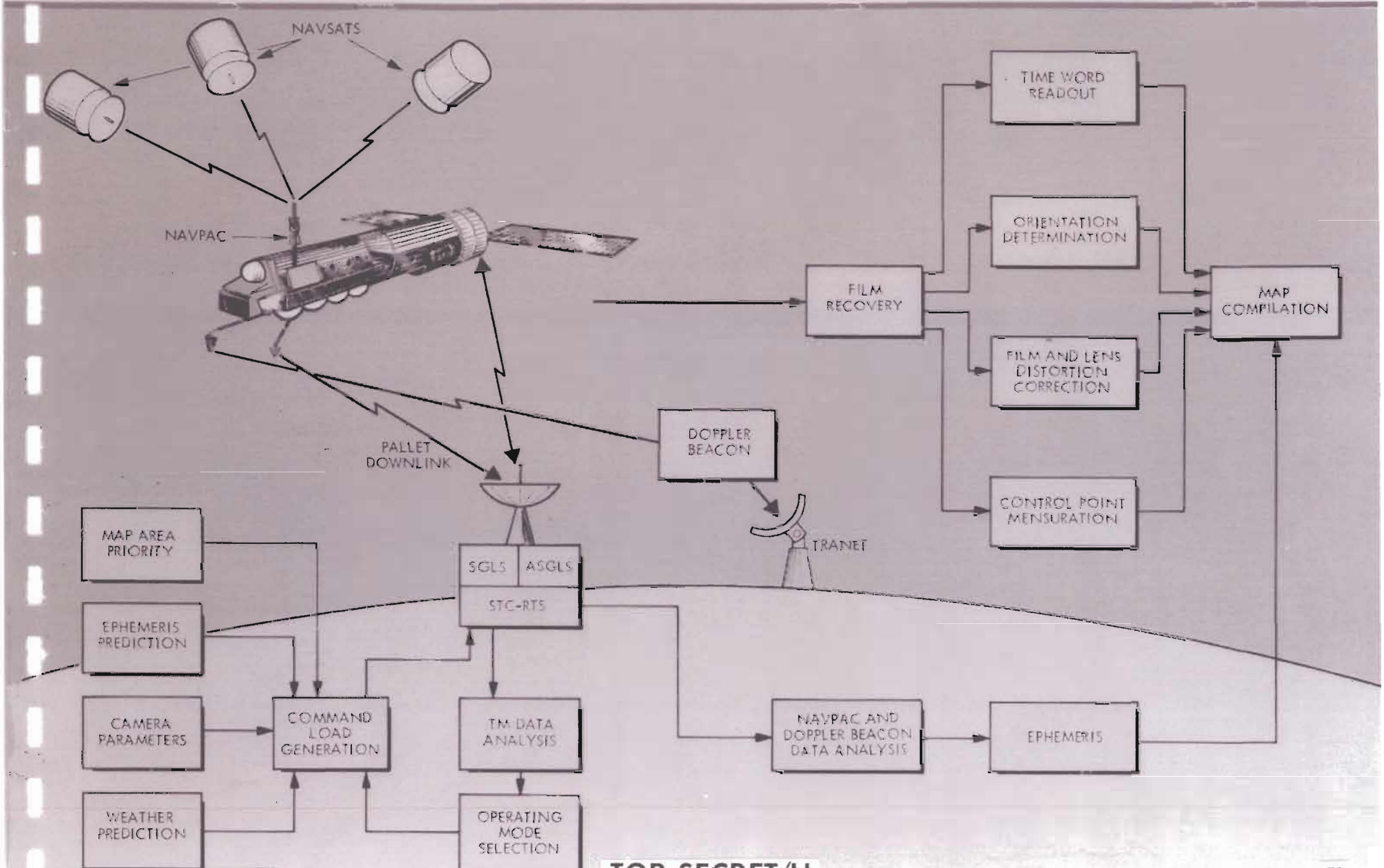
ACQUISITION

EXPLOITATION



PUBLICATION

MAPPING CAMERA DATA FLOW



TERRAIN FRAME

50% REDUCTION OF FULL (9 x 18 INCH) TERRAIN FRAME

IDENTIFICATION OF FULL FRAME COVERAGE

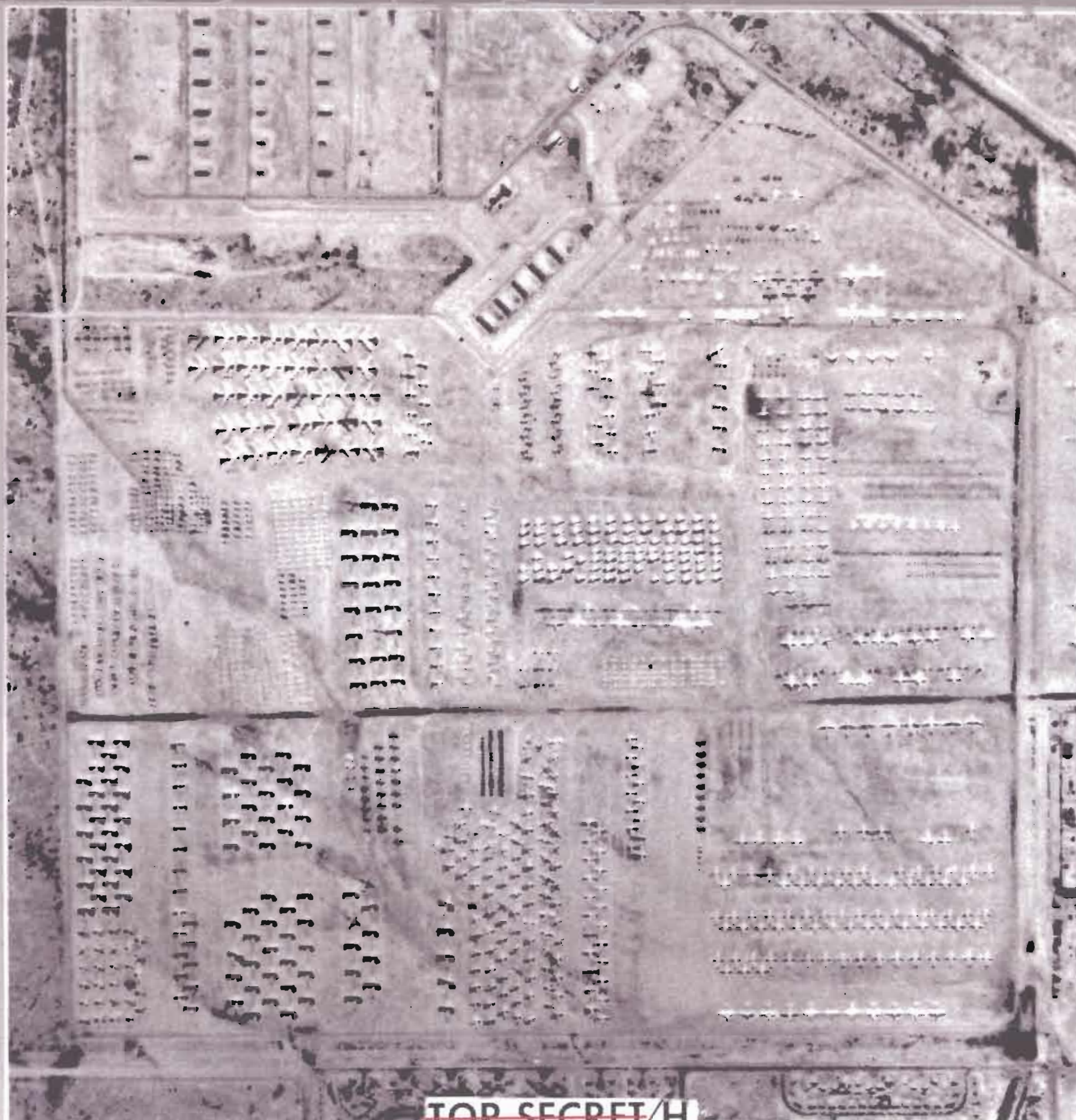
ORIGINAL DESIGN PHOTO

- WILLIAMS AFB (20 X)
- EK 3400 FILM (MISSIONS 1205 - 1208)

PRODUCT IMPROVEMENT

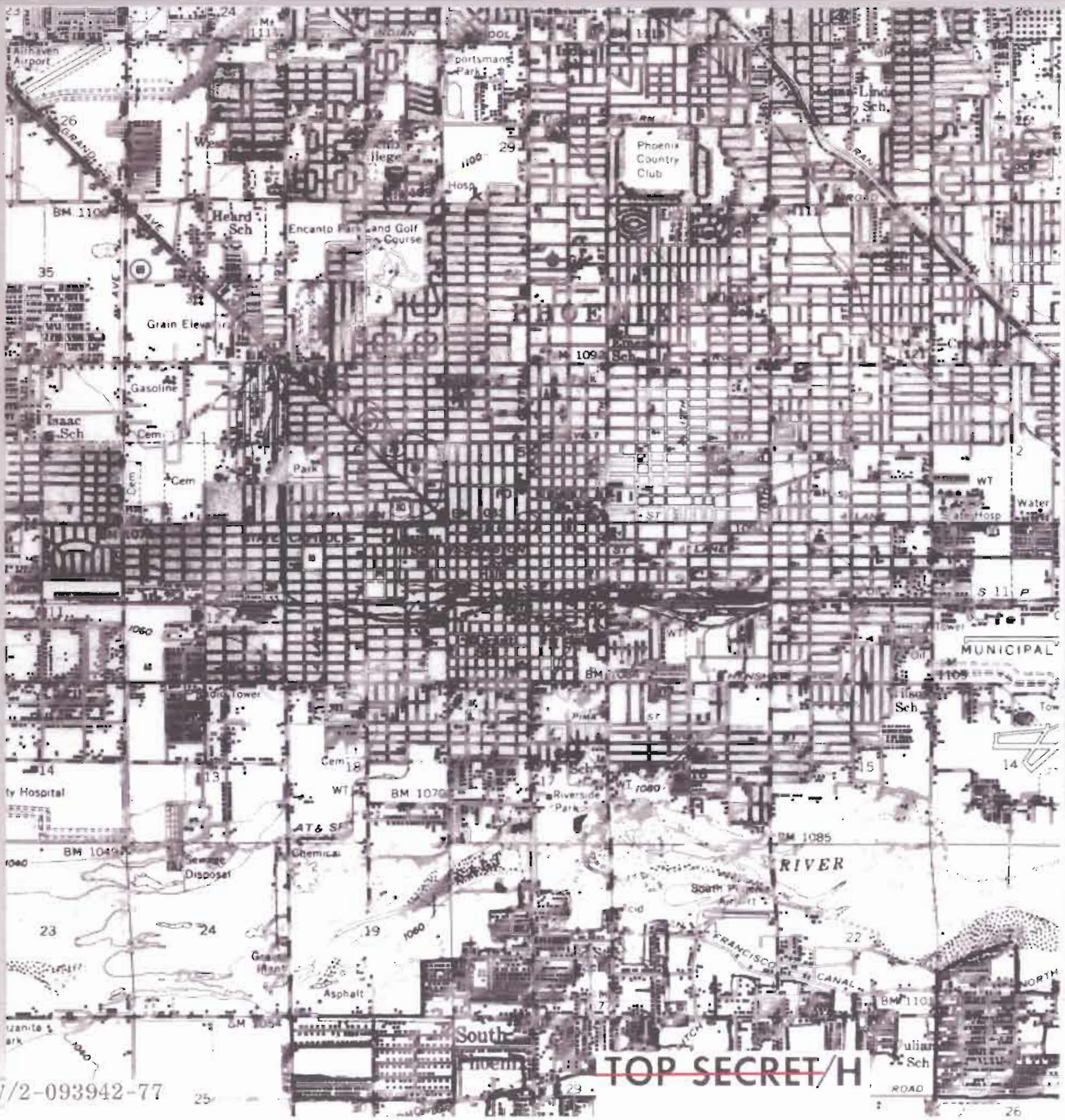
- MIDLAND TEXAS AIR TERMINAL (20 X)
- EK 3414 FILM (MISSIONS 1209 AND UP)

STORAGE SITE



- DAVIS MONTHAN AFB (40X)
- MISSION 1211 EK 3414 FILM

TERRAIN PHOTO OVERLAY 1211



- UNITED STATES GEOLOGICAL SURVEY 1:62,000 MAP PUBLISHED 1959
- TERRAIN PHOTO OVERLAY MISSION 1211 1976

~~TOP SECRET~~/H

TOP SECRET/H

TERRAIN PHOTO OVERLAY 1211

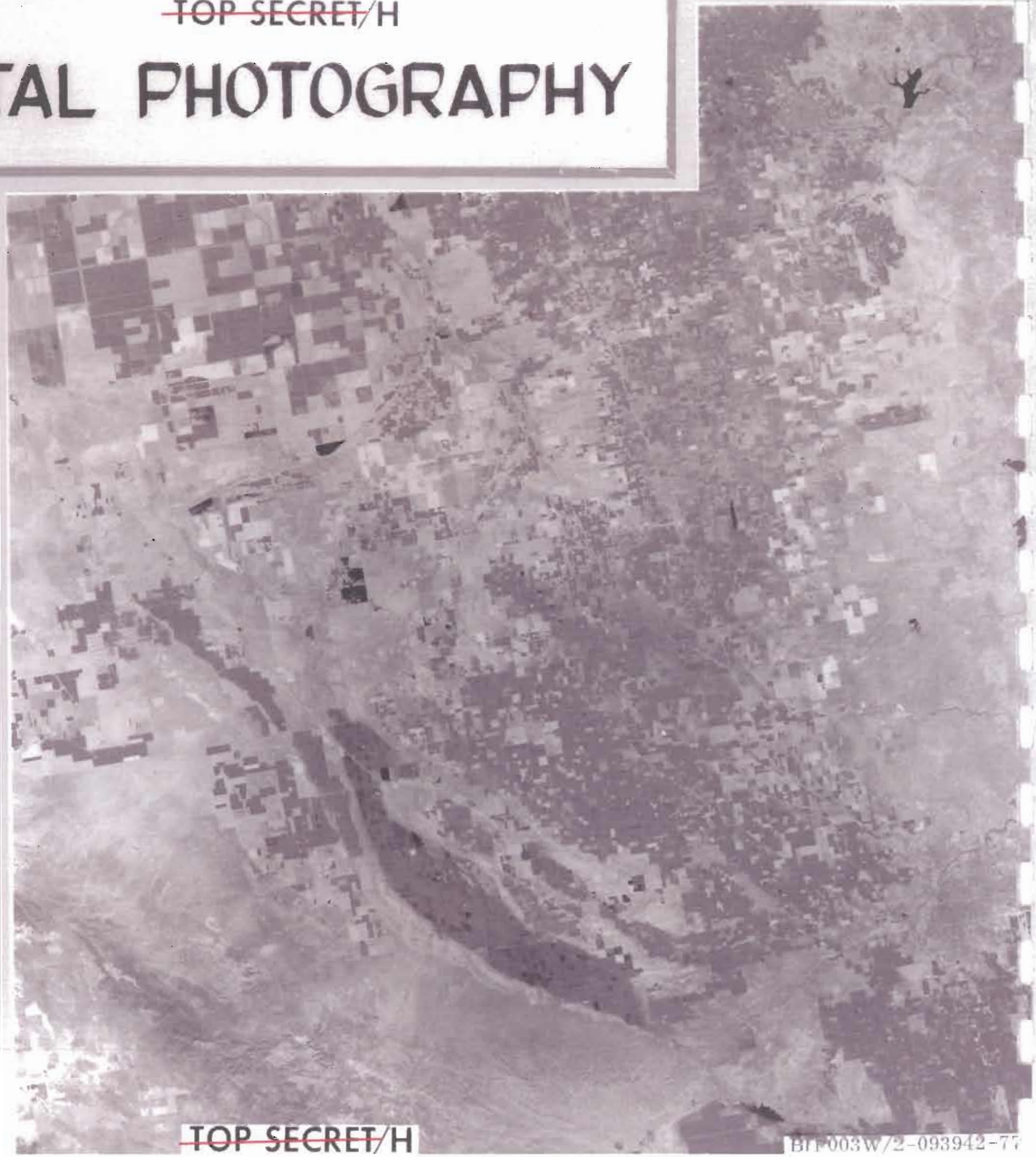
- UNITED STATES GEOLOGICAL SURVEY 1:62,000 MAP PUBLISHED 1959
- TERRAIN PHOTO OVERLAY MISSION 1211 1976

BIF003W/2-093942-77

TOP SECRET/H

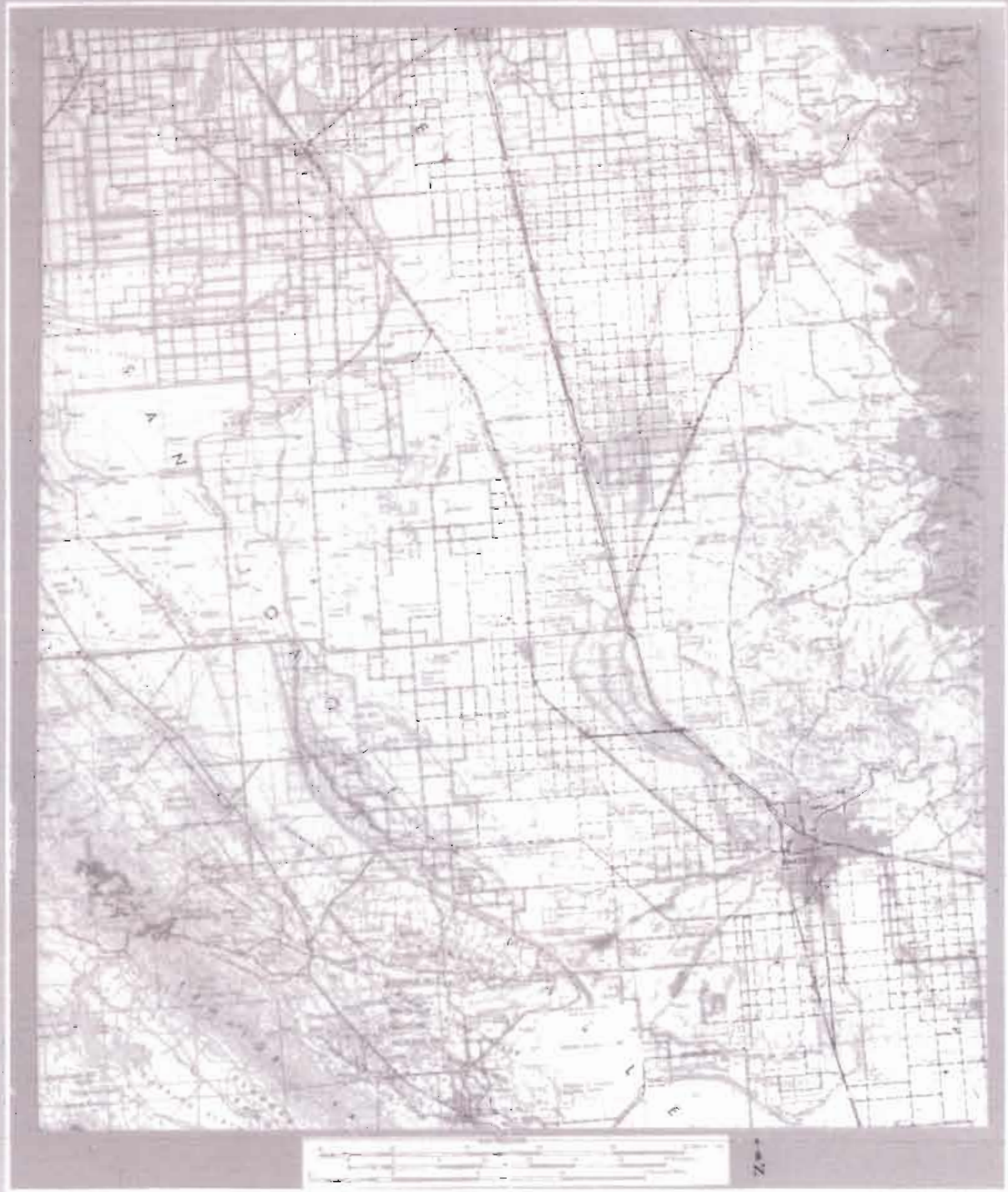
EXPERIMENTAL PHOTOGRAPHY

- SAN JOAQUIN VALLEY
- MISSION 1206
  CONTACT PRINT
  S0131 FILM
  (IR FALSE COLOR)



SAN JOAQUIN VALLEY

- US GS MAP OF SAN JOAQUIN VALLEY



AREA ACCESSED PER MISSION

ACTUAL TERRAIN COVERAGE

MISSION (NUMBER)	MISSION LENGTH (DAYS)	TOTAL AREA ACCESSED (THOUSAND SQ NM)	EQUIVALENT AREA ACCESSED (SQ NM)		
			CONUS (2.26 M)	S. AMERICA (5.20 M)	AFRICA (8.95 M)
1205	40	5894	2.6 X	1.1 X	0.6 X
1206	42	6282	2.8 X	1.2 X	0.7 X
1207	58	6671	3.0 X	1.3 X	0.7 X
1208	60	6487	2.9 X	1.3 X	0.7 X
1209	59	6773	3.0 X	1.3 X	0.8 X
1210	52	6668	3.0 X	1.3 X	0.7 X
1211	60	6919	3.1 X	1.3 X	0.8 X
1212	62	7363	3.3 X	1.4 X	0.8 X
1213	112	8099	3.6 X	1.6 X	0.9 X

GLOBAL COVERAGE 1212

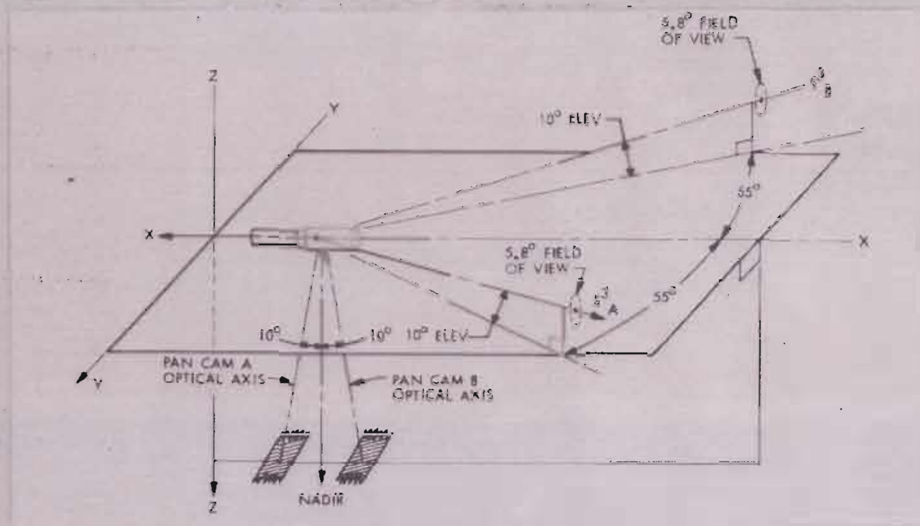
METRIC PAN CAMERA SYSTEM-ATTITUDE DETERMINATION

The metric pan camera attitude determination provides accurate coordinates of selected geographic points to be used as control points for compiling maps. It derives image space angles from measured space coordinates and requires auxiliary data to establish absolute coordinates and base distances; e.g., accurate ephemeris data and time of exposure, the angular orientation of the stellar relative to the pan terrain camera (interlock), the stellar angular orientation and camera angular motion history are the required data.

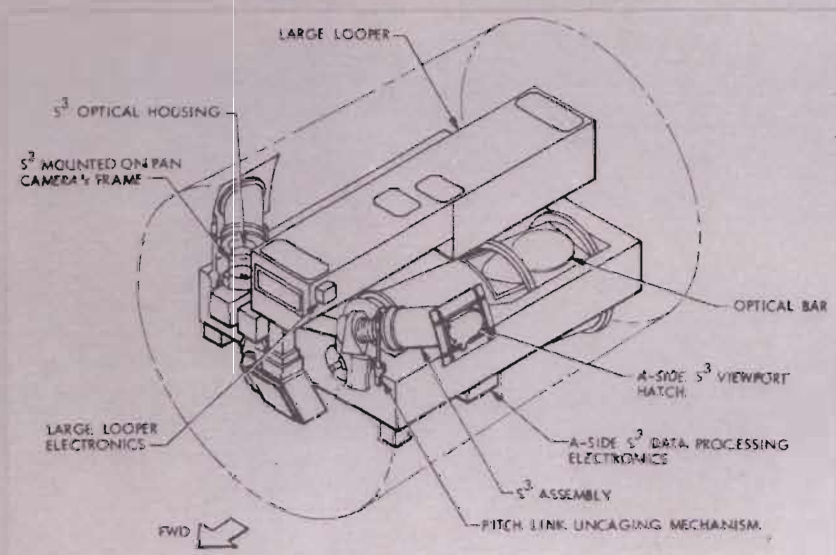
Stellar orientation data is acquired by a solid state electronic camera system accurate enough to determine pan camera line-of-sight pointing to within 5 arc seconds (1 σ). Two stellar cameras will be mounted on the TCA frame, one on each side of the SV, with line-of-sight elevation of 10 degrees up from horizontal and 55 degrees aft in azimuth. Data of star image detections will be processed and stored in existing on-board recorder. This data will be read out to supporting tracking stations and will be processed off-line. Film markings will be provided correlating stellar camera star image detections and pan photography time.

SV rigid body motion history during photography is obtained from the current ARM rate gyros through the existing telemetry system. Vibration and thermal distortion motions are accounted for in on-ground data processing. Implementation is scheduled for SV-17 and up superseding the Mapping Camera System (MCS) previously described.

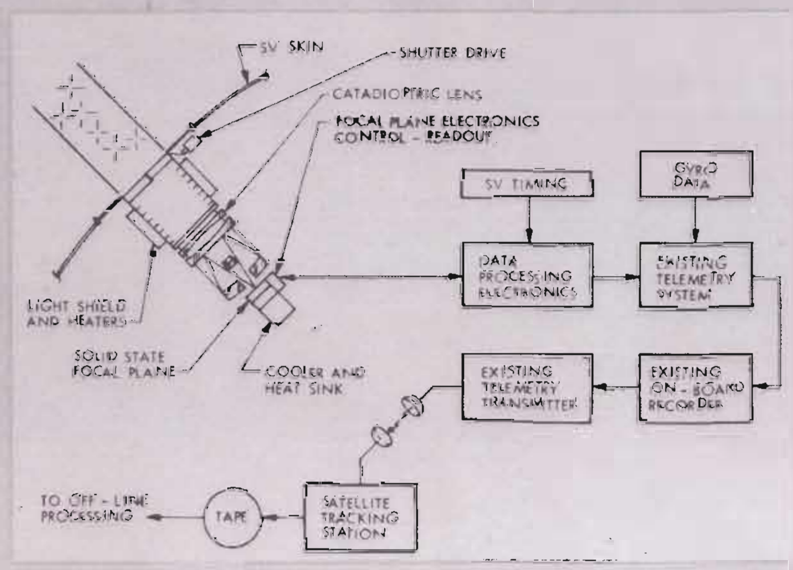
METRIC PAN CAMERA SYSTEM



ATTITUDE DETERMINATION



STELLAR SOLID STATE (S^3) CAMERA ASSEMBLY



STELLAR CAMERA DATA FLOW

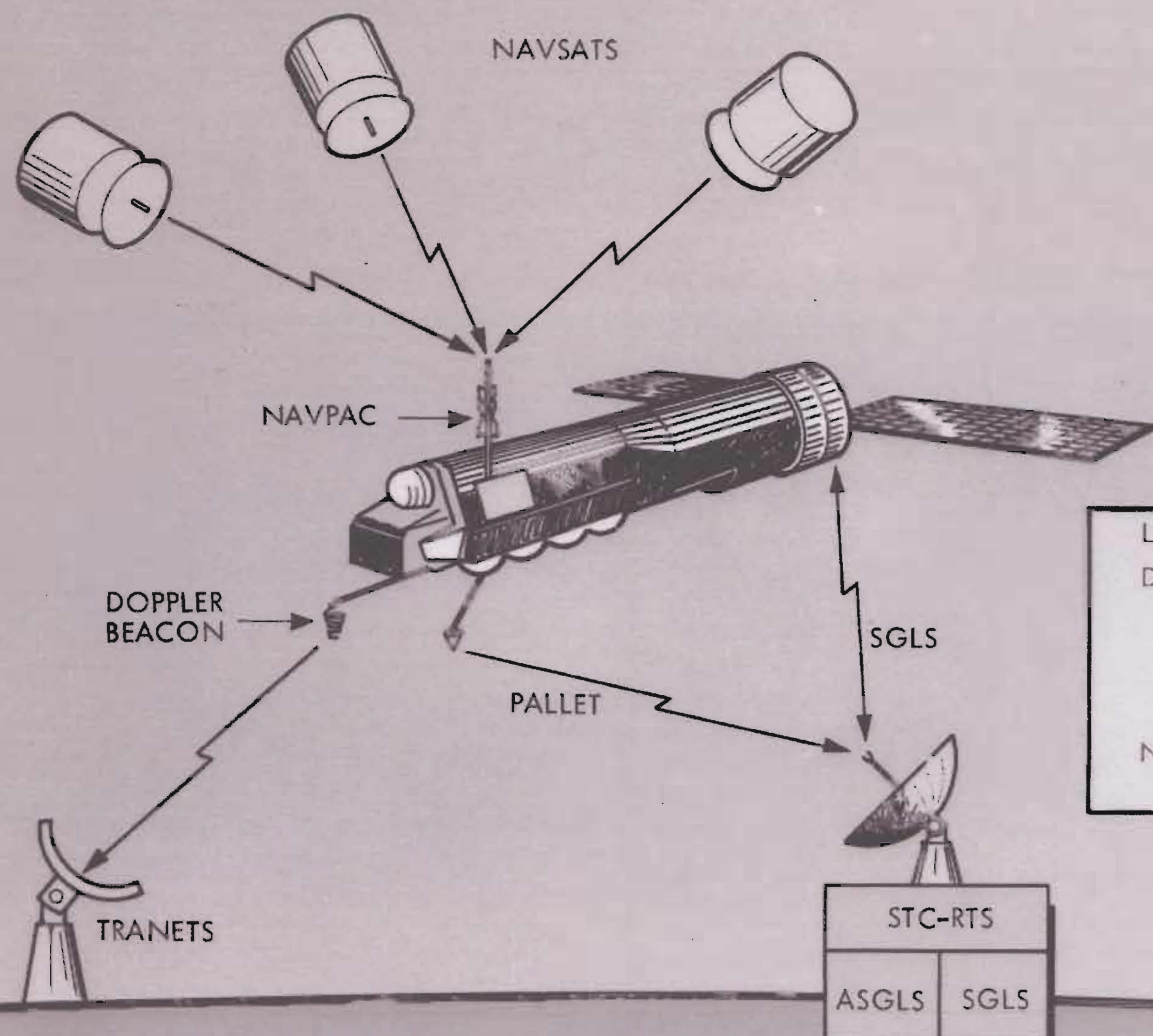
METRIC PAN CAMERA SYSTEM-LOCATION DETERMINATION

The primary tracking system for the reconstruction of an accurate ephemeris has been the Doppler Beacon System (DBS) using a worldwide network of geoceivers. This subsystem is a dual oscillator of ultra high stability which provides a method for the accurate tracking of the Satellite Vehicle by the supporting station network. The electronics and the antenna are currently mounted on the mapping camera system. The plan is to install the antenna on the forward bulkhead starting with SV-17, which will be configured without a mapping camera system.

The DBS will be redundant to the Navigational Package (NAVPAC), which will be the primary means by which a precision ephemeris can be reconstructed for mapping. NAVPAC consists of two sensing systems plus associated control and data processing hardware. The antenna/receiver system can acquire up to three Navy Navigation Satellites (NAVSATS) simultaneously and track the doppler and refraction frequencies. The miniature electrostatic accelerometer (MESA) provides data on all non-gravitational accelerations sensed. The delta processing unit collects, sorts, and time annotates all the data, recording NAVPAC times at which NAVSAT time marks are received, thus calibrating the NAVPAC clock. Timing accuracy is expected to be 1-2 microseconds.

NAVPAC is mounted on the -Y pallet with the antenna erected vertically above.

METRIC PAN CAMERA SYSTEM



LOCATION DETERMINATION

DBS ACCURACY

±200 FT IN-TRACK
±175 FT CROSS-TRACK
±100 FT RADIAL
ORBITAL VELOCITY ±0.12 FT/SEC

NAVPAC ACCURACY

≤ 30 FT ALL 3 AXIS

[redacted]

[redacted]

TOP SECRET/H

[redacted]

[redacted]

[redacted]

SATELLITE BASIC ASSEMBLY

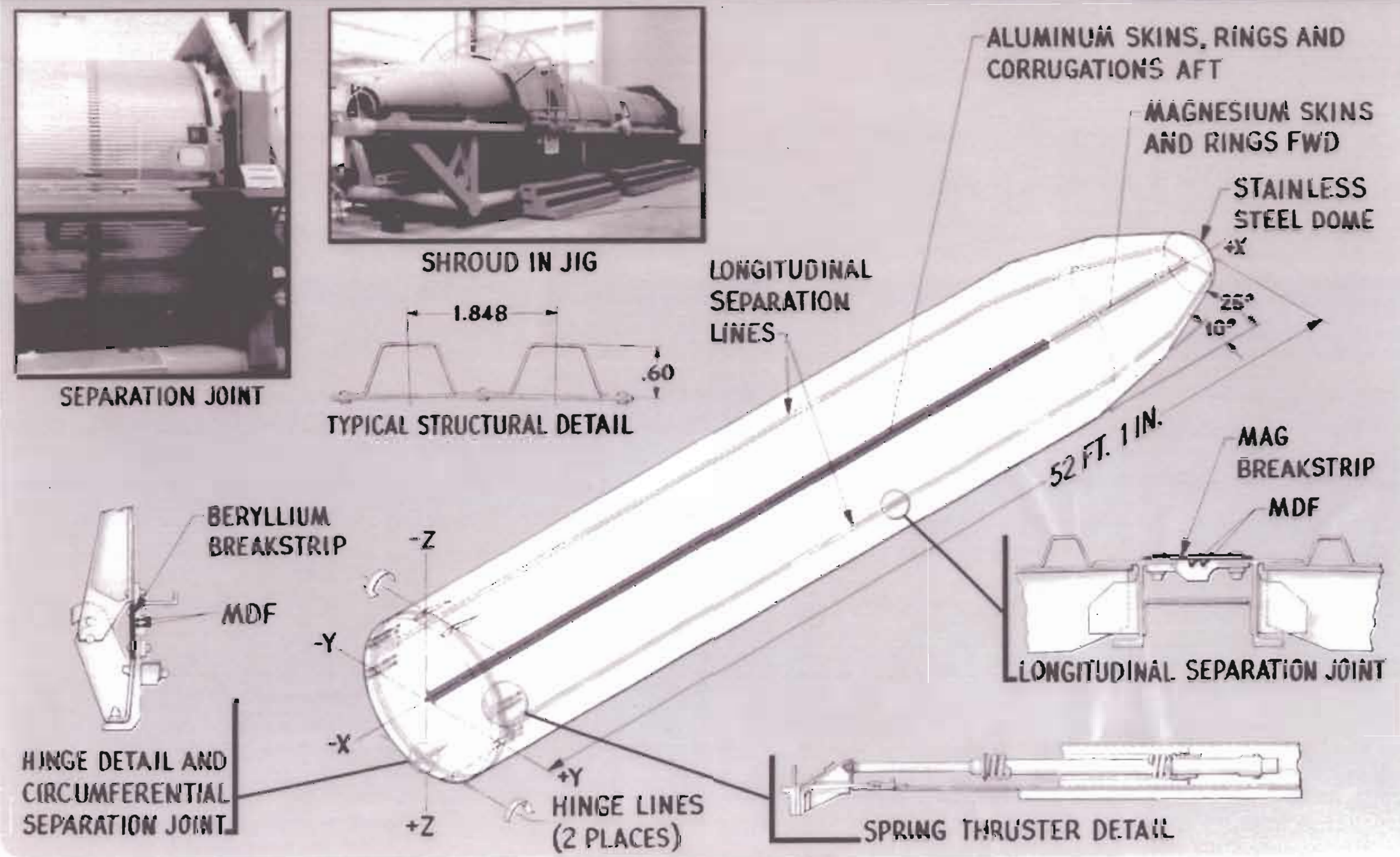
SHROUD CONFIGURATION

The shroud provides a protective enclosure for the payload on the launch pad and during ascent. It is a corrugated monocoque aluminum cylinder 52 ft long and 10 ft in diameter. Through air conditioning umbilicals and ducting the temperature and humidity are maintained at the desired values while on the launch pad.

Twenty-four removable doors provide access for servicing reentry vehicle igniters, sub-satellite trickle charge and arming, alignment checks of attitude reference to two-camera assembly reference axes, shroud thruster spring cocking, and shroud final pyro arming.

The shroud separates from the Satellite Vehicle after the pyrotechnic agent, Mild Detonating Fuse (MDF), breaks the magnesium longitudinal and beryllium circumferential breakstrips. Springs initiate the shell separation and then the acceleration from the booster Stage II cause the halves to fall away from the SV. No single failure in the pyrotechnic or electrical system will prevent shroud separation.

SHROUD CONFIGURATION



THERMAL CONTROL

Temperature control is maintained primarily by passive design techniques, with augmentation by electric heaters as required for special control and thermal uncertainties. The two-camera assembly is passively maintained within $70 \pm 23^{\circ}F$ and the film supply within $70 \pm 30^{\circ}F$ by isolating them from the earth-facing environment and coupling to the upper-vehicle surfaces (cocoons). The temperature gradient requirement along the film path is $5^{\circ}F$ or less and cannot be met with a passive design; temperature sensors, heaters and control logic are required.

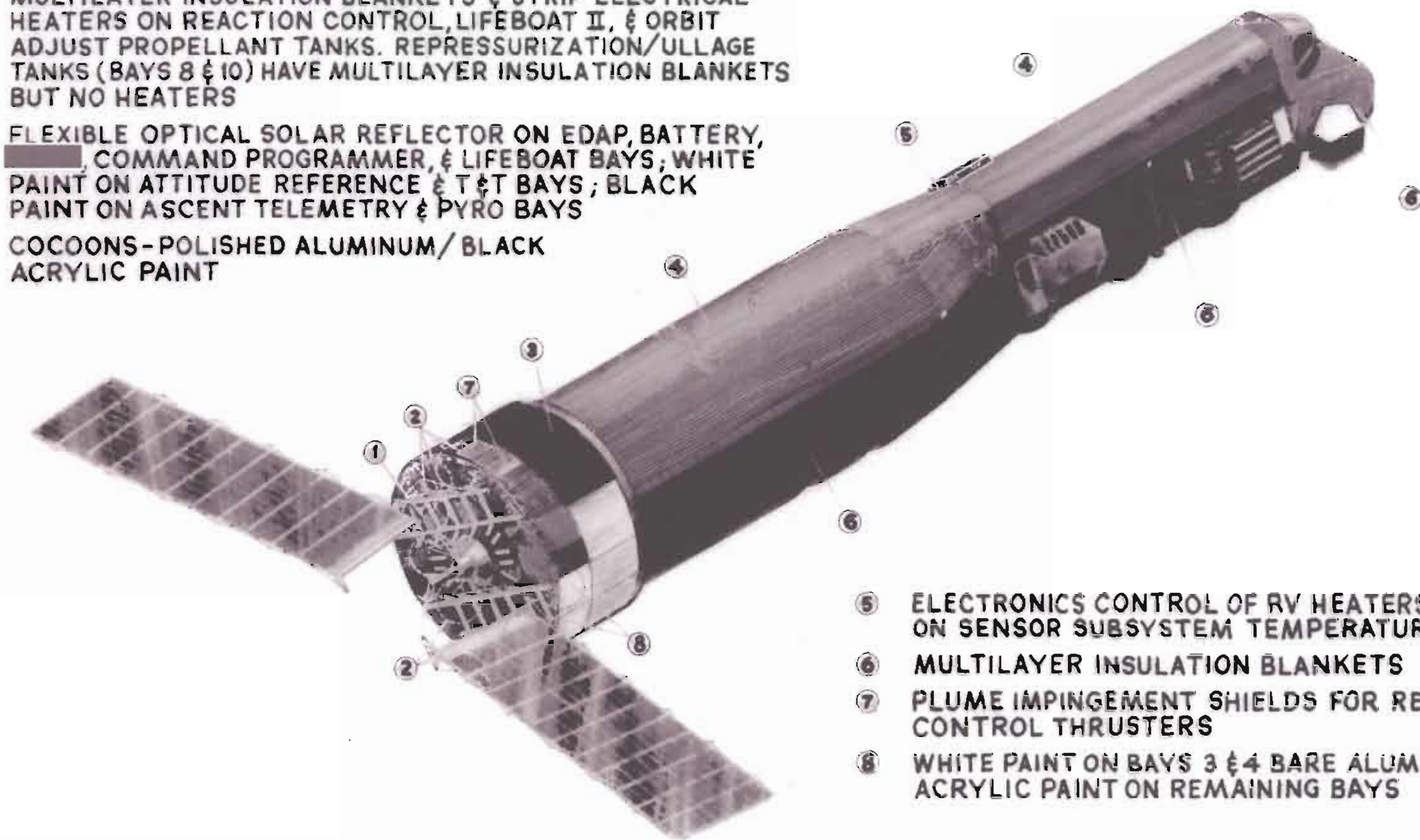
In the Aft Section, the conflicting requirements of keeping the electronic equipment temperature down and the propellant and thruster temperatures up cannot be met passively. Heaters are provided to keep the OAS propellant above $70^{\circ}F$, to heat the OAS engine to $70^{\circ}F$ before starting, to keep the RCS engines above $100^{\circ}F$, and to prevent hydrazine from freezing in the RCS tanks and OAS valves. However, these heaters are usually not required for nominal conditions.

Rechargeable (type-40) batteries are provided with heaters because the $30^{\circ}F$ to $70^{\circ}F$ temperature limits are tighter than the passive design uncertainties allow. The Lifeboat tanks can be heated to increase their impulse capacity.

The thermal design provides required temperature control over a beta angle range of -8 to +60 degrees for the complete range of vehicle activity level and resulting power dissipation with a single paint pattern. Larger negative beta angles are not permitted since the contamination of the thermal control surface by the booster causes the batteries to run at too high a temperature. When [redacted] metric pan camera stellar sensors are flown, the beta angle is limited to +30 degrees.

THERMAL CONTROL

1. ORBIT ADJUST VALVE SHIELD & HEATER
2. MULTILAYER INSULATION BLANKETS & STRIP ELECTRICAL HEATERS ON REACTION CONTROL, LIFEBOAT II, & ORBIT ADJUST PROPELLANT TANKS. REPRESSURIZATION/ULLAGE TANKS (BAYS 8 & 10) HAVE MULTILAYER INSULATION BLANKETS BUT NO HEATERS
3. FLEXIBLE OPTICAL SOLAR REFLECTOR ON EDAP, BATTERY, [redacted], COMMAND PROGRAMMER, & LIFEBOAT BAYS; WHITE PAINT ON ATTITUDE REFERENCE & T&T BAYS; BLACK PAINT ON ASCENT TELEMETRY & PYRO BAYS
4. COCOONS-POLISHED ALUMINUM/ BLACK ACRYLIC PAINT



5. ELECTRONICS CONTROL OF RV HEATERS-BASED ON SENSOR SUBSYSTEM TEMPERATURE
6. MULTILAYER INSULATION BLANKETS
7. PLUME IMPINGEMENT SHIELDS FOR REACTION CONTROL THRUSTERS
8. WHITE PAINT ON BAYS 3 & 4 BARE ALUMINUM/BLACK ACRYLIC PAINT ON REMAINING BAYS

SATELLITE BASIC ASSEMBLY STRUCTURE

The SBA structure, shown in the cut-away drawing, is of semimonocoque construction. The booster adapter section has aluminum skin, rings, and stringers. This section contains the booster separation joint, which uses 2-1/2 grain/ft of mild detonating fuse to break a circumferential beryllium strip.

The OAM/RCM section has corrugation-reinforced aluminum skin with aluminum and magnesium internal structure. This section contains the propulsion elements and the solar array modules.

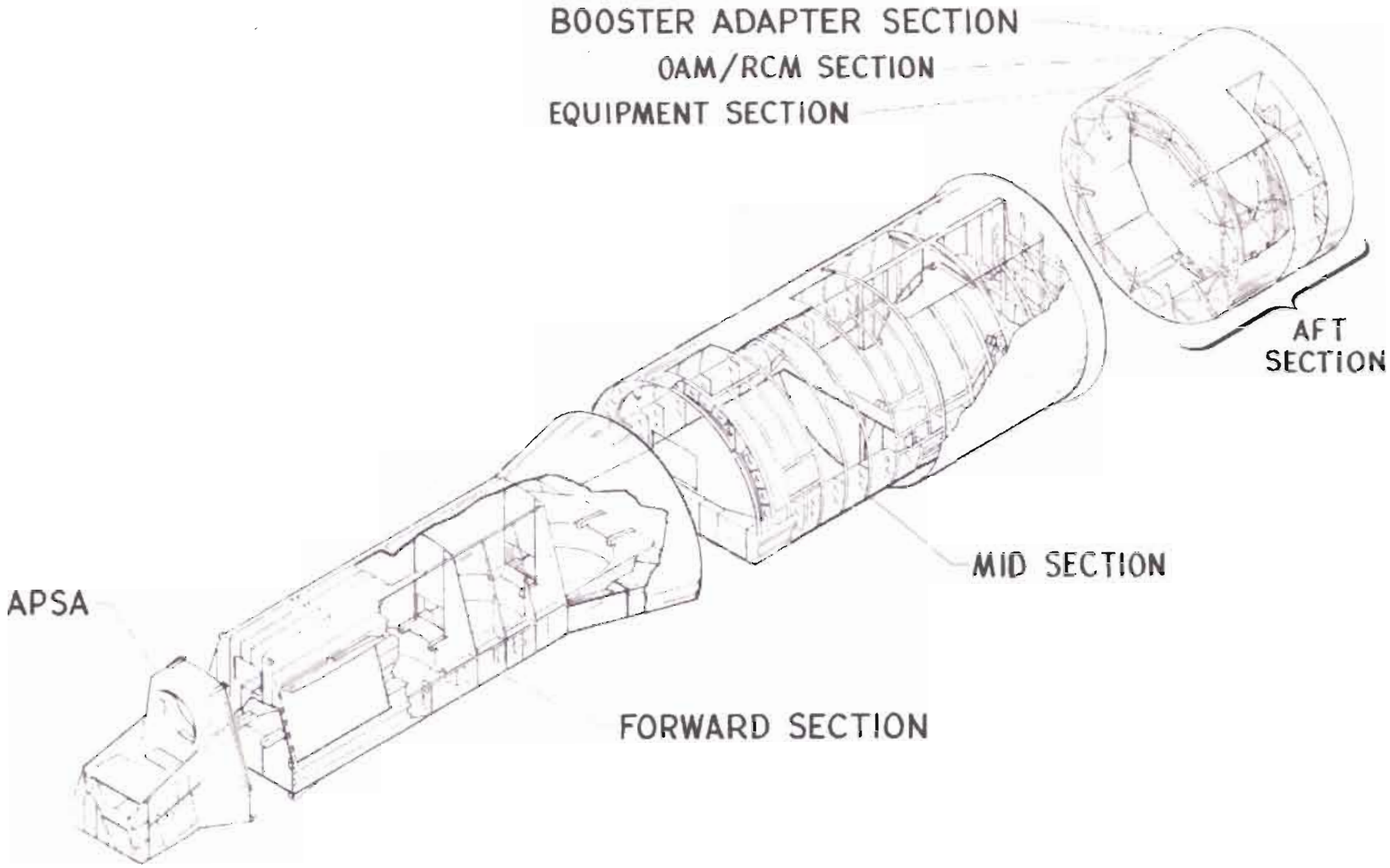
The equipment section has twelve removable corrugation reinforced aluminum skin panels bolted to an aluminum tubular internal structure which supports honeycomb equipment panels. Guidance, communication, command, and power components are mounted on these panels as subsystem modules.

The Mid-Section has a short titanium conical section and a cylindrical section of magnesium skin, with magnesium hat-section longitudinal stiffeners. Magnesium and titanium internal structure supports the primary payload.

The Forward Section has aluminum and magnesium skin with magnesium hat-section longitudinal stiffeners. The internal magnesium and aluminum structure with titanium fittings supports the four (4) reentry vehicles. The Mapping Camera System, [redacted] are supported on the external surfaces of the Forward Section.

The Mapping Camera System is supported in the Auxiliary Payload Structure Assembly (APSA).

SATELLITE BASIC ASSEMBLY STRUCTURE



SATELLITE BASIC ASSEMBLY-AFT SECTION

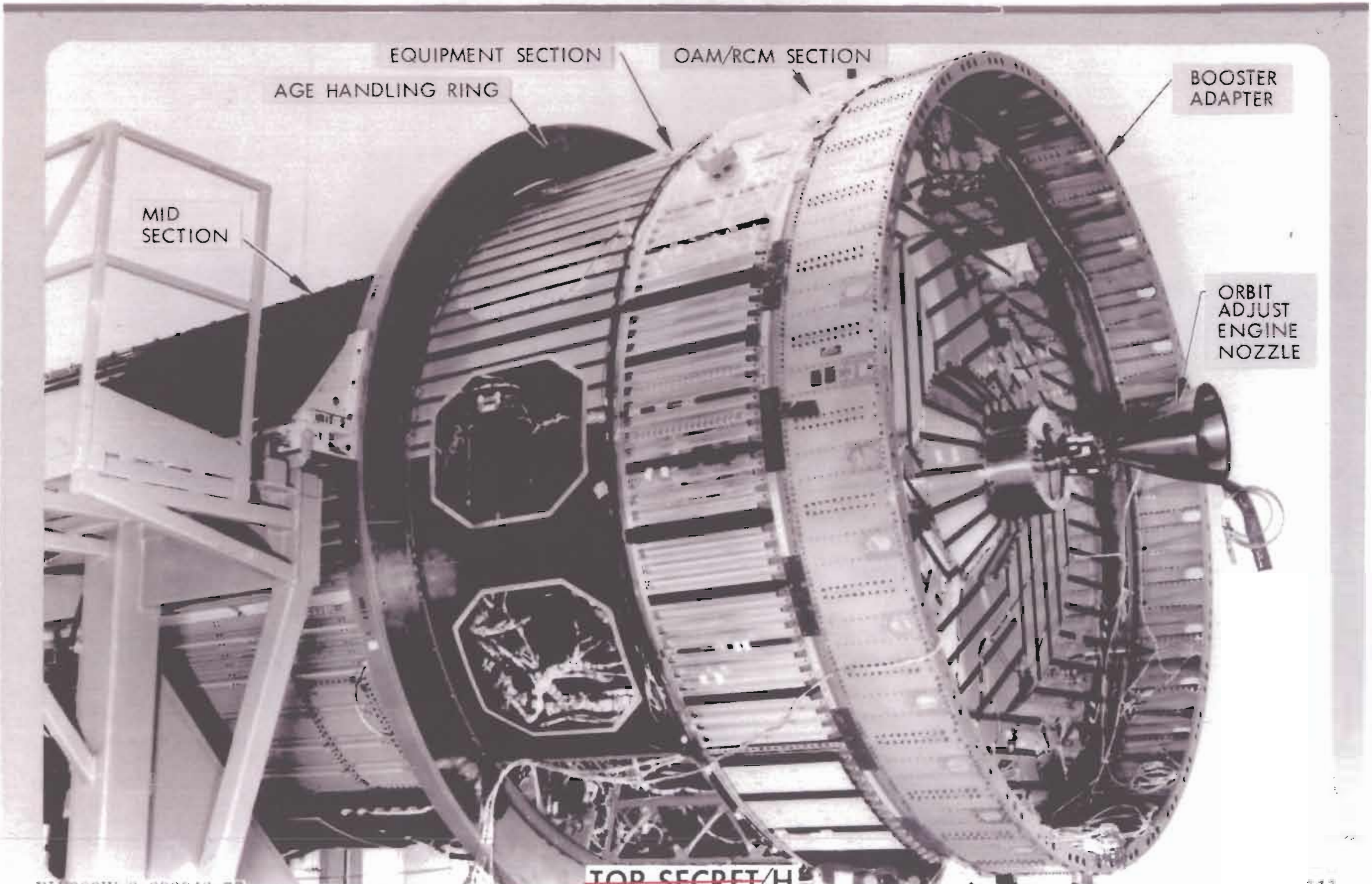
The Aft Section consists of an equipment module, a booster adapter section, and an Orbit Adjust Module/ Reaction Control Module (OAM/RCM). It is 10 ft in diameter and 5 ft long. This section is a semimonocoque structure with a corrugated aluminum external skin. It weighs approximately 3500 pounds, including all equipment, less expendables. The Aft Section provides environmental protection and thermal control during ground, ascent, and orbital operations. The structure is capable of withstanding the dynamic and static conditions imposed during all phases of ground handling, launch, ascent, and orbit. The Aft Section interfaces with the booster, Mid Section, ground AGE, main electrical umbilical, pressurization and propellant loading lines, and the battery cooling lines.

The booster adapter section mates the Satellite Vehicle to the Titan IIID booster. The adapter is equipped with 70 square inches of vent area. The separation joint with a redundant pyrotechnic system is a part of this section.

The OAM/RCM section houses and supports the OAS/RCS hydrazine systems which provide orbit and attitude control, the independent lifeboat freon gas system which provides emergency attitude control, and the solar array modules which generate power. This section interfaces with ground pressurization and propellant loading lines. The solar array modules which mount on the aft bulkhead adjacent to the OA engine nozzle are not shown in the photograph.

The equipment section consists of 12 equally spaced, equally sized bays, each capable of supporting up to 500 pounds of equipment on individual trays. Two bays are presently unused and are available for growth items. Each equipment bay provides sufficient access to allow complete module installation and removal at the factory and pad as shown in the lower completely open bay. The other bays as shown have non-flight panels with ground access doors used in factory assembly and test. This section interfaces with the main electrical umbilical and the Mid Section.

SATELLITE BASIC ASSEMBLY-AFT SECTION



ATTITUDE CONTROL

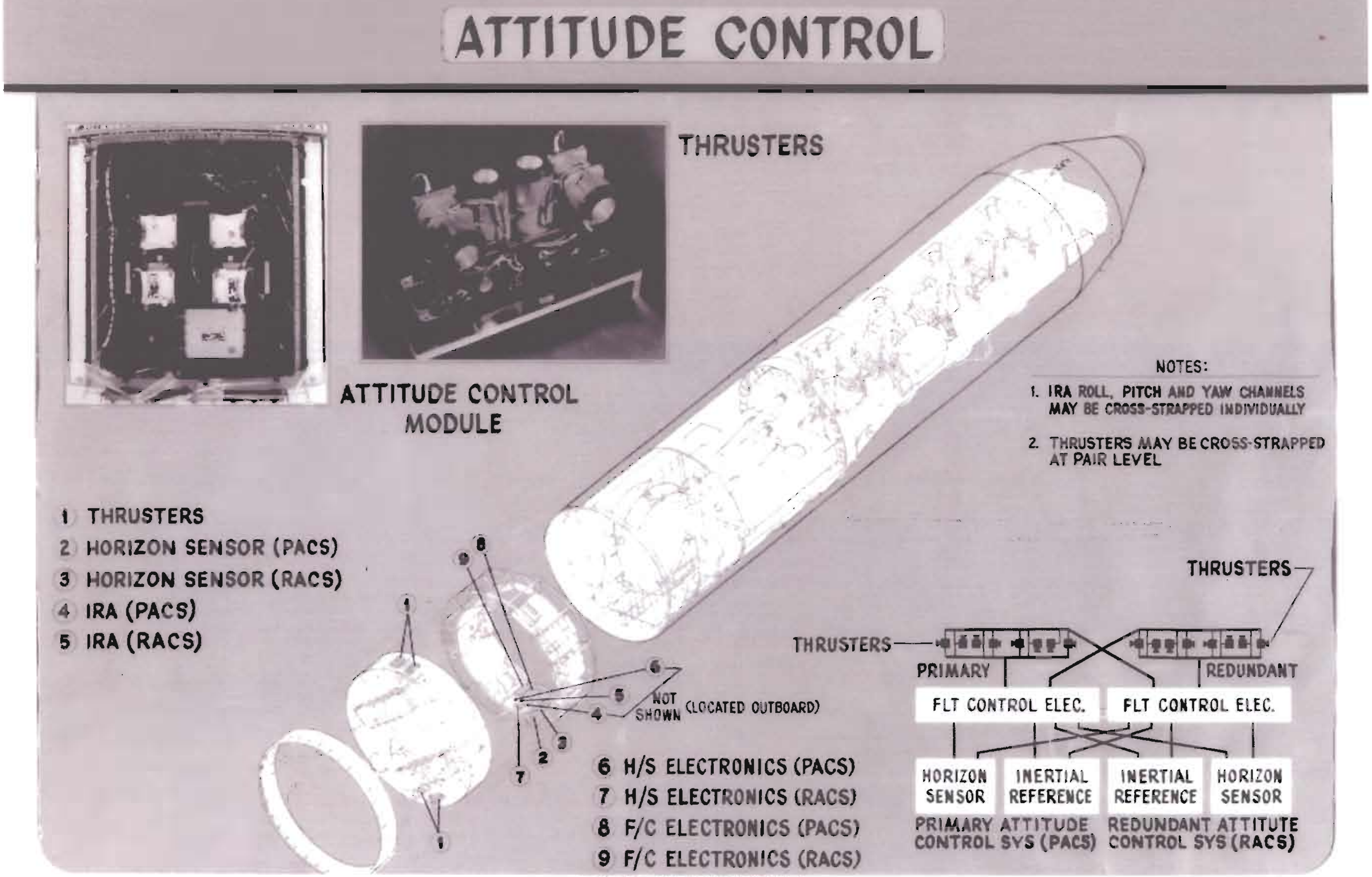
The Attitude Control System (ACS) provides earth-oriented attitude reference and rate sensing. It develops RCS thruster firing signals to bring the vehicle to a commanded attitude and to maintain attitude and rate within the accuracies shown below. The ACS also provides measurements of vehicle attitude and rate during search/surveillance operation to the accuracy shown.

The ACS is a three-axis rate gyro-integrator system with updating in pitch and roll by horizon sensor and in yaw by gyro-compassing. Error signals generated by the gyros and horizon sensor are combined in the flight control electronics, and modulated by pseudo-rate circuits in each axis to provide thruster firing commands with the impulse bit control necessary to meet the tight rate control and short settling-time requirements.

All elements are redundant for malfunction correction. Cross-strapping between redundant and primary ACS components (horizon sensors, gyros, flight control electronics assembly) is possible to permit selection of non-failed components to drive the RCS thruster.

	Control Requirements			Measurement Requirements		
	Pitch	Roll	Yaw	Pitch	Roll	Yaw
For search/surveillance operations						
Attitude accuracy (deg)	0.7	0.7	0.64	0.4	0.4	0.5
Rate accuracy (deg/sec)	0.014	0.021	0.014	0.001	0.001	0.001
During non-horizontal operations						
Attitude accuracy (deg)	3	1	1			
Rate accuracy (deg/sec)	0.15	0.15	0.15			

Setting time from search/surveillance disturbances: Stereo 0.2 seconds, Mono 6 seconds


ATTITUDE CONTROL
THRUSTERS
ATTITUDE CONTROL MODULE
NOTES:
1. IRA ROLL, PITCH AND YAW CHANNELS MAY BE CROSS-STRAPPED INDIVIDUALLY
2. THRUSTERS MAY BE CROSS-STRAPPED AT PAIR LEVEL
1 THRUSTERS
2 HORIZON SENSOR (PACS)
3 HORIZON SENSOR (RACS)
4 IRA (PACS)
5 IRA (RACS)
NOT SHOWN (LOCATED OUTBOARD)
6 H/S ELECTRONICS (PACS)
7 H/S ELECTRONICS (RACS)
8 F/C ELECTRONICS (PACS)
9 F/C ELECTRONICS (RACS)
THRUSTERS
THRUSTERS
PRIMARY
REDUNDANT
FLT CONTROL ELEC.
FLT CONTROL ELEC.
HORIZON SENSOR
INERTIAL REFERENCE
INERTIAL REFERENCE
HORIZON SENSOR
PRIMARY ATTITUDE CONTROL SYS (PACS)
REDUNDANT ATTITUTE CONTROL SYS (RACS)

ORBIT ADJUST AND REACTION CONTROL

An Orbit Adjust System (OAS) and Reaction Control System (RCS) provide the forces necessary to control the vehicle orbit and the vehicle attitude in orbit, respectively. The OAS provides injection error correction (if required), drag and perigee rotation makeup, and deorbit of the Satellite Vehicle at the end of the mission. The RCS provides pitch, yaw, and roll control via 8 thrusters.

OAS and RCS both use catalytic decomposition of monopropellant hydrazine to generate thrust. For reliability, the systems are pressure-fed, with the pressurizing gas enclosed in the propellant tank with the hydrazine. This results in declining or blowdown pressure characteristics; the thrust level of the OAS engine declines from 250 to 100 pounds and that of the RCS engines from 6 to 2 pounds. A quad-redundant valve operated by the command system controls flow to the OAS engine. The ACS generates signals that control the firing of the RCS engines.

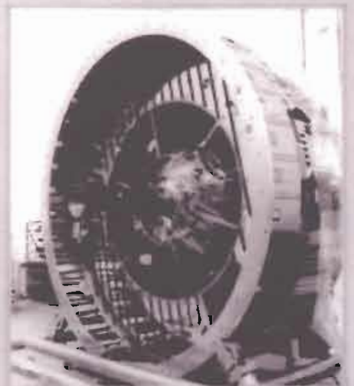
On SV-15 the 62-inch diameter OAS tank can be loaded with up to 4000 pounds of propellant with two spheres containing high pressure nitrogen (isolated by pyro valves and admitted into the OA tank at times selected during the mission) to maintain the pressure within the desired operating range. This propellant can be utilized in OA burns to provide velocity increments of 2 ft/sec to 400 ft/sec. A passive (surface tension) propellant management device maintains propellant at the tank outlet at all times, permitting engine firings in any attitude.

On Vehicles SV-13 and SV-14 the two nitrogen tanks are manifolded directly with the OA tank and provide enough ullage space to permit 3700 pounds of propellant to be loaded within the operating pressure range.

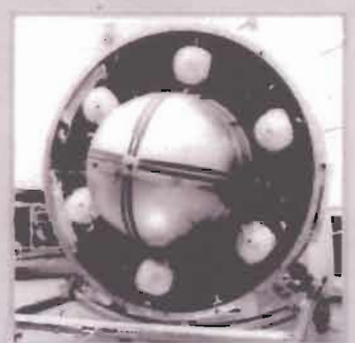
The four 22-in. diameter RCS tanks provided capacity for 450 to 540 pounds of propellant. Propellant orientation is maintained by diaphragms. The thruster impulse bit (0.15 lb-sec or less, depending on blowdown status) is compatible with the tight rate-control requirements. A complete redundant set of thrusters is provided for malfunction protection; either set can be supplied by the four tanks and each pair of thrusters can be driven by the primary or redundant ACS valve drivers.

A transfer line is provided between the OAS and RCS tanks to permit propellant exchange to optimize the use of on-board propellant for each mission.

ORBIT ADJUST & REACTION CONTROL

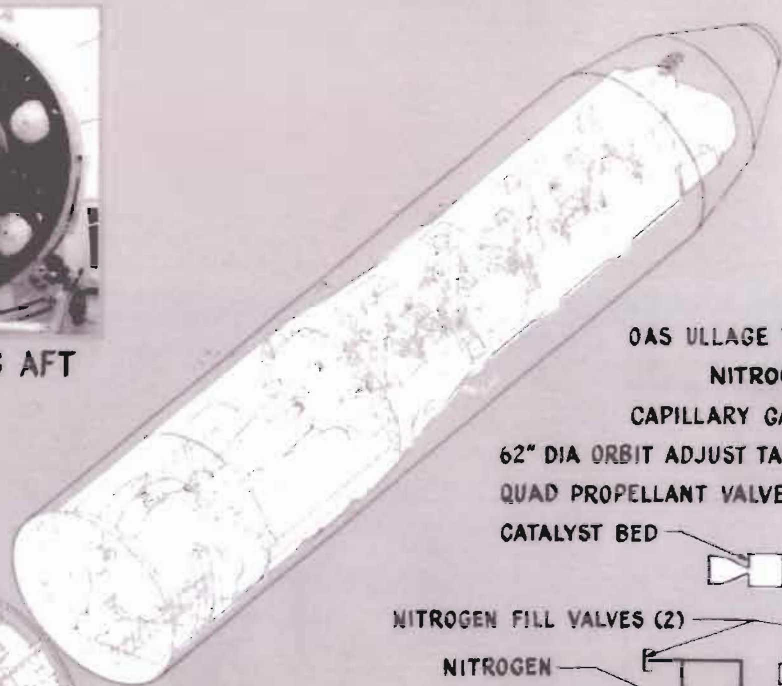


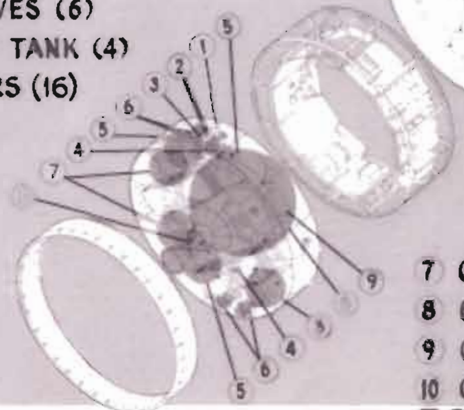
VIEW LOOKING FORWARD

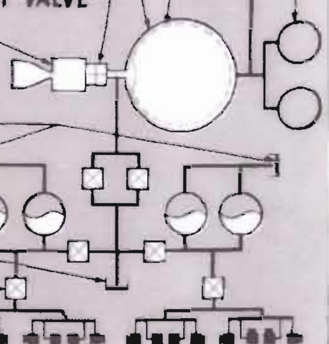


VIEW LOOKING AFT

1. OAS FILL VALVE
2. RCS GAS FILL VALVES (2)
3. RCS PROPELLANT FILL VALVE
4. ISOLATION VALVES (6)
5. RCS GAS/PROP TANK (4)
6. RCS THRUSTERS (16)







7. OAS ULLAGE TANKS (2)
8. 62" DIA. ORBIT ADJUST TANK
9. OA/RCM J-BOX
10. ORBIT ADJUST ENGINE

ELECTRICAL DISTRIBUTION AND POWER

Power to operate the Satellite Vehicle is provided by solar arrays deployed from the Aft Section following separation from the booster. Rechargeable NiCd batteries (type-40) provide energy storage to meet dark-side-earth and peak power requirements. Unregulated power is distributed throughout the vehicle to using equipment within a 24 to 33 vdc range.

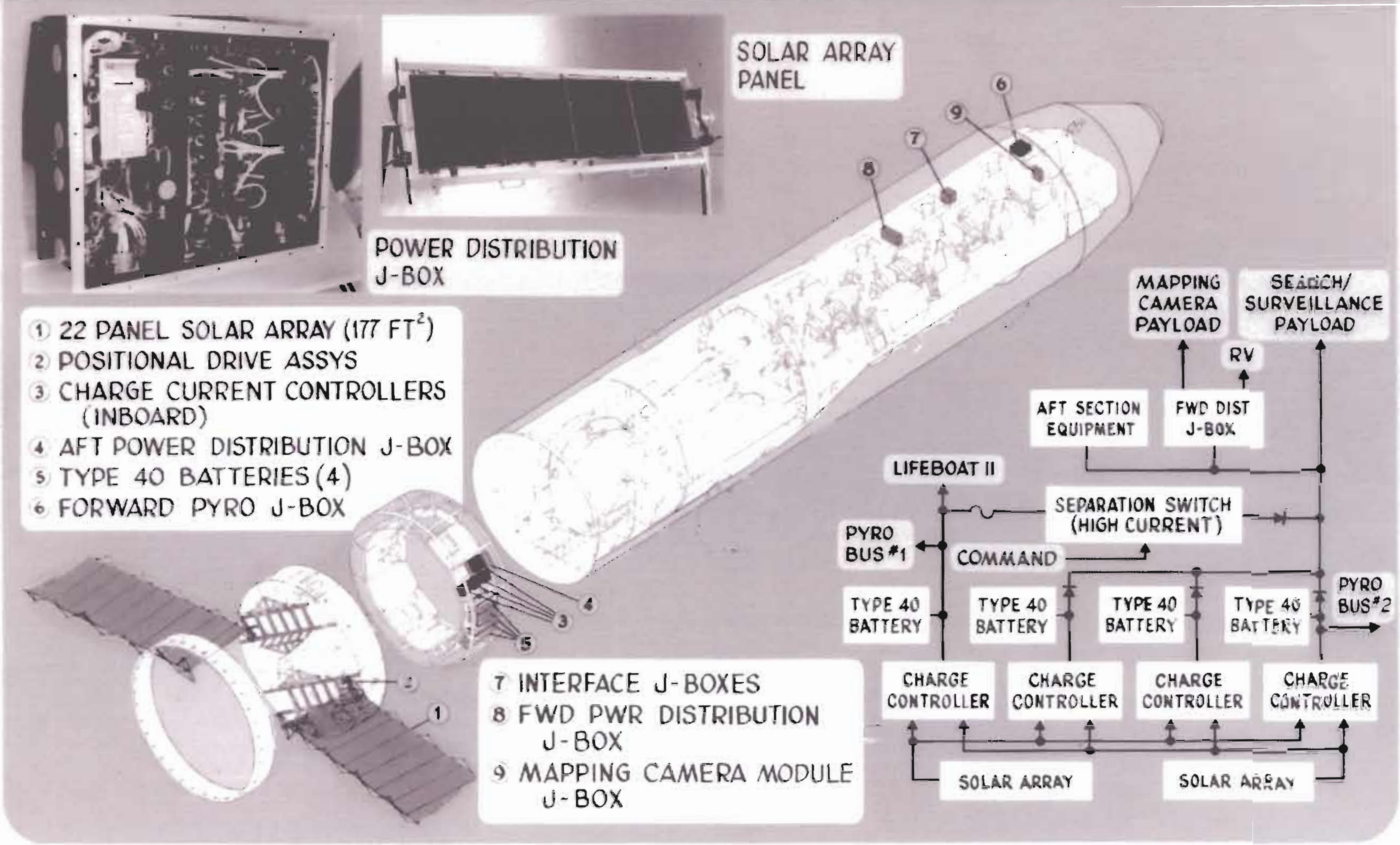
The power generation and storage system comprises four parallel segments, with an array section, charge controller, and battery in each to reduce the effect of a failure; a single malfunction will not terminate the mission. Fusing of equipment, limiting minimum wire size, and isolating voltage-critical circuits add to the reliability.

The power system is capable of providing approximately 11,000 watt-hours/day of usable power over a beta angle range of -8 to +60 deg by adjusting the array angle about the vehicle roll axis. This will support at least 52 minutes per day of search/surveillance and mapping camera system operation.

Power for the lifeboat system is provided by one type-40 battery from the main power system. Equipment necessary for recovery vehicle and Satellite Vehicle deorbit can be switched to this battery for emergency operations. Depletion of the batteries below 55 percent or an excessive load on the main power system will automatically isolate the lifeboat system and its battery. This assures adequate power for the emergency operations. The lifeboat system can be reconnected to the main system by command if the anomaly can be corrected.

Pyro power is provided by either of two type-40 batteries from the main power system and distributed by redundant circuits.

ELECTRICAL DISTRIBUTION & POWER

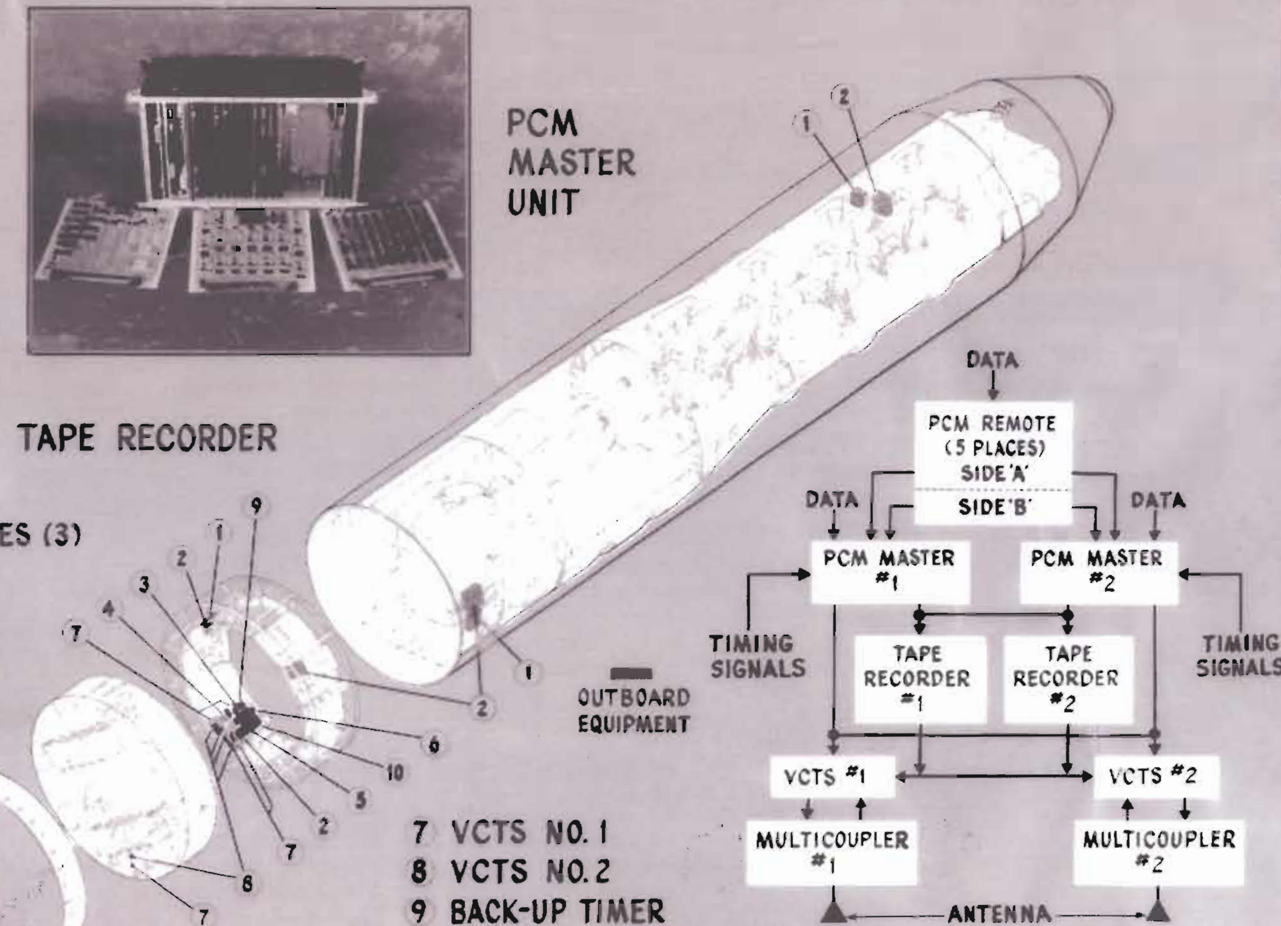


TELEMETRY AND TRACKING

The SGLS-compatible telemetry subsystem provides PCM real-time data (ascent at 48 kbps, engineering analysis at 128 kbps, and orbit at 64 kbps), and PCM tape recorded data (48 kbps played back at 256 kbps). The PCM telemeter provides status data for normal mission operation, test operations and evaluation, command acceptance confirmation, and postflight evaluation. Each tape recorder storage allows the monitoring of the SV temperature profile by periodic sampling. Over 1500 data sources are monitored – some at up to 500 samples per second.

The SGLS-compatible tracking subsystem provides range measurement information, including slant range (50 ft maximum 1σ bias error and 60 ft rms maximum noise error), range rate (0.2 ft/sec maximum 1σ error), and angle-of-arrival (1.0 milliradian maximum 1σ bias error and 1.0 milliradian rms maximum noise error).

TELEMETRY & TRACKING



TAPE RECORDER

1 INSTRUMENTATION J-BOXES (3)
2 PCM REMOTE (5)
3 PCM MASTER NO. 1
4 PCM MASTER NO. 2
5 TAPE RECORDER NO. 1
6 TAPE RECORDER NO. 2
7 VCTS NO. 1
8 VCTS NO. 2
9 BACK-UP TIMER
10 CONTROL J-BOX TYPE-1

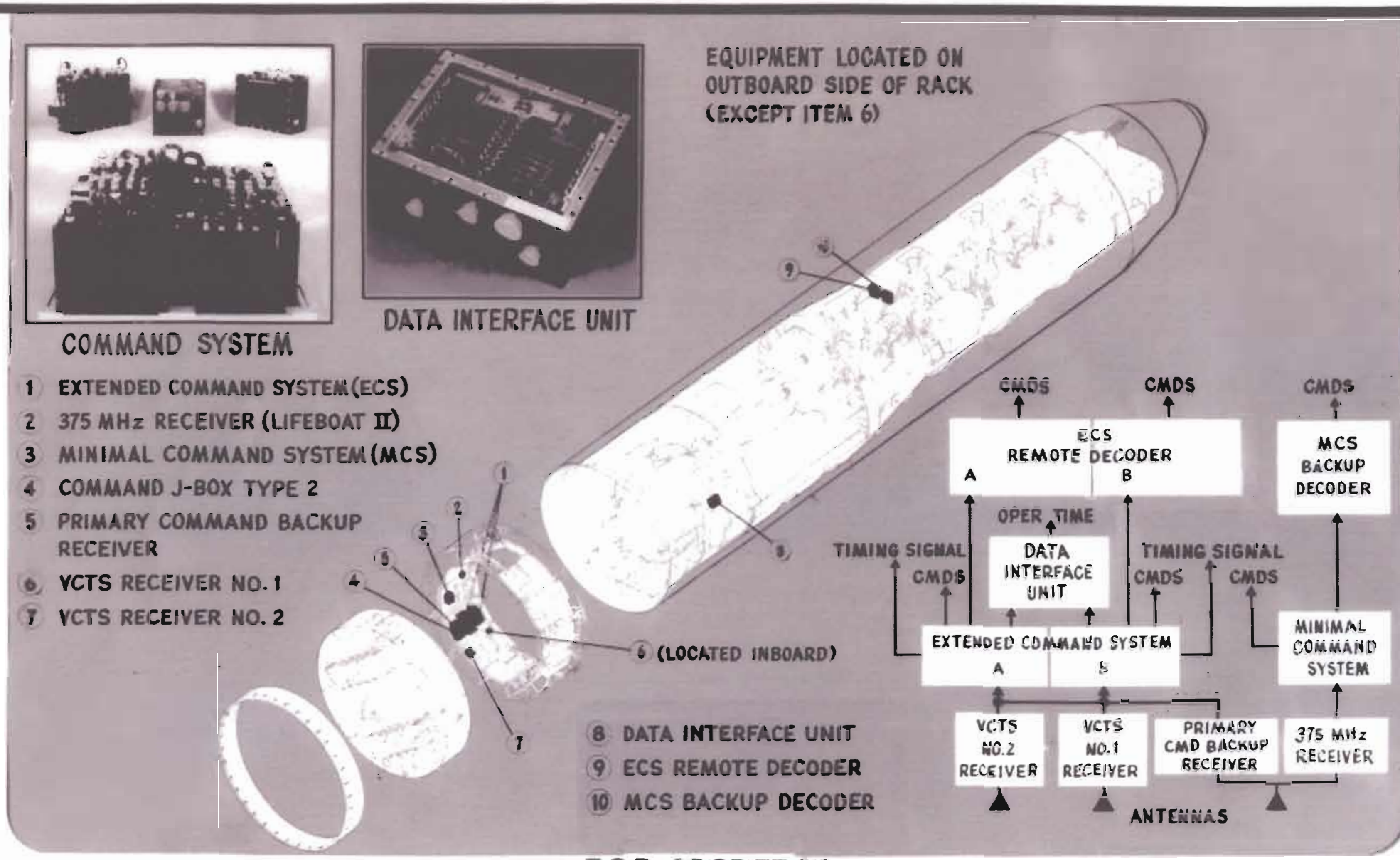
COMMAND AND TIMING

The Extended Command System (ECS) provides real-time and stored-program command capability. The SGLS compatible ECS system with complete redundancy provides 64 real-time and 626 stored-program commands with a memory capability of 1152 commands. Ninety-six secure command operations are possible. On SV-15 and up the number of secure command operations will be increased to 192. The ECS provides operational commands to perform primary and secondary missions, the capability to configure the vehicle into various operational modes, a pre-flight test and checkout capability, security for critical functions, and a time signal to the PCM and the payload.

The Minimal Command System (MCS) provides 28 real-time and 66 stored-program commands with a memory capability of 53 commands. Ten secure command operations are available. The MCS provides lifeboat commands for an independent capability of recovery RVs and initiating SV deboost and the capability to obtain real-time and recorded telemetry data.

The Data Interface Unit (DIU) provides for the generation, storage and transfer of time information to the search/surveillance camera, mapping camera, telemetry, [redacted] The DIU also provides the mapping camera system and pan camera time request pulse to the NAVPAC experiment.

COMMAND & TIMING



LIFEBOAT II

The lifeboat system provides emergency capability to initiate separation of two Reentry Vehicles (RV) and to deorbit the Satellite Vehicle in the event of a complete failure of the main power system. the attitude control system, or the extended command system.

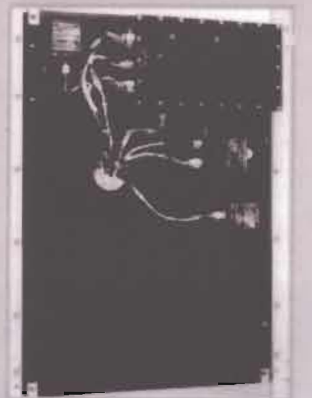
Emergency operational control is provided by the 375 MHz receiver and minimal command system, with capability for real-time, stored-program, and secure commands.

Attitude control for RV releases and SV deorbit is provided by earth-field sensing magnetometers, rate gyros, and a cold gas (freon 14) control force system. Lifeboat is capable of RV releases and SV deorbit operations on both south-to-north and north-to-south passes.

Power to keep the system ready for use, and for the emergency operations is provided by a type-40 battery and 1/4 of the solar arrays from the main power system. The OAS engine and the redundant SGLS, PCM, tape recorder, and other equipment necessary for RV release, SV deorbit, and recovery of vehicle diagnostic data are switched from the main power system to the lifeboat bus for the emergency operations. In a nominal tumbling mode, enough power is generated to keep this emergency mode operating until the vehicle reenters.

LIFEBOAT II

OUTBOARD VIEW

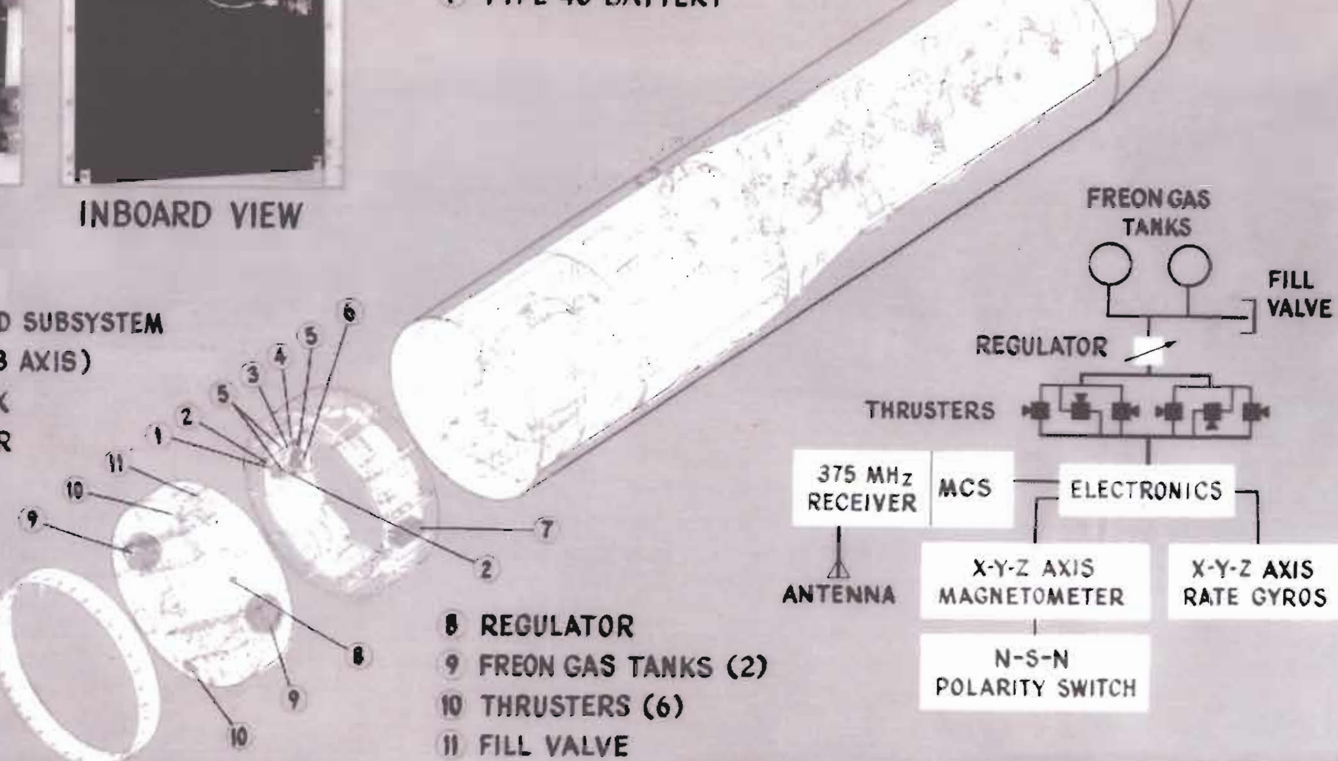


INBOARD VIEW

5 RATE GYRO (3)
6 ELECTRONICS
7 TYPE 40 BATTERY

1 MINIMAL COMMAND SUBSYSTEM
2 MAGNETOMETER (3 AXIS)
3 LIFEBOAT II J-BOX
4 375 MHz RECEIVER

8 REGULATOR
9 FREON GAS TANKS (2)
10 THRUSTERS (6)
11 FILL VALVE



HARDWARE FLOW

The HEXAGON integrated test program begins at the piece-part level and continues through component, module and vehicle levels of assembly. Testing at progressive levels of assembly permits workmanship faults to be identified and eliminated early in the test program.

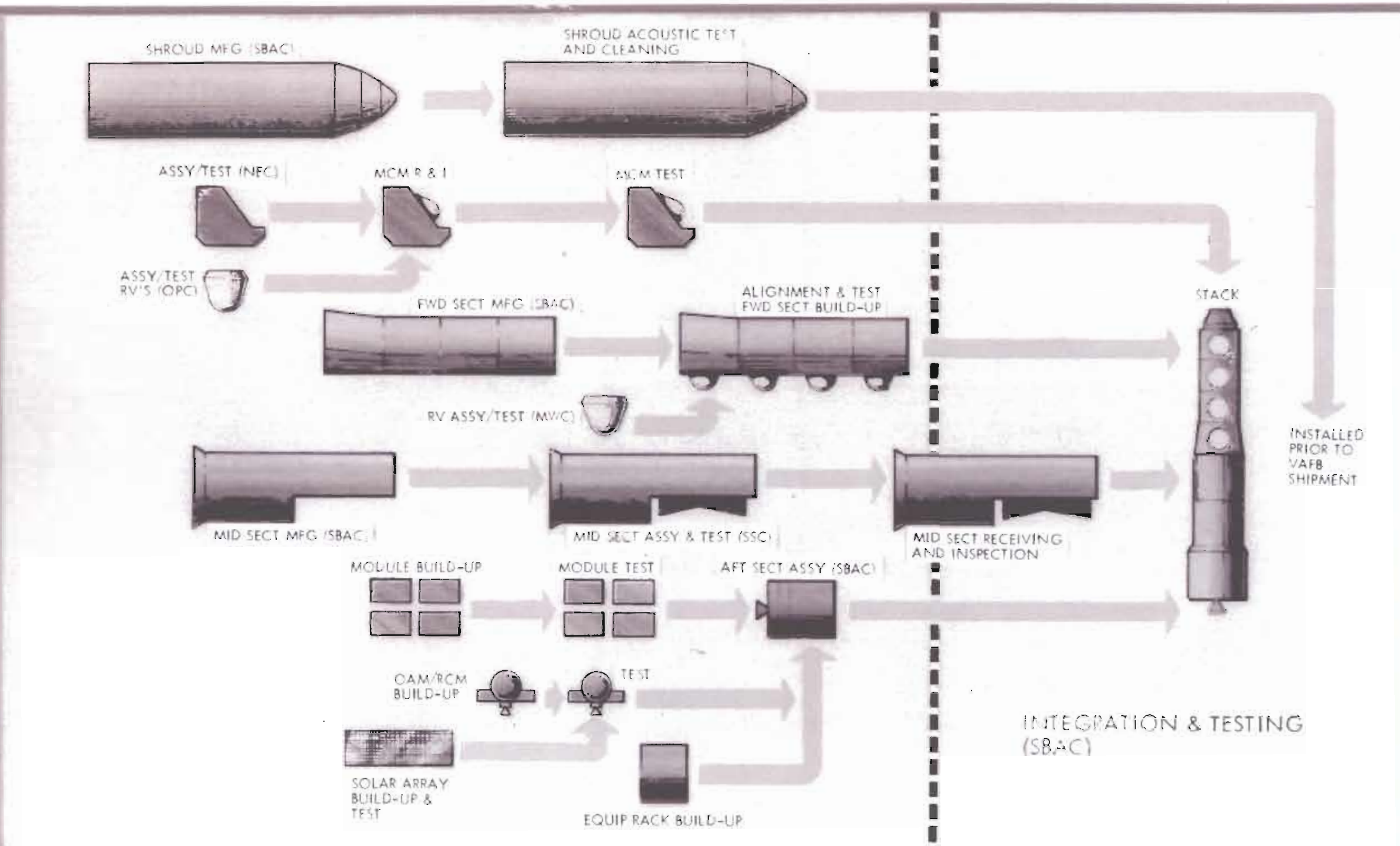
The SBA piece-parts are subjected to electrical and environmental stress and visual inspection tests to verify piece-part specification. The SBA components are subjected to ambient, random vibration, temperature-vacuum and burn-in acceptance tests for early detection and correction of design, parts and manufacturing defects. The components are then assembled into the aft section modules or installed in the forward and mid-sections. The aft section electronic modules are subjected to ambient, acoustic and thermal vacuum tests. The propulsion module and solar array modules are subjected to ambient and acoustic tests.

The sections are then mated to form the Satellite Vehicle which is then ready for the system level tests prior to VAFB shipment.

The nomenclature shown on the accompanying illustration indicates the contractor where manufacturing or testing occurs:

SBAC – Satellite Basic Assembly Contractor (Lockheed)
MWC – Midwest Contractor (McDonnell Douglas)
NEC – Northeast Contractor (Itek)
OPC – Our Philadelphia Contractor (General Electric)
SSC – Sensor Subsystem Contractor (Perkin-Elmer)

HARDWARE FLOW



HARDWARE FLOW

The objective of the factory-to-pad test program is to demonstrate flight readiness of each vehicle at the factory and to perform vehicle checkout and launch preparations at the launch complex.

The assembled vehicle is tested as a system with payload electrical simulators to verify compatibility of the SBA equipment with the payload interfaces. The payloads are then electrically connected to the Satellite Basic Assembly (SBA) and the vehicle is tested to verify performance and compatibility.

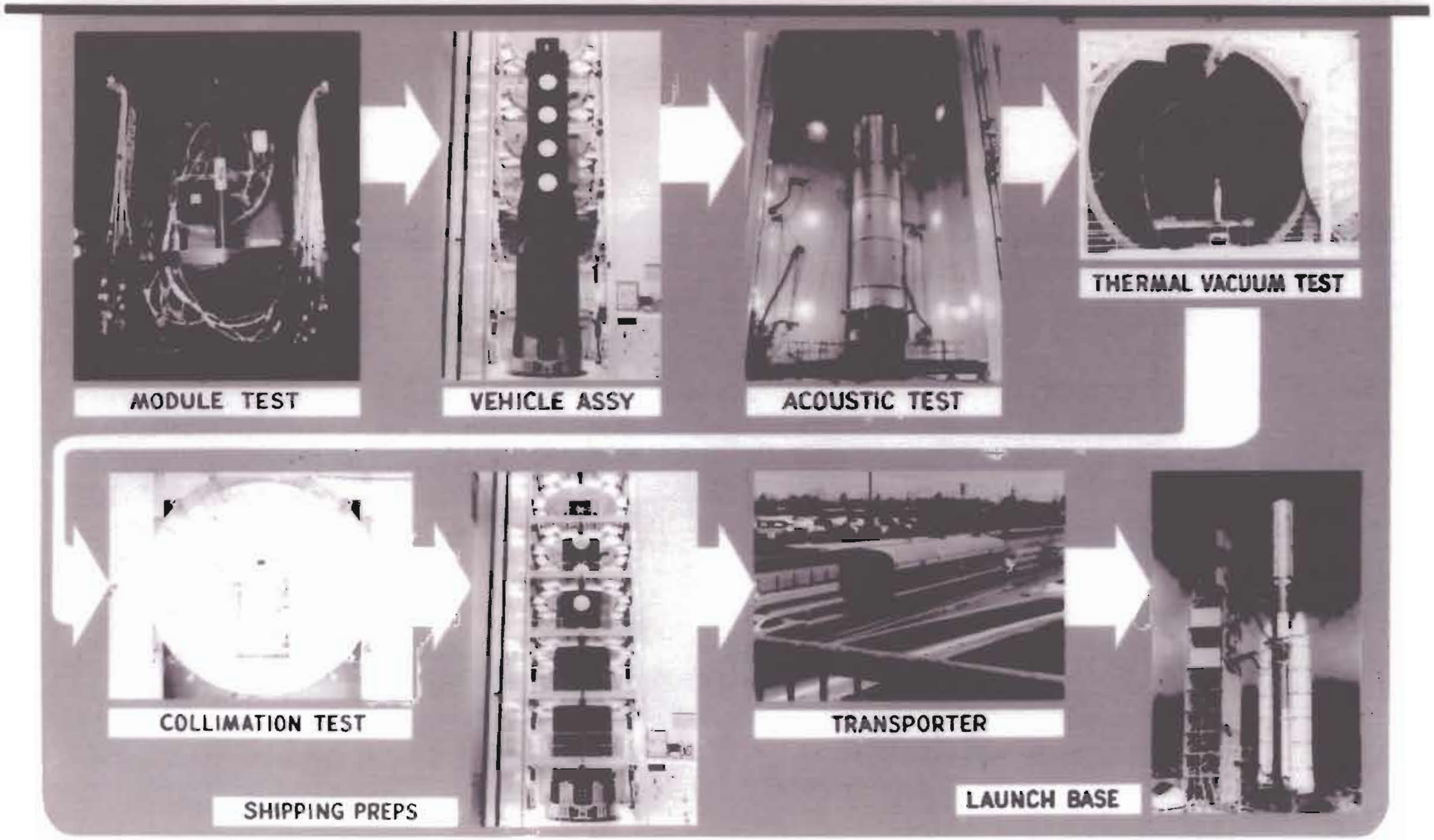
The vehicle is subjected to an acoustic test and is monitored during the exposure to verify proper SV health and status. The vehicle is then tested to verify that it survived the acoustic environment. The vehicle is next subjected to a thermal vacuum test with the aft section subjected to two thermal cycles and the payloads subjected to one thermal cycle. Aft section performance tests are conducted at low and high temperatures and typical mission profile tests are performed on the payloads including film transfers to each reentry vehicle.

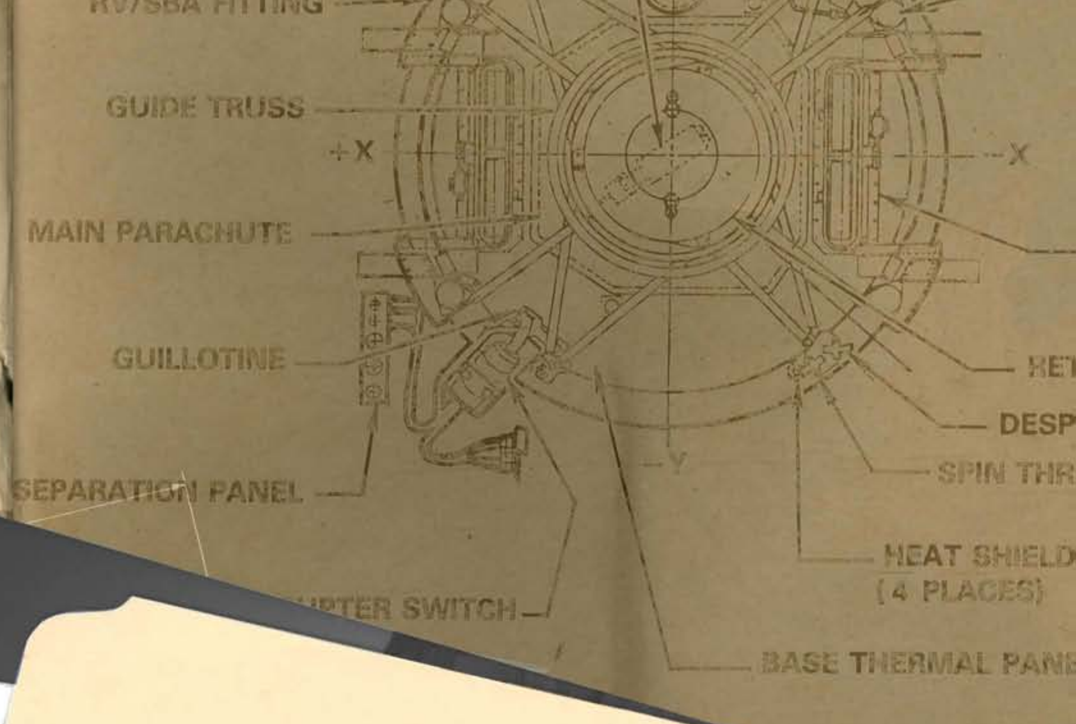
A collimation test of the Two Camera Assembly (TCA) is performed at vacuum to verify optical performance and to determine the flight focus setting for the camera system. The mapping camera flatness is verified and the flight setting for the film path pressure makeup is determined.

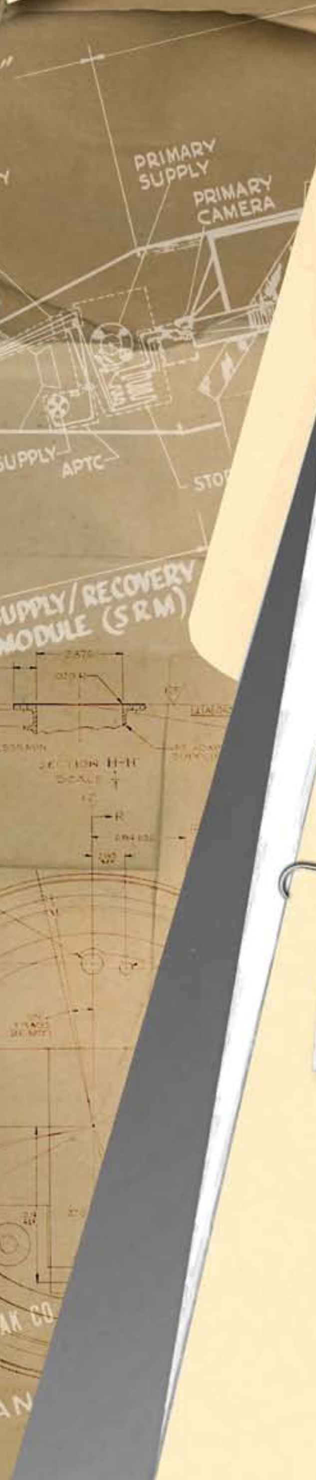
The vehicle is then prepared for shipment which includes flight film loading [redacted] A systems test is then performed to verify systems performance. Final shipping preparations are performed and the shroud is installed. The vehicle is then transported to the launch base.

The vehicle is mated to the booster and an Aerospace Vehicle (AV) systems test is performed to verify that the SV operates properly and to verify compatibility between the AV and the Vandenberg tracking station and the Satellite Test Center. Final flight preparations consisting of propellant loading and pyrotechnic installation is performed. The countdown is initiated and consists of the final SV functional test and launch configuring for lift-off, roll back of the Mobile Service Tower, flight command loading, performing terminal count and launching the Aerospace Vehicle.

HARDWARE FLOW







CRITICAL TO US SECURITY:
THE GAMBIT AND HEXAGON SATELLITE RECONNAISSANCE SYSTEMS

SECTION III: CONTRIBUTIONS DOCUMENTS

This set of documents describe the intelligence capabilities of the systems as well as their successes. Gambit and Hexagon were each designed for specific intelligence purposes. However, they worked together by providing more flexible and persistent imagery coverage for countering the threats posed by U.S. adversaries including China and the Soviet Union.

The first document in this section is a 1967 report prepared for then Director of the National Reconnaissance Office (DNRO), Alexander Flax, which summarizes the Gambit program. The report is rich in historical details, system capabilities, and management approaches. The report summarizes the growth in capabilities as the system matured, the technical problems encountered, and procurement aspects such as the incentive fee structure and costs.

DNRO John McLucus requested a similar report for Gambit-3, also known as program 110. Although the report was prepared early in the life of the Gambit-3program, we included it in this compendium because it was modeled after the earlier Gambit report. The two together provide a unique opportunity to compare the systems at this point in time. Like the Gambit report, we also find rich details of the programs uses and early successes. The report also addresses intelligence value, satellite operations, technical issues, and procurement costs.

American space companies were essential partners in the NRO's successful satellite programs. We have included two corporate documents from Lockheed Missiles and Space Company. The documents describe the successful launch of late Gambit vehicles. In a letter from Lockheed's Reginald R. Kearton to DNRO Flax, Kearton identifies intangible reasons for the Gambit including cooperation and management harmony between the military and contractors. He identifies tangible factors of success including effective design, effective launch preparations, and realistic cost estimation.

In an interesting memo concerning Hexagon, a National Photographic Interpretation Center (NPIC) manager describes the innovations that Hexagon prompted in the exploitation of imagery. The memo identifies innovations in equipment, management, and personnel management. The memo also identifies how Hexagon influenced consideration and analysis of intelligence targets.

Finally, we included the second volume of The KH-9 Search and MC&G Performance Study. The study reviews KH-9 performance and briefly summarizes the satellite system, the evolution of search requirements, and names specific examples of contributions made by KH-9 to the mission. The study concludes that Hexagon, in general, satisfied the most important intelligence requirements.

LIST OF CONTRIBUTIONS DOCUMENTS

1. Report: *Analysis of Gambit Project*, 24 August 1967.

2. Report: *Analysis of Gambit (110) Project*, Brigadier General William G. King, 28 April 1970.

3. Report Excerpts: *Program 206-II System Performance*, Lockheed Martin Missiles and Space Company, undated.

4. Letter: *Major Factors Contributing to Program 206-II Success*, written to Alexander Flax, 13 November 1966.

5. Memorandum: *Innovations and Trends in Exploitation in the Western Geographic Division, IEG caused by the KH-9 System*, 20 March 1973.

6. Report: *The KH-9 Search and MC&G Performance Study (Volume II)*, National Photographic Interpretation Center, October 1977.

DEPARTMENT OF THE AIR FORCE
DIRECTORATE OF SPECIAL PROJECTS (OSAF)
AF UNIT POST OFFICE, LOS ANGELES, CALIFORNIA 90045

BYE-70792-67

Cy 1

29 August 1967

REPLY TO ATTN OF: SP-1

SUBJECT: Summary Analysis of Program 206 (GAMBIT)

TO: Director, NRO (Dr. Flax)

1. On completion of Program 206 (GAMBIT), I asked [redacted] to undertake a summary analysis of the overall program. This report is his work. I believe that you will find it interesting, including all of the appendices as well as the summary discussion.

2. With the exception of one Agena failure and one Atlas failure, both of which resulted in no orbit being attained, all of the mission catastrophic failures and most of the other serious failures were in GE equipment. Some payload difficulties existed throughout the program lifetime but no payload difficulty seriously affected the accomplishment of the primary objectives of any mission. Note that, although only four payloads clearly exceeded (bettered) the specification on resolution, 11 more were at the very threshold of bettering it, as may be seen from the graph on resolution versus flight number in Attachment 2.

3. On an overall basis, considering all SAFSP contracts on the program, including our estimate of final figures as explained in the report, the principal contractors earned the following fee as a percent of actual cost (obviously a higher percent of the original target costs where actuals exceeded target, lower where actuals were under target):

GE	5.6%
LMSC........	7.4%
EK..........	7.7%

4. The new incentive applied to 19 of the last 20 vehicles of the GE -580 contract; 15 of these vehicles were flown, of which 14 were generally successful, with an average performance score of 86.3%.

5. The difficulties encountered in this program are not necessary characteristics of this business. As an illustration, we have drawn

EXCLUDED FROM AUTOMATIC REGRADING: DOD DIR 5200.10 DOES NOT APPLY

HANDLE VIA BYEMAN CONTROL SYSTEM ONLY

heavily on this experience in laying out and proceeding with Program 110 (GAMBIT-3). It is a much more complex system, and the comparison of the first seven flights with the GAMBIT experience illustrates the degree to which we have been successful in this regard.

JOHN L. MARTIN, JR
Brigadier General, USAF
Director

1 Atch
Analysis of Gambit Project
24 Aug 67 w/5 Atch

DEPARTMENT OF THE AIR FORCE
DIRECTORATE OF SPECIAL PROJECTS (OSAF)
AF UNIT POST OFFICE, LOS ANGELES, CALIFORNIA 90045

BYE-70792-67

2 4 AUG 1967

REPLY TO ATTN OF: SP-2

SUBJECT: Analysis of GAMBIT Project

TO: SP-1 (Gen Martin)

1. Purpose and Scope

a. This paper analyzes the effectiveness of the recently completed GAMBIT (206) project, which launched 38 missions, all but two of which achieved orbit. One of the 36 orbiting missions was not recovered.

b. The following parameters are addressed: intelligence, operations, technical, procurement, and cost.

c. The Quarterly Program Review as of 31 Dec 1966 (BYE 66207-67) contained a summary comparison of GAMBIT operations in calendar years 1965 and 1966. Portions of the data on which that comparison was based were in error, and are superseded by correct data in this analysis.

d. This basic paper summarizes the results of the analysis. The attachments contain details in narrative, tabular and chart form.

2. Intelligence

a. Photographs of [redacted] intelligence targets were recovered during the life of the GAMBIT project. Not all of these were useable because of cloud cover or degraded resolution. The total number of targets photographed as used in this analysis does not distinguish between target priorities, mono versus stereo, or resolution obtained.

b. GAMBIT provided the intelligence community with the first high resolution (2-3 ft) satellite photography of denied areas. The community has stated that the intelligence value of this photography was extremely high.

c. There was steady growth in the capability of the GAMBIT system to obtain photography, as seen in the following table of calendar year averages.

Targets Photographed

CY	Per Flight	Per Day	Per Rev
63	[redacted]		
64			
65			
66			
67			

d. The contract specification for GAMBIT ground resolution was 2 to 3 ft (135 lines/mm). The total take of any single mission contained photographs with a variety of resolutions because of flight and ground conditions. Considering only the best resolution obtained on any flights, the results of the 36 missions achieving orbit may be tabulated as follows:

Resolution		Number of Flights	%
[redacted]		4	11.1
2 to 3 ft		21	58.3
3 to 10 ft		3	8.3
Worse than 10 ft		7	19.5
Not recovered		1	2.8
	TOTAL	36	100%

e. Thus, 69.4% of all flights obtained some photography that was within specification, 27.8% obtained photography worse than specification and 2.8% obtained no photography.

3. Operations

a. The system was originally designed for a nominal 5-day life, but operations began with shorter planned orbital lifetimes. The first 5-day mission was No. 17, nearly two years after No. 1. Lifetimes were extended to 6 days by mission No. 26 and to 8 days by mission No. 30. The 36 flights achieving orbit had the following orbital lives:

Days	Number of Flights
8	7
7	2
6	4
5	4
4	8
3	1
2	5
1	5
Total	36

b. Of 36 recovery attempts, 35 capsules were successfully recovered by air. On mission No. 13, which had flown 4 days (67 revs), the recovery vehicle separated but there was no retrofire. The capsule impacted in the ocean and was lost.

c. The 36 orbiting vehicles accomplished a total of 2,716 operational revs (before RV separation) or a total of 169.745 operational days. Of these, 136.445 operational days (80.4%) were acceptable, i.e., days in which the satellite operated so as to permit a mission which could achieve 75% of the planned reconnaissance. On the other 19.6% of the days, system anomalies degraded performance.

d. The first three flights were planned in the "hitch-up" mode, wherein the Agena stage did not separate from the OCV. Only nadir photography was possible.

4. Technical

a. Major problems encountered in development, test, production and operation can be categorized into the following divisions:

(1) Deficient handling, selection, testing and quality control of parts and components.

(2) Inadequate design

b. Changes in procedures, 100% selection of piece parts, additional testing and emphasis on quality control solved most of the deficiencies in parts and component failures. Some of the most significant of these were

(1) Redesign of harness connections and potting procedures eliminated a rash of early electrical problems where connecting pins were bent or pulled loose.

(2) In analyzing a DC powe r supply problem several black boxes were opened which disclosed faulty wiring, contamination and lack of thorough inspection. This disclosure resulted in increased emphasis on quality control, but also prompted a new series of thermal vacuum and shake tests in order to identify possible failures prior to launch. In addition identical tests were instituted at the factory and at Vandenberg to disclose failures occurring during shipment.

(3) A serious battery problem occurred which was traced to a change in design not accompanied by a necessary change in procedure. The battery exploded damaging critical flight components. A vent line to the vehicle's exterior was added to minimize recurrence, and battery checkout and fill procedures were updated.

(4) A series of servo failures on the crab and stereo systems were traced to improper handling of parts; lead screws were cut down to fit without reanodizing, allowing contaminants to build up when operated on orbit.

c. The possibility of the command system issuing false commands when triggered by voltage transients was never completely solved. Logic circuits were "hardwired" into the vehicles that prevented the operation of simultaneous commands which together would be catastrophic.

(1) The inability of the horizon sensor to discriminate between sky and very cold earth areas resulted in loss of stability. This started

a development cycle on a new sensor, some models of which were flown on the Agena for testing. However, because of cost and long lead times, a procedure was adopted to turn off the sensors and go inertial over those cold earth masses. Further development was discontinued.

(2) Impingement of cold gas from the roll nozzles resulted in a forward thrust to the vehicle destroying accurate position knowledge. The nozzles were moved back for one flight and studies were made as to moving them outward from the vehicle. Instead, we were able to calculate the added thrust for each roll accurately enough to discontinue further development.

(3) One capsule loss because of anomaly in ejection programmer led to a design of redundant wiring within the recovery vehicle.

(4) Electro-magnetic interference throughout the vehicle resulted in a series of changes. A power amplifier was removed from the telemetry transmitters, but signal strength remained sufficient for operation. The 6-volt power supply was filtered and refiltered many times to reduce interference with the command system. This problem was never really solved. Interference in the horizon sensor system from the Rate Attitude Gyros and the stabilization amplifiers started a study in elimination of the RAGS. This turned out to be too difficult and a replacement system was not available, so the gain was reduced along with a reduction in sensitivity of the sensors.

(5) Beginning with the second flight, failures persisted with the environmental door. The original pneumatic actuator was eventually backed up by an electric motor. Then the pneumatic system was discarded in favor of an all-electric system with a pyro backup to guarantee a fail-open condition. The first flight of the electric system failed because of a switch relay - which was then changed to a magnetic type.

(6) An outer shield separation failure because of a buildup of tolerances and a change in design of a pyro by the vendor resulted in a new, stronger pyro and some design changes in the separation mechanism.

(7) Polystyrene capacitors were eliminated from the primary camera drive system and from the supply torque motor after a number of failures. The wrong type of lubricant resulted in variable running rates for the platen drive motor.

(8) Degradation in results was traced to thermal effects on the primary and stereo mirrors. A new design resulted in segmented potting of the mirrors to the casing. Also the temperature specifications were changed during optical testing at the factory and at the launch base.

(9) Some servo failures were caused by arcing between relay contacts and case. This was corrected by modifying the design, purchasing new relays, and reinspecting decoders.

d. Although it is believed (erroneously) in some quarters that once a space project becomes operational, the quantity of technical changes decreases significantly, the GAMBIT experience was to the contrary, and in this respect was typical of all reconnaissance satellite effort. It was necessary to introduce technical changes throughout the entire life of the GAMBIT project for two reasons: to correct design deficiencies which usually resulted in on-orbit anomalies and to improve the operational effectiveness of the system. As an illustration of these changes, Atch 6 shows the Contract Change Notifications (CCN) history of GE-580, the contract on which the last 20 OCVs were procured. The originally negotiated price of [redacted] was increased by the technical changes (and also to a slight degree by a cost overrun) to [redacted] a growth of 73% over the three year period of performance. These changes were all necessary, and in fact were the means by which the operational performance was improved significantly during the later stages of the project.

5. Procurement

a. Of the total dollar cost of the GAMBIT project, nearly [redacted] was incurred on SAFSP contracts and the remaining [redacted] on SSD and CIA contracts.

b. The SAFSP contracts were of the following types:

	Total	White	Black
CPFF	10	8	2
CPIF	14	12	2
FFP	5	4	1
L/C (terminated)	1	1	0
	30	25	5

c. The most significant procurement development on the GAMBIT project was the introduction of a new incentive structure devised by Gen Martin. Previous structures, written at a time when cost was the principal concern and the effect of GE workmanship problems on flight performance was not yet apparent, had emphasized cost at the expense of performance. Under the new structure, the only way the contractor could earn fee was by successful in-flight performance. There were only negative incentives on cost and schedule, to insure responsible financial and production effort by the contractor. (Atch 4 describes the structure.)

d. Cost experience on the major contracts was:

(1) Eastman:

While CPFF, over-ran [redacted] (6.7%)

While CPIF, under-ran [redacted] (4.2%)

(2) GE:

-76	(CPFF)	over-ran	[redacted]	(7.3%)
-155	(CPIF)	over-ran	[redacted]	(3.8%)
-432	(CPIF)	over-ran	[redacted]	(7.1%)
-580	(CPIF	over-ran	[redacted]	(26.2%)
-7705	(CPFF)	over-ran	[redacted]	(.9%)
-2106	(CPIF)	broke even		

(3) LMSC:

-92	(CPFF)	Over-ran	[redacted]	(2.8%)
-506	(CPIF)	under-ran	[redacted]	(3.9%)
-670	(CPIF)	under-ran	[redacted]	(7.3%)

e. Schedule experience showed that GE consistently lost fee on schedule, and only [redacted] gained fee in this parameter. Since the OCV was the pacing component in the system, GE schedule delays impacted on the launch dates.

f. Performance experience showed fee gain by all contractors except on GE -155 (smallest GE contract for 4 OCVs) which lost [redacted] on performance. Contracts having the old performance incentive showed small fee gains for performance. The only contract with the new performance incentive (GE-580) showed a fee gain of [redacted] for the performance parameter (of a possible gain of [redacted]; however, cost and schedule penalties resulted in a net fee loss.

g. Of all the GAMBIT contractors, GE posed the greatest workload by far in contract administration. Agreements reached at top management level were disseminated to lower levels slowly and/or with varying accuracies of interpretation. Positions taken during negotiations were more often intractable, resulting in discontinuance of negotiations. There were frequent disputes concerning whether directed work was within contract scope, and a growing tendency to request new contractual coverage for all minor directions from the SAFSP project office. These, combined with other examples too numerous to mention here, reflected unfavorably on GE's capability to manage the project. This is confirmed by Gen Martin's letters to DNRO in 1965 (BYE 40317-65 and BYE 40329-65) in which the poor GE performance was documented.

6. <u>Cost</u>

a. As of 30 June 1967 the GAMBIT project had cost [redacted] Final contract settlements over the next few years will cause minor changes in this amount.

b. The [redacted] includes the [redacted] cost of hardware purchased for GAMBIT but reallocated by DNRO without reimbursement to other SAFSP projects. [redacted]

c. The non-recurring costs for development, industrial facilities, and one-time support totalled [redacted] or 24.3% of the total program cost. Two-thirds of the development cost was for development of the satellite vehicle by GE, and 18% was for development of the payload by EKC.

d. Determination of unit costs is difficult because of overlapping contract periods and fiscal year accounting. It is possible to make a fairly accurate division of the recurring costs into two groups: those associated with the first 10 flights and those associated with the last 28 flights. On this basis the unit costs of a GAMBIT flight averaged [redacted] for the first 10 and [redacted] for the last 28.

e. On a more arbitrary basis, the recurring costs were allocated to the vehicles flown in each calendar year, i.e., the cost of the four flights in CY 1963 was determined to be [redacted], etc. This allocation gives the following comparisons [redacted]

	63	64	65	66	67
Average Cost per flight	[redacted]				
Average Cost per day in orbit					
Average Cost per target photographed					

f. It is perhaps more meaningful after a project is completed to lump all costs (recurring and non-recurring) into one total and then determine the above averages. This gives [redacted]

Average Cost per flight	[redacted]
Average Cost per day in orbit	
Average Cost per target photographed	

7. Summary

The GAMBIT project can be said to have been highly successful in that:

a. It produced the first high resolution satellite photography and thus filled the gap created by the cessation of U-2 flights following the Powers incident.

b. Its record of successful launches, orbits and recoveries far surpassed the records of earlier systems, especially during comparable periods of the initial four years.

c. It advanced the state of the art to the point where a follow-on larger system could be developed and flown so successfully that GAMBIT could be phased out.

d. The record of cost control showed a steady decrease in cost of days in orbit and cost of targets photographed.

e. Specific technical, procurement and cost problems successfully resolved during the GAMBIT project improved the capability of SAFSP, and indeed the NRO, to prosecute other satellite projects.

[redacted]

[redacted] Colonel, USAF
Vice Director

5 Atch
1. Proj history and list of flts
2. Graphs
3. Flt anomalies
4. Procurement Data
5. Cost Data

Attachment 1

Project History

1. A detailed historical record of the GAMBIT project is contained in the official SAFSP history being compiled by Mr Robert Perry. Volumes completed to date are on file in SP-3. Following is a summary of a few key points.

2. GAMBIT was the first NRO satellite project to produce reconnaissance photographs with high (2-3 ft) ground resolution. (The CORONA project, which began earlier and is still operating, produces photography of 8-15 ft resolution. In the SAMOS series, the one E-1 flight achieved about 100 ft resolution, the one E-5 camera flight (LANYARD) achieved 7-12 ft resolution, and no photography was recovered from the five E-6 flights.)

3. The photography produced by GAMBIT has been extremely valuable to the intelligence community.

4. GAMBIT has been managed entirely by SAFSP, which office had complete responsibility for development, production and operation of all system components. This contrasts with CORONA, where the CIA has responsibility for the sensor subsystem. For cover purposes, GAMBIT was overtly placed under ostensible SSD management until Dec 1962, when the overt assignment was changed to SAFSP; however, SAFSP covertly had the complete management responsibility from the outset.

5. There were a number of overt designators used throughout the life of the GAMBIT project:

Sep 1961	Exemplar
Dec 1961	Cue Ball and 483A
Feb 1962	698AL
Aug 1962	206

6. After earlier SAFSP parametric work had established feasibility, official GAMBIT go-ahead was given in Sep 1961. The first flight was launched 12 Jul 1963 and the thirty-eighth and final flight was launched

4 June 1967. The first three flights were flown in the "Hitch-up" mode, wherein the Agena stage was not separated, but orbited attached to the Orbital Control Vehicle (OCV). In the remaining thirty-five flights, the Agena was programmed to separate and the OCV was the orbiting vehicle.

7. Principal components and their manufacturers were:

Payload	EKC
OCV	GE
RV	GE
Agena Stage	LMSC
Atlas Booster	GDA
S/I Camera	Itek
Horizon Sensor	Barnes

8. During the life of the project there were these changes in key personnel:

a. DNRO:

Sep 1961 - Mar 1963	Dr J V Charyk	(Initial Development)
Mar 1963 - Sep 1965	Dr B McMillan	(Final Dev and 22 Flights)
Sep 1965 - Jun 1967	Dr A H Flax	(16 Flights)

b. Director of Special Projects:

Sep 1961 - Jun 1965	Gen R E Greer	(Dev and 19 Flights)
Jul 1965 - Jun 1967	Gen J L Martin Jr	(19 Flights)

c. Project Director:

Sep 1961 - Dec 1962	Col Q Riepe	(Initial Development)
Dec 1962 - Aug 1966	Col W G King Jr	(Final Dev and 31 Flights)
Sep 1966 - Jun 1967	[redacted]	(7 Flights)

9. The following pages contain a list of the thirty-eight GAMBIT launches.

BYE-70792-67

~~TOP SECRET~~

SPECIAL HANDLING

List of GAMBIT Flights

Sequence	OCV#	Launch Date	Orbit	Orbital Revs	Days on Orbit: Total	Days on Orbit: Acceptable	Targets Photographed	Best Ground Resolution (ft)	Recovery
1	951	12 Jul 63	Yes.	18	1.125	.50	[redacted]	3.5	Yes
2	952	6 Sep 63	Yes	34	2.125	2.125	[redacted]	2.5	Yes
3	953	25 Oct 63	Yes	34	2.125	2.125	[redacted]	3.0	Yes
4	954	18 Dec 63	Yes	18	1.125	0	[redacted]	N/A	Yes
5	955	25 Feb 64	Yes	34	2.125	0	[redacted]	N/A	Yes
6	956	11 Mar 64	Yes	51	3.188	3.188	[redacted]	3.0	Yes
7	957	23 Apr 64	Yes	66	4.125	4.125	[redacted]	2.5	Yes
8	958	19 May 64	Yes	34	2.125	1.0	[redacted]	2.0	Yes
9	959	6 Jul 64	Yes	34	2.125	0	[redacted]	50.0	Yes
10	960	14 Aug 64	Yes	66	4.125	1.0	[redacted]	7.0	Yes
11	962	23 Sep 64	Yes	67	4.188	4.188	[redacted]	7.0	Yes
12	961	8 Oct 64	No	0	0	0	[redacted]	N/A	N/A
13	963	23 Oct 64	Yes	67	4.188	0	[redacted]	N/A	No
14	964	4 Dec 64	Yes	16	1.0	.5	[redacted]	2.1	Yes
15	965	23 Jan 65	Yes	67	4.188	4.188	[redacted]	2.0 (b)	Yes
16	966	12 Mar 65	Yes	67	4.188	4.188	[redacted]	2.4	Yes
17	967	28 Apr 65	Yes	83	5.188	5.188	[redacted]	2.0	Yes
18	968	27 May 65	Yes	83	5.188	5.188	[redacted]	2.0	Yes

~~TOP SECRET~~

SPECIAL HANDLING

HANDLE VIA BYEMAN
CONTROL SYSTEM ONLY

List of GAMBIT Flights
(cont'd)

Sequence	OCV#	Launch Date	Orbit	Orbital Revs	Days on Orbit Total	Days on Orbit Acceptable	Targets Photographed	Best Ground Resolution (ft)	Recovery
19	969	25 Jun 65	Yes	18	1.125	0	[redacted]	N/A	Yes
20	970	12 Jul 65	No	0	0	0	[redacted]	N/A	N/A
21	971	3 Aug 65	Yes	67	4.188	0	[redacted]	N/A	Yes
22	972	30 Sep 65	Yes	67	4.188	4.188	[redacted]	[redacted]	Yes
23	973	8 Nov 65	Yes	18	1.125	.25	[redacted]	N/A (c)	Yes
24	974	19 Jan 66	Yes	83	5.188	5.188	[redacted]	2.0	Yes
25	975	15 Feb 66	Yes	84	5.250	5.250	[redacted]	2.0	Yes
26	976	18 Mar 66	Yes	99	6.188	5.250	[redacted]	2.0	Yes
27	977	19 Apr 66	Yes	98	6.125	6.125	[redacted]	2.0	Yes
28	978	14 May 66	Yes	99	6.188	6.188	[redacted]	2.0	Yes
29	979	3 Jun 66	Yes	99	6.188	6.188	[redacted]	2.3	Yes
30	980	12 Jul 66	Yes	131	8.188	5.50	[redacted]	2.5	Yes
31	981	16 Aug 66	Yes	130	8.125	6.75	[redacted]	2.0	Yes
32	982	16 Sep 66	Yes	115	7.188	7.188	[redacted]	2.0	Yes
33	983	12 Oct 66	Yes	131	8.188	8.188	[redacted]	[redacted]	Yes
34	984	2 Nov 66	Yes	115	7.188	0	[redacted]	N/A	Yes
35	985	5 Dec 66	Yes	131	8.188	8.188	[redacted]	2.5	Yes

List of GAMBIT Flights
(cont'd)

Sequence	OCV#	Launch Date	Orbit	Orbital Revs	Days on Orbit Total	Days on Orbit Acceptable	Targets Photographed	Best Ground Resolution (ft)	Recovery
36	986	2 Feb 67	Yes	131	8.188	8.188	[redacted]	2.2	Yes
37	987	22 May 67	Yes	131	8.188	8.188	[redacted]	[redacted]	Yes
38	988	4 Jun 67	Yes	130	8.125	8.125	[redacted]	[redacted]	Yes
	TOTALS			2,716	169.745	136.445	[redacted]		

Notes:

(a) Targets shown for flights 1 and 14 are cloud free targets photographed and do not include other targets photographed.

(b) Resolution on flight 15 was 2.0 ft on day 1 but degraded to 10 ft on day 4.

(c) Resolution on flight 23 was so poor it was not measurable.

Attachment #2

Graphs

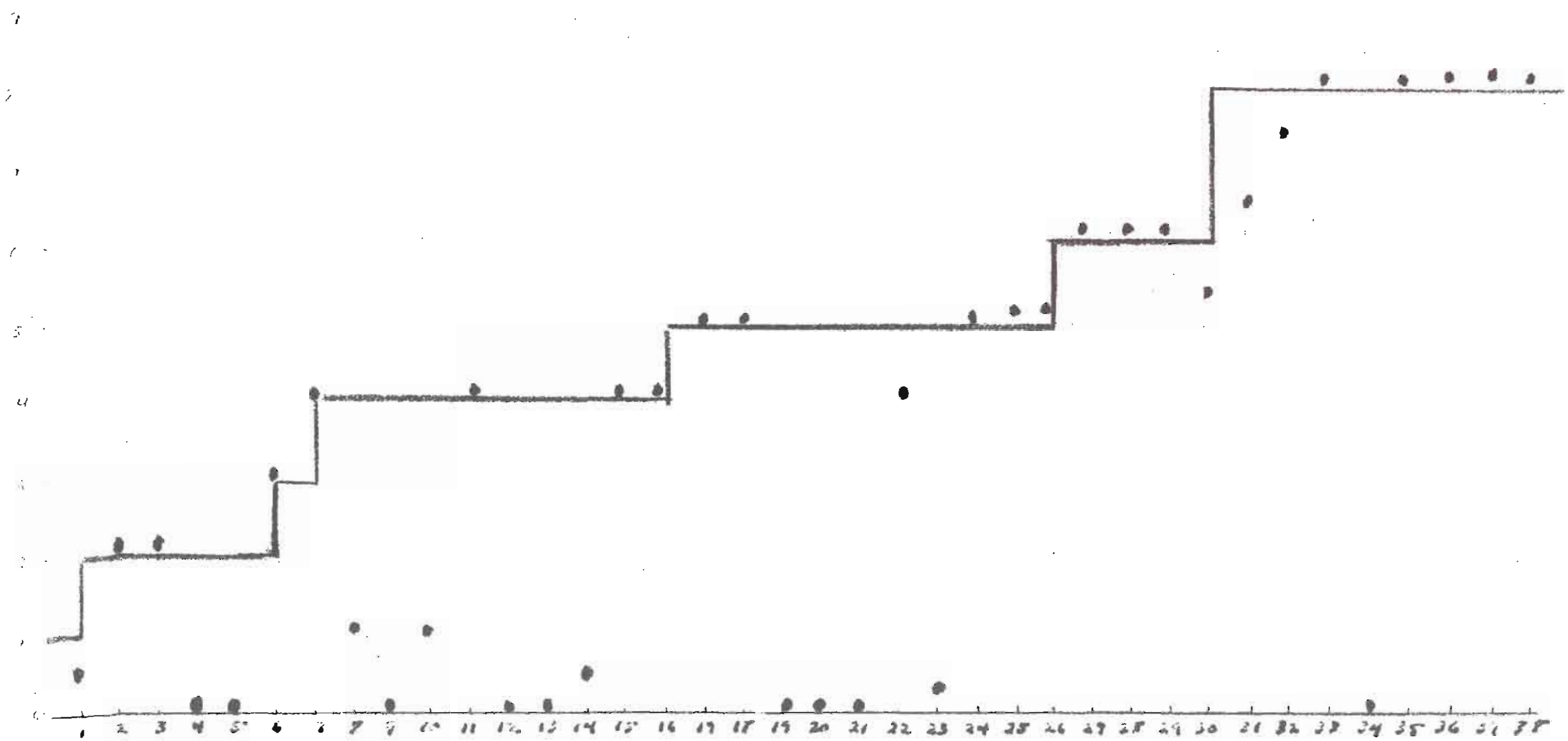
1. Total targets photographed, by mission.
2. Average targets photographed, by calendar year.
3. Orbital Life by mission, actual vs planned.
4. Acceptable Life by mission, actual vs planned.
5. Ground Resolution, actual (best) vs specified.
6. Costs, per flight, per day and per target.

SPECIAL HANDLING

TOP SECRET

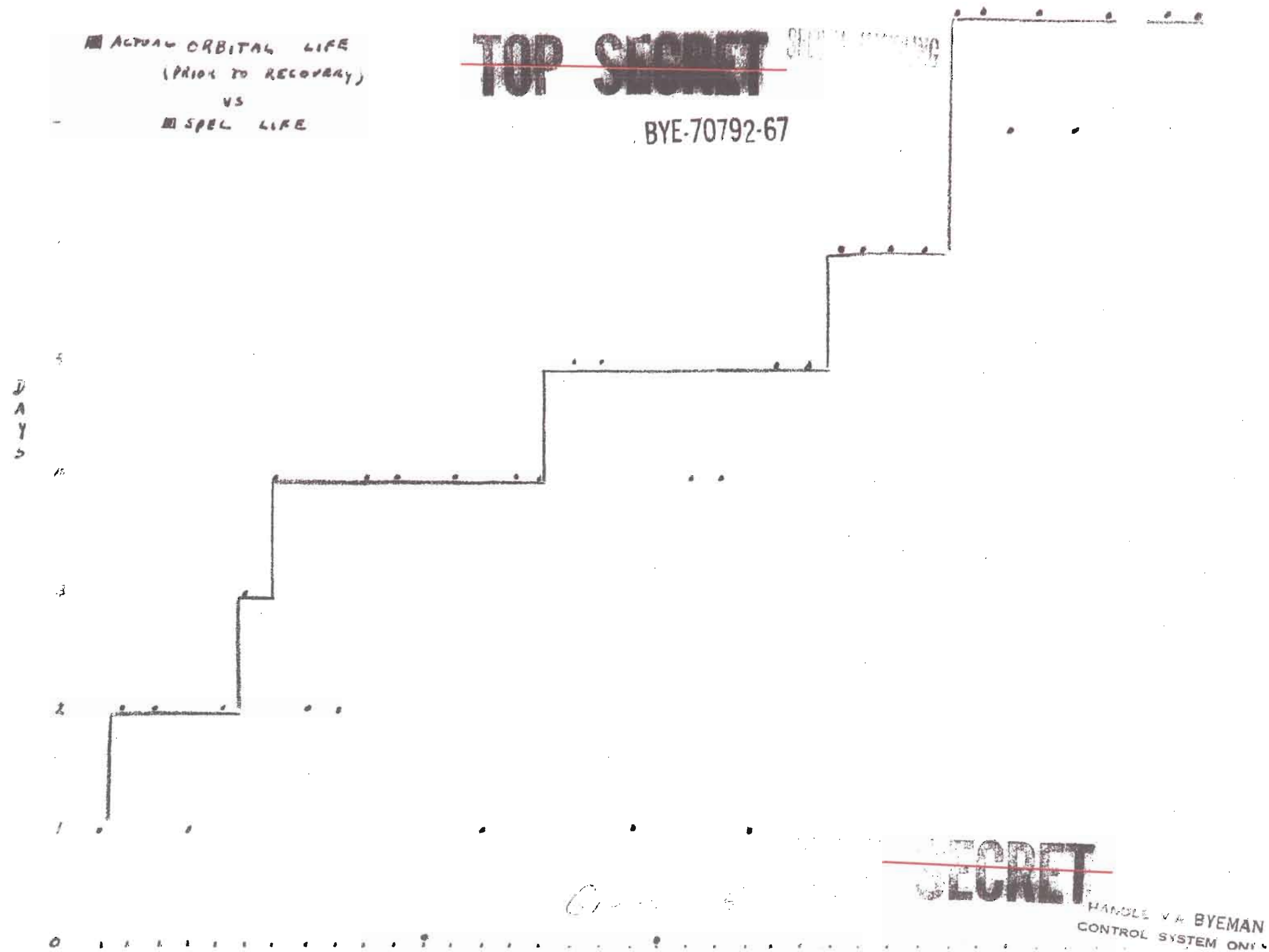
BYE-70792-67 SPECIAL HANDLING

ACTUAL ACCEPTABLE DAYS ON ORBIT
VS
PLANNED DAYS



SPECIAL HANDLING BYEMAN

BYE-70792-67



TOP SECRET SPECIAL HANDLING BYE-70792-67

SECRET HANDLING

Attachment #3

GAMBIT Flight Anomalies

	Days on Orbit		
Vehicle	Total	Acceptable	Principal Anomalies
951	1.1	.5	Agena gas depletion, vehicle unstable.
952	2.1	2.1	Same
953	2.1	2.1	None
954	1.1	0	RAGS package overheat and loss of rate. Vehicle unstable. OCV did not deboost.
955	2.1	0	Excessive yaw through rev 16. Environmental door did not open on rev 22.
956	3.1	3.1	Excessive settling times
957	4.1	4.1	Bad component in horizon sensor mixer box caused pitch bias equal to 4 miles in-track error beginning rev 42.
958	2.1	1.0	Unstable in all three axes from rev 16. Horizon sensor could not discriminate over Antarctic.
959	2.1	0	Same
960	4.1	0	Slit misalignment and improper temperature correction caused out-of-focus condition. Unable to load programmer after rev 19.
962	4.1	4.1	Improper temperature correction caused out-of-focus condition.
961	0	0	No orbit. Agena engine failure.
963	4.1	0	No retrofire on RV. Capsule lost.
964	1.0	.5	Loss of power to stabilization system on rev 9. Vehicle unstable.

GAMBIT Flight Anomalies
(cont'd)

Vehicle	Days on Orbit Total	Days on Orbit Acceptable	Principal Anomalies
965	4.1	4.1	Payload temperature anomalies. Stereo mirror stuck forward.
966	4.1	4.1	Stereo mirror stuck in 0 degree on rev 16. Mono photography only.
967	5.1	5.1	Primary door actuator.
968	5.1	5.1	Same
969	1.1	0	Power supply malfunction during ascent.
970	0	0	No orbit. Booster failure.
971	4.1	0	DC/DC power converter failed. Vehicle unstable.
972	4.1	4.1	High gas consumption. Roll maneuvers restricted on day 4.
973	1.1	.25	High gas consumption caused early mission termination.
974	5.1	5.1	Stereo mirror failed to drive to proper angle beginning rev 25.
975	5.2	5.2	Crab servo mechanism failed to move from zero. Stellar shutter malfunctioned.
976	6.1	5.2	S/I camera intermittent between revs 40 and 59. No commanding attempted after rev 71.
977	6.1	6.1	Slit position commanding anomaly. Slow platen drive motor.
978	6.1	6.1	Torque motor failure
979	6.1	6.1	Stabilization system performed improperly.
980	8.1	5.5	Vehicle clock malfunctioned, resulted in 58 degree pitch down, pressurization of the orbit propellant tanks and driving platen to full forward position.

GAMBIT Flight Anomalies
(cont'd)

Vehicle	Days on Orbit: Total	Days on Orbit: Acceptable	Principal Anomalies
981	8.1	6.7	Stereo mirror stuck 0 degrees on rev 9, resulting in mono only
982	7.1	7.1	High gas consumption
983	8.1	8.1	Low thrust roll control valve leaked intermittently.
984	7.1	0	Outside hatch failed to jettison, preventing main camera photography.
985	8.1	8.1	Excessive time for roll at low rate.
986	8.1	8.1	Software selected wrong slit on revs 7 through 25. Primary stored command system inoperative on rev 126.
987 *	8.1	8.1	None
988 *	8.1	8.1	None

* Although both of these flights achieved planned performance, GE did not earn the maximum fee on the performance portion of the incentive structure [redacted] per flight) for the following reasons. Prior to these flights, GE completed an analysis of component vibration data obtained on previous flights, from which they concluded that some components on these two vehicles would probably exceed the vibration levels for which they had been qualified originally. Accordingly, GE considered that some adjustment should be made in the fee structure for these two vehicles. The government contracting officer proposed to score each of these two flights at the average performance score awarded on the previous 13 flights [redacted] per flight), or to fly them under the full incentive provisions, with the provision that the same option would have to apply to both flights and would have to be elected prior to the first of these two flights. GE accepted the option of the average performance score, with the result

that these two flights earned a total performance fee of [redacted] as opposed to [redacted] that would have otherwise been earned by the actual performance of the vehicles. The government contracting officer's rationale in accepting the apparent risk of guaranteeing GE a performance fee prior to flying either of these vehicles was based on the following considerations:

a. Both vehicles at the time of the settlement on the average performance option had already been completely manufactured and shipped to the launch base, this manufacturing cycle having been carried out under the full terms of the incentive contract. Thus, the incentive had already had all possible effect on the quality of these two vehicles, except for the actual launch activities, all of which were under detailed supervision of experienced Air Force personnel at Vandenberg AFB.

b. These two vehicles had had all previously established improvements carried out completely in the above manufacturing process. Therefore, they had a higher probability of successful operation than any of the preceding 13 flights.

Attachment 4

Procurement Data

GENERAL

1. SAFSP contracted for the payloads, Orbital Control Vehicles (OCVs), Agena peculiars, Recovery Vehicles (RVs), horizon sensors, mission planning and miscellaneous support effort.

2. SSD contracted for the Atlas boosters and launch service, standard Agena and launch services, satellite control, aerospace MTS and miscellaneous support effort. Funds for these items were released to SSD by SAFSP.

3. CIA contracted for the S/I cameras, film, roll joints, and certain RV parts. Funds for these items were released to CIA by the NRO comptroller at SAFSP request.

4. The SAFSP contracting was accomplished by an [redacted] procurement division collocated with the GAMBIT project office. Division chiefs were:

[redacted] Sep 1961 - May 1965
Jun 1965 - Jun 1967

INCENTIVES

5. Several types of incentive structure were used. Following is a narrative description of them, showing actual results obtained:

General Electric

a. Contract -76 (white) and [redacted] (black) covered development and production of the first six OCVs and RVs.

(1) -76 began as CPFF, but a performance incentive was introduced on the last two flights. Under this incentive, 100 possible points could be

earned during orbit and recovery and 70 points was par. At par the contractor received target fee, at above par he earned additional fee up to a maximum increase of [redacted] per flight, and below par he lost fee up to the same maximum. Of the two flights, one earned maximum fee and one lost maximum fee, thus canceling each other. The cost overrun was 7.5%, but since there was no cost incentive, this did not penalize GE. Final fee situation was (% is of actual cost):

Target fee
Maximum possible fee
Actual fee
[redacted]

(2) [redacted] was CPFF throughout, with a fixed fee of [redacted] (6.4%). There was a small overrun of less than 1%.

b. There followed a series of four follow-on white contracts and one black contract with a life covering the lives of all four white contracts.

(1) -155 (white) produced four OCVs. It had the same performance incentive as -76, but added a negative schedule incentive penalizing GE [redacted] per week up to a maximum penalty of [redacted] as well as a cost incentive under which GE could earn or lose 7.871% respectively of underruns or overruns up to a maximum gain/loss of [redacted]. Actual results were losses on all three parameters:

Performance
Schedule
Cost

Total
[redacted]

Final fee situation was (% is of actual cost)

Target fee
Maximum possible fee
Actual fee
[redacted]

(2) -432 (white) produced 12 OCVs. It had the same general performance incentive, except that the par was higher and the maximum gain/loss per flight was [redacted] The negative schedule incentive was [redacted]

per week penalty up to a maximum penalty of [redacted] The cost incentive had graduated sharing ratios with maximum gain/loss of [redacted] Actual results were:

Performance	[redacted]	gain
Schedule		loss
Cost		loss
Net		loss

Final fee situation was (% is of actual cost):

Target fee	[redacted]
Maximum possible fee	
Actual fee	

(3) -580 (white) produced 20 OCVs, of which 16 were flown. The incentive structure was changed significantly effective with the second of these 20 OCVs.

(a) For the first OCV, the performance incentive was generally the same as -432, except that the par was higher and the maximum gain/loss per flight was [redacted] There was a savings clause that where final score was lower than par the score would be adjusted to equal the average of previous flights on this contract but not lower than par. The negative schedule incentive was [redacted] per week penalty up to a maximum penalty of [redacted] The cost incentive was generally the same as on -432 except that the maximum gain/loss was [redacted]

(b) Effective with the second of the 20 OCVs, the incentive structure changed. The performance incentive was based on a list of critical events and on the ratio of the number of revs until the first critical event occurs to the number of planned revs. GE could earn an additional 7.5% above target fee of 7.5% for having no critical events during all the planned revs, and lose fee progressively because of critical events down to the point where there was no fee if a critical event occurred at 50% of the planned revs. There was a savings clause under which SAFSP could unilaterally award a higher fee if the intelligence obtained indicated a higher % of mission achievement. Maximum gain/loss per flight on performance was [redacted] for OCVs 2 through 11 and [redacted] for OCVs 12 through 20 (8-day birds). (The last four birds were not flown and were awarded average performance fees of [redacted] each.) Schedule incentive was negative only, with penalties of [redacted] per day up to a maximum penalty of [redacted]. Cost incentives were negative only, with sharing ratio of 80/20 up to [redacted] overrun and 70/30 thereafter, up to a maximum penalty of [redacted]

(c) Pending completion of contract termination, we estimate the following results:

Performance
Schedule
Cost

Net [redacted]

(d) Final fee situation is estimated to be (% is of actual cost):

Target fee
Maximum possible fee
Actual fee [redacted]

(4) [redacted] was to have produced three OCVs. This was issued as a letter contract which was negotiated but terminated before the definitive contract was executed. The OCVs were in various stages of completion at the time of termination. [redacted] was to have had the same incentive structure as [redacted], but since it was terminated from letter contract status there was no incentive operation. Actual fee paid was [redacted] as set by the terminating contracting officer. This is 7.6% of actual cost.

(5) [redacted] was a black contract covering mission - revealing aspects of the production of all but the first six OCVs and RVs. It had incentives on two elements:

(a) <u>Performance.</u> The incentive was on how well GE integrated the CIA-furnished S/I cameras. GE could earn points on the following formula:

$$\frac{100 \times \text{no. pairs of acceptable photos obtained}}{95\% \text{ of no. pairs available at liftoff}}$$

The maximum fee gain/loss per flight was [redacted] Pending completion of contract termination, we estimate the contractor will earn about [redacted] on performance.

(b) Cost. The contractor could lose or earn 20% of overruns or underruns up to a maximum gain/loss of [redacted] Pending completion of contract termination, we estimate no gain or loss on cost.

(c) Estimated final fee position (% of actual cost):

Target fee	[redacted]	(7.5%)
Maximum possible fee		(12.5%)
Actual fee		(7.6%)

Eastman Kodak

(6) All the GAMBIT payload development and the production of 45 payloads [redacted] was done on black contract [redacted].

(a) The contract began as CPFF in Oct 1960 and was converted to CPIF in May 1964 effective with the 23d payload. At the time of conversion we recognized a cost overrun of [redacted] (6.7%) and in effect started over again from scratch on the CPIF basis.

(b) From payload no. 23 on, the incentive was on cost only, with fee gain/loss of 3% of target cost without dollar limit (up to 15% of cost). Pending completion of contract termination, we estimate EKC will earn a fee gain of [redacted]

(c) Final fee situation will thus be (% is of actual cost):

Target fee	[redacted]	(7.3%)
Maximum possible fee		(15%)
Actual fee		(7.8%)

Lockheed

(7) White contract -92 called out development work and the peculiarization of 10 Agenas as GAMBIT stages. It was CPFF, with a fixed fee of [redacted]

(8) White contract -506 was a CPIF follow-on for peculiarization of 12 Agenas, with incentives on cost only. LMSC earned a fee gain of [redacted] Final fee situation was (% is of actual cost):

Target fee	[redacted]	(7.0%)
Maximum possible fee		(8.8%)
Actual fee		(7.4%)

(9) White contract -670 was a CPIF follow-on for peculiarization of 13 Agenas, with incentives on performance and cost. LMSC earned fee gains of [redacted] on performance and [redacted] on cost for a total gain of [redacted]. Final fee situation was (% is of actual cost):

Target fee	[redacted]	(4.9%)
Maximum possible fee		(11.2%)
Actual fee		(7.8%)

(10) White contract -874 was a CPIF follow-on for peculiarization of 6 Agenas, with incentives on performance and cost. Pending completion of contract termination, we estimate LMSC will earn a fee gain of [redacted] on performance and break even on cost, with the following final fee situation (% is of actual cost):

Target fee	[redacted]	(5.2%)
Maximum possible fee		(11.2%)
Actual fee		(7.8%)

(11) None of the above LMSC CPIF contracts contained the new incentive structure described for GE [redacted].

<u>Barnes</u>

(12) White contract -666 was a CPIF contract for production of 17 model 155 sensors, with incentives on schedule and cost. The contract was terminated, and there was no fee gain/loss because of the incentives. Actual fee paid was [redacted] as set by the terminating contracting officer.

(13) White contract -840 was a CPIF contract for production of 20 model 151 sensors, with incentives on cost and schedule. Pending

completion of contract termination, we estimate the following results:

Schedule	[redacted]	gain
Cost		gain
Total		gain

Final fee position will thus be (% is of actual cost):

Target fee	[redacted]	(3.5%)
Maximum possible fee		(8.4%)
Actual fee		(7.6%)

TRW

(14) White contract -841 was a CPIF contract for mission planning software, with incentive on cost only. This was a follow-on to earlier CPFF and FFP contracts. The contractor broke even on cost. The actual fee was thus the target fee of [redacted] which was 8.2% of actual cost.

(15) White contract -1014 was a CPIF follow-on contract to -841, but provided mission planning for both GAMBIT and G-3. The contract is still active. We estimate the GAMBIT portion of the work will break even on cost, and that the actual fee for GAMBIT will be the target fee of [redacted] which is 4.5% of cost.

6. Listings

The following pages contain listings of SAFSP contracts for GAMBIT and a summary of results of those which had incentive features.

List of SAFSP GAMBIT Contracts

Number	Type	Secur	With	For	Life	Final Price	Fee Earned (% of actual cost)
PAYLOAD							
[redacted]	CPFF for 22 then CPIF	Black	EKC	Dev and Production of 45 payloads	Oct 60-Jul 67	[redacted]	(7.8%)
OCV							
-76	CPFF	White	GE	Dev, Prod and Launch of 6 OCV	Dec 61-May 64	[redacted]	(6.3%)
-155	CPIF	White	GE	Prod and Launch of 5 OCV	May 62-Sep 64	[redacted]	(5.8%)
-432	CPIF	White	GE	Prod and Launch of 11 OCV	Apr 63-Sep 65	[redacted]	(7.1%)
-580	CPIF	White	GE	Prod and Lnch of 20 OCV (part.term)	Mar 64-Jun 67	[redacted]	(2.7%)
-988	L/C	White	GE	Prod and Lnch of 3 OCV (term)	Mar 66-Mar 67	[redacted]	(7.6%)
[redacted]	CPFF	Black	GE	Mission Revealing work on 10 SVs	Dec 60-Sep 64	[redacted]	(6.4%)
	CPIF	Black	GE	Same, plus Incentives on Integration of 32 GFE S/I Cameras	Oct 63-Jun 67	[redacted]	(7.6%)
AGENA PECULIARS							
-92	CPFF	White	LMSC	10 Vehicles	Mar 62-Jun 64	[redacted]	(7.0%)
-506	CPIF	White	LMSC	12 Vehicles	Feb 64-Jun 65	[redacted]	(7.4%)
-670	CPIF	White	LMSC	13 Vehicles	Apr 65-Oct 66	[redacted]	(7.8%)
-874	CPIF	White	LMSC	6 Vehicles	Apr 66-Jun 67	[redacted]	(7.8%)
HORIZON SENSOR							
-503	CPFF	White	Barnes	Sensor Development	Nov 63-Apr 64	[redacted]	(7.6%)
-666	CPIF	White	Barnes	17 Model 155 Sensors	Sep 64-Nov 65	[redacted]	(7.0%)
-840	CPIF	White	Barnes	20 Model 151 Sensors	Apr 65-May 66	[redacted]	(7.6%)
-160	CPFF	White	EKC	1 Prototype and 4 Flight Models	May 62-Dec 64	[redacted]	(5.8%)

List of SAFSP GAMBIT Contracts (Cont)

Number	Type	Secur	With	For	Life	Final Price	Fee Earned (% of actual cost)
SOFTWARE							
-145	CPFF	White	STL	Mission Planning	Apr 62-Jun 64	[redacted]	(7.2%)
-622	FFP	White	STL	Mission Planning	Jul 64-Jun 65	[redacted]	
-841	CPIF	White	TRW	Mission Planning	Jul 65-Apr 66	[redacted]	(8.2%)
-1014	CPIF	White	TRW	Mission Planning	Apr 66-Apr 67	[redacted]	(10.9%)
MISCELLANEOUS							
-438	CPFF	White	GE	Pad Modification	Aug 63-Oct 63(	[redacted]	
-749	FFP	White	AVCO	Angle Detector	Feb 65-Nov 65	[redacted]	
-757	FFP	White	Philco	Spiral Decay Study	Feb 65-Jan 66	[redacted]	
-895	FFP	White	[redacted]	D C Power Supply Failure Analysis	Sep 65-Nov 65	[redacted]	
-0014	CPFF	White	GE	Command Gen and Software	Dec 66-current	[redacted]	(8.2%)
[redacted]	FFP	Black	LMSC	Cutter/Sealer and Parts	Oct 64-Nov 65	[redacted]	
[redacted]	CPFF	Black	GE	Command Generation	Jul 65-Dec 66	[redacted]	(7.3%)
-533	CPIF	White	GE	Engineering Study	Jan 64-Jun 64	[redacted]	(7.0%)
-665	CPFF	White	EKC	VAFB support	12 Oct 64-curr	[redacted]	(8.4%)
RELATED WORK (Funded by GAMBIT)							
-790	CPIF	White	STL	Mission Optimization	20 Apr 65-20 Apr 66	[redacted]	(8.2%)
-573	CPFF	White	[redacted]	Low Altitude Study	9 Mar 64-27 Jul 64	[redacted]	(7.1%)

Overall Fee Earnings

Principal SAFSP Contractors on Total GAMBIT Work

Contractor	No. of Contracts	Actual Cost ($ mil)	Actual Fee ($ mil)	Actual Fee (% of Actual Cost)
GE	10	[redacted]		5.6
EKC	3			7.7
LMSC	4			7.4
STL/TRW	4			9.2
Barnes	3			7.1
[redacted]	1			7.1
	26			6.1 (average)

Note: Above dollar figures represent all SAFSP GAMBIT contracts except five small FFP contracts.

Results of Incentive Features on GAMBIT Contracts

Contract	Fee Gain (Loss) for: Performance	Schedule	Cost	Net Fee Gain (Loss)	Resultant Fee Earned	% of Actual Cost
GE -155	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	5.8
GE -432	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	7.1
GE -533	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	7.0
GE -580	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	2.7
GE -2106	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	7.6
EKC [redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	7.8
LMSC -506	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	7.4
LMSC -670	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	7.8
LMSC -874	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	7.8
Barnes -666	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	7.0
Barnes -840	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	7.6
TRW -841	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	8.2
TRW -1014	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	4.5

* Estimated

Attachment #5

COST DATA

1. The total program of [redacted] includes the following:

a. Thirty-eight satellite vehicles launched plus two complete for storage and two complete except for systems test. Additional parts for three systems are included. The cost does not include the long term storage of the excess hardware.

b. Forty payloads excluding a possible underrun of [redacted] recoverable in FY 1968 or 1969.

c. Forty-five Atlas boosters and launch services for thirty-eight launches. Five boosters have been reallocated to [redacted] but costed against GAMBIT. These have been removed from the unit cost recapitulation shown on the page referred to in paragraph 2.b., below. The launch services cost includes maintenance of capability at WTR until 30 June 1967.

d. Forty-five Agenas and launch services for thirty-eight launches. Five Agenas have been allocated to [redacted] and the costs have been treated the same as the Atlas costs, above. Forty sets of Agena peculiar equipment were procured.

e. Aerospace, mission planning, and general support costs include effort through 30 June 1967.

2. The following pages show:

a. GAMBIT cost summary by FY with line items as in monthly Financial Status Reports.

b. Non-recurring investment summary, unit cost for the development phase of 10 launches, and unit cost for the remaining units. Each line item shows the inclusive equivalent units.

c. Development cost by fiscal year. This information relates directly to that referred to in 2.a., above.

d. Flight cost per calendar year. This summary shows the cost in the calendar year of the flight and does not consider long lead funding.

SPECIAL HANDLING

~~SECRET~~

BYE-70792-67 [redacted]

GAMBIT COST SUMMARY

	FY 62	FY 63	FY 64	FY 65	FY 66	FY 67	TOTAL
WHITE	[redacted]						
Spacecraft							
Atlas							
Atlas Launch							
Agena							
Agena Peculiars							
Agena Launch							
Satellite Control							
Mission Planning							
Aerospace							
Industrial Facilities							
General Support							
Subtotal							
BLACK							
Spacecraft							
Command Generation							
Payload							
Subtotal							
GRAND TOTAL							

Attachment 5a

~~SECRET~~

SPECIAL HANDLING

HANDLE VIA BYEMAN
CONTROL SYSTEM ONLY

[redacted]

GAMBIT NON-RECURRING AND RECURRING

PER UNIT COST SUMMARY

	Non-Recurring	Recurring for Systems 1-1 1-10	Recurring for Remaining Systems (1)	TOTAL
Satellite Vehicle	[redacted]			
Satellite Control				
Payload				
Agena Peculiars				
Atlas				
Atlas Launch				
Agena				
Agena Launch				
Aerospace				
Mission Planning				
Industrial Facilities				
General Support				

(1) Number in parenthesis shows the inclusive numbers of equivalent systems.

(2) [redacted] does not include 5 Atlas vehicles [redacted] and 5 Agena vehicles [redacted] reallocated to [redacted]

Attachment 5b

SPECIAL HANDLING

~~SECRET~~

BYE-70792-67

NON-RECURRING INVESTMENT FY SUMMARY

	FY 62	FY 63	FY 64	FY 65	FY 66	TOTAL
Spacecraft	[redacted]					
Payload						
Satellite Control Peculiars						
Agena Peculiars						
General Support						
Industrial Fac.						
Total						

SPECIAL HANDLING

Attachment 5c

~~SECRET~~

HANDLE VIA BYEMAN CONTROL SYSTEM ONLY

BYE-70792-67

~~SECRET~~

	CY 63	CY 64	CY 65	CY 66	CY 67	Cost of Residual Units Not Flown	Cost of Transfer To Other Project
Satellite Vehicle	[redacted]						
Satellite Cont. Pec.							
Payload							
Agena Peculiars							
Atlas							
Atlas Launch							
Agena							
Agena Launch							
Aerospace							
Mission Planning							
General Support							
Total							

The totals by CY plus cost of residual units plus non-recurring of [redacted] reconciles to the program of [redacted]

Attachment 5d

[redacted]

~~SECRET~~

Attachment #6

CCN History of GE Contract [redacted]

TOP SECRET

HANDLE VIA BYEMAN CONTROL SYSTEM

~~(S)~~ NATIONAL RECONNAISSANCE OFFICE
WASHINGTON, D.C.

[redacted]

THE NRO STAFF

— I think you will find this interesting

AWF

Yes. Jd

19 September 1967

MEMORANDUM FOR DR. FLAX

SUBJECT: Summary Report of GAMBIT Program

STATEMENT OF THE PROBLEM

General Martin has submitted a summary of the GAMBIT program.

DISCUSSION

The highlights of the report are as follows:

General Martin's cover letter points out that:

(1) Most of the serious failures were associated with the GE equipment.

(2) The overall fee of 5.6% for GE versus the LMSC and EK fees of 7.4% and 7.7% reflects the GE problems.

(3) Four missions had ground resolutions [redacted] and 11 had resolutions approaching or equal to 2 feet.

[redacted] analysis summarizes the growth in capability as the system matured, the technical problems encountered, and the procurement aspects such as the incentive fee structure and costs.

Attachment #1 consists of a short project history.

Attachment #2 consists of 6 graphs:

Graph 1 - Targets per mission

Graph 2 - Average targets per mission by calendar year

Graph 3 - Acceptable versus planned days on orbit

HANDLE VIA BYEMAN CONTROL SYSTEM

TOP SECRET
EXCLUDED FROM AUTOMATIC REGRADING DOD DIRECTIVE 5200.10 DOES NOT APPLY

CONTROL NO. Internal
COPY 1 OF 1 COPIES
PAGE 1 OF 2 PAGES

Graph 4 - Days prior to recovery versus planned days on orbit

Graph 5 - Actual (best) ground resolution by flight

Graph 6 - Costs per flight, per day, and per target

Attachment #3 is a summary of flight anomalies. A footnote concerning the last two missions explains that even though the missions had no major problems, GE did not get the maximum performance incentive for these flights because prior to the flights GE accepted the Government contracting officer's offer to score the flights at the average score awarded on the previous 13 flights.

Attachment #4 is primarily an analysis of the effect of the incentive contracts.

Attachment #5 tabulates the total costs.

Attachment #6 is the CCN history of GE Contract [redacted] which illustrates [redacted] comment (in paragraph 4d of his report) that the quantity of technical changes do not decrease as a space project becomes operational.

RECOMMENDATION

That you take note of this report.

ALBERT W. JOHNSON
Major, USAF

~~TOP SECRET~~

BYE-16762-70

Cy 3, 1 pg

DEPARTMENT OF THE AIR FORCE
OFFICE OF SPECIAL PROJECTS (OSAF)
AF UNIT POST OFFICE, LOS ANGELES, CALIFORNIA 90045

28 April 1970

REPLY TO ATTN OF: SP-1

SUBJECT: Analysis of Gambit (110) Project

TO: DNRO (Dr McLucas)

1. As you requested, the subject report is submitted as an analysis of Gambit (110), Flights 1 through 22, covering the same aspects as a previous report of Gambit (206).

2. I think you will consider the success this program has had with obtaining higher resolution photography and in reducing cost per target as quite acceptable. With the further increase in primary film capacity, dual recovery units and projected use of increased battery power and [redacted] you can expect some further improvements in these areas for the follow-on systems.

/S/
WILLIAM G KING, JR
BrigGeneral, USAF
Director

1 Atch
[redacted] Letter, subject as above, w/5 Atchs

EXCLUDED FROM AUTOMATIC REGRADING; DOD DIR 5200.10 DOES NOT APPLY

~~TOP SECRET~~ /G

Handle Via
BYEMAN
Control System Only

FROM: [redacted]

SUBJ: Analysis of Gambit (110) Project

TO: SP-1

1. Purpose and Scope:

a. This paper analyzes the effectiveness of the recently completed Gambit (110) Project, Flights 1 through 22. The following parameters are addressed: Intelligence, Operations, Technical, Procurement and Costs.

2. Intelligence:

a. As for the missions associated with the 20 successful recoveries, [redacted] intelligence targets were programmed into the flight vehicles. Only 56.5%, [redacted], of the programmed targets were processed and readout into clear usable intelligence photography. The difference between targets programmed and targets readout was a result in some cases of operational problems causing pointing errors or degraded resolution, but most significantly, a result of target cloud cover.

b. As can be seen from Attachment 2 (Figures 1 and 2), the number of programmed and readout targets steadily increased. This was attributed to: (1) an increase in mission lifetime; (2) choosing launch times so as to take advantage of summer high sun angles to permit ascending, as well as decending photography; (3) a more accurate orbit drag prediction, thus decreasing the photography burst time and film used; (4) an increase in film quantity with the use of ultra-thin base film; (5) an increase in desired targets; and (6) improvements in software used for target selection.

c. In addition to the increase in target acquisition, there was also a trend of improvement in best ground resolution as shown in Attachment 2 (Figure 5). The increase in resolution was mostly a result of better optic materials, better optics polishing controls and better optics alignment and focusing procedures at the Eastman Kodak Company factory. A specification goal was set to achieve [redacted] resolution, while at 90 nm altitude, of a target with a two to one contrast ratio. This goal was achieved and slightly surpassed with the final mission, Flight 22, which had a best ground resolution of [redacted] determination.

3. <u>Operations</u>:

a. Of the 22 missions attempted, 2 flights (Flights 5 and 11) were complete failures. Flight 5 did not reach orbit because the Titan IIIB Second Stage failed 16 seconds after start. The Flight 11 re-entry vehicle parachute deployment system failed during re-entry causing all of its filmed targets to be lost in the water.

b. Two systems were injected into orbit with far higher energy than planned. A ground guidance station problem at Vandenberg AFB resulted in a termination of ground guidance commands and permitted the Flight 18 Titan IIIB Second Stage to burn to depletion even after desired velocity had been reached. The Agena added its planned increase in velocity leaving the injection velocity and the apogee altitude far too high. Flight 18 had a later orbit adjust problem which caused an early mission termination on Day 7. Flight 19 injection velocity meter under-measured the change in velocity produced by the Agena main engine. The Agena burned to depletion. Apogee altitude was 598 nm. The specified maximum apogee altitude of 270 nm was more than doubled.

c. Other than the complete failures of Flights 5 and 11, and the early termination of Flight 18, the other flights were considered very successful. Although most of the 19 successful flights did have some flight hardware problems and operational constraints, Operations personnel were able to use redundant systems and change operating procedures to continue the missions until successfully completed.

d. The most significant operational details for each flight are given in Attachment 3. Some important flight data are given in Attachment 1, Table 1.

4. <u>Technical</u>:

a. Photographic Payload Section

(1) Camera-Optics Module

(a) During the conceptual phase of the Gambit (110) system, it was recognized that the large optics which provided the main performance improvement over the previous Gambit (206) program would provide the most serious manufacturing and testing challenge. Initial attempts to introduce unconventional manufacturing techniques and substrates for the large reflectors failed, resulting in dependence on conventionally polished [redacted] fused silica reflectors. Two important developments resulted in the successful employment of the conventional techniques: interferometer testing and selectro-plating. By using the interferometry to draw a map of the surface errors in the reflective pieces, and the selectro-plating to fill in the surface where indicated by the interferometry, the overall surface irregularities could be reduced to specified value. System assembly and testing showed steady improvement from the first unit on. By Flight 18, both the optical components and the assembled camera-optics module were being produced at or very near specification quality.

(b) A persistent problem with primary camera drive smoothness was present on all units in the form of fine corduroy banding at 250 Hz on the primary photography. Performance loss due to this lack of smoothness was calculated to vary from none to 30% loss of resolution. A satisfactory fix has not been determined.

(2) Satellite Re-entry Vehicle (SRV)

(a) The SRV employed on Flight 11 failed to deploy its main parachute and was lost in the recovery zone near Hawaii. Failure investigation did not pinpoint the failure cause, but weaknesses in design were discovered and corrected in the area of the thermal cover bridle and its deployment system. (A similar failure on Flight 25 second SRV in the subsequent double bucket series indicated that the true failure may have been inadequate design of the thermal cover ejection system for the flight environment encountered. It appears that the solution is to deploy the thermal cover earlier.) The SRV was essentially the same as the Gambit (206) model, and except for the catastrophic failure on Flight 11, the SRV operated well.

(3) Electromechanical Hardware

(a) Except for minor random failures, the electromechanical (non-optical) portions of the photographic payload section performed reliably. No major problems were encountered in deployment.

(4) Post Flight Evaluation of System Performance

(a) While post flight measures of photographic quality showed a parallel improvement with the improvements in optical quality shown by factory test, a performance, or resolution, gap appeared to exist between the levels of the two. On some flights, this gap was as much as 60% of the factory predicted resolution. Two possible causes of the resolution gap were investigated: hardware malfunction between factory test and flight and inadequate analytical modeling of system performance. These two possibilities were explored in parallel, with no firm conclusions reached at the end of the series.

b. Satellite Control Section (SCS)

There were no major technical problems associated with the SCS in the Gambit (110) program. The hardware was essentially a continued production to that used on the Gambit (206) program. The inadequate design and quality control problems which were corrected on Gambit (206) were successfully carried through on Gambit (110). Most of the technical effort on this program was directed to enhancing the reliability of the hardware and adding a Redundant Attitude Control System (RACS) on

Vehicle 16. This improvement had the capability of providing redundancy to the Primary Attitude Control System (PACS) for on-orbit vehicle attitude control only. The availability of RACS proved extremely fortunate: on Flight 17 PACS failed and RACS was activated on Rev 40 and operated successfully for the remainder of the flight; on Flight 20 PACS failed and RACS was activated on Rev 52 and operated successfully for the remainder of the flight.

c. Roll Joint (RJ)

The original RJ used on Vehicles 1 through 11 used a belt drive with a brushless motor for the primary servo system. Redundancy was provided by a second brush-type motor which could be irreversibly engaged but which would also drive the primary motor and belt if used. Capability of the RJ was 1,250 rolls at a roll rate of [redacted] degrees/second. For Vehicles 12 through 15 the servo systems were changed to two brush-type motors with friction drive. To provide a fully reversible dual system, the friction drive engage mechanism was changed from a spring loaded pyro activated device to spring loaded, electrical linear actuators. Capability was extended to 2,250 total rolls with an average roll rate of [redacted] degrees/second. For Vehicles 16 through 22 the redundant drive motor was replaced with a new design "long-life" motor. With a new Servo Electronics Assembly, including an inverter, the redundant system could now operate on unregulated power. The primary purpose for these changes to the redundant system on Vehicle 16 was to gain flight experience on one of the two "long-life" (7,000 roll capability) servo systems which would be effective on Vehicle 23.

5. <u>Procurement:</u>

a. Of the approximate total of [redacted] cost for Gambit (110) [redacted], was contracted directly by Special Projects for the satellite system and related support. Procurement of the remainder was handled by Space and Missile Systems Organization (SAMSO) for the booster system and related support. Funds were provided to SAMSO by SAFSP.

b. Five of the program's major contracts implemented a novel incentive fee arrangement personally developed by Major General John Martin, Jr for use on satellite systems. His paper entitled, "A Specialized Incentive Contract Structure for Satellite Projects" has become the established incentive guide for satellite programs. His approach emphasizes vehicle system performance, with cost and schedule trade-offs.

c. Details of the program contractual arrangements are contained in Attachment 4.

6. <u>Cost</u>:

a. As of 1 April 1970, the Gambit (110) project, Flights 1 through 22, had cost [redacted]. Final contract settlements over the next few years may cause minor changes in this amount.

b. Of the [redacted] was determined as recurring cost for the 22 flights. An estimate of individual flight recurring cost by calendar year was made in an effort to show the trend of decrease in cost per mission day flown and also the decrease cost per clear target readout. Because of long lead funding, the recurring cost attributed to a calendar year of flights may not have been funded during the calendar year in which the launches occurred. Because of overlapping contract periods, recurring costs were divided between those associated with the first six flights and those associated with the last sixteen flights. Recurring cost of the [redacted], Redundant Roll Joint System and Redundant Attitude Control System were not effective until Flights 10, 12 and 16 respectively. Recurring cost by calendar year then followed by adding recurring cost of those flights launched during a calendar year.

c. From the supporting attachments the following data of Table C-1 was gathered so as to determine the succeeding data of Table C-2.

TABLE C-1

Calendar Year	No. of Flights	No. of Primary Mission Days Flown	Clear Targets Readout	Recurring Cost	Total Cost
1966	3	20	[redacted]	[redacted]	
1967	6 + 1*	59			
1968	7 + 1*	67			
1969	4	40			
Total	22	186			[redacted]

All costs are in [redacted]
* Mission Failures

TABLE C-2

Calendar Year	Cost per Flight	Cost per Mission Day	Cost per Clear Target Readout
1966*	[redacted]		
1967*			
1968*			
1969*			
22 Launch Average**			

All costs are in [redacted] dollars

* Recurring cost only
**Total Cost

Most significant from the above data is that the cost per target was constantly going down to an average in calendar year 1969 of about [redacted] per clear target readout. Fortunately, costs per target of Gambit (110) were far more favorable than for Gambit (206) which considered for the majority of cases, targets recovered rather than cloud free targets. (Reference report to SP-1, "Analysis of Gambit Project" dated 24 August 1967.)

d. More detailed recurring and non-recurring cost data are included in Attachment 5. Costs per flight, per mission day and per clear target readout by calendar year are charted on Attachment 2, Figure 6.

7. Summary:

The Gambit (110) project, Flights 1 through 22, was highly successful in that:

a. Its capability of obtaining high resolution photography was good from its beginning and was continually bettered until its conclusion to the point only considered possible at its onset.

b. With the cost inflation of wages and materials, its cost per mission day and cost per filmed target continued to decrease.

c. The record of successful missions completed even if not perfect, was outstanding.

d. Action was taken to add features to increase reliability such as the Redundant Attitude Control System which proved to be required on Flights 17, 18 and 20. Action was taken to increase capability as in the case of technical improvements with the optics system.

[redacted]

5 Atchs
1. Project History
2. Graphs
3. Flight Brief
4. Procurement Data
5. Cost Data

Following is a narrative description of each contract and the results thereof:

Lockheed Missiles and Space Company

a. AF-619 (White) Covered the design, development test and production of the peculiarization of the first six SS-01B Standard Agena vehicles into GAMBIT Satellite Control Section (SCS) vehicles. Originally negotiated as a conventional cost-plus-incentive-fee contract, it was changed to incorporate the above "Specialized Incentive" structure prior to the first launch. Target fee was [redacted] equal to 13.8 percent of target cost. (The target fee was reduced from 15 percent due to non-vehicle related changes I.E. AGE and STE) No schedule incentive was used. Cost incentive was negative only, shared at a ratio of 85/15 up to 9 percent of target cost. All six of the vehicles were scored at 100 percent success. The contract experienced a cost penalty of [redacted] due to an overrun of [redacted] (equal to 6.8 percent of target cost). As a result the contract final fee is [redacted] equal to 13.0 percent of target cost.

b. [redacted] covered design development test and production of the first six roll joints (PAS) and was also originally negotiated as a conventional cost-plus-incentive-fee contract with conventional cost, schedule and performance arrangements. However, concurrent with the change in AF-619 the "Specialized Incentive Contract Structure" was implemented. The same performance and cost parameters as those on AF-619 were used. Vehicle performance was identical to AF-619. The contract experienced an overrun of 17.6%. As a result the final adjusted fee rate was 10.44 percent. Final fee is as follows:

Target fee	[redacted]
Actual fee	

c. Contracts AF-896 (white) and [redacted] (black) were originally negotiated as sustaining follow-on effort for peculiarization of sixteen additional SS01B Standard Agena vehicles into GAMBIT SCS vehicles and roll joints (PAS's), respectively. However, the contracts were amended to include the development (non-recurring) effort associated with longer life, redundant capability vehicles to be flown on subsequent contracts.

(1) AF-896 originally covered engineering, manufacturing, test and launch support of sixteen SCS vehicles. Later the changes were added for long life development, SGLS, RACS & DACS. The same incentive structure as AF-619 was used, with the addition of a schedule incentive penalty of one-half percent of target cost up to a maximum [redacted] applied at [redacted] per day. Cost incentive penalties applied over a range up to 9% of target cost. Cost sharing ratios of 90/10 from 9%-15% over target cost, 80/20 from 16%-30% and 70/30 from 31 to 45% were applied. Actual results were 100% vehicle performance, schedule penalties of [redacted] and a cost penalty of [redacted] actual results were:

Target fee	[redacted]
Final fee	

(2) [redacted] produced sixteen PAS's (roll joints) and all development and non-recurring effort for the long life redundant capability. The identical incentive fee parameters as AF-896 were employed. An overrun of 1% was incurred. All vehicles were on schedule and 100% successful performance was scored. Actuals were:

Target fee
Final fee [redacted]

General Electric Light Military Electronics Department, Later: Aerospace Electronics Department

a. Contracts AF-594 and AF-897 (both white) covered the development and production efforts of the vehicle Command Subsystems including STE, AGE and facilities.

(1) AF-594 was negotiated as a CPIF with cost and schedule parameters. Under this incentive arrangement the contractor shared cost variances from target cost up to plus or minus 5% at the ratios of 85/15. Target fee was 8.0%. The contractor could earn as much as 13% or lose down to 3%, respectively, for underruns or overruns to a maximum gain/loss of [redacted]. Schedule incentive was a penalty of [redacted] for the first unit and [redacted] for each subsequent flight unit up to a maximum of [redacted]. All six flights were flown at 100% success. Pending completion of determination of final costs the following are the estimated fee results:

Target fee
Cost Penalty
Schedule Penalty
Net loss
Net fee [redacted]

(2) AF-897 was negotiated as a CPIF-P contract utilizing the "Specialized Incentive Contract Structure" of 15% for performance and covered flight units 10 through 25. Of the sixteen flights flown, fourteen were scored at 100% success. Of the two units flown with anomalies, Flight 7 was scored at [redacted] penalty points and Flight 16 at [redacted] penalty points resulting in a total fee loss of [redacted]. Cost incentives were negative only and had sharing ratios of 90/10 up to 15% over target cost, 80/20 from 16 to 30% and in excess of 30% to a maximum of [redacted]. Schedule and combined system test penalties of minus 1% respectively were applied to each unit to a maximum of [redacted] for each parameter. Flight unit 13 experienced a system test failure of [redacted]. No schedule penalties were experienced. Pending completion of final cost, the following are the final results: ($ earned)

Target fee
Par Performance
Adjusted Performance
C/ST Failure (loss)
Cost (loss)
Net fee [redacted]

General Electric - Re-Entry Systems Department

a. Black contract [redacted] covered the production of SRV's 6 thru 22. (All development work and flight models 1 through 5 was accomplished on a subcontract basis under prime contract AF-2108 with Eastman Kodak.) The contract was a FPIF contract with cost and delivery incentives. Cost ceiling was 11.7% with sharing of 70/30. Schedule incentive was 1% of target cost over 4 weeks, shared at the rate of 10% for the week 1, 25% for week 2, 30% for week 3 and 35% for week 4. The contractor experienced an overrun of [redacted] and all deliveries were on time. Final results are:

Cost
Fee [redacted] (fee loss of [redacted])
Price

General Electric - Spacecraft Department

a. White contract AF-693 was a CPIF contract for mission planning software. Cost share ratio was 85/15. The contract target fee was [redacted] 8.5% of target cost. Final fee was increased to [redacted] due to an underrun.

b. White contract [redacted] was a CPFF contract for mission planning software with a fixed fee of [redacted] equivalent to 8.3% of final estimated cost.

c. White contract [redacted] is a CPFF follow-on contract to [redacted] to provide continuing software support. The contract is still active. The fixed fee is [redacted] 8.6% of estimated cost.

d. White contract AF-636 was a CPIF contract with target cost of [redacted] and cost incentives only at a sharing ratio of 86/14. The effort was for a SCS parallel study. The target fee was increased by an underrun and the final fee amount was [redacted] to 8.2%.

TRW, Inc.

a. White contract [redacted] was a CPIF contract, with cost incentives only and a sharing ratio of 75/25, to provide mission planning software for earlier versions of GAMBIT vehicles. The contract remained active over the transition from the earlier versions. Target fee was [redacted]. The final adjusted fee is expected to be [redacted] as a result of reduction due to an overrun.

b. White contract [redacted] was a CPIF follow on to [redacted]. Cost incentives only were applied at the ratio of 75/25. Target fee was [redacted]. Actual fee is expected to be [redacted] when final rates are established and the contractors underrun computed.

Eastman Kodak

Contract [redacted] covered development, test production and launch support for Photographic Payload Section vehicles number one through twenty-two including facilities, STE, AGE and launch support. The first five SRVs were included in this contract on a subcontract basis with GE-RSD. The contract effort also included design, development and test of the follow-on Dual-Recovery version PPS. A CPFF contract was negotiated at a fixed-fee rate of 7.7%. Final fee is expected to be [redacted], equivalent to 6.18% of final estimated cost.

LIST OF SAFSP GAMBIT CONTRACTS

NUMBER	TYPE	SECURITY	WITH	FOR	LIFE	FINAL PRICE	FEE EARNED (% OF ACTUALS)
AF-619	CPIF-P	(White)	LMSC	Des. Dev. & Prod 6 SCS	Jul 64-Aug 67	[redacted]	13.0
[redacted]	CPIF-P	(Black)	LMSC	Des. Dev. & Prod 6 PAS	Jul 64-Aug 67		10.4
AF-896	CPIF-P	(White)	LMSC	Des. Dev. & Prod 16 SCS (includes: SGLS, DRM, FACS, RACS.)	Jan 66-Dec 69		13.9
[redacted]	CPIF-P	(Black)	LMSC	Des. Dev. & Prod 16 PAS	Jan 66-Jul 69		14.5
AF-594	CPIF-PV	(White)	GE-LMED	Des. Dev. & Prod 9 C/SS	May 64-Aug 67		4.4
AF-897	CPIF-P	(White)	GE-AED	Des. Dev. & Prod 22 C/SS	Nov 65-Aug 68		13.3
[redacted]	FPIF	(Black)	GE-RSD	Recurring 17 RSVs	Dec 65-Jul 69		10.4
	CPFF	(Black)	EKC	Des. Dev. & Prod 22 PPS	Mar 64-Dec 69		6.2
[redacted]	CPIF	(White)	TRW	Software	Apr 66-Dec 67		10.8
	CPIF-V	(White)	TRW	Software	Jan 68-Nov 69		10.9
AF-693	CPIF-V	(White)	GE-Spacecraft	Software	Sep 64-Feb 67		9.2
[redacted]	CPFF	(White)	GE-Spacecraft	Software	Jul 68-Current		8.6
AF-0014	CPFF	(White)	GE-Spacecraft	Software	Dec 66-Jul 68		8.3

BYE-16762-70

TOP SECRET

LIST OF SAFSP GAMBIT CONTRACTS (Con't)

NUMBER	TYPE	SECURITY	WITH	FOR	LIFE	FINAL PRICE	FEE EARNED (% of ACTUALS)
MISCELLANEOUS							
AF-636	CPIF	(White)	GE-ASPD	SCS Parallel Study	Jul 64-May 65	[redacted]	8.2
[redacted]	CPFF	(Black)	Perkin-Elmer	Glass Polishing	Oct 66-Sep 68	[redacted]	7.8
Related Work:							
[redacted]	CR	(Black)	[redacted]	[redacted]	Jul 66-Current	[redacted]	0
[redacted]	CPFF	(Black)	LMSC	[redacted]	Aug 66-May 69	[redacted]	8.2
[redacted]	FFP	(Black)	Sylvania Corp	[redacted]	Apr 67-Sep 69	[redacted]	N/A
[redacted]	FFP	(Black)	Sylvania Corp	[redacted]	Aug 66-Current	[redacted]	N/A

BYE-16762-70

TOP SECRET

Handle Via BYEMAN

TOP SECRET

OVERALL FEE EARNING

PRINCIPAL SAFSP CONTRACTORS ON TOTAL GAMBIT WORK

CONTRACTOR	NO. OF CONTRACTS	ACTUAL COST [redacted]	[redacted]	ACTUAL FEE (% OF ACTUAL COST)
LMSC	5	[redacted]	[redacted]	12.3
GE	7	[redacted]	[redacted]	8.3
EKC	1	[redacted]	[redacted]	6.2
TRW	2	[redacted]	[redacted]	9.8
OTHERS	4	[redacted]	[redacted]	.02
	19	[redacted]	[redacted]	8.84 (average)

TOP SECRET

Handle Via BYEMAN Control System Only

BYE-15762-70

TOP SECRET

RESULTS OF INCENTIVE FEATURES ON GAMBIT CONTRACTS

CONTRACT	FEE GAIN (LOSS) FOR: PERFORMANCE	SCHEDULE	COST	NET FEE GAIN (LOSS)	RESULTANT FEE EARNED	% OF ACTUAL COST
LMSC - 619	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	13.0
LMSC - [redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	10.4
LMSC - 896	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	13.9
LMSC - [redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	14.5
GE - 594	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	4.4
GE - 897	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	13.3
GE - [redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	10.4
GE - 693	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	9.2
GE - 636	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	8.2
TRW - [redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	10.8
TRW - [redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	10.9

* Estimated

** Reduction due to combined system test failure.

TOP SECRET

Handle Via BYEMAN ...al System Only

BYE-16762-70

ATTACHMENT 1

PROJECT HISTORY

1. As was the Gambit (206) project, Gambit (110) was managed entirely by SAFSP, which had responsibility for development, production and operation of all system components. With this span of responsibility, SAFSP was able to coordinate efforts towards obtaining increasingly better resolution photography. The final Gambit (110) mission obtained a best ground resolution by [redacted] target determination of [redacted]. Gambit (110) initial development began in March 1964, approximately 28 months before the first Gambit (110) flight of July 1966. The success of Gambit (110) project brought about the termination of Gambit (206) project which had its thirty-eighth and last flight in June 1967.

2. The launch system configuration of the Gambit (110) project differed considerably from that of the Gambit (206) project. Major launch system changes incorporated at the onset of Gambit (110) were:

a. The two-stage Titan IIIB was the booster for ascent from the pad.

b. A roll joint was used between the payload and the Agena stage. In this configuration, the payload and Agena orbited together throughout the mission with roll joint movements as required for photographs in track or either side of track. The Agena was the orbit control vehicle or Satellite Control Section, as well as the orbit injection booster.

c. The Gambit (110) Photographic Payload became a separate section which adapted to the Agena (Satellite Control Section). This configuration differed very much from the earlier Gambit arrangement in which the payload fit within the orbital control vehicle. The Gambit (110) optics were arranged to achieve a focal length of 160 inches, a change from 77 inches for the Gambit (206) system.

d. The "factory-to-pad" concept became a reality with Gambit (110). The Titan IIIB booster, Agena with roll joint, and photographic payload section were shipped separately to Vandenberg AFB and assembled on the launch pad. This required more thorough testing at the "factory" before shipment and reduced the testing and hardware changes required at Vandenberg AFB.

3. Two important changes made during the deployment of Gambit (110) were:

a. The primary film was changed from a thin base to an ultra-thin base which increased the film capacity from about 3,000 feet to about 5,000 feet. Ultra-thin base film was used on Flights 3 through 22.

b. A Redundant Attitude Control System (RACS) was first flown and tested during solo flight or Flight 16. Fortunately, the RACS was included on all subsequent Agena vehicles and was necessarily used during the primary portion of Flights 17, 18 and 20.

4. Principal components and their manufacturers were:

Payload	EKC
Re-entry Vehicle	GE/RESD
Agena Stage	LMSC
Command Subsystem	GE/AE
Titan IIIB	Martin Marietta

5. During the life of the project, these were the key personnel:

a. DNRO:

Mar 64 - Sep 65	Dr B. McMillan	Initial Development
Sep 65 - Mar 69	Dr A. H. Flax	Development, Flights 1 through 20
Mar 69 - Conclusion	Dr J. McLucas	Flights 21 and 22

b. Director of Special Projects

Mar 64 - Jul 65	MajGen R. Greer	Initial Development
Jul 65 - Conclusion	MajGen J. Martin, Jr	Development, All Flights

c. Program Director

Mar 64 - Sep 66	Col W. King, Jr	Initial Development, Flight 1
Sep 66 - Jun 68	Col [redacted]	Flights 2 through 14
Jun 68 - Conclusion	Col [redacted]	Flights 15 through 22

6. The following Table 1 contains some important data about each of the 22 Gambit (110) flights.

ATTACHMENT 2

GRAPHS

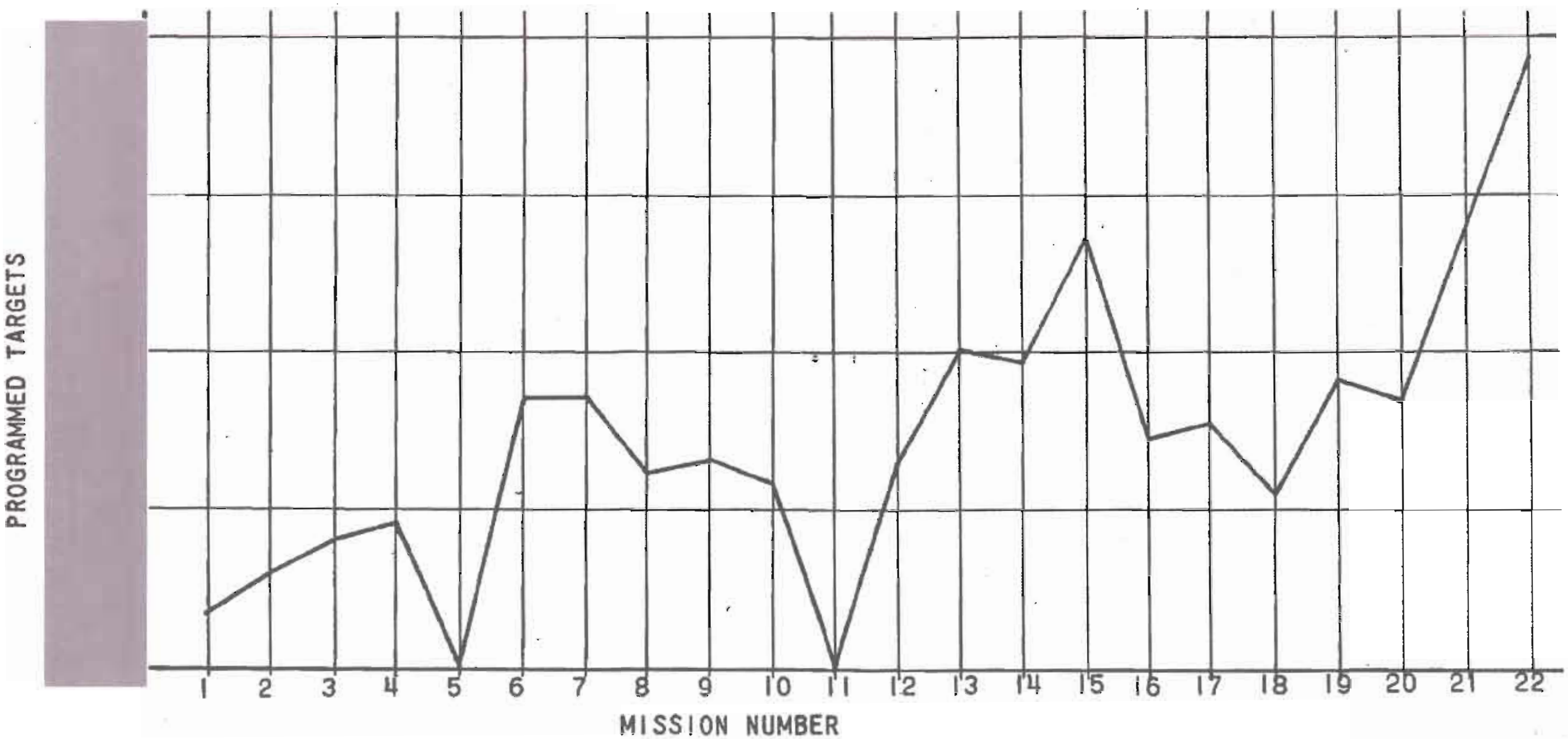


Figure 1 TOTAL PROGRAMMED TARGETS BY MISSION

BYE-16762-70

ATTACHMENT 5

GAMBIT (110) COST DATA - VEHICLES 1-22

1. The total program of [redacted] includes the following:

a. Twenty-two satellite vehicles, boosters, Agenas, payloads, and recovery vehicles launched. Some vehicles are configured with RACS [redacted] and Redundant Roll Joints with effectivities as indicated.

b. Titan IIIB costs include the [redacted] allocated directly to the Titan SPO for development of the booster, required pad modifications, and payment for the first booster/Agena and their associated launch costs.

c. Command Subsystem costs include twenty-two flight systems and nine spares.

d. Aerospace, Mission Planning and General Support costs include effort through the final launch of Vehicle 22 (June 1969).

e. Although non-recurring investment costs are segregated in total on the contracts, they are not segregated by fiscal year. The allocation shown is based on the best judgment of the Program Office.

BYE-16762-70

TOP SECRET

[redacted]

GAMBIT NON-RECURRING INVESTMENT
BY FISCAL YEAR - VEHICLES 1-22

	FY-64	FY-65	FY-66	FY-67	FY-68	FY-69	TOTAL
WHITE							
Spacecraft	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Booster Hardware	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Booster Pad Mod	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Command Subsystem	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Agena Hardware	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
RACS (eff #16)	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Agena Improvement	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Pad Disaster Pool	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
GE Parallel Study	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Industrial Facilities	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Sub-Total	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
BLACK							
PAS/Roll Joint	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Payload	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Recovery Vehicle	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Redundant R/J (eff #12)	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted] (eff #10)	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Equipment Move	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Industrial Facilities	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Sub-Total	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
GRAND TOTAL	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

TOP SECRET

Handle Via
[illegible]
Control [illegible]

[redacted]

GAMBIT (110) COST SUMMARY - VEHICLES 1-22

	FY-64	FY-65	FY-66	FY-67	FY-68	FY-69	TOTAL
WHITE	[redacted]						
Spacecraft							
Booster Hardware							
Booster Launch							
Booster Pad Mod							
Command Subsystem							
Agena Hardware							
Agena Launch							
RACS (eff #16)							
OTEX (eff #10)							
Agena Improvement							
Pad Disaster Pool							
GE Parallel Study							
Aerospace							
Mission Planning							
Industrial Facilities							
General Support							
Sub-Total							
BLACK	[redacted]						
PAS/Roll Joint							
Payload							
Recovery Vehicle							
Redundant R/J (eff #12)							
[redacted] (eff #10)							
Equipment Move							
Industrial Facilities							
Sub-Total							
GRAND TOTAL							

~~TOP SECRET~~

[redacted]

GAMBIT (110) NON-RECURRING AND RECURRING PER UNIT COST SUMMARY VEHICLES 1-22

	Non-Recurring	Recurring/Unit Systems 1-6 ①	Recurring/Unit Systems 7-22 ①	TOTAL
WHITE				
Spacecraft	[redacted]			
Booster Hardware				
Booster Launch				
Booster Pad Mod				
Command Subsystem				
Agena Hardware				
Agena Launch				
RACS (eff #16)				
OTEX (eff #10)				
Agena Improvement				
Pad Disaster Pool				
GE Parallel Study				
Aerospace				
Mission Planning				
Industrial Facilities				
General Support				
Sub-Total				
BLACK	[redacted]			
PAS/Roll Joint				
Payload				
Recovery Vehicle				
Redundant R/J (eff #12)				
[redacted] (eff #10)				
Equipment Move				
Industrial Facilities				
Sub-Total				
GRAND TOTAL				

① Numbers in parenthesis show the inclusive number of equivalent systems.

② 6 flight units plus 3 spares

③ 16 flight units plus 6 spares

~~TOP SECRET~~

Handle Via

BYE-1 762-70

~~TOP SECRET~~

[redacted]

GAMBIT (110) FLIGHT COST BY CALENDAR YEAR
VEHICLES 1-22

	CY-66 (3)	CY-67 (7)	CY-68 (8)	CY-69 (4)	TOTAL
WHITE	[redacted]				
Spacecraft					
Booster Hardware					
Booster Launch					
Command Subsystem					
Agena Hardware					
Agena Launch					
RACS (eff #16)					
OTEX (eff #10)					
Aerospace					
Mission Planning					
General Support					
Sub-Total					
BLACK	[redacted]				
PAS/Roll Joint					
Payload					
Recovery Vehicle					
Redundant R/J (eff #12)					
[redacted] (eff #10)					
Sub-Total					
GRAND TOTAL					

The above summary shows the costs in the calendar year of flight and does not consider long lead funding.

The totals by Calendar Year plus the cost of nine spare Command Subsystems [redacted] plus the non-recurring of [redacted] reconciles to the total program cost for Vehicles 1-22 of [redacted].

Numbers in parenthesis reflect the number of flights during the calendar year indicated.

~~TOP SECRET~~

Handle Via
Contr Only

Figure 2 AVERAGE TARGETS PER MISSION BY CALENDAR YEAR

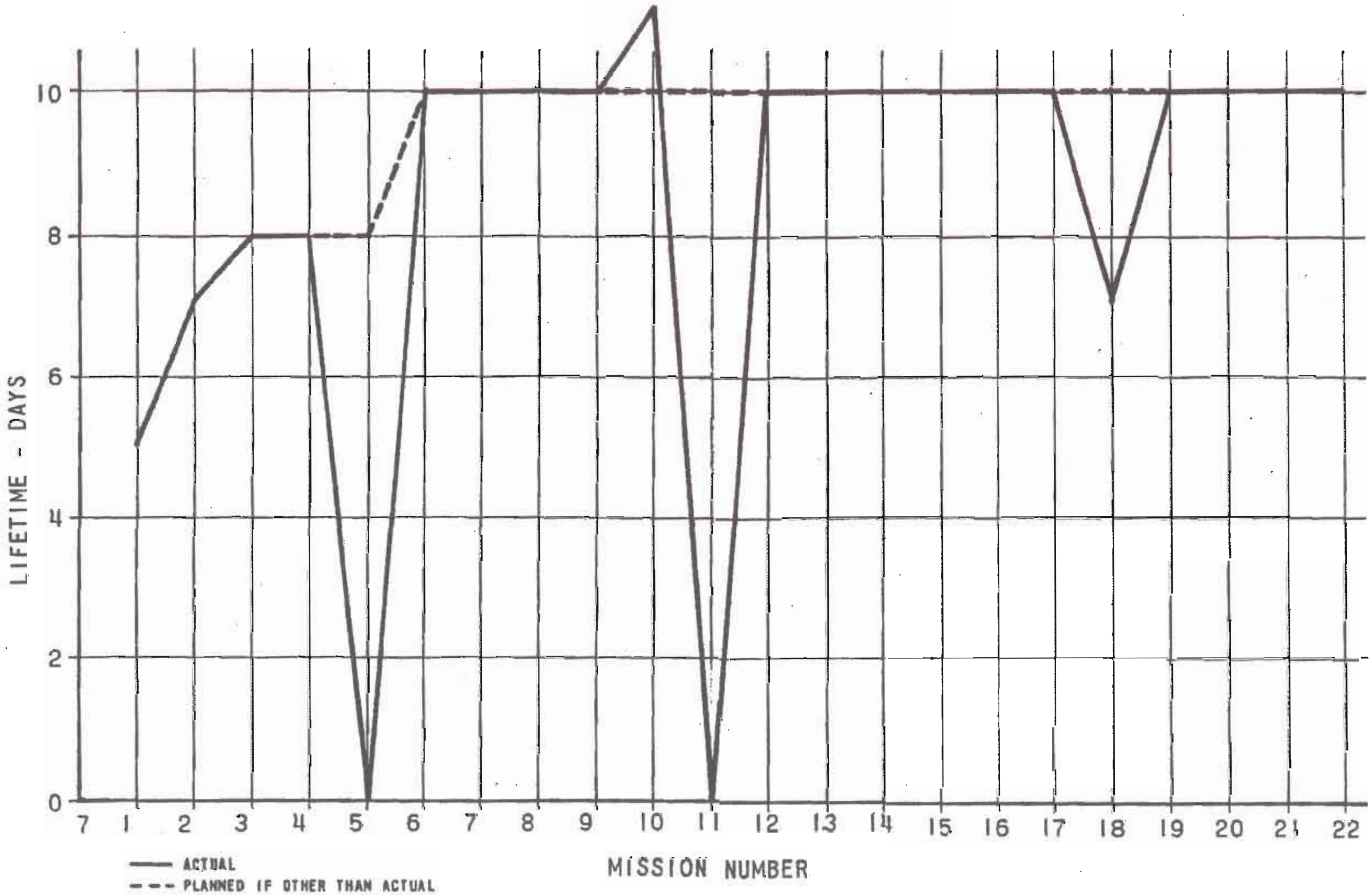


Figure 3 ACTUAL vs PLANNED ORBITAL LIFETIME BY MISSION
(SOLO MISSION NOT INCLUDED)

TOP SECRET

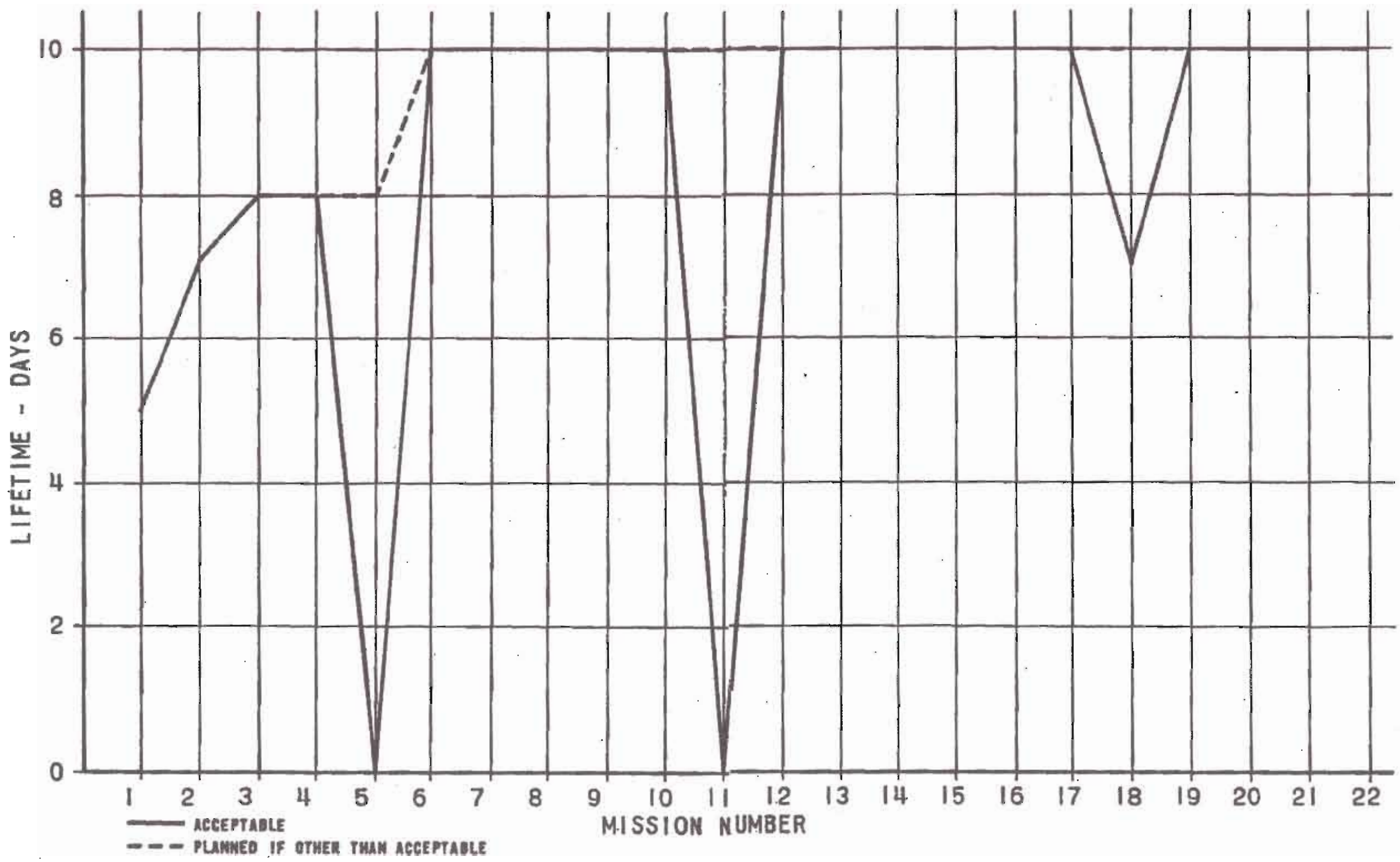


Figure 4 ACCEPTABLE vs PLANNED ORBITAL LIFETIME BY MISSION
(SOLO MISSION NOT INCLUDED)

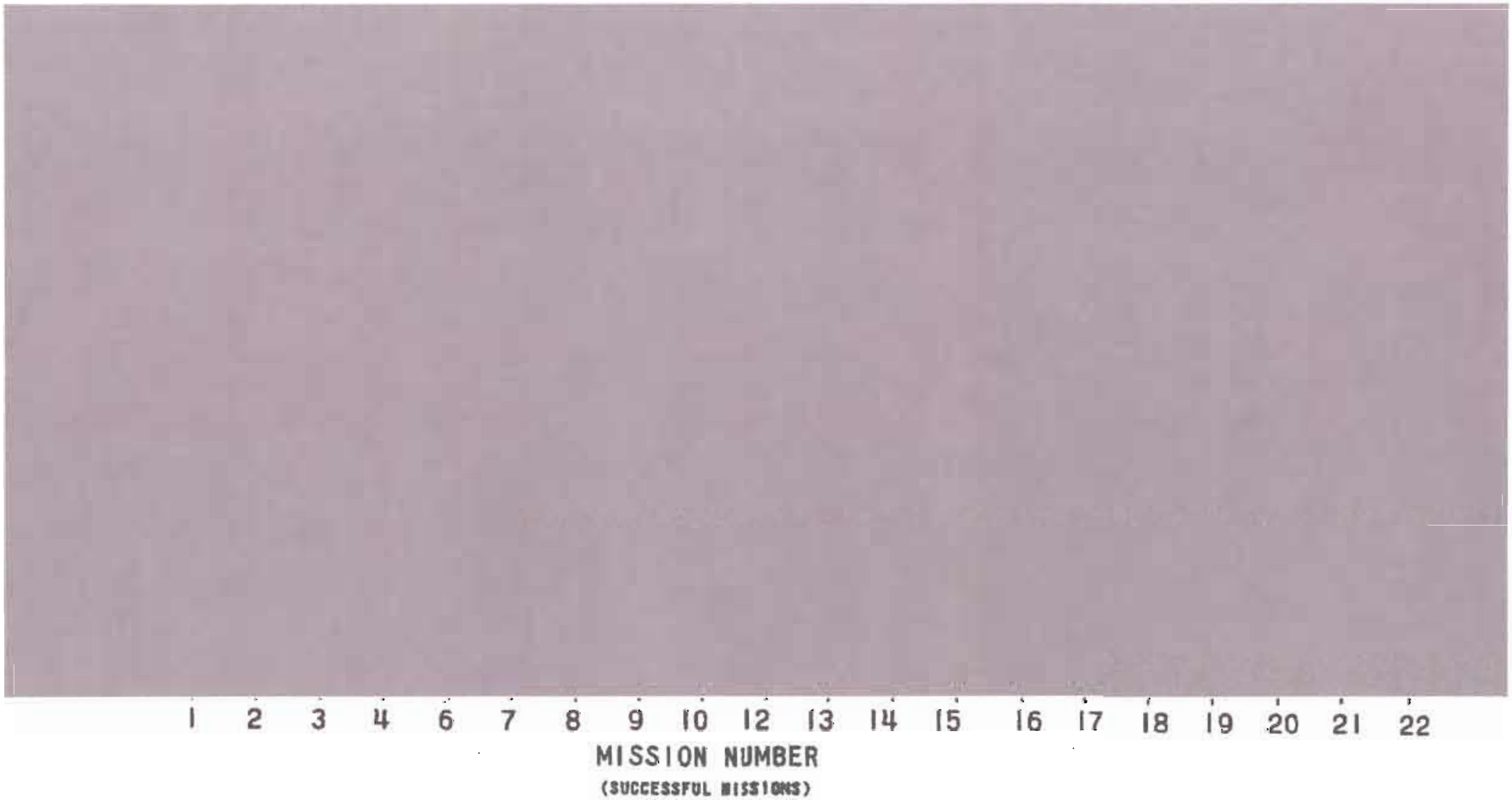


Figure 5 BEST GROUND RESOLUTION [redacted] BY MISSION

TOP SECRET

TABLE 1

GAMBIT (110) FLIGHT DATA

FLIGHT NO.	LAUNCH DATE	LAUNCH TIME (GMT)	INCLINATION (DEGREES)	APOGEE/PERIGEE AFTER INJECTION (NM)	RECOVERY REV	RECOVERED	DEBOOST REV	TARGETS PROGRAMMED	TARGETS READOUT	BEST RESOLUTION (INCHES)	PRINCIPAL PROBLEMS DURING OPERATION
1	29 Jul 66	1830	94.15	150.33/84.43	83	Yes	130	[redacted]	[redacted]	[redacted]	APTC shutter malfunction (APC intermittent); Slit position fixed (No. 4); RJ constrained, ± 35°
2	28 Sep 66	1907	94.0	176.07/83.93	115	Yes	147	[redacted]	[redacted]	36	APTC disable prior to flight (erratic behavior of advance mechanism)
3	14 Dec 66	1814	109.5	221.95/82.64	131	Yes	162	[redacted]	[redacted]	[redacted]	ECS command system problem, memory channel 22, Revs 28-31; APTC (APC shutter, intermittently stuck open)
4	24 Feb 67	1959	107.0	231.2/76.90	131	Yes	163	[redacted]	[redacted]	27	APTC (APC shutter failed in open position, Rev 46)
5	26 Apr 67	1800	-	-	-	No	-	[redacted]	[redacted]	-	Titan IIIB Second Stage failure (ΔV 8,000 fps low); Failed to obtain orbit
6	20 Jun 67	1615	111.42	196.15/75.21	164	Yes	165	[redacted]	[redacted]	[redacted]	Titan IIIB Second Stage skirt failure (ΔV of 88 fps low); RJ positioning error, Rev 64, certain angles were unattainable to end of flight
7	16 Aug 67	1707	111.58	252.91/79.95	163	Yes	195	[redacted]	[redacted]	[redacted]	Primary RJ release failed (B/U system functioned properly); ECS failure (delay line 12, Rev 39; delay line 11 intermittent, Revs 62-65)
8	19 Sep 67	1837	106.12	241.97/70.93	163	Yes	164	[redacted]	[redacted]	[redacted]	None
9	25 Oct 67	1915	111.56	243.70/74.21	163	Yes	164	[redacted]	[redacted]	[redacted]	Film handling system stalled (primary, Rev 155, Loss 200')
10	5 Dec 67	1845	109.57	248.90/77.09	178	Yes	179	[redacted]	[redacted]	[redacted]	SCS pitch valve intermittent failure to fire, Rev 103; ECS Decoder 2 failure, Rev 163; TC failure, Rev 37

BYE-16762-70

TOP SECRET

Handle Via
BYEMAN
Control System Only

GAMBIT (110) FLIGHT DATA (Con't)

TABLE 1
Page 2

FLIGHT NO.	LAUNCH DATE	TIME (GMT)	INCLINATION (DEGREES)	APOGEE/PERIGEE AFTER INJECTION (NM)	RECOVERY REV	RECOVERED	DEBOOST REV	TARGETS PROGRAMMED	TARGETS READOUT	BEST RESOLUTION (INCHES)	PRINCIPAL PROBLEMS DURING OPERATION
11	18 Jan 68	1904	111.54	241.12/70.90	163	No	274	[redacted]	[redacted]	-	SRV parachute deployment system failed
12	13 Mar 68	1951	99.87	235.94/73.26	163	Yes	164	[redacted]	[redacted]	[redacted]	TC failed, Rev 4
13	17 Apr 68	1700	111.50	246.25/73.84	163	Yes	196	[redacted]	[redacted]	[redacted]	None
14	5 Jun 68	1733	110.55	251.11/69.89	163	Yes	196	[redacted]	[redacted]	[redacted]	Tape recorder failed, Rev 66
15	6 Aug 68	1630	110.0	250.60/69.36	162	Yes	163	[redacted]	[redacted]	[redacted]	TLM Ch 10 and 11 failed, Rev 9; [redacted] Rev 76; TC shutter failure
16	10 Sep 68	1830	106.0	235.81/70.77	163	Yes	238	[redacted]	[redacted]	[redacted]	Extended Command System failed on Rev 124
17	6 Nov 68	1910	106.0	224.32/72.71	163	Yes	212	[redacted]	[redacted]	[redacted]	PACS right head horizon sensor failed, Rev 38; RACS took over on Rev 41
18	4 Dec 68	1923	106.20	405.97/75.47	111	Yes	127	[redacted]	[redacted]	[redacted]	Ground guidance problem, Titan IIIB Second Stage burn to depletion; SPS single engine burn, Rev 93
19	22 Jan 69	1910	106.153	597.08/74.76	161	Yes	181	[redacted]	[redacted]	[redacted]	V/M failed, Agena burned to depletion; ECS Decoder 2 failed to execute PSPC's
20	4 Mar 69	1930	92.027	253.68/73.62	161	Yes	224	[redacted]	[redacted]	[redacted]	PACS failure, Rev 52 (Thrust valve); APC failure, Rev 24
21	15 Apr 69	1730	108.78	261.55/74.76	163	Yes	244	[redacted]	[redacted]	[redacted]	Ground guidance problem, slight inclination error; ECS Decoder 2 relay driver failed open; RACS failure, Rev 217
22	3 Jun 69	1649	110.03	239.07/75.36	163	Yes	179	[redacted]	[redacted]	[redacted]	None

~~SECRET~~

LMSCB115417

4-6-10

1999 00043 B-7 E-4

SECTION 1

SYSTEM PERFORMANCE

A. MISSION OBJECTIVES

The first flight vehicle of Program 206-II consisted of the booster SLV-5B/66-8131, satellite control section (SCS) 58205/4751, and a forward satellite vehicle section (FSVS). The forward section included a recovery capsule.

The planned mission was as follows:

a. Five days of stable orbit operation with recovery on orbit 83.

b. Three days of solo operation to exercise the SCS, including yaw around maneuvers, secondary propulsion system (SPS), main engine deboost, and orientation via the backup stabilization system (BUSS).

B. FLIGHT RESULTS

The mission was accomplished according to plan, and all objectives associated with the SCS were met.

The vehicle was launched from PALC-2 Pad 3 at the Western Test Range on 29 July 1966 at 1130:19.81 PDT on the second countdown. The initial countdown on 28 July 1966 was aborted at T-1 minute because of a test fault indication at the WECO ground guidance station.

The velocity at Stage II shutdown was low by 8.8 ft/sec., due to a slightly early shutdown command from the WECO guidance system. The Agena velocity gained was 8634.53 ft/sec., 0.9 ft/sec. higher than the velocity meter setting. Attitude discrepancies existed in the SLV-5B and in the SS-01B, but the cumulative result gave a near-nominal trajectory.

All telemetry channels displayed two short data loss periods during Stage II ignition, one loss for 450 milliseconds and another for 105 milliseconds, separated by 85 milliseconds of data. Two unexplained data dropouts occurred at 318.46 seconds and 325.13 seconds from liftoff.

The tracking and S-band commanding was satisfactory with the exception of lower than normal signal strength after two days on orbit and some intermittent break-up of the S-band beacon pulses as received by the ground radar. These anomalies did not affect tracking or commanding.

An aerial recovery of the capsule was made on orbit 83.

During the three days of solo operations, three yaw-around maneuvers were made, and three SPS burns were accomplished.

On orbit 130 deboost was accomplished with the main engine.

Following deboost, orientation via the BUSS to the local magnetic vector was successfully accomplished.

C. CONCLUSIONS

The operation was conducted according to plan and all objectives were accomplished. The problems encountered did not degrade the mission.

D. RECOMMENDATIONS

1. Full advantage should be taken on future flights of the opportunity to accumulate additional data on performance of the Secondary Propulsion System during solo flight.

2. Conduct a study and test program on the susceptibility of the S-band RF cable assemblies to define the leakage mechanism.

3. Monitor future operations closely to obtain good time correlation of any S-band anomalies regarding signal strength and beacon characteristics.

4. Record vehicle time along with other recorded data by the vehicle tape recorder.

5. Efforts should continue to evaluate the possible cause and analyze the effects of the vehicle motion during the period between SECO and Stage II-Agena separation.

SS-1
H15-B 10

Lockheed
MISSILES
& SPACE
COMPANY

November 13, 1966

REGINALD R. KEARTON
VICE PRESIDENT

Dear Al:

The attached paper is the result of our hindsight look at Program 206-II which we recently discussed. For your information, I have discussed this paper with John Martin and have given him a copy of same.

I hope it will be of some use to you, as I am sure it will help us.

Sincerely,

The Honorable A. H. Flax
Assistant Secretary of the Air Force
(Research and Development)
The Pentagon
Washington 25, D. C.

(Attach.)

MAJOR FACTORS CONTRIBUTING TO PROGRAM 206-II SUCCESS

It was believed that a useful purpose might be served in a hindsight review of the factors which contributed to the early success of the Program 206-II.

Preliminary examination indicated two broad categories of influence, i.e., intangible and tangible factors. It should be noted that the term intangible might be defined as discernible but hard to quantify factors which represented the subjective judgment of the contractor. The tangible, on the other hand, were those elements which would be easy to quantify and which any viewer would be unlikely to refute.

First of the intangibles were:

- The amount and nature of the cooperation between the Air Force System Program Office (SPO), including the Aerospace Corporation support, and the LMSC Program Organization.
- The contractor program office which had made available to it an abundance of appropriately experienced personnel, together with a degree of projectization which was effective through the delegation of necessary authority.
- A carefully devised incentive contract biased toward technical performance which resulted in a powerful management tool for motivation of all employees associated with the program to promote early and continued success.

A discussion of these factors follows:

1. From the beginning of the program there has existed a stable and tight SPO/LMSC relationship which has led to a very high level of mutual trust and confidence in the technical administration of this program. Effectiveness of the relationship has been aided by the tight change control on the general systems specification which had no significant changes after the first six months of the program. Problems, when first identified, have been given prompt attention by the Air Force/Aerospace/LMSC team, thus allowing timely resolution. Examples are such problem areas as the Command Programmer and the SCF software. These represented significant program features which were GFE to LMSC, which required and got decisive Air Force/Aerospace action.

2. This whole environment was aided by the LMSC choice of experienced key personnel who were given adequate authority to perform their job. As a result of the LMSC management trainee concept on programs extant at the initiation of 206-II, such as Standard Agena, 206-I, 241, and others, properly trained people were provided at no detriment to the existing programs. The physical co-location of all concerned LMSC elements led to de facto total projectization in all parts of the program. These circumstances were further aided by the LMSC program management concept of delegating cost, schedule, and technical responsibility for end-item segments.

In this approach, all system and subsystem personnel were given extensive training early in the program on the total system technical approach as well as the contractual incentive provisions. In addition, techniques were developed to measure the individual's cost, schedule, and technical performance on a weekly basis. This technique, together with comprehensive design reviews and hardware audit programs, permitted program motivation to extend from the Group Engineers to the supporting organizations such as Manufacturing and Product Assurance.

3. The incentive contract which featured vehicle performance had the desired result. It was of particular importance that all performance was to be measured as a negative from optimum. In other words, any performance less than perfection represented a loss to the company rather than a more classic approach which provided a potential gain. The contract will experience a cost overrun of 5% or less. This did not result from irresponsible fiscal management, but rather many program decisions which were believed to contribute to better reliability. These actions were broadly within the scope of the contract but not foreseen. They did not represent difficult trade-off decisions, since it was believed that vehicle performance would offset the penalty to the company.

Turning now to the tangible factors:

Endorsement of CDP philosophy

- A timely, carefully reviewed, effective design. This included minimum technical risks with emphasis on those which were considered of a higher risk.
- A novel spacecraft testing concept embracing factory readiness before shipment to the launch pad, with least possible testing needed at that point.
- Realistic costs with an underlying philosophy of both Air Force and company management of allowing only what was necessary, but at the same time that which was essential to ensure mission success.

A discussion of these factors follows:

1. The program was able to draw upon the existence of a well thought out preliminary design. It is to be noted that the final design is almost identical to the design originally proposed by LMSC with the exception of changes in the Command Subsystem and the addition of certain redundant features. The willingness of the Air Force to accept LMSC's proposal permitted an extremely orderly program. This was further aided by the existence and execution of a detailed and logical development program which allowed six months for design, six months for component fabrication and development, six months for systems qualification, and six months for manufacturing flight hardware and preparing for launch. This program plan, combined with the Development Test Vehicle, permitted the inevitable problems to be absorbed in almost one year of detailed systems testing.

Also noteworthy was the highly coordinated and cooperative management of the significant interfaces, particularly that between the LMSC hardware and that of the payload contractor. It should be noted that the higher risk areas (many of which were based on prior proven hardware of similar functional purpose) received special attention in all areas from systems analysis through the intervening steps such as concept, design, interface analysis, manufacture, etc., to the final factory systems test.

2. Implementation of the factory to pad concept with the firm backing of the SPO created the situation wherein flight hardware after being thoroughly tested at the factory was delivered to the launch pad in such condition that no anomalies existed. Corollary to this has been the implementation of computer programmed checkout using the RF linkage which permitted the accurate testing of flight hardware to a much greater depth than which has been possible before by manual means with hard wire connections. The value of this test method was further strengthened by requiring that the confidence tests at the launch pad be functionally identical to those executed at the factory during final Systems Test.

3. The extensive preparations by both the Government and the Contractor, both before and after contract award, resulted in an agreed upon and well understood work statement. This, in turn, made possible credible detailed cost agreements which, as the program evolved, were easy for both the SPO and Contractor to relate to work yet to be accomplished. In all of this operation, the Contractor operated upon the philosophy that the most effective program was one which provided an adequate emphasis on those areas which allowed the now demonstrated early success.

BYE-5

TOP SECRET

CONTROL NO. TCS-6884/73
Cy 2

REFERRED TO OFFICE	RECEIVED			RELEASED		SEEN BY	
	SIGNATURE	DATE	TIME	DATE	TIME	NAME & OFFICE SYMBOL	DATE
ACL							
	[illegible]						

Handle Via Indicated Controls

TALENT -KEYHOLE

....

....

....

....

WARNING

This document contains information affecting the national security of the United States within the meaning of the espionage laws U. S. Code Title 18, Sections 793 and 794. The law prohibits its transmission or the revelation of its contents in any manner to an unauthorized person, as well as its use in any manner prejudicial to the safety or interest of the United States or for the benefit of any foreign government to the detriment of the United States. It is to be seen only by personnel especially indoctrinated and authorized to receive information in the designated control channels. Its security must be maintained in accordance with regulations pertaining to TALENT-KEYHOLE Control System.

TOP SECRET

TALENT-KEYHOLE
CONTROL SYSTEM ONLY

~~TOP SECRET RUFF~~

TCS-6884/73
20 March 1973

Copy 2

MEMORANDUM FOR : Chairman, EXSUBCOM

THROUGH : Acting Chief, Imagery Exploitation Group, NPIC

SUBJECT : Innovations and Trends in Exploitation in the Western Geographic Division, IEG Caused by the KH-9 System

1. The advent of the KH-9 system caused some innovations over and above those normally expected when a new system becomes operational. We were prepared, in WGD, for the basic differences and advantages of the KH-9 and anticipated that the system would be of great benefit in satisfying our geographic area search requirements. The KH-9 has proven its value in the search; the innovations caused by the system have been accepted and absorbed; and some trends in exploitation due to the advent of the KH-9 have surfaced.

2. The innovations involved the subjects listed below:

a. New equipment:
Optics; light tables; film storage shelves

b. New film handling procedure:
Film separated by geographic areas.

c. Target readout:

Four bucket time-span (45-70 days) permitted more likelihood of changes occurring at targets during the mission; more targets covered by photography of better interpretability; increased probability of covering targets in normally cloudy regions (E. Europe).

d. Personnel:

Training and familiarity with the KH-9; need for some augmentation to handle increased workload.

CLASSIFIED BY 013170
EXEMPT FROM GENERAL DECLASSIFICATION SCHEDULE OF E. O. 11652, EXEMPTION CATEGORY: § 5B(1), (2), (3) or (4) (circle one or more)
AUTOMATICALLY DECLASSIFIED ON
Date Impossible to Determine
(unless impossible, insert date or event)

~~TOP SECRET RUFF~~

WARNING NOTICE
SENSITIVE INTELLIGENCE SOURCES AND METHODS INVOLVED

HANDLE VIA
TALENT-KEYHOLE
CONTROL SYSTEM ONLY

TCS-6884/73
20 March 1973

SUBJECT : Innovations and Trends in Exploitation in the Western Geographic Division, IEG Caused by the KH-9 System

e. Management:

Increased problems of PI motivation to search the large quantity of film; more awareness of interrelated intelligence items due to increased frequency and number of targets covered; need to organize so as to provide both in-depth geographic area knowledge and flexibility of PI strength.

3. Trends in exploitation based upon our KH-9 experience include:

a. More emphasis on the dynamic targets and less on those that have remained relatively static.

b. Increased emphasis on searching for new targets.

c. An increasing need for the PI to know the current situation in a geographic area so that his analyses will more directly address the intelligence problem, he can more accurately assess what he sees, and anticipate and look for new developments.

[redacted]
Deputy Chief
Western Geographic Division, IEG/NPIC

Distribution:
Cy 1 - Chairman, EXSUBCOM
2 - NPIC/IEG
3&4 - NPIC/IEG/WGD

SDA-A-2-C

Vault

14 00016806D

~~Top Secret~~

16.12

[redacted]

~~NOFORN~~

(See inside cover)

1

DR HANS MARK, UNDER SECRETARY, AIR FORCE/
BRIG GEN WILLIAM L. SHIELDS, DIRECTOR,
SAFSS.-4C1000 PENTAGON

THE KH-9 SEARCH AND MC&G PERFORMANCE STUDY

VOLUME II
HISTORICAL PERFORMANCE SUMMARY

Handle via
TALENT-KEYHOLE
Channels

~~Top Secret~~

TCS-9923/77

OCTOBER 1977

Copy No 1

Printed by the
NATIONAL PHOTOGRAPHIC INTERPRETATION CENTER

DISSEMINATION CONTROL ABBREVIATIONS

NOFORN-	Not Releasable to Foreign Nationals
NOCONTRACT-	Not Releasable to Contractors or Contractor/Consultants
PROPIN-	Caution-Proprietary Information Involved
USIBONLY-	USIB Departments Only
ORCON-	Dissemination and Extraction of Information Controlled by Originator
REL . . .	This Information has been Authorized for Release to . . .

THE KH-9 SEARCH AND MC&G PERFORMANCE STUDY

VOLUME II

HISTORICAL PERFORMANCE SUMMARY

OCTOBER 1977

Reverse side blank

FOREWORD

Presented in this volume is a review of the KH-9 performance against the standing search and MC&G requirements for the first twelve missions. Included are a brief description of the KH-9 satellite system, the evolution of the search and MC&G requirements, collection statistics, and some specific examples of the unique contributions made by the KH-9 system while performing the search mission. The majority of the data presented was extracted from existing reports and publications by the participating organizations.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

GLOSSARY

ACRES	Area Collection Requirements Evaluation System
APTC	Astro-Positioning Terrain Camera
COMIREX	Committee on Imagery Requirements and Exploitation
DMA	Defense Mapping Agency
GRD	Ground Resolved Distance
IDF	Installation Data File
MC&G	Mapping, Charting and Geodesy
MCS	Mapping Camera Subsystem
NAEF	National Area Exploitation File
NIIRS	National Imagery Interpretability Rating Scale
NRO	National Reconnaissance Office
NRP	National Reconnaissance Program
NTB	National Target Base
USIB	United States Intelligence Board
USGS	United States Geological Survey
WGS	World Geodetic System

Reverse side blank

1.0 INTRODUCTION

This historical review was performed in response to Task 2 set forth in the Terms of Reference for the KH-9 Search and MC&G Performance Study and a companion [redacted]

1.1 Objectives

The objectives of this review were to establish in quantitative terms the KH-9 historical performance against the standing broad area search and MC&G requirements and to establish a reference against which new collection strategies, when applied to new collection requirements, could be judged.

1.2 Participants

The data presented in this volume was compiled by a working group chartered by the HOSS steering Group. Participating in the working group were representatives from a program element of the National Reconnaissance Office, COMIREX/IC Staff, Defense Mapping Agency, National Photographic Interpretation Center, and Defense Intelligence Agency. These organizations were responsible for compiling and collating the information in this report.

2.0 KH-9 SYSTEM DESCRIPTION OVERVIEW

The KH-9 System was developed to collect stereoscopic broad area imagery at a resolution adequate for both general search and surveillance. It collects imagery in the two to twenty-foot GRD range. The satellite vehicle contains two camera systems - a dual camera panoramic system and a stellar terrain camera system. Imagery collected by the panoramic system is used primarily for search and general surveillance, but it does have MC&G applications. The stellar terrain camera system, first flown in 1973 on satellite vehicle number 5, provides DMA with imagery at the required quality and metric accuracies for point positioning to establish a suitable data base for the production of MC&G products.

2.1 The Satellite System

The KH-9 satellite consists of three major sections - the forward, the mid, and the aft sections. The forward section contains the four reentry vehicles for recovery of film exposed by the panoramic cameras; the stellar terrain mapping camera and the fifth reentry vehicle for recovery of its film; [redacted].

The midsection contains the dual camera panoramic system, its film supply and the supporting electronics. The dual camera system provides for stereoscopic coverage within 60 degrees either side of nadir.

The aft section contains all of the equipment for control of the satellite vehicle in orbit. An orbit adjust subsystem provides propulsion for correction of velocity errors, drag makeup, and vehicle de-orbit at mission completion. An attitude control subsystem provides earth-oriented control and stabilization about all three vehicle axes - yaw, pitch and roll. The electrical distribution and power subsystem generates, controls, and distributes electrical power. The tracking, telemetry and command subsystem provides vehicle tracking, telemetry and command function capabilities .

2.1.1 Operational Characteristics of the Dual Camera Panoramic System

The panoramic cameras have 60-inch focal lengths and are mounted side-by-side. The port or forward-looking camera (Camera A) is pitched 10 degrees forward from vertical and the starboard, or aft-looking camera (Camera B) is pitched 10 degrees aft from the vertical. Operated together, the two cameras yield a 20-degree stereoscopic convergence angle at nadir. At 60 degrees obliquity, the convergence angle is 10 degrees. Camera A scans the surface of the earth from right to left, while the Camera B scans from left to right. There is a half frame overlap between Camera A and Camera B frames. The system can be operated in any of 16 different photographic modes. A mode is defined by a selection of scan width and scan center. There are four selectable scan widths, 30, 60, 90, or 120 degrees and seven selectable scan center placements, 0, ±15, ±30, or ±45. Table 2-1 summarizes the characteristics of panoramic camera system.

The amount of film carried for each camera varies. Earlier missions carried from 100 to 110 thousand feet. Mission 1212 carried 120 thousand feet on Camera A and 117 thousand feet on Camera B. The film is exposed on a frame-by-frame basis. The frame width is 6.6 inches and length varies from about 2.6 feet for a 30-degree scan width operation to about 10.5 feet for a 120-degree operation. Ground coverage at 90 nautical miles is approximately 9 nautical miles in-track at nadir and up to 315 nautical miles cross-track depending on selected mode.[1]

Image quality and scale vary across the film format depending on the altitude of the satellite and the viewing angle (scan angle) used. While flying at altitudes of 80 to 90 nautical miles, the system nominally produces imagery in the 2-foot to 20-foot GRD range when allowed to operate across the full range of scan angles. At extremely high scan angles, the usefulness of the imagery is degraded considerably due to high distortion. To eliminate this problem, recent KH-9 missions have not been allowed to operate outside a 45-degree obliquity angle. When such restrictions are imposed, the GRD range is usually between 2 and 10 feet producing imagery which range in NIIRS of 2 to 6 of which the majority is NIIRS 4 or better.

[1] These statistics are based on exposed film footage. For each operation taken and for each frame exposed, there is an associated unexposed footage. Due to hardware problems experienced on early KH-9 missions, the camera systems have not been allowed to operate in the film rewind mode, a capability designed to reduce the amount of unexposed film due to start-up and shutdown of the camera systems. This operational restriction results in some twenty to twenty-five percent of the film being returned unexposed. The percentages vary from mission-to-mission as it is dependent on the combination of modes of operations taken.

Missing Page 3

TABLE 2-2

KH-9 OPERATIONAL SUMMARY

MISSION NUMBER	ORBITAL PARAMETERS INCLINATION/PERIGEE/APOGEE	LAUNCH DATE	MISSION DURATION	FILM (FT)*	
				CAMERA A	CAMERA B
1201	96.4°/99.3/165.1 nm	15 Jun 71	31	100,826	100,502
1202	97.0°/86.1/186.7 n.m.	20 Jan 72	39	110,945	110,298
1203	96.9°/95.5/137.3 n.m.	7 Jul 72	57	103,170	107,728
1204	96.5°/85.3/156.6 n.m.	10 Oct 72	68	107,568	110,804
1205	95.7°/85.3/158.5 n.m.	9 Mar 73	63	108,197	110,141
1206	96.2°/87.7/154.4 n.m.	13 Jul 73	74	109,700	102,732
1207	96.9°/88.7/154.4 n.m.	10 Nov 73	102	107,390	106,243
1208	94.5°/85.5/164.0 n.m.	10 Apr 74	105	108,891	106,712
1209	96.7°/85.3/155.7 n.m.	29 Oct 74	129	116,813	111,806
1210	96.4°/88.8/157.0 n.m.	8 Jun 75	120	115,189	110,502
1211	96.3°/90.0/138.3 n.m.	4 Dec 75	116	113,502	111,107
1212	97.0°/90.1/138.0 n.m.	8 Jul 76	154	120,521	116,904
1213	97.0°/90.5/138.1 n.m.	27 Jun 77	—	121,371	118,570

*Differences in film footage between Camera A and Camera B is due to special films (color and/or infrared) which are thicker than the normal black and white.

overlap, respectively. At 95 nautical miles,each frame covers an area of approximately 71 by 142 nautical miles. The terrain camera carries approximately 3,330 feet of film. This yields about 2,000 frames of photography.

The two stellar cameras provide a means for accurately determining the attitude of the terrain camera at the exact time of exposure. They are oriented in such a way that the star field is photographed simultaneously with the acquisition of terrain photography. The film format consists of two adjacent frames which are 70 mm by 110 mm. The stellar cameras together consume approximately 2,000 feet of film which yields about 2,000 pairs of stellar frames. See Table 2-3 for a summary of the MCS features and Table 2-4 for mission statistics.

A doppler transponder accompanies the MCS frame camera. The on-board transponder is tracked by a 42-station TRANET and GEOCEIVER network, resulting in a worldwide camera on-orbit position determination capability accurate to 27, 18 and 9 meters (one sigma) for in-track, cross-track and radial components, respectively.

3.0 REQUIREMENTS

3.1 Standing Search

3.1.1 Evolution of Search Requirements

The following paragraphs trace the evolutionary process responsible for the present structure and dimensions of the Intelligence Community's standing requirements for periodic broad area coverage of the Communist countries and regions of conflict in the Middle East.

TABLE 2-3
SUMMARY OF MAPPING CAMERA SUBSYSTEM FEATURES

	TERRAIN	STELLAR
Camera Type	Frame	Frame
Focal Length	12 inches	10 inches
Format Size	9 x 18 inches	2.8 x 4 inches
Field of View		25 x 16 degrees
In-Track	73.7 degrees	—
Cross-Track	41.1 degrees	—
Modes	10, 70 and 78 percent, frame-to-frame overlap	—
Nadir Field of View	71 x 142 n.m.	
Resolution	20 to 30 feet*	6th magnitude stars
Film		
Type	3414	3401
Width	9.5 inches	2.8 inches
Capacity	Approximately 3,300 feet	Approximately 2,000 feet
Data Return	1 reentry vehicle**	

*In technical terms, this means 50 cycles/mm at 2:1 contrast.
**The stellar film is returned with the terrain film.

TABLE 2-4
SUMMARY OF MAPPING CAMERA MISSIONS

MISSION NUMBER	MISSION DURATION (DAYS)	FILM (FT)	
		TERRAIN	STELLAR
1205	42	3200	1960
1206	42	3197	1995
1207	58	3355	2000
1208	60	3301	1966
1209	59	3243	1945
1210	53	3150	2092
1211	60	3253	2135
1212	62	3068	2102

3.1.1.1 Late 50's and Early 60's

To understand the initial requirements for satellite-borne broad area collection, it is necessary to recall the environment of the late 1950's. Although U-2's had been overflying the Communist countries for several years, a large fraction of the Eurasian landmass had yet to be photographed even once. The other sources of intelligence then available seemed to be unearthing new problems about as fast as they were solving old ones. The maps in our possession were old and/or unreliable. The weapon systems perceived to be the major threats embodied technology too new to support reliable assessments of just where and how they could be deployed. The quality of the imagery needed to detect the as-yet-unseen ICBM deployment sites could only be guessed at.

Under these circumstances, the initial requirement, issued in 1958, called for coverage of the entirety of the Eurasian communist countries every six months. A resolution of twenty feet was judged to be adequate unless the Soviets deployed mobile or transportable ICBMs, in which case resolutions of ten feet or better might be needed. In July 1960, shortly before the launch of the first successful imaging satellite mission, the need for 20-foot resolution was reaffirmed. The value of stereo coverage was not addressed, and that potential issue soon disappeared, as the camera system adopted was designed to operate in stereo.[2]

Although the initial standing requirements lacked specific guidance concerning collection priorities, the dominance of the threat posed by the Soviet ICBM program to a large extent controlled the pattern of collection during the early years of the imaging satellite program. Long before the summer of 1960 - indeed, as soon as the USSR began to deploy strategic missiles - the Intelligence Community singled out certain regions as the most promising for launch sites. These delineations fairly quickly became quite sophisticated and, as it turned out, accurate. Twenty-three of the 26 Soviet ICBM complexes are located in or very close to regions described as likely deployment areas.

---

[2] Memorandum from Ad Hoc Intelligence Requirements Committee to Director, ARPA, 8 December 1958 (Reprinted in USIB-D-33.6/6, 10 March 1960); USIB-D-33.6/8, 5 July 1960.

Many of the basic collection concepts employed today had been enunciated by the time of the first successful flight:

> "The photographing system must be capable of obtaining coverage of denied areas at object resolutions of approximately 20 feet, 5 feet [redacted] on a side."
>
> "The system must provide for repeat coverage of targets at these various resolutions, depending on the nature of the target and the intelligence problem involved."
>
> "The periodicity of this repeat coverage will also depend on the nature of the target and the intelligence situation, as well as on other sources that can be brought to bear on it."
>
> "From an ideal point of intelligence utility, many of the high priority and highest priority targets should be covered at intervals on the order of 1 to 6 months, but the reconnaissance system should have sufficient flexibility to permit the coverage to be timed to meet the needs of the specific intelligence situation as it develops."
>
> "The photo system should be capable of obtaining coverage and readout within 24 hours on selected objectives anywhere within Soviet territory ..."
>
> "It is imperative that current, indisputable information be available on (targets where Soviet strategic strike forces are located) to accurately assess Soviet capabilities and intentions and to enable effective retaliatory strike planning ..."

As soon as broad area photography began to be received in quantity, the United States Intelligence Board called for the development of a procedure through which the Community might assess its significance "with respect to confirming the presence or absence of ICBM deployment in areas which have been covered. In addressing this need, the Director of NPIC pointed out that

> 'There are essentially three basic parts to the problem: establishment of definitions for rating photography on a qualitative basis; determining the significance of varying levels of cloud cover; and developing mechanical procedures for recording and reporting the desired information.'

Beginning in mid-1961 and continuing for a number of years, the status of coverage of the Soviet rail net was reported out regularly, but the procedures employed had serious shortcomings. Not until the early 1970's, when the National Imagery Interpretability Rating Scale was developed, did there become available a workable system for recording photographic quality. And the 'mechanical procedures for recording and reporting' became operational only within the past few years."[3]

As a practical matter, some of the film frames returned by a broad area mission will be free of clouds, while others will be completely filled with them. In some cases the ground will be partially obscured, at times by randomly scattered clouds and at times by solid formations that are the borders of broad weather fronts. Where transportation arteries are present, some of the cloud-free photography will be limited to the ground on one side of the line. Consequently, in accounting for coverage of transportation routes, the minimum area to be recorded must be defined. In the procedure adopted for recording coverage of the Soviet rail net, the minimum cloud-free segment counted was a rectangle showing at least eight miles of line and the ground on both sides of it to a depth of at least fifteen nautical miles. The selection of eight and fifteen miles was arbitrary and was not based on any objective analysis. Indeed, at the time the criteria was established, hardly any coverage existed on which to make an analysis.[4]

3.1.1.2 The Mid-Sixties

In early 1963, the USIB asked the committee then responsible for imagery requirements development to furnish updated guidance. The subsequent effort uncovered a split opinion as regards the quality requirement. The Department of Defense agencies judged that a capability "to permit recognition of low-contrast objects 10 feet on a side" would be satisfactory, while CIA believed there was a need to see objects five feet on a side. There was general

[3] The USIB Directive quoted and the NPIC response both can be found in USIB-D-33.11/3, 14 November 1961. The "good," "fair," and "poor" ratings used for so many years to describe the quality of imagery were first defined in this document. Notice that the wording of the USIB Directive shows recognition of the potential that imagery possesses for confirming the absence of activities.

[4] For evidence of the early use of these criteria, see NPIC/IM16/61, 25 August 1961 and CIA/RR GP 61-141, 18 October 1961.

agreement that a swath width "on the order of 200 miles" was needed, and the Defense Department agencies stated that the six million square miles constituting the so-called built-up areas of the Communist countries should be covered every 45 days, and the remainder of these countries should be covered every 90 days. The "practical impossibility" of obtaining complete coverage of such large areas over such short time spans was noted, however.[5]

Following its discussion of the papers submitted by the requirements committee, the USIB instructed that they be forwarded to the NRO for study and comment. Then followed more than a year of intensive activity that bore fruit in July 1964 with the USIB's endorsement of a recommendation that work proceed rapidly toward achievement of

> "A single capability for search and surveillance with a continuous stereoscopic ground coverage equivalent to KH-4 and a resolution equivalent to KH-7 ..."

This guidance was the basis for the development of the KH-9 system.[6]

With the question of image quality out of the way, the Community next turned to reconsideration of frequency and distribution. In March 1965, the USIB forwarded to the NRO guidance intended to permit the launch rates of KH-4 satellites to be sized "for the next two years or so." This guidance, the first long-term standing search requirement sent to the NRO by the USIB in nearly five years, called for cloud-free coverage of the entire Sino-Soviet area semiannually, with priority to be given to built-up parts. The impossibility of achieving complete coverage was recognized, however, and the requirement was backed up with a recommendation that a program of ten successful launches per year be planned. Statistical evaluations by the NRO had indicated that such a rate would result in coverage of about 90 percent of the Sino-Soviet landmass semi-annually.[7]

In the summer of 1966 the USIB furnished amplification of the KH-9 guidance levied two years before. The need for a swath width "at least" equivalent to the KH-4's and a resolution equivalent to the KH-7's was reaffirmed. On the basis of "the results obtained and general satisfaction with search coverage acquired over the last 18 months with the KH-4" the frequency and distribution of the required coverage was modified as follows:

> "Search Mission. KH-9 should have the capability to provide stereoscopic, cloud-free (about 90 percent) photography of about 80-90 percent of the built-up areas of the Sino-Soviet bloc (approximately 6.8

---

[5] USIB-D-41.14/4, 28 January 1963; USIB-D-41.14/28, 19 April 1963. In USIB-D-41.14/28, also disseminated on 19 April, the built-up areas were identified as "the European Satellites, European and trans-Ural USSR, the area within 100 miles on either side of the Trans-Siberian railroad between Petropavlovsk and Kharbarovsk, the Soviet Far East, south central Asia, the provinces of "old" China, Manchuria, North Korea, North Vietnam, and the Arctic coast during the summer period."

[6] USIB-D-41.14/36, 25 April 1963; USIB-D-41.13/11, 31 July 1964. In USIB-D-41.14/294, 21 June 1966, the Board made clear that what it had in mind was a swath width of at least 150 miles and a resolution of "3-5 feet over the total format."

[7] USIB-D-41.14/229, 19 March 1965 and USIB-D-41.14/235, 26 March 1965.

million sq. nm.) semiannually and should provide similar coverage of about 75 percent of the undeveloped areas (2.8 million sq. nm.) annually ... In addition to search of the Sino-Soviet bloc, KH-9 should provide the capability to acquire coverage of contingency areas in other parts of the world on demand."

This guidance possessed several new features. The call for complete coverage that previously had been specified was dropped in favor of levels that experience indicated were realizable. They were, in addition, levels the Community judged to be adequate to meet essential needs - subjective judgments that were, however, based on feel rather than on technical analysis. Then too, for the first time in official guidance, the distinction between built-up and undeveloped regions was delineated on a map (see Figure 3-1). Also new at the USIB level was the Community's acceptance of imagery less than completely cloud-free as adequate for search. And new for the KH-9 was the recognition of areas outside the Communist countries that might have to be acquired.[8]

Coverage needs for the non-Communist countries were not expected to exceed three million square nautical miles annually.

The requirement also described a non-search role to be performed by the system:

"Surveillance Mission. In recognition of the capability of the KH-9 to obtain high resolution area coverage...we believe it appropriate to specify frequency of coverage in terms of surveillance of geographic areas representing target clusters ... Based on target distribution, we have identified about one hundred clusters ranging in size up to 120-mile by 120-mile areas in which approximately 70 percent of current targets are located."

Although potential cluster areas had been identified, no delineations were included in the USIB guidance, and the NRO was told that experience with KH-9 collection would have to precede confident identification of collection frequencies; until then, "for planning purposes" it should anticipate covering 80 percent of the cluster areas quarterly.

Later in 1966, the Community brought the standing requirements for KH-4 collection into line with those established for the KH-9. Although it found the principle of obtaining complete coverage of broad areas still attractive, the Community "had learned through experience that operational considerations make the fulfillment of such a requirement highly unlikely under normal circumstances." For this reason, it endorsed a program calling for approximately ten successful KH-4 launches annually, which it believed would yield stereoscopic, cloudfree coverage of:

- More than 80 percent of the built-up areas semiannually;
- More than 80 percent of the undeveloped areas annually;
- Approximately 2.5 million square miles outside the Bloc annually;

[8] USIB-D-41.14/294, 21 June 1966 and USIB-D-41.14/296, 20 July 1966. Use of the KH-4 for periodic search of non-Communist countries was specified in the 1965 guidance for that system.

- Approximately eight million square miles of mapping coverage annually;
- And "A residual of approximately five percent of the film per mission for unique, one-time search or surveillance tasks."[9]

3.1.1.3 The 1969 Amplification

The requirement sent to the NRO in late 1969 reaffirmed the concept and basic structure outlined in 1966, amplified major elements within it, and introduced several new features. One major innovation was the adoption of the 1:50,000 World Area Grid (WAG) cell, an area averaging about 12 by 18 nautical miles, as a unit of account for categorizing and arraying area coverage requirements. The WAG system, which already had been adopted by the NRO as a tool for use in the management of collection, permitted the Community to delineate and differentiate areas much more finely than was possible theretofore.[10]

The built-up areas were defined in terms of their proximity to transportation. In the absence of possessing any technique for defining "proximity" scientifically, the Community stuck with the figure adopted in 1961 - 15 miles. If any portion of a WAG cell fell within 15 miles of a transportation artery, the entire cell should be counted as part of the built-up area. At least 80 percent of these built-up area cells should be kept covered with cloud-free and interpretable photography not older than six months.

Another feature was the precise delineation of 108 target clusters and the specification that quarterly coverage of each be obtained - to at least the 85-percent level in the case of a fourth of them and to at least the 70-percent level in the case of the remainder. The objective of this coverage was search as well as surveillance, for the clusters were recognized as the most likely areas for new targets to appear since "new installations of military importance are frequently located near or within facilities of similar nature ..."

These more precise delineations of the cluster and built-up regions, depicted in Figure 3-2, led to their combined sizes being reduced from 6.8 million square miles to about 5.1.[11]

Further, the standing requirements areas were expanded to include Mongolia and the regions of conflict in the Middle East, and then were divided into seven geographical categories: USSR, China, North Korea, Mongolia, Eastern Europe, Middle East, and North Vietnam. The basis for this differentiation was recognition that the intelligence problems connected with one part of the world frequently are distinct from those connected with others, and the satisfaction of requirements for coverage of one part does not necessarily influence the requirement for coverage of another.

The guidance pointed out that special requirements associated both with search and with surveillance would be levied prior to and during each KH-9 mission. The quantity of

[9] USIB-D-41.15/79, 16 September 1966.

[10] USIB-D-46.4/32, 10 November 1969.

[11] The delineation of the cluster and built-up regions on the basis called for in the requirements was a large and complex task performed by the Office of Basic and Geographic Intelligence in CIA. COMIREX's request that OBGI undertake the responsibility is discussed in COMIREX-D-13.3/1, 20 January 1970.

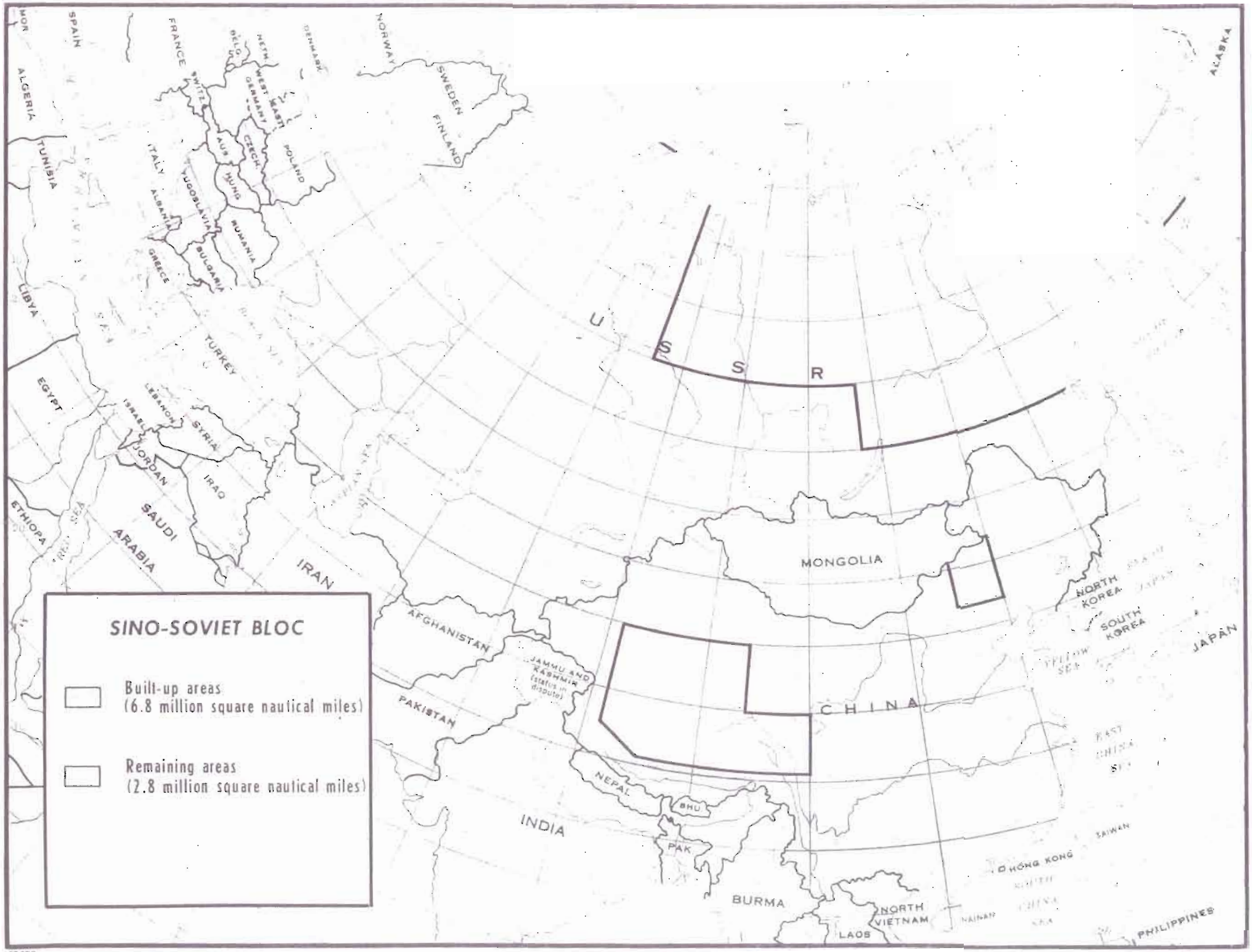


FIGURE 3-1. MAP WHICH SHOWS FIRST BREAKOUT OF BUILT-UP AND UNDEVELOPED REGIONS

Secret

TCS-9923/77

~~Top Secret~~

KH-9 Area Coverage Objectives

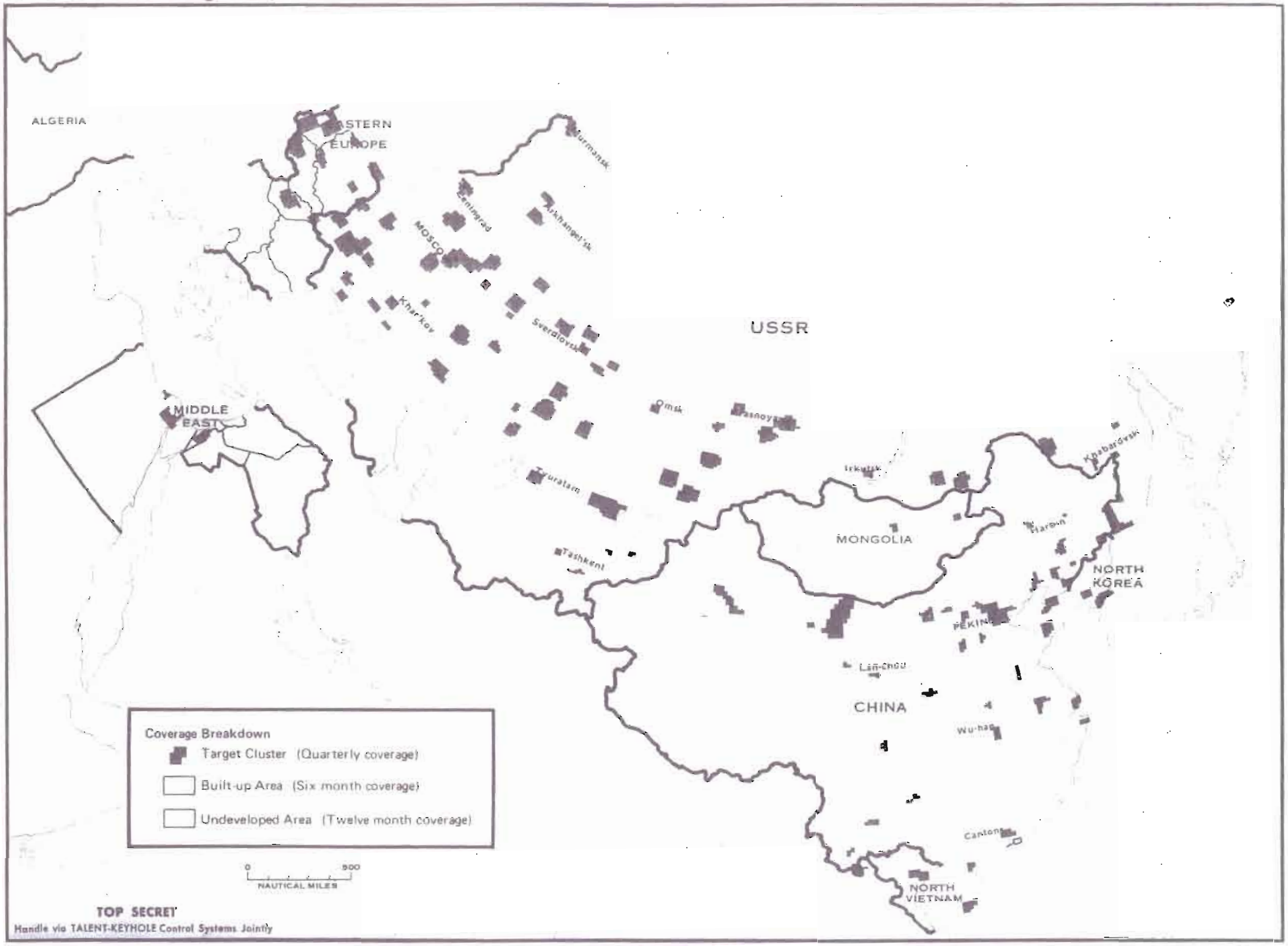


FIGURE 3-2. MAP SHOWING THE ADDITION OF TARGET CLUSTERS

~~Top Secret~~ Ruff

Missing Page 15

air, ground, sea and space operations, and for intelligence and military planning. The geodetic data derived from satellite imagery provides the military with tens of thousands of accurate point locations needed for operation of strategic and tactical weapon systems.

Satellite imagery requirements to support these various military MC&G production activities have several different aspects. They include coverage of various areas of the world by imagery of varying degrees of resolution and metric fidelity, which includes: calibration, attitude determination (pitch, roll and yaw at instant of exposure), and accurate determination of camera location at time of exposure (latitude, longitude and elevation determined by means of a doppler device and timing marks on the film). Among the technical requirements that are satisfied in whole or in part by the current configuration of the NRP satellite systems is the derivation of specific levels of horizontal and vertical accuracy of targets and other positional data for maps and feature analysis - both on a World Geodetic System (WGS), as well as on a more localized regional datum basis.

Operational weapon systems including Minuteman II/III, Polaris, Poseidon, Lance, Pershing, B-52, and F-111 are dependent on this positional information and on maps and charts for navigation and target strike.

3.2.1 Evolution of MC&G Requirements

Military MC&G has employed satellite photography since 1960. With the aid of this photography, DMA and its predecessor organizations have produced over 50,000 different maps and charts out of a current requirement which exceeds 80,000 worldwide, levied by the Unified and Specified Commands, the Military Services and the Intelligence Community.

Photographic coverage of metric accuracy (currently provided by the KH-9 MCS) and medium to medium-high resolution (2 to 10 feet , such as that provided by the KH-9 panoramic camera) is indispensable at present, and will continue to be into the 1980s, for the production and updating of these MC&G products to support operational needs.

The satellite systems of earlier NRP projects were limited by evolving system design and state-of-the-art improvements for hardware/software components from which optimum on-orbit performance could be generated. The three-inch focal length frame cameras of the KH-4, KH-5, and KH-8 APTC (Astro-Positioning Terrain Camera) were initially employed to provide the early 1960 era worldwide MC&G coverage. This coverage has some of the features needed for metric fidelity. Much of the coverage included the stellar index camera coverage for attitude determination, but much of it does not permit positioning of points to accuracies sufficient for a significant number of MC&G products.

Only five of the KH-4 Dual Improved Stellar Index Camera (DISIC) missions had the doppler transponder which provided good positional data. About 20 million square nautical miles of KH-4 DISIC frame was collected worldwide between 1962 and 1972, and 16 million square nautical miles of KH-4 DISIC with doppler was collected worldwide between 1970 and 1971. Nearly all of the Eurasian Communist countries were covered. The KH-4 DISIC frame coverage with doppler provides accuracy of 76 meters for horizontal positioning.

Standing Requirements

Area Redelineation

- Clusters
- Built-up area
- Undeveloped area
- Remote area
- Topographically unuseable area

(depicted in terms of 12 x 18 nm WAG-50 cells)

Limited Area Directed Search

	No. of Target Clusters	Total Area (in thousand nm^2)
USSR	[redacted]	213
China		70
[redacted]		7
		16
		306

Broad Area Stragetic Search (in thousands nm^2)

	Built-up Area	Undeveloped Area	Remote Area	Topographically Unsuitable Area	Total Search Area**
USSR	2,218	2,105	2,003	327	6,866
[redacted]	302	102	0	0	404
China	1,116	922	566	143	2,817
[redacted]	48	255	153	0	456
	39	0	0	0	46
	37	21	0	0	58
	147	62	22	0	247
	3,907	3,467	2,744	470	10,894

[redacted]

***Includes total of Limited Area Directed Search*

Missing Page 19

Missing Page 20

KH-5 was a frame camera system which provided MC&G coverage of more than 43 million square nautical miles from 1962 through 1964, primarily for geodetic positioning. This system had a three-inch focal length terrain frame camera and a stellar camera. Since it did not include a doppler geodetic package, this photography gives a best accuracy of only 230 meters horizontal. This material temporarily satisfied some of the early accuracy requirements for positioning, but for the 1970 time period the KH-5 coverage cannot be relied upon for production of Class A maps at scales of 1:250,000 and larger because 1:250,000 maps require a horizontal accuracy of 127 meters.

The KH-8 APTC system included a three-inch focal length frame terrain camera, which provided imagery from Mission 4301, August 1966, until the end of Mission 4340, November 1973. Since the APTC did not include a doppler geodetic package, this coverage cannot be used for accurate point positioning. APTC ground resolution was estimated to be about 180 feet compared with 120 feet for the KH-4 DISIC, and 20-50 feet for the KH-9 MCS. The APTC generally has provided an additional source of photographic coverage in areas not otherwise covered. However, this imagery source will only be used in particularly low priority areas with high cloudiness, where only small scale mapping is scheduled.

Most of the three-inch focal length photography is now out of date and cannot, therefore, be used for revising maps whose cultural information is out of date. Utilization of the three-inch coverage is more costly than is the use of the KH-9 MCS coverage. It is also questionable whether the uncontrolled three-inch frame coverage has significantly enhanced MC&G production unless controlled KH-9 MCS coverage is available.

3.2.1.1 Non-Metric Requirements

Area requirements for panoramic imagery include the entirety of the Eurasian Communist countries and approximately 22.4 million square nautical miles of the remaining land areas of the world for a total of 32.8 million square nautical miles. The collection parameters are for 90% cloud-free coverage: stereoscopic for original compilation and monoscopic for revisions and map updates. This requirement was not subdivided into priority areas; however, the compilation of panoramic requirements submitted for each KH-9 mission are prioritized. Standing search requirement areas are not tasked for MC&G collection since MC&G needs in this area are generally satisfied by panoramic imagery collected in response to Intelligence Community requirements.

Of the more than 10 million square miles in the Communist countries, roughly 1.3 million square nautical miles for original compilation remain to be covered in quality adequate for MC&G. See Figure 3-5. Approximately 2.5 million square nautical miles outside the Eurasian Communist countries required for MC&G are in tropical areas that traditionally experience extremely heavy cloud cover. Charts and maps of these areas are required but because of the poor weather resources are generally not programmed to collect these areas.

In general, original compilation coverage or recoverage of the 22.4 million square nautical miles (outside the Eurasian Communist countries) is needed to form a data bank of pan-

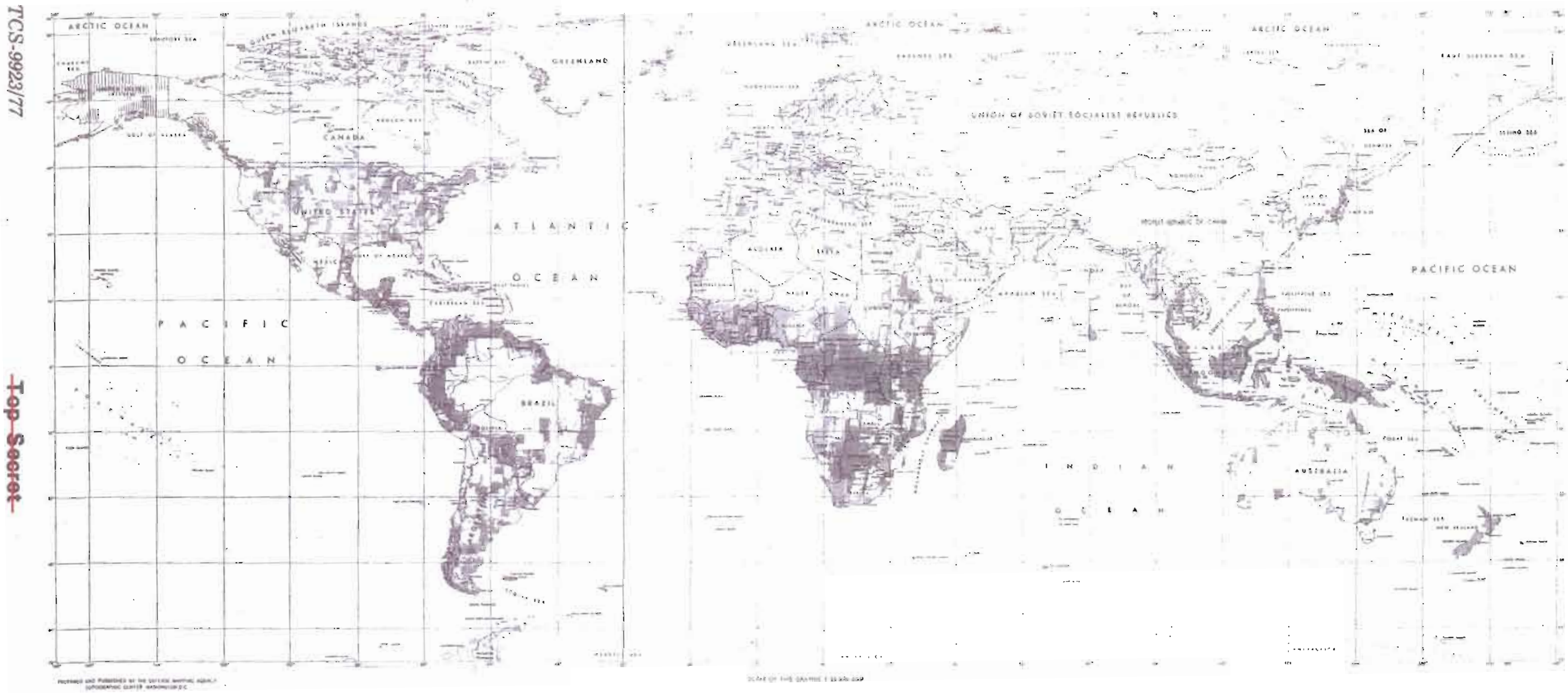
Missing Page 22

Search Area Requirements

FIGURE 3-5.

TCS-9923/77

Top Secret



MC&G REQUIREMENTS FOR
PANORAMIC CAMERA MSN 1213

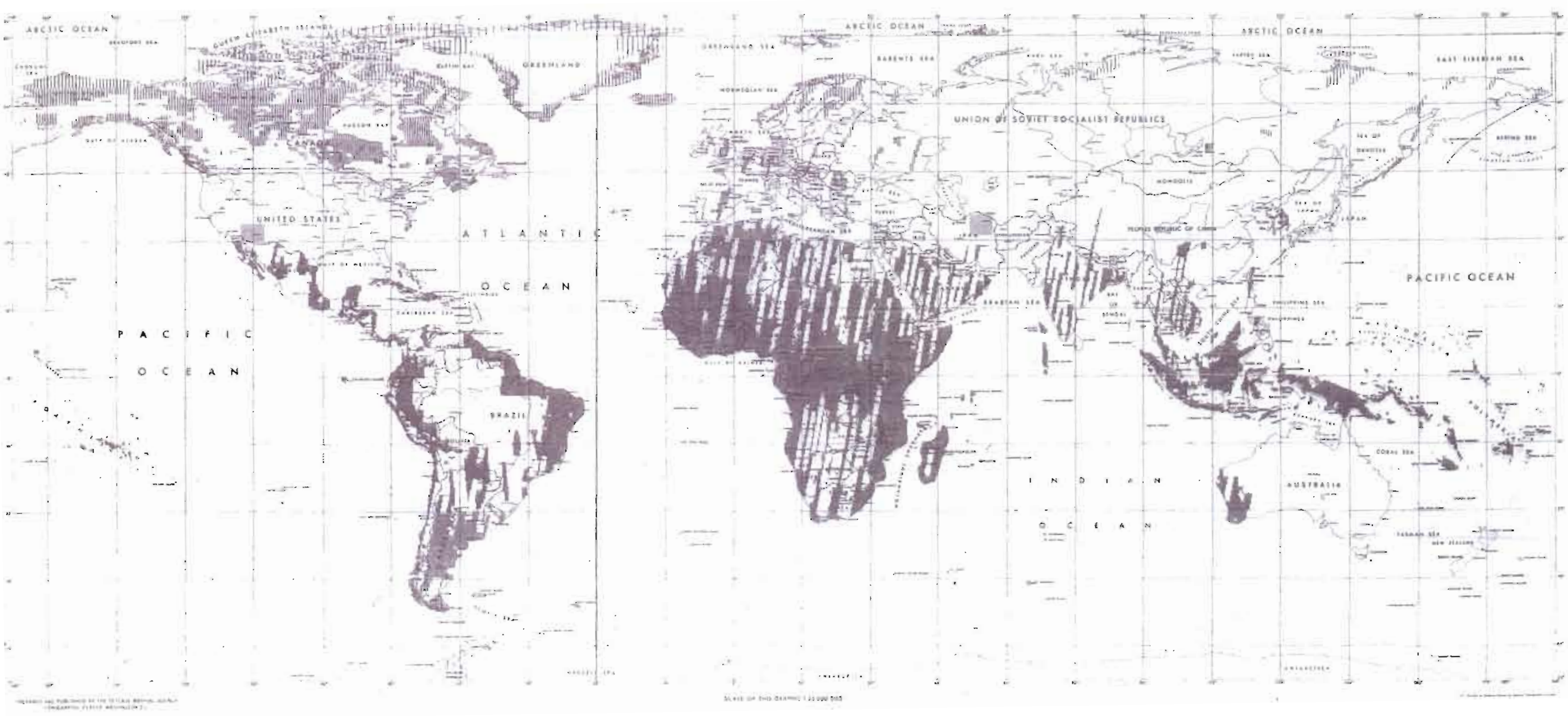
HIGH
LOW
MONO

FIGURE 3-6.

Top Secret RUFF

TCS-9923/77

~~Top Secret~~



MC&G REQUIREMENTS FOR
12" MAPPING CAMERA MSN 1213

HIGH
LOW
DIAGNOSTICS

FIGURE 3-7.

~~Top Secret~~ RUFF

3.2.2.1 Point Target Requirement

High content monoscopic satellite materials are used to update airfield features, produce large-scale city maps and generate port/harbor charts. The total validated requirement (as of FY 76) for point target coverage is 45,900 which is made up of 42,500 airfields, 1,600 city graphics, and 1,800 ports/harbors. An active target file for collection containing 3,000 prioritized point targets is maintained operationally. This file is continuously monitored and updated as point targets are accessed by satellite systems. KH-9 film is not allocated against these unique targets; however, the targets are included in the collection file to add emphasis for imaging in conjunction with MC&G and intelligence requirements. At least 2,-300 targets are required per year, based on the specified sample rates.

3.2.2.2 Broad Area Non-Metric Requirements

The Broad Area MC&G coverage requirements are for both monoscopic and stereoscopic panoramic imagery to satisfy original compilation and product revision. The current KH-9 requirement is for 9.6 million square miles outside the Eurasian Communist countries. The MC&G Broad Area coverage requirement is divided into two collection categories: stereoscopic coverage which is divided into two priorities (high and low) and monoscopic coverage (see Figure 3-6, Table 3-1 and Table 3-2).

TABLE 3-1

ANNUAL MC&G REQUIREMENTS FOR KH-9 PANORAMIC COVERAGE

FY 1972-78 USIB-Approved Non-Communist Areas*

(Stereo, 90% Cloud-Free, Millions of Square Nautical Miles)

Fiscal Year	Military		Civil	Total
	First Time	Recoverage	First Time	
1972	1.5	0.5	0.3	2.3
1973	2.0	3.0	0.3	5.3
1974	1.5	2.5	0.3	4.3
1975	1.0	2.0	0.3	3.3
1976	0.5	2.0	0.3	2.8
1977	0.3	1.5	0.3	3.1
1978	0.0	2.0	0.3	2.3
Total	6.8	13.5**	2.1	22.4

*Excludes the Sino-Soviet Area and important areas of the Middle East, on which pan coverage is provided in response to intelligence requirements. Also incudes the U.S. Geological Survey requirement for coverage of 0.3 million square nautical miles of the U.S. annually.

**Military recoverage requirements for non-Communist areas extend beyond FY 1978 at an annual rate of 2.0 million square nautical miles. This requirement is a continuing one, to satisfy requirements for periodic updating of MC&G products.

TABLE 3-2
MC&G REQUIREMENT FOR KH-9 PAN COVERAGE BY MAJOR GEOGRAPHIC REGIONS

REGION	USIB APPROVED	TOTAL DMA WAG CELL AREA REQUIREMENTS (Millions of Square Nautical Miles)	REMAINING REQUIREMENT
Sino-Soviet Area	10.2[1]	10.4[1]	-1.3[2]
Eurasia	[redacted]		
Africa plus Sinai			
North America			
South America			
Other			
Total[3]	[redacted]		

[1] DMA requirements in the Sino-Soviet area are satisfied by Intelligence collection activities. They are included in this table to show the scope of the requirements. Sino-Soviet area collection is not included in the totals.

[2] This shortfall has been identified to ICRS.

[3] The USIB-approved requirement of 21.5 million square nautical miles converts to 22.4 million square nautical miles in the DMA ACRES file which uses WAG cells for accounting.

3.2.2.3 Metric Requirements

The MC&G metric requirements are for both monoscopic and stereoscopic frame imagery to satisfy original compilation, point positioning, and island positioning. The current KH-9 requirement is for 18.5 million square miles throughout the world, including the Eurasian Communist countries. The mission objective for vehicle 13 is to collect 1.8 million square miles. The MC&G metric requirement is divided into two collection categories: stereoscopic and monoscopic coverage, which are divided into two priorities (high and low), see Figure 3-7 and Table 3-3 for a summary of the current MCS requirements.

With respect to positioning accuracy required for MC&G products, they are either relative or absolute. Relative accuracy refers to the relationship of features on a map grid or local reference datum. The accuracy required for relative relationship currently does not exceed areas larger than 300 x 300 square nautical miles. Absolute accuracy is worldwide and refers to relationship to the WGS.

The metric accuracy requirements are related to target horizontal position error and vertical position error. The horizontal position error is termed circular error (CE) which is defined as the radius of the circle in the horizontal plane centered at the estimated target location in which the true position of the target lies with a given probability. The vertical position error is termed linear error (LE).

TABLE 3-3
MC&G REQUIREMENTS FOR KH-9 MCS COVERAGE BY MAJOR GEOGRAPHIC REGION
(Stereo, 50% Cloud-Free Millions of Square Nautical Miles)

Region	USIB Approved	Total DMA WAG Cell Area Requirements	Remaining Requirement
Sino-Soviet Area	10.2	10.4	1.9
Eurasia	5.2	5.4	2.1
Africa plus Sinai	8.8	8.8	6.2
North America	5.2[1]	5.7[1]	4.7
South America	5.4	5.5	4.8
Other	2.2[2]	4.0	3.5
Total	37.0	39.8[3]	23.2

[1] USIB-approved requirements excludes 1.2 million square nautical miles of the U.S.

[2] Australia only.

[3] The USIB-approved requirements converts to 39.4 million square nautical miles in the DMA ACRES file which uses WAG cells for area delineation. Recent mission requirements have totaled 39.8 million square nautical miles which include the USGS Antarctica request of 0.4 million square nautical miles.

As indicated in Table 3-4, a technical objective to support advanced weapon systems with 23 meters (CE 90% probability) with reference to the WGS is the driving future requirement for the horizontal accuracy portion of the military MC&G products. This technical objective, which would be in direct support of both the Advanced MX-ICBM and the new Cruise Missiles, would require repositioning all of the targets in the National Target Base (NTB).

The NTB currently consists of approximately 42,000 targets used by strategic forces in the implementation of the Single Integrated Operations Plan (SIOP). The accuracy requirement for positioning targets in the NTB has become incrementally more stringent, as weapon systems have improved, from over 300 meters in the mid-60's to a current requirement of 62 meters horizontally.

Stringent vertical WGS accuracies related to the NTB, Short-Range Attack Missiles (SRAM) radar reference points and mini-bloc data for B-52 penetration route planning are concentrated in the Sino-Soviet areas. Present validated requirements call for 29 meters LE at 90% probability vertical accuracy in positioning of the NTB targets. The technical objective for the Advanced MX-ICBM is 17 meters at 90% probability for the NTB targets. Other vertical requirements are shown in Table 3-4.

TABLE 3-4

MC&G PRODUCT ACCURACY AND RESOLUTION REQUIREMENTS

Product	Horizontal (CE 90%)			Vertical (LE 90%)			Contour Interval	Contour Accuracy	Ground Resolution (ft)
	WGS	¹MG/LD	Pt to Pt	WGS	MG/LD	Pt to Pt			
- Line Maps & Charts									
1:50,000 Class A		25m			10m		20m	10m	2
1:250,000 Class A		127m			25m		50m	25m	10
1:200,000 Class A		101m			25m		50m	25m	10
- Point Positioning									
Strategic									
Post FY 75	62m			29m					3
MX ICBM*	23m			17m					3
IRBM (1980)*			30-40m			**			3
SRAM (RFP)	62m		300nm	29-46m					3
- Tactical									
Pershing II		24m 6nm			25m	**			3
OAP			30m 16m						3
LANCE		22m	31m		12m	17m			3
PPDB current³		20m 300nm	28m 300nm						3
PPDB future*		11m 300nm	16nm 300nm						3
- Digital Data									
Mini-bloc				30m MSL²					10
Penetration RTE				30m MSL					10
DLMS II		25m			10m			10m	2
DLMS I		101m			25m			25m	10
TERCOM*	23		33m		7m	10m			5

*Technical Objective for Advanced Weapon System
**Requirement for Vertical Not Stated to Date
¹MG/LD - Military Grid and Local Datum
²MSL - Mean Sea Level
³PPDB - Derived on WGS, transformed to local datum

4.0 PERFORMANCE EVALUATION

KH-9 photography routinely provides unique intelligence critical to maintenance of current order of battle, agreement monitoring, weapons system deployment, and industrial and agricultural developments. It is indeed a very difficult task to measure the "real" intelligence output of the system. With only a KH-9 mission on orbit, it generally represented the totality of the available U.S. satellite imagery capability, and therefore, its application was directed toward any and all important new requirements. For example, a significant portion of the target coverage obtained by KH-9 resulted from directed collection against special intelligence problems or was the outgrowth of standing requirements for search purposes. The classic means of measuring the performance against standing search requirements is in terms of gross coverage statistics, age distributions, and, recently, quality distributions in terms of NIIRS.

Measuring KH-9 performance against MC&G collection requirements is, to a large extent, more straightforward given that the system delivers the required image quality and mode (mono or stereo), and the necessary data for point positioning at the required accuracies. The most significant evaluation criteria is the gross cloud-free square nautical miles returned by mission.

4.1 Coverage Statistics

Three types of coverage statistics are presented in this section - gross coverage, age distributions, and NIIRS distributions.[14] Gross coverage statistics are presented for both area search and point target surveillance. These statistics show area attempted, area cloud-free, and film used. Age distributions are graphical ways of viewing KH-9 effectiveness in meeting the standing search collection objectives. NIIRS distributions provide a means for assessing the interpretability of the imagery.

Two types of NIIRS distributions are presented in this section - point ratings and area ratings. The point ratings are ratings assigned to point targets by the photointerpreter during the exploitation process. These ratings are generally applied while viewing the imagery in stereo and are maintained in the Installation Data File (IDF) by NPIC.

The area ratings are applied during the search exploitation process. Unlike the point ratings, they are applied to large areas. They are assigned to film segments. For film exposed within 30 degrees of obliquity, the ratings are assigned for every 15 degrees of obliquity and for every 7-1/2 degrees of obliquity for film exposed outside 30 degrees. Area ratings are assigned while viewing the imagery monoscopically. The ratings are maintained in the National Area Exploitation File (NAEF). Most of the KH-9 imagery receives an area NIIRS rating.

The ratings contained in both files represent a single photointerpreter's assessment of the imagery. For large samples, the difference in mean rating between point ratings and area ratings is about .4 NIIRS units with the point ratings being higher. This is due primarily to the fact that the point ratings are assigned while viewing the imagery in stereo at higher magnifications and the mono ratings are assigned at lower magnification while viewing the image monoscopically.

4.1.1 Performance Summaries for Broad Area Search

4.1.1.1 Gross Coverage Achievements

Table 4-1 summarizes the gross coverage achievements of all past KH-9 missions. It shows also the number of unique COMIREX targets imaged by each mission. The total imaging capacity of the KH-9 system has averaged about 19 million square nautical miles per mission. The first three KH-9 missions were flown at higher altitudes and employed higher

[14] The NIIRS rating system became operational in 1974. Until its advent there was no systematic way of assessing the overall interpretability of imagery produced by satellites. It was designed for application to point targets, but soon after its development it was applied to search imagery. The first KH-9 mission to be NIIRS rated was 1207.

TABLE 4-1

KH-9 Coverage Achievements

KH-9 Missions			Coverage Accomplishments (Million sq. NM)					
			World-Wide		Communist Countries & Middle East			
Mission Number	Launch Recovery Dates	Life-time Days*	Total Imagery	Gross Cloud-Free	Total Imagery	Cloud-Free Gross	Cloud-Free Unique	Unique Targets Imaged***
1201	15 Jun 71 - 16 Jul 71	31**	15.9	8.3	11.2	3.6	3.2	6,932
1202	20 Jan 72 - 28 Feb 72	39	21.1	15.4	16.1	12.7	11.0	10,488
1203	7 Jul 72 - 2 Sep 72	57	28.4	16.4	22.6	13.8	11.5	11,813
1204	10 Oct 72 - 17 Dec 72	68	18.8	12.0	14.2	9.1	5.6	10,155
1205	9 Mar 73 - 11 May 73	63	17.5	12.7	12.7	9.4	6.3	11,074
1206	13 Jul 73 - 25 Sep 73	74	18.9	12.4	15.1	9.6	6.2	12,011
1207	10 Nov 73 - 20 Feb 74	102	18.0	14.3	13.8	11.4	7.3	12,862
1208	10 Apr 74 - 24 Jul 74	105	16.6	11.9	13.0	9.3	6.3	12,101
1209	29 Oct 74 - 7 Mar 75	129	18.6	14.4	14.1	11.2	7.6	13,696
1210	8 Jun 75 - 6 Oct 75	120	17.4	13.5	13.6	10.7	5.6	13,664
1211	4 Dec 75 - 29 Mar 76	116	23.1	17.3	17.6	14.1	8.2	14,275
1212	8 Jul 76 - 9 Dec 76	154	17.9	12.5	12.6	8.9	6.2	14,827

*Imaging days on orbit, not counting days of launch as an actual day on orbit.

**RV-3 was lost on 1201.

***COMIREX target population has ranged from about 15,000 in the earlier missions to about 17,000 on the most recent missions.

obliquity scan sectors than present KH-9 missions. These factors resulted in larger amounts of coverage, but at a lower average quality than current missions. Due to operational problems, mission 1211 operated mostly in the mono mode. This resulted in an unusually high amount of coverage, but at reduced quality.

Tables 4-2 through 4-5 provide a more detailed breakout of the imaging capacity by mission and by primary area of interest to missions 1209 through 1212. A KH-9 system typically images cloud-free about 13 million square nautical miles. In general terms, about 45-50 percent of an average mission's film is used against the USSR (emphasis on SALT); about 15-20 percent is used against China (emphasis on missile search); 5-10 percent against Eastern Europe (emphasis on MBFR baseline); and about 3-5 percent against other Communist countries. Overall, about 75 percent of the coverage attempted is against Communist countries. Another 15-20 percent is used against the Middle East and Third World requirements. The remaining 7-8 percent of the film is used in the U.S. for satellite engineering tests, prelaunch film testing, and for mapping and other support, including U.S. civil applications.

4.1.1.2 Age Distributions

Age distributions or status curves are a graphical way of viewing KH-9 effectiveness in meeting the standing search collection objectives. Generally speaking, the requirement has been to collect eighty percent of each of the delineated search areas within the specified coverage period.

TABLE 4-2

KH-9 Coverage-Mission 1209

(29 October 1974—7 March 1975)

Collection Category	Size of Area (million sq nm)	Percent Film Used	Coverage (million sq nm)		
			Attempted Gross	Cloud-Free Imagery Acquired	
				Gross	Unique
Primary Intelligence					
USSR	6.7	46.7	8.9	6.8	4.9
[redacted]	.4	5.5	1.1	.7	.4
China	2.8	22.1	4.2	3.6	2.4
[redacted]	.5	2.2	.4	.4	.4
[redacted]	.1	2.2	.4	.2	.1
[redacted]	.5	5.1	1.0	.7	.4
Subtotal	11.0	83.8	16.0	12.4	8.6
Other					
Free World	35.9	10.6	2.0	1.6	1.4
United States**	2.8	5.6	.6	.5	.4
Total	49.7	100.0	18.6	14.5	10.4

*Includes portions of [redacted]

**US coverage includes MC&G (military and civilian) and Engineering Calibration.

TABLE 4-3
KH-9 Coverage-Mission 1210
(8 Jun 75 - 6 Oct 75)

Collection Category	Size of Area (million sq nm)	Percent Film Used	Coverage (million Square Nautical Miles) Attempted Gross	Cloud-Free Imagery Acquired: Gross	Unique
Primary Intelligence					
USSR	6.87	44.1	8.61	6.79	3.74
Eastern Europe	[redacted]				
China	2.82	16.6	2.54	1.88	1.28
Other	[redacted]				
Total Communist Countries					
Middle East					
Free World					
Subtotal					
Other					
United States	2.8	6.9	.76	.57	.50
TOTAL	52.20	100.0	17.4	13.54	8.11

Figures 4-1, 4-2 and 4-3 illustrate the status of search coverage satisfaction of primary requirements in relation to the 50, 80, and 90 percent satisfaction levels. It should be noted that the data in these figures are shown in terms of the area delineations which have been used in KH-9 requirements to date.

In spite of some interruptions to continuity of coverage at the desired rates, the KH-9 program has, in general, satisfied the most important of the non-time-sensitive requirements in terms of quality, quantity, and continuity of imagery flow. There have been short periods since KH-9 has been operational when important intelligence situations could not be monitored. These gaps were due to such factors as launch delays and extended periods of bad weather.

4.1.1.3 NAEF NIIRS Distributions

NIIRS distributions and cumulative distributions for search coverage rated from KH-9 missions 1209 through 1212 are provided in Figures 4-4 through 4-7. These distributions are single photo-interpreter ratings extracted from the National Area Exploitation File. Generally speaking, 55 to 65 percent of the unique images rated are rated NIIRS 4 or better. For the gross area rated, mission 1211 received significantly poorer area ratings than any of the other missions. This fact is not completely understood. The fact that Mission 1211 was predominantly a monoscopic mission should not affect the ratings significantly since all area ratings are assigned while viewing the imagery monoscopically.

TABLE 4-4

KH-9 COVERAGE

MISSION 1211***

(4 December 1975 - 29 March 1976)

Collection Category	Size Million Sq. NM.	% Film Used	Coverage (Million Sq. NM)		
			Attempts (Gross)	Cloud-Free (Gross)	Cloud-Free (Unique)
Primary Intelligence					
USSR	6.87	47.2	10.83	8.91	5.00
[redacted]	.40	4.8	1.14	.63	.33
China	2.82	19.8	4.36	3.63	2.25
Other	.56	3.3	.67	.55	.38
Total Communist Countries	10.65	75.1	17.00	13.72	7.96
[redacted]	.25	4.9	.61	.37	.20
Free World	38.50	13.8	4.61	3.14	2.34
Subtotal	49.40	93.8	22.22	17.23	10.50
Other					
U.S.	2.84	6.2	.87	.10	.09
MC&G (incl Military)**		2.0	.28	.06	.06
Test/Engineering		1.8	.08	.02	.01
Pre-launch Film Tests		1.0			
Special Intell. Support		0.4	.11	.01	.01
Direct Civil Applications		1.0	.40	.01	.01
Grand Totals	52.24	100.0	22.09	17.33	10.59

[redacted]

**The square nm of USGS coverage includes a portion that supports both the military and civilian mapping uses.

***High coverage levels resulted from necessity to operate mission primarily in the monoscopic mode.

TABLE 4-5
KH-9 COVERAGE
MISSION 1212
(8 July 1976 - 9 December 1976)

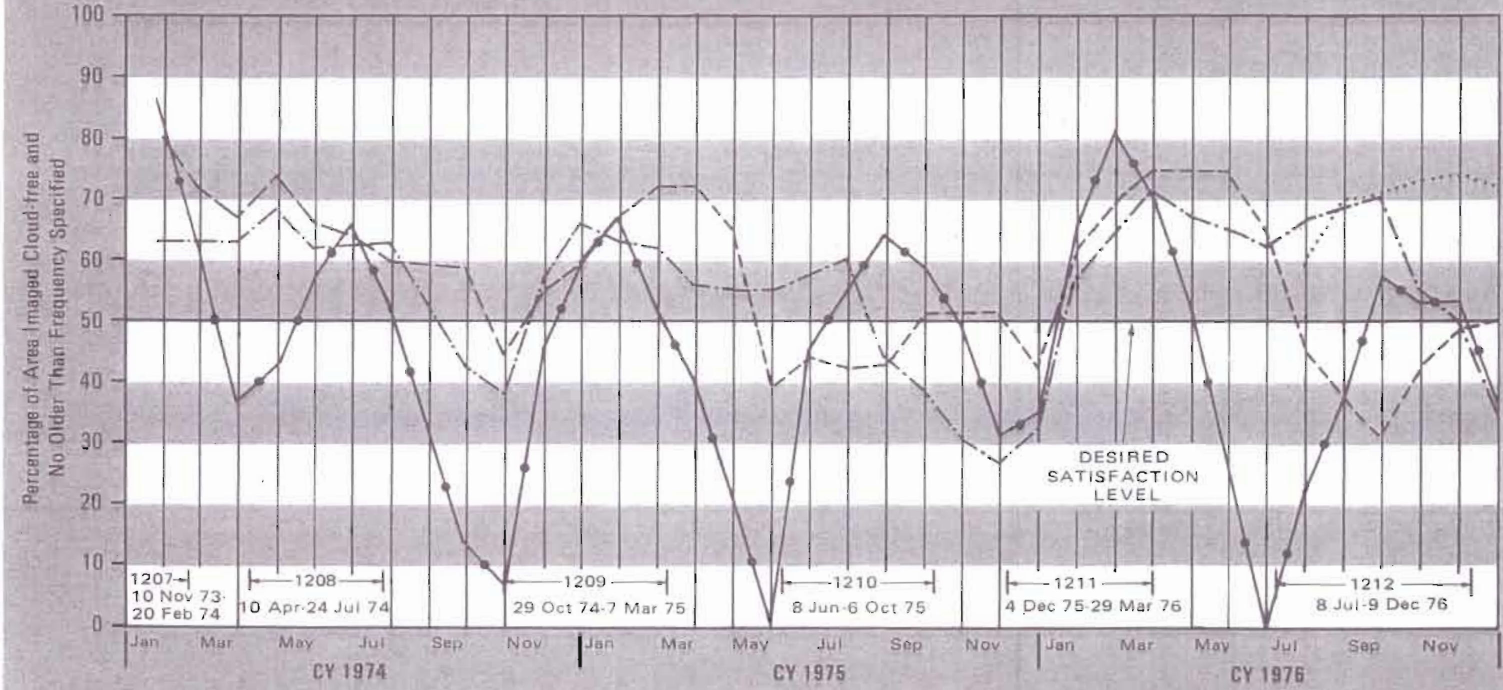
Collection Category	Size Million Sq. NM.	% Film Used	Coverage (Million Sq. NM) Attempts (Gross)	Cloud-Free (Gross)	Cloud-Free (Unique)
Primary Intelligence					
USSR	6.87	45.7	7.45	5.14	3.59
Eastern Europe	[redacted]				
China	2.82	18.6	3.32	2.52	1.80
Other	[redacted]				
Total Communist Countries					
Middle East*					
Free World					
Subtotal					
Other					
U.S.	2.84	6.6	.82	.63	.57
MC&G (incl Military)**		1.7	.29	.21	.19
Test/Engineering		2.7	.42	.33	.30
Pre-launch Film Tests		1.5			
Special Intell. Support		.4	.06	.05	.04
Direct Civil Applications		.3	.05	.04	.04
Grand Totals	52.24	100.0	17.87	12.49	9.14

*Middle East includes the [redacted]

**The square nm of USGS coverage includes a portion that supports both the military and civilian mapping uses.

FIGURE 4-1

Status of Search Coverage Satisfaction for Primary Requirements (Jan 74 thru Dec 76)
50% Level



*Requirement is to achieve an age distribution of coverage so that 50% of the respective areas have been seen at the stated frequency.

Note: Status is shown as of the end of each month.

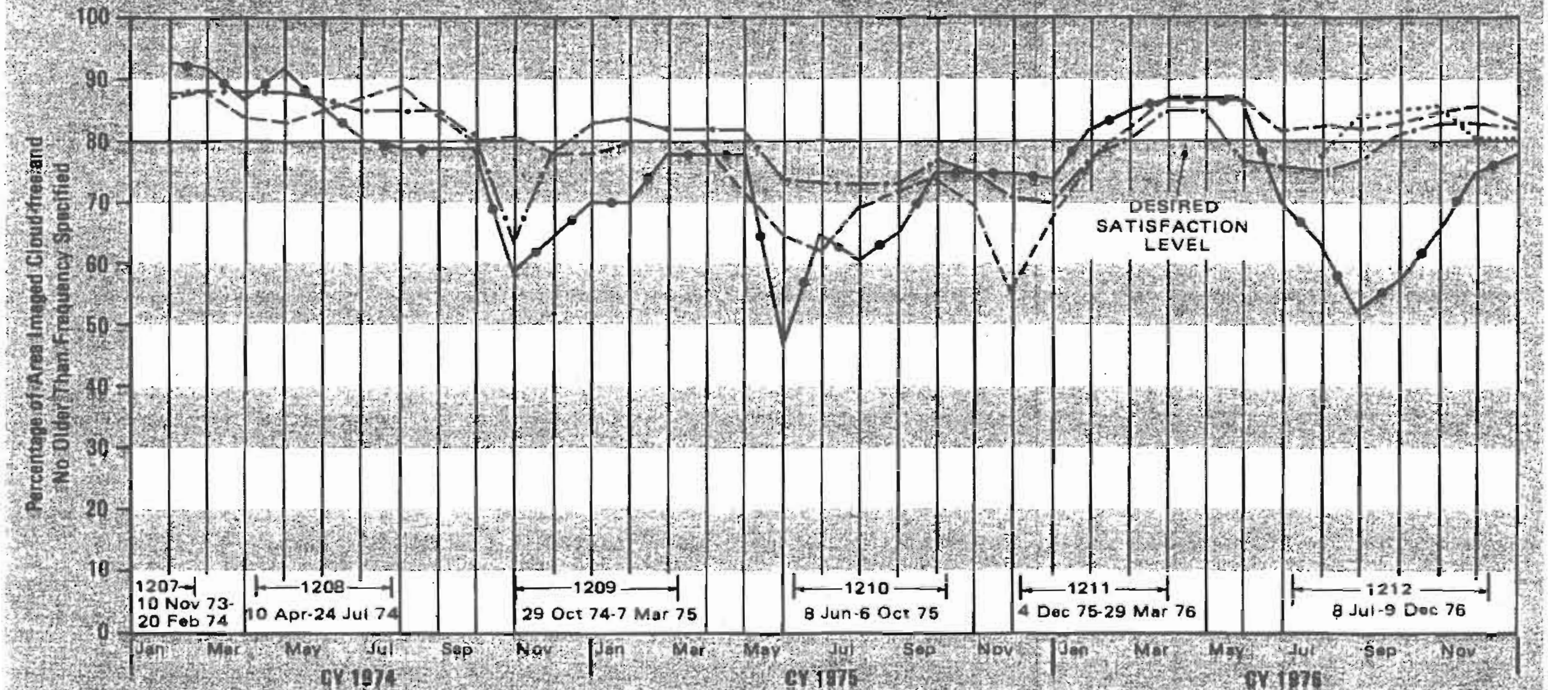
Note: The topographically unuseable category resulted in a further refinement of the collection requirements.

Requirement	Area (million sq. nm)	Frequency*
Built-up	3.9	3 month
Undeveloped	3.5	6 month
Remote	2.7	9 month
Topographically Unuseable	.5	12 month

FIGURE 4-2

Status of Search Coverage Satisfaction for Primary Requirements (Jan 74 thru Dec 76)

80% Level



*Requirement is to achieve an age distribution of coverage so that 50% of the respective areas have been seen at the stated frequency.

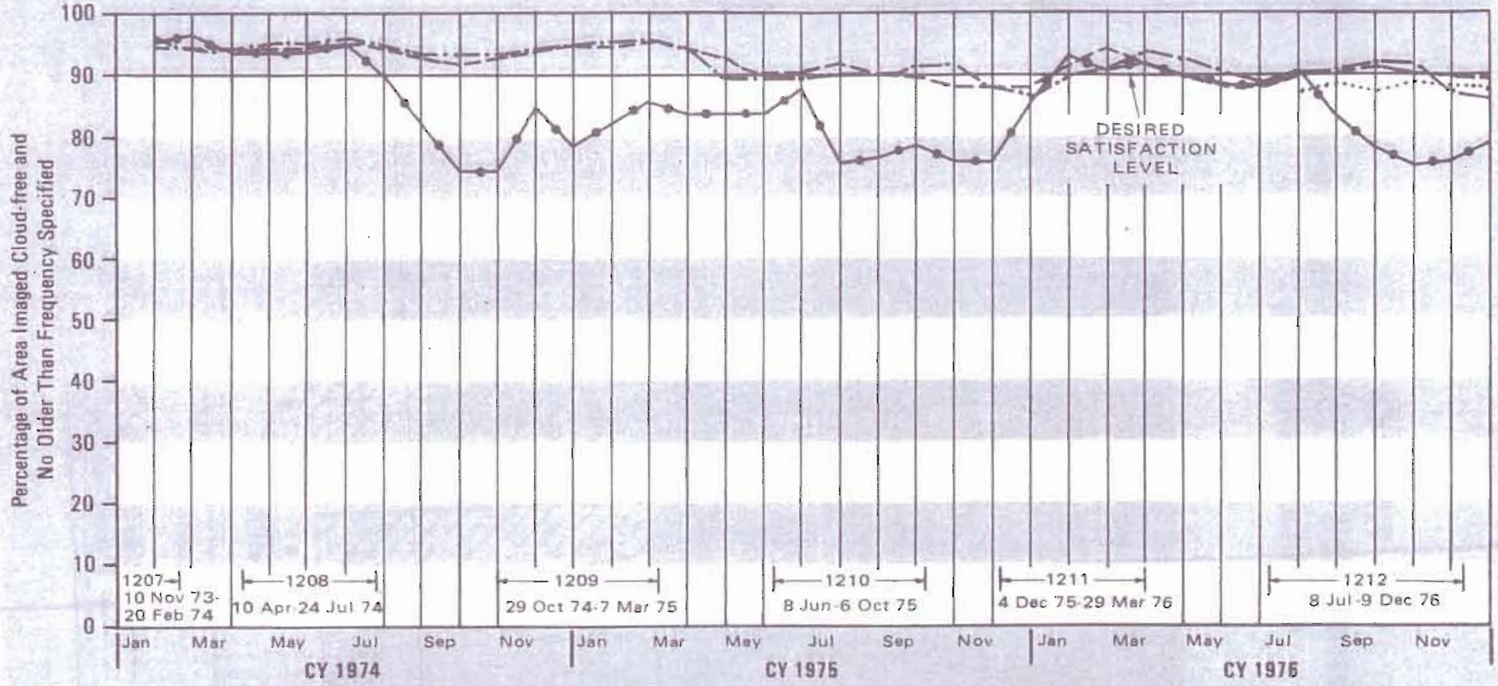
Note: Status is shown as of the end of each month.

Note: The topographically unuseable category resulted in a further refinement of the collection requirements.

Requirement	Area (million sq. nm)	Frequency*
Built-up	3.9	3 month
Undeveloped	3.6	6 month
Remote	2.7	9 month
Topographically Unuseable	.5	12 month

FIGURE 4-3

Status of Search Coverage Satisfaction for Primary Requirements (Jan 74 thru Dec 76)
90% Level



*Requirement is to achieve an age distribution of coverage so that 50% of the respective areas have been seen at the stated frequency.

Note: Status is shown as of the end of each month.

Note: The topographically unuseable category resulted in a further refinement of the collection requirements.

Requirement	Area (million sq. nm)	Frequency*
—•— Built-up	3.9	3 month
— — — Undeveloped	3.5	6 month
—·— Remote	2.7	9 month
········ Topographically Unuseable	.5	12 month

~~Top Secret~~

~~Top Secret~~ RUFF

FIGURE 4-4

NAEF NIIRS DISTRIBUTION AND CUMULATIVE DISTRIBUTION FOR KH-9 MISSION 1209

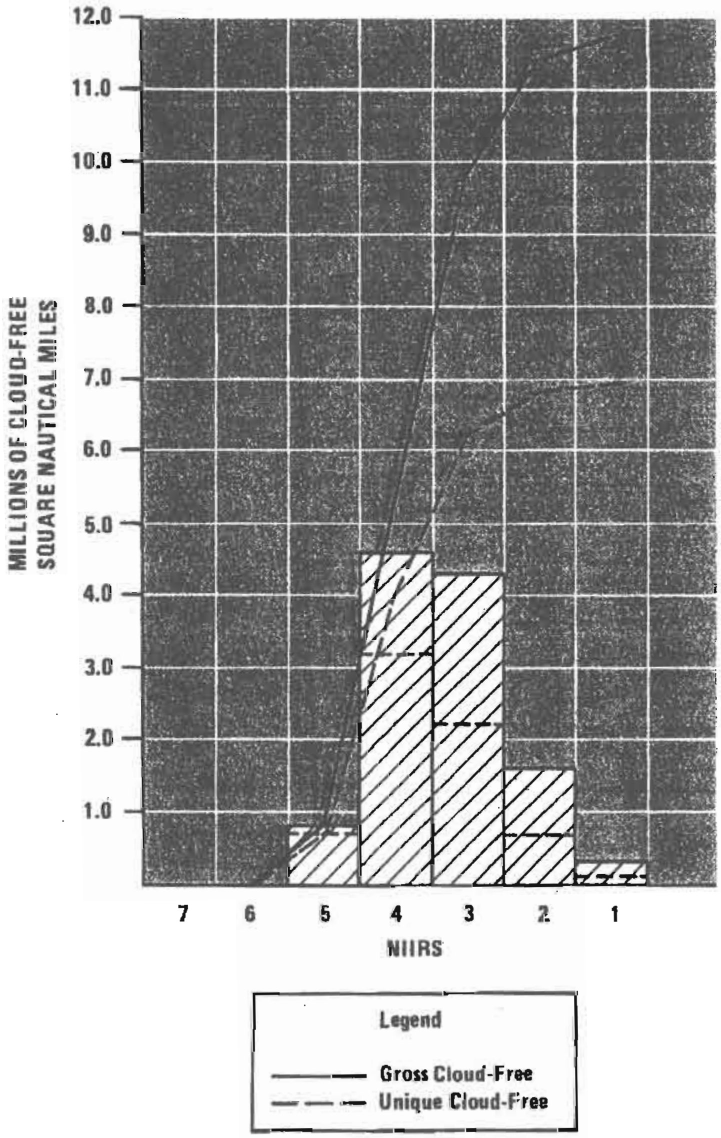


FIGURE 4-5

NAEF NIIRS DISTRIBUTION AND CUMULATIVE DISTRIBUTION FOR KH-9 MISSION 1210

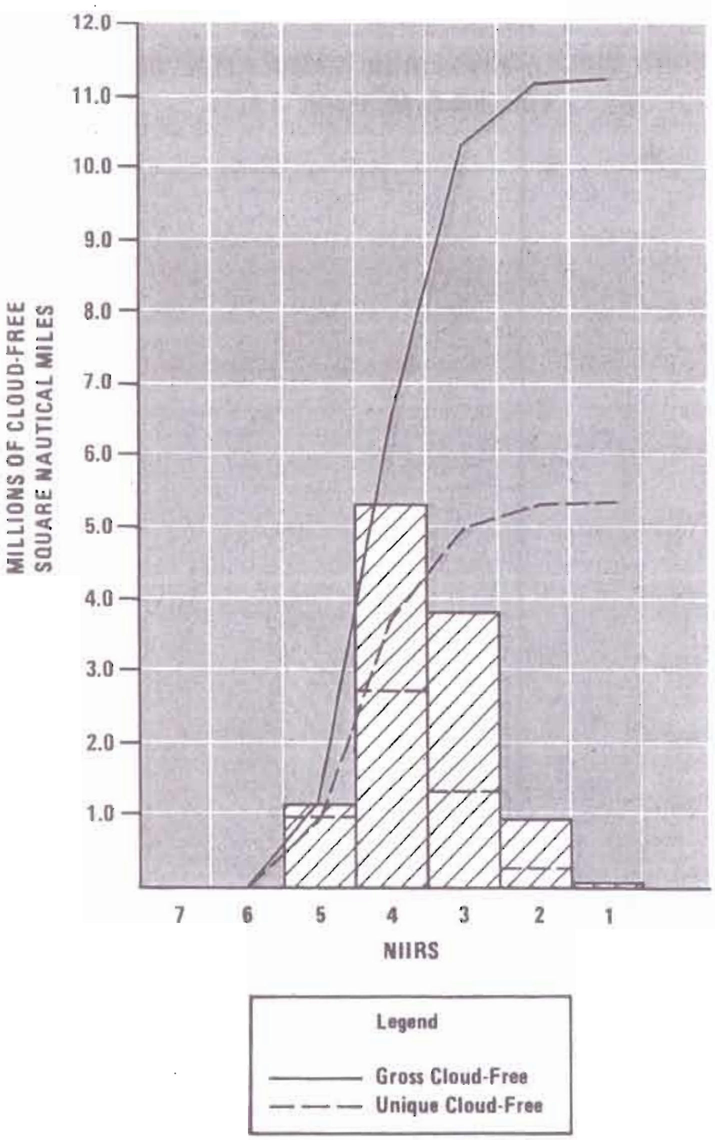


FIGURE 4-6
NAEF NIIRS DISTRIBUTION AND CUMULATIVE DISTRIBUTION FOR KH-9 MISSION 1211

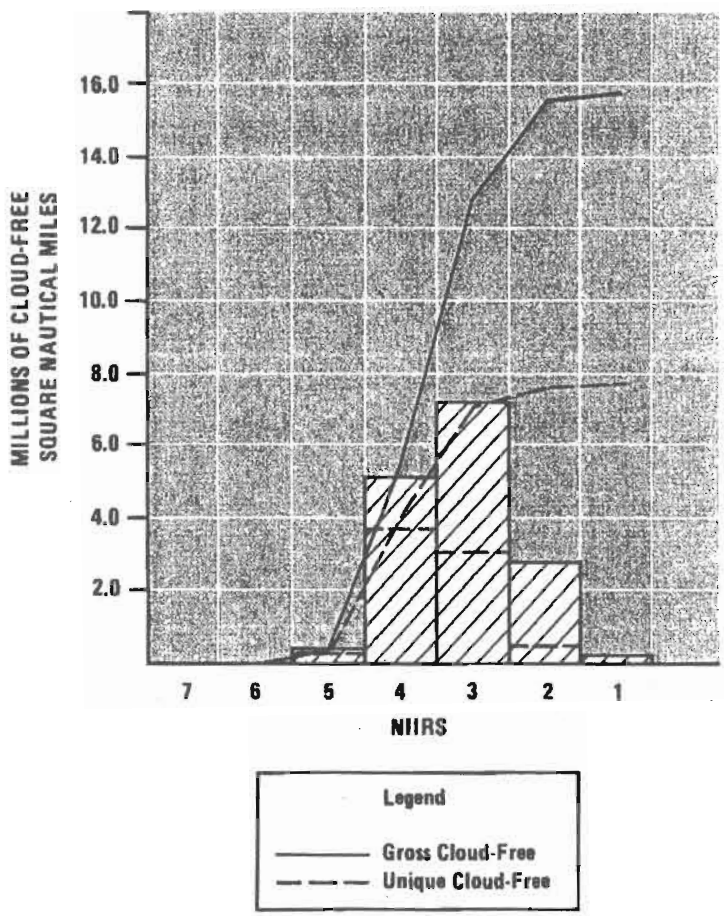
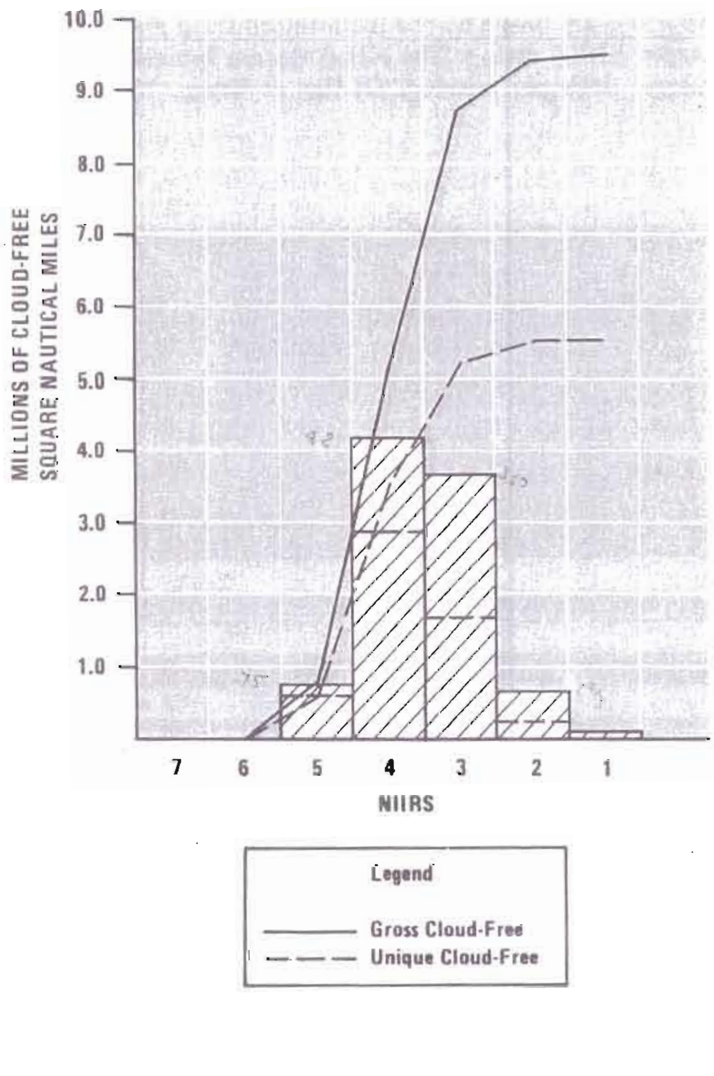


FIGURE 4-7
NAEF NIIRS DISTRIBUTION AND CUMULATIVE DISTRIBUTION FOR KH-9 MISSION 1212



4.1.2 Target Surveillance Coverage

The single most unique characteristic of the KH-9 system is its ability to provide photographic coverage of large geographic areas at a quality adequate for general point target surveillance. In the course of collecting search imagery, it typically covers 40 to 60 thousand point targets (COMIREX and non-COMIREX targets) per mission. If the surveillance requirement is non-time critical and the quality requirement for these targets is for NIIRS 4 imagery or less, there is an extremely high probability that the KH-9 coverage will periodically satisfy the surveillance needs.

Target coverage statistics for COMIREX targets are presented for missions 1210, 1211, and 1212. For each mission Tables 4-6, 4-7 and 4-8 give a breakout by country of the unique target and Figures 4-8, 4-9 and 4-10 provide NIIRS overall cumulative and distributions. The NIIRS distributions are based on the Installation Data File and reflect a single photointerpreter point target NIIRS rating. The KH-9 system typically covers about 80 percent of the COMIREX target deck per mission. Of this coverage, 70 to 80 percent is NIIRS 4 or better.

[redacted]

USSR	8,014	7,533	94
[redacted]			
China	3,460	2,294	66
[redacted]			
TOTAL	[redacted]		

[redacted]

Missing Page 47

Missing Page 48

FIGURE 4-8

NIIRS DISTRIBUTION AND CUMULATIVE DISTRIBUTION OF UNIQUE [redacted] COVERED ON KH-9 MISSION 1210

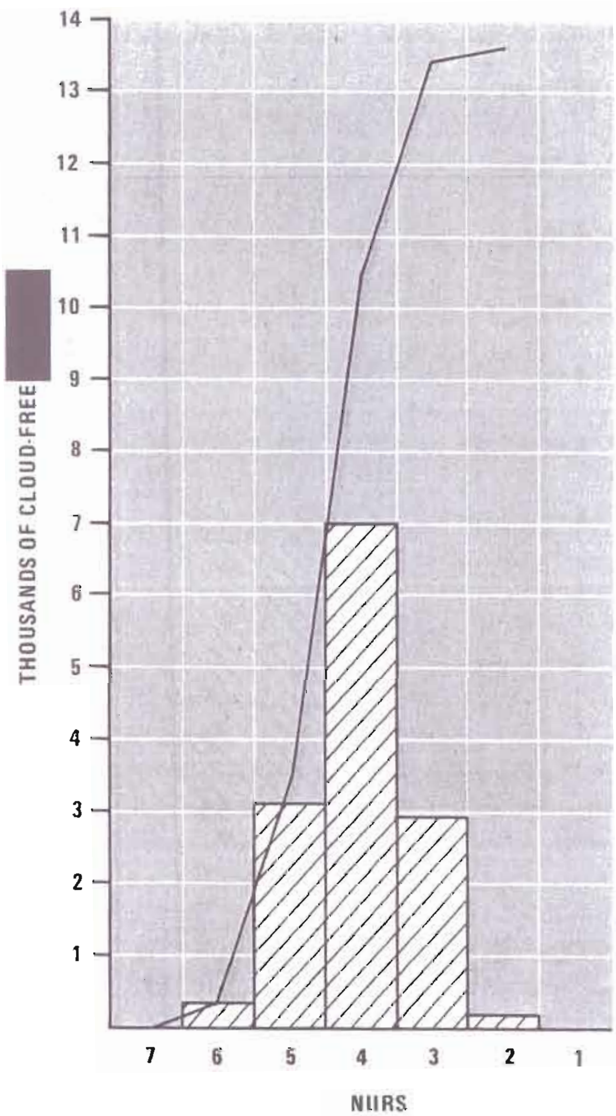


FIGURE 4-9

NIIRS DISTRIBUTION AND CUMULATIVE DISTRIBUTION OF UNIQUE COMIREX TARGETS COVERED ON KH-9 MISSION 1211

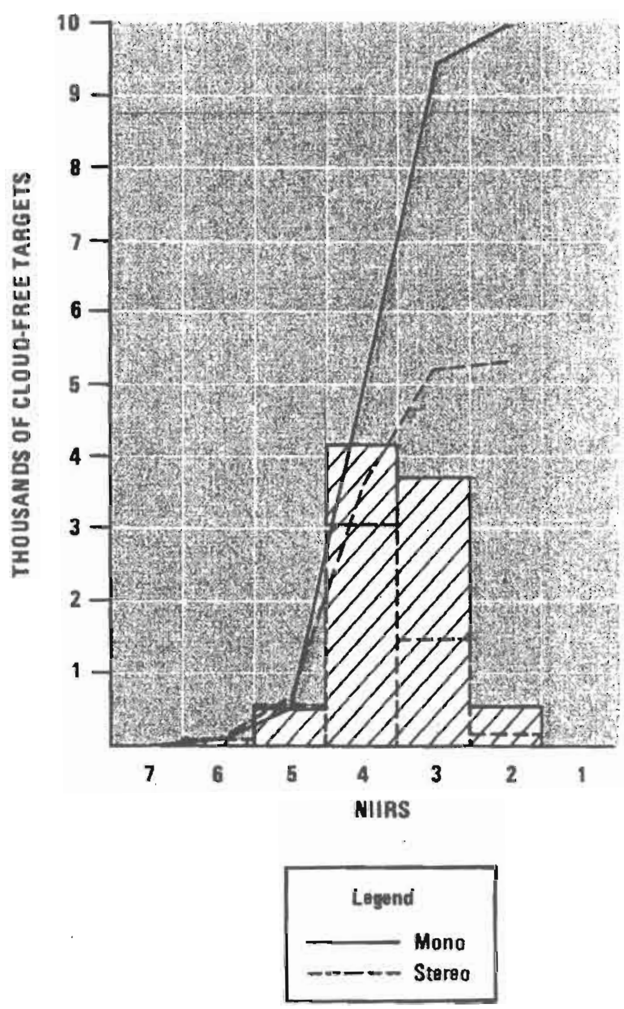
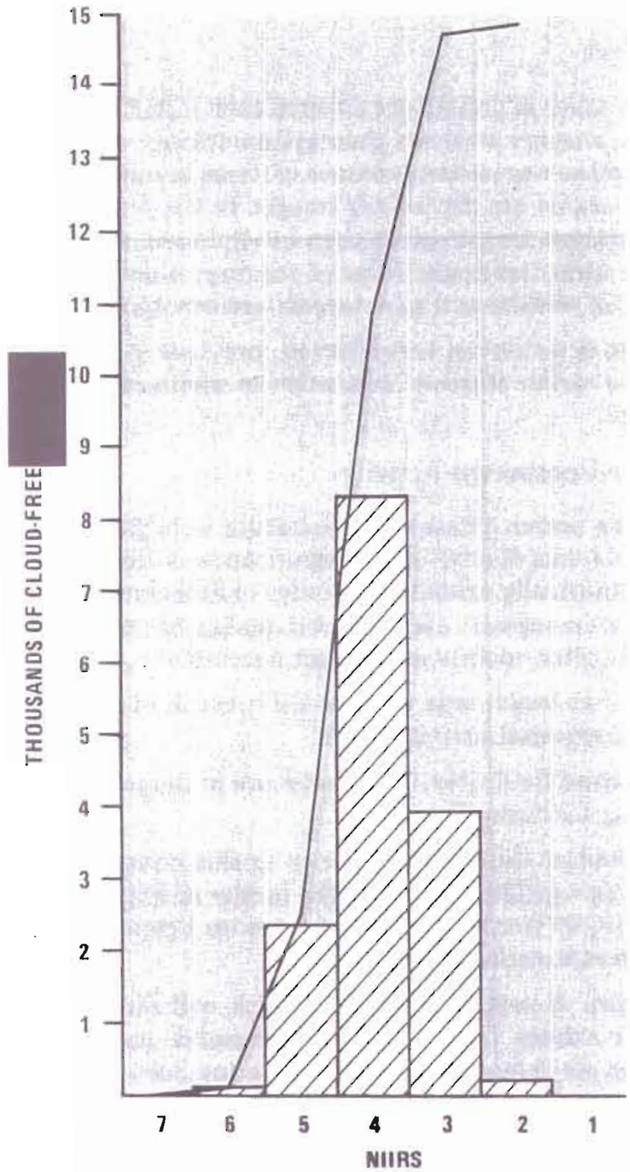


FIGURE 4-10

NIIRS DISTRIBUTION AND CUMULATIVE DISTRIBUTION OF UNIQUE [redacted] COVERED ON KH-9 MISSION 1212



4.2.2 Function-Unique Contributions

Function-unique contributions are provided by KH-9 because of its function of satisfying the standing and special search requirements. The contributions are unique because to date no other system has been able to provide them to the degree shown by the KH-9. It is reasonable to assume that other search systems, which satisfy the standing and special search requirements, might provide some or all of these contributions.

4.2.2.1 Standing Search

Millions of square miles of ground are covered each KH-9 mission to satisfy the standing search requirements. Imagery analysts then systematically examine the imagery to report significant changes and to negate the presence of items of military significance. In addition, tens of thousands of targets are necessarily imaged in the process of collecting such a large area of ground. Since these targets must then be exploited, good quality stereo is essential for providing reliable target readouts. Most of the targets now imaged by targeting systems were discovered during search, and new targets are constantly being found.

And if new targets or activities are detected, previous KH-9 coverage usually provides the only images of the earlier stages of construction where cable and foundation configurations can be analyzed.

4.2.2.1.1 Transient or Unexpected Activity

The purpose of the search phase of exploitation is to find significant changes and to negate the presence of items of intelligence significance. Millions of square nautical miles of ground must be systematically examined in order to find changes or to assure that there are none. KH-9's ability to image vast areas at good quality has made the detection of small, often camouflaged, and often mobile equipment successful.

While no attempt has been made to show the breadth of search finds, a few of the more significant recently discovered activities are:

(1) Chinese SSM fixed field sites. These sites are in mountainous ravines and some lack permanent identifying features (Figure 4-13).

[redacted]

(3) New SAM Sites. A new complex at Norilsk will directly affect SIOP penetration routes through the northern USSR, an SA-5 complex under construction at Gremika significantly upgrades air defense of a major operating base for SSBN's, and a chain of 18 new SA-2 and SA-3 sites and two SAM support facilities were found from Zavitinsk to Lesozavodsk in the far eastern Soviet Union.

[redacted]

[redacted]

[redacted]

Missing Page 57

Missing Page 58

Missing Page 59

(2) February 1976: Detected field activity of SS-20. Detected movement of SS-20 launch site from Kapustin Yar to Gladkaya. The search area was extended from 30-nautical-mile to 50-nautical-mile radius about ICBM complexes.

(3) February 1976: Similarity noted between Scaleboard and SS-20 exercises and track activity.

(4) October 1976: Detected sliding-roof buildings as possible launch sites in time of heightened alert.

4.2.2.2.2 Directed Search

KH-9 has proved invaluable when the general location of a target or activity is known, but the location is not known precisely enough for acquisition by a targeting system. Typical examples:

- Nuclear Tests. After a Chinese nuclear test at Lop Nor, or a peaceful Soviet test, interpreters are generally required to locate the site in an effort to determine the type and purpose of the test. Seismic locations are not accurate enough for the site to be pinpointed in most cases without broad area coverage (Figure 4-15).

- Missile Failures. After a failure, missile components can impact in an ever-widening triangle downrange from missile test centers. Their discovery must rely on broad area coverage. Once located, the debris of the impacts may necessitate retargeting for higher resolution coverage for identification and mensuration of debris or sections of the missile which survived the crash.

- Civil Defense. A general search has been conducted to determine the extent of the civil defense program in the Soviet Union. Thousands of personnel shelters have been constructed, and many are not near known military targets and have therefore not been covered by KH-8 or KH-11 imagery. KH-9 stereo coverage is used for conducting this kind of search.

4.2.2.2.3 Historical Studies

Past KH-9 missions are regularly used to provide historical information on newly identified targets or activities. Once the Imagery Analyst identifies a new activity (usually as a result of good collateral information or of a find on higher quality imagery), he examines past KH-9 coverages to answer such questions as: When did the activity begin? What did the activity look like in its earlier stages? How widespread is the activity? And what events prompted the activity at that particular time? Once certain patterns or signatures have been established on higher quality targeting imagery, activities can be identified even on lower quality search imagery. For example, KH-8 imagery showed that certain motorized rifle regiments (MRRS) had added field artillery in a certain pattern. Analysts could then go back to KH-9 coverages, and armed with this information, could identify other upgraded MRRS.

[redacted]

[redacted]

Some other results provided by historical studies:

(1) Newly identified stockpiles of bridging equipment had been present for years so they did not represent a sudden change in Soviet practices, subduing rumors of impending hostilities.

(2) A motorized rifle regiment in the Leningrad Military District was trained in air mobile tactics, allowing for more mobility than was previously expected. Previous coverages showed this capability to be common throughout the district.

(3) Collateral information showed that previously unidentified storage bunkers could be used to protect reserve grain from nuclear fallout as a civil defense measure. Reexamination of previous KH-9 coverages identified some 30 more bunkers, provided approximate dates of construction, and so allowed analysts to speculate what national events prompted the construction of the storage bunkers.

4.3 MC&G Collection Summary

The criteria for evaluating KH-9 imagery collection against MC&G requirements are contained in Table 4-9. One of the more significant parameters is the gross cloud-free square nautical miles returned by missions against validated MC&G requirements. Cloud-free assessment reports are generated on World Area Grid (WAG) cell (12 x 18 square nautical miles) and WAG subcell (3 x 3 square nautical miles) basis. Even though the information on individual cloud-free subcells is available,the size of the area reported is smaller than the minimum area required. Satellite image resolution requirements for MC&G purposes vary with the scale and type of the product. The most stringent requirements for ground resolution to meet image content needs of military MC&G products is 2 feet for 1:50,000 line maps and for DLMS Level II digital culture and terrain data. This is more important for the panoramic imagery than for the stellar terrain imagery. The KH-9 panoramic imagery taken at altitudes of 82-132 nautical miles (the range of altitudes for missions 1201 through 1212) meets and in many cases exceeds the MC&G requirements for ground resolution distance (GRD) or NIIRS. Similarly, KH-9 MCS frame imagery taken at 84-156 nautical miles (the range of altitudes for MCS operations on missions 1205 through 1212) will, for certain products, provide the required GRD. The remainder of this section presents coverage satisfaction statistics for the panoramic and stellar terrain camera systems in terms of cloud-free imagery.

4.3.1 Panoramic Collection Summaries for MC&G

The current USIB-approved KH-9 panoramic imagery requirements are for 22.4 million square nautical miles, shown in Table 3-1. Current satisfaction levels against these requirements are shown in Table 4-10. This table is based primarily on the actual KH-9 collection and excludes the Sino-Soviet area and most of the important search or point target areas in the Middle East, for which MC&G requirements are generally met.

[redacted]

[redacted]			
Cloud Freeness		90-100%	50-100%
[redacted]			
Image Quantity		10% of Film Load	97% of Film Load
[redacted]			
Attitude	Pitch	15°	5°
	Roll	5°	5°
	Yaw	15°	5°
[redacted]			
Obliquity		0° - 45°	—
[redacted]			
Special Constraints		Free of Glare, Haze, and Heavy Snow	Same as Pan

The total panoramic imagery from the KH-9 sensors collected against the 22.4 million square nautical miles military and civil requirement is 8.9 million square nautical miles (see Table 4-11). Figure 4-16 shows graphically the MC&G priority panoramic collection versus the film allocation. Also depicted is the first-time and total panoramic imagery collection for MC&G priorities from the first 12 KH-9 missions. This figure confirms the below par performance against the total MC&G priority panoramic imagery requirement. Table 4-12 summarizes panoramic coverage by major geographical region.

4.3.2 MCS Collection Summary

Status of collection efforts for the Mapping Camera Subsystem is summarized in Table 4-13 and Figure 4-17 for MC&G metric requirements. Table 4-13 shows in detail the current requirement status by major world areas. There remains 23.2 million square nautical miles to be collected against the original 37 million approved requirement.

Relative to the positioning requirements, present KH-9 MCS imagery together with other calibration data provides 41 meters absolute horizontal and 23 meters absolute vertical point positioning accuracy. More than 21,000 NTB points have already been positioned to this accuracy and the remainder are positioned to accuracies from 300 to 62 meters horizontally and from 200 to 29 meters vertically.

TABLE 4-10

SUMMARY OF KH-9 PANORAMIC MC&G COVERAGE FOR NON-COMMUNIST AREAS
(Stereo, 90% Cloud Free)

	(Millions of Cloud-Free Square N.M.)		
	Original Requirement	Area Collected By Dec 1976	Remaining Requirement
Military			
First Time (FY 72-77)	6.8	3.2	3.6
Recoverage (FY 72-78)	13.5	6.9	6.6
Subtotal	20.3	10.1	10.2
Civil			
First Time (FY 72-78 @ 0.3 msnm per year)	2.1	0.9	1.2
Total	22.4	11.0[1]	11.4

[1] Includes KH-4 coverage of 2.1 million square nautical miles collected in FY 1972. This figure includes 0.5 million square nautical miles of first-time coverage and 1.6 million square nautical miles of recoverage.

4.3.3 Exploitation

An overview of the DMA production process is portrayed in Figure 4-18. These processes are built on the assumption of the continued availability of both panoramic (wide area coverage) and frame imagery (high metric accuracy) as basic input. The output is a complete spectrum of DMA products, many of which are currently in a digital form. Advances in autocartography, for example, have made possible the extraction of mapping data from film imagery in digital form, and the subsequent generation of maps and charts from this digital data base. Proven reductions in project pipeline time and consequent cost savings have led to an increasing use of autocartography in DMA mapping activities; this trend is confidently predicted to continue. Similarly, requirements for MC&G products to support cruise missile

TABLE [illegible]

KH-9 PANORAMIC COVERAGE

MILITARY AND CIVIL ACQUISITION

(Millions of Square Nautical Miles)

Mission	First Time		Recoverage		Total		Combined
	Military	Civil	Military	Civil	Military	Civil	Total
1201	.190	.141	.055	.213	.245	.354	.599
1202	.078	.028	.139	.088	.217	.116	.333
1203	.298	.064	.752	.021	1.050	.085	1.135
1204	.328	.059	.280	.022	.608	.081	.687
1205	.166	.126	.567	.116	.742	.242	.984
1206	.452	.051	.442	.004	.894	.055	.949
1207	.208	.057	.345	.074	.553	.131	.684
1208	.202	.050	.521	.017	.723	.067	.790
1209	.281	.121	.433	.017	.714	.138	.852
1210	.246	.127	.220	.085	.466	.212	.678
1211	.051	.001	.172	.049	.223	.050	.273
1212	.176	.086	.464	.172	.640	.258	.898
Total	2.674	.911	4.399	.878	7.073	1.789	8.862

ANNUAL PAN COVERAGE

(Millions of Square Nautical Miles)

Mission	First Time		Recoverage		Total		Combined
	Military	Civil	Military	Civil	Military	Civil	Total
1971	.190	.141	.055	.213	.245	.354	.599
1972	.702	.151	1.171	.131	1.873	.282	2.155
1973	.826	.234	1.363	.194	2.189	.428	2.617
1974	.483	.171	.954	.034	1.437	.205	1.642
1975	.297	.128	.392	.134	.689	.262	.951
1976	.176	.086	.464	.172	.640	.258	.898
Total	2.674	.911	4.399	.878	7.073	1.789	8.862

FIGURE 4-16

FIRST TIME MC&G PAN COVERAGE AND FILM USED FOR KH-9 MISSIONS 1201 - 1212

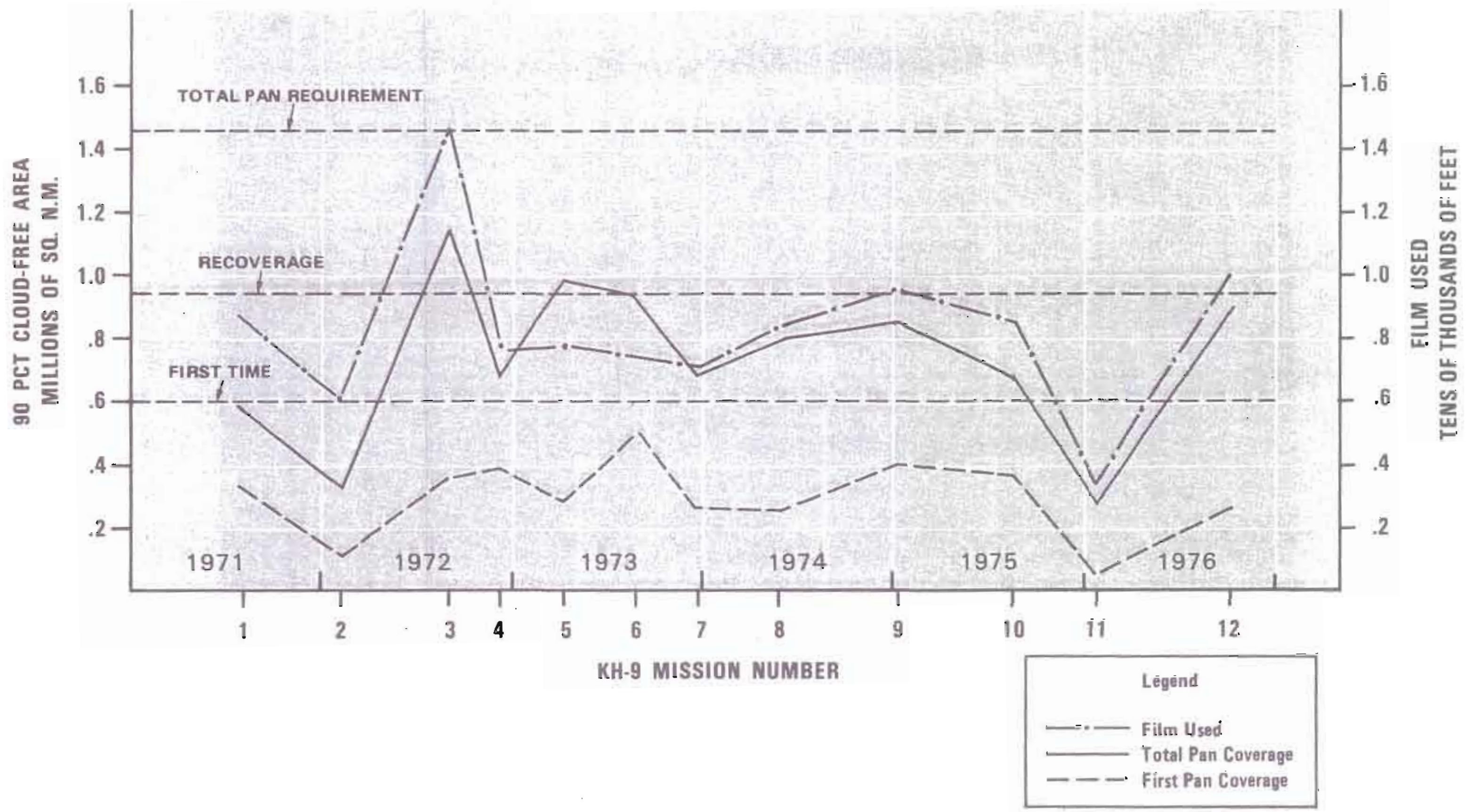


TABLE [illegible]

MILITARY AND CIVIL MC&G
PANORAMIC COVERAGE BY MAJOR GEOGRAPHICAL REGION

Worldwide, Including Sino-Soviet Area
(Stereo, 30% Cloud-Free)

	(Millions of Square Nautical Miles)						
	Sino-Soviet Area	Eurasia	Africa Plus Sinai	North America	South America	Other	Total
USIB Approved Requirements	10.2[1]	5.0	5.9	4.2	3.6	2.6	21.3
Total Requirements DMA WAG Cell Area	10.4[1]	5.2	6.2	4.4	3.8	2.8	22.4[3]
Collected by End of December 1976 (Missions 1201-1212)[4]	9.1[1]	3.7	2.5	2.4	1.8	0.6	11.0
Balance Current Requirement	1.3[2]	1.5	3.6	2.0	2.0	2.2	11.4

[1] DMA requirements in the Sino-Soviet area are satisfied by intelligence community collection activities. They are included to show the scope of the requirements. Sino-Soviet area collection is not included in the totals.
[2] This shortfall has been identified to [illegible].
[3] The USIB approved requirement of 21.5 million square nautical miles converts to 22.4 million square nautical miles in the DMA ACRES file, which uses WAG cell areas.
[4] All statistics of coverage are given in terms of 12 x 18 nm WAG cells.

TABLE 4-13

STATUS OF MILITARY AND CIVIL MC&G MCS COVERAGE

(Stereo, 50% Cloud-Free)

	Millions of Square Nautical Miles						
	Sino-Soviet Area	Eurasia	Africa Plus Sinai	North America	South America	Other	Total
USIB-Approved Requirements	10.2	5.2	8.8	5.2[1]	5.4	2.2[2]	37.0
Total Requirements DMA WAG Cell Area	10.4	5.4	8.8	5.7[1]	5.5	4.0	39.8[3]
Collected by End of of Dec 1976 (Msns 1205-1212)[4]	8.5	3.3	2.6	1.0	0.7	0.5	16.6
Balance-Current Requirement	1.9	2.1	6.2	4.7	4.8	3.5	23.2

[1] USIB-approved requirement excludes 1.2 million snm of the U.S.

[2] Australia only.

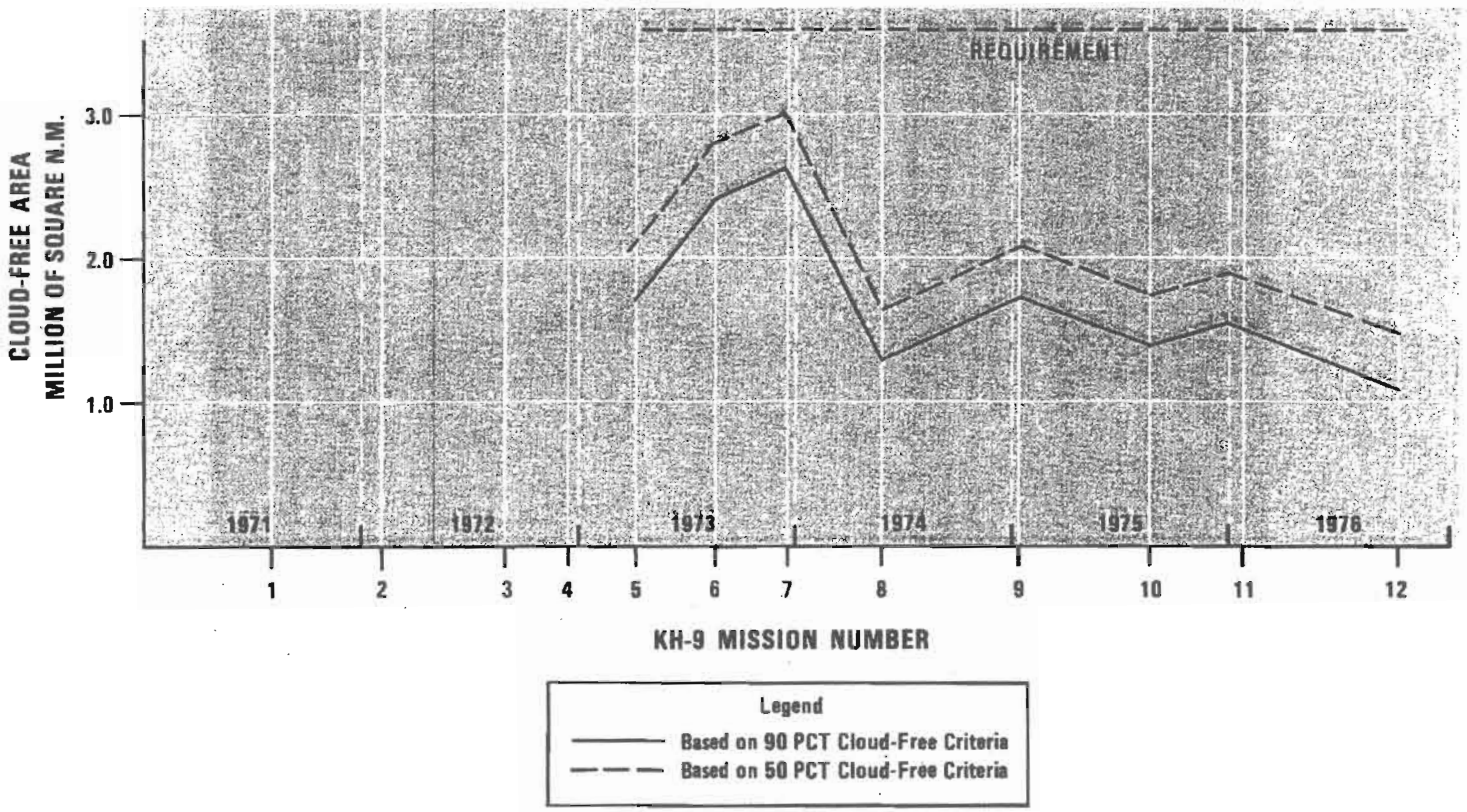
[3] The USIB-approved requirement of 37.0 million snm converts to 39.4 million snm in the DMA ACRES file, which uses WAG cell areas. Recent mission requirements have totaled 39.8 million snm which include the USGS Antarctica request, 0.4 million snm.

[4] All statistics of coverage are given in terms of 12 x 18 nm WAG cells.

FIGURE 4-17

MC&G MCS COVERAGE
FOR KH-9 MISSIONS 1205 - 1212

MCS COVERAGE AT 50 PCT = 16.7 MILLION SQ. N.M.
MCS COVERAGE AT 90 PCT = 13.7 MILLION SQ. N.M.



~~Top Secret~~

~~Top Secret~~ RUFF

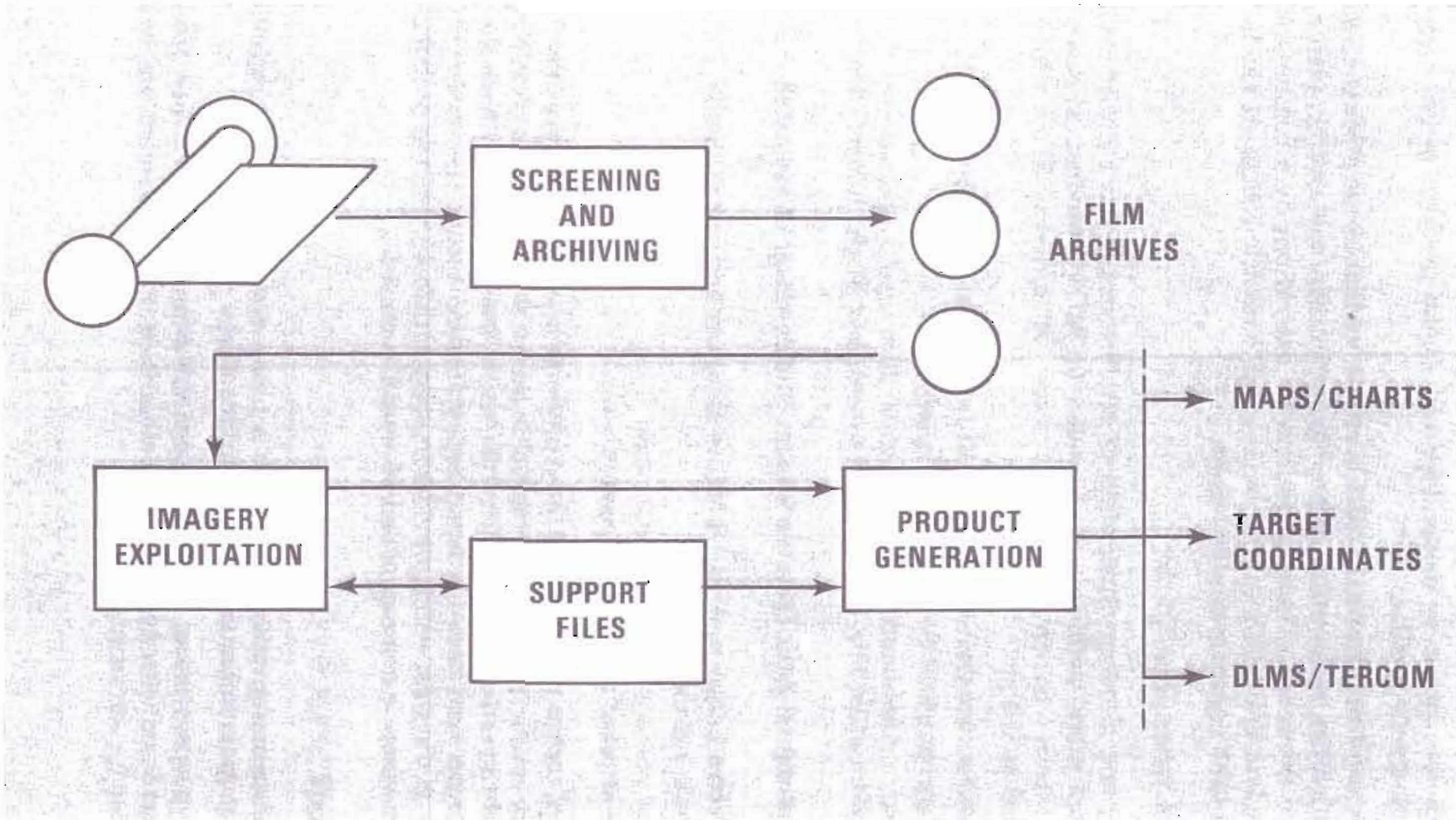


Figure 4-18. DMA MC&G Production Overview

applications, precision guided reentry vehicle targeting, and low-level attack aircraft penetration missions dictate increasing demand for such digital products as terrain height matrices and radar reflectivity profiles.

Between the raw imagery and the final products are the various image processing operations, typified by rectification, registration, orthophoto generation, mosaicking, planimetry extraction, and feature extraction. These operations are carried out by a combination of manual, optical and hybrid optical/digital techniques, and currently constitute the bulk of DMA project pipeline time requirements and costs.

4.3.3.1 MC&G Product Description

Mapping, Charting and Geodesy exploitation of satellite imagery is a direct result of military and intelligence users' worldwide requirements for MC&G products and services. These products and services currently consist of some 230 different items which can generally be categorized as follows:

Compilation and revision of standard topographic maps and charts.

Generation of aeronautical data for chart overlays.

Generation and maintenance of information files and publications: Automated Airfield Information File, Notices to Mariners, and Flight Information Publications.

Development of digital data bases for storage and retrieval of extracted data.

Generation of data bases, such as DLMS, to simulate and operationally support aerospace terrain sensors.

Development of photogrammetric data bases.

Determination of point target coordinates.

The principal source for the generation of these products is satellite photography. To be useful for accurate map production, these photographic materials must possess qualities exhibiting sufficient resolution and metric stability. Currently, satellite imagery from the KH-9 sensors is the most economical form of imagery for application against the various MC&G requirements. It is the only system which provides imagery satisfactory for the production of MC&G products where synoptic coverage of denied areas is required.

Line Maps and Charts

Maps are a graphic representation, usually on a plane surface and at an established scale, of natural and manmade features on the surface of the earth.

Charts are special purpose maps, generally designed for navigation, in which essential map information is combined with various other data critical to the intended use, such as aeronautical information for aeronautical charts.

The DMA family of maps and charts has developed over a number of years in a variety of scales and specialized formats designed to support different requirements, specifications and weapon systems. In general, cartographic products depend on the operation supported - land, sea, air, or combination. The intended use of a product also dictates such factors as scale, datum, grid and the nature and extent of features portrayed (planimetry, topography, radar return, intelligence, etc.). Table 4-14 summarizes representative cartographic products produced by DMA.

TABLE 4-14

SUMMARY OF SELECTED DMA CARTOGRAPHIC PRODUCTS

Approximate Map/Chart Scale	Optimum Accuracy (90% Probability)		Reference System Particulars				Representative Projects(s)
	Horizontal (m)	Vertical (m)	Hori. Datum	Vert. Datum	Projection	Military Grid	
1:3,000,000	1500	—	Unsp	MSL	M	—	Naval Warfare Planning Chart
1:2,000,000	1000	150	Unsp	MSL	LCC/PS	GEOREF	Jet Navigation; LORAN and OMEGA Chart
1:1,000,000	500	75	Unsp	MSL	LCC/PS	GEOREF/ ACLANT	Operational Navigation; Bottom Contour Charts
1:600,000	300	45	Unsp	Local	M	UTM/UPS	Coastal Nautical Charts
1:500,000	250	38	Unsp	MSL	LCC/PS	GEOREF	Tactical Pilotage Charts
1:250,000	127	25	Pref	MSL	TM	UTM/UPS	Joint Operations Graphics
1:200,000	101	25	Pref	MSL	LCC/PS	UTM/UPS	Air Target Charts
1:100,000	50	15	Pref	MSL	TM	UTM/UPS	Topographical Line Maps
1:75,000	38	13	Local	Local	M	UTM/UPS	Harbor and Approach Charts
1:50,000	25	10	Local	MSL	TM	UTM/UPS	Large Scale Topo Line Maps and Combat Charts
1:25,000	13	3	Local	MSL	TM	UTM/UPS	Large Scale Topo Line Maps

Unsp - Unspecified
Pref - Preferred
MSL - Mean Sea Level
M - Mercator
LCC - Lambert Conformal Conic
PS - Polar Stereographic
TM - Transverse Mercator
GEOREF - World Geographic Reference System
ACLANT - Allied Command Atlantic
UTM - Universal Transverse Mercator
UPS - Universal Polar Stereographic

The scale of a map or chart depends on its intended purpose. A measure on the graphic represents an increasingly greater distance on the ground as the scale decreases. As shown in Table 4-14, large scale maps are applicable for ground and sea operations. The scale determines the amount and generalization of detail portrayed and limits the potential accuracy of horizontal and vertical information.

The accuracy of a cartographic product depends on the basic source material and the compilation/reproduction processes. The optimum horizontal accuracy for a cartographic product (Class A) is expressed in the meter equivalence of 0.5 millimeters at map scale (90% probability), and the vertical accuracy at one-half the contour interval (90% probability). The combination of scale and accuracy can subsequently affect the significance of the horizontal and vertical datum of the graphic.

Missing Page 76

Missing Page 77

tracking network. The camera calibration data are used to analytically remove effects of lens distortions and film shrinkage from the MCS terrain camera image. The stellar cameras are used to determine the attitude of the MCS terrain camera at the instant of exposure. The doppler transmitter and tracking network are used to develop a more accurate ephemeris of the MCS camera's position, and the timing data on the film permit determination of the camera's location at the instant of exposure, to provide accuracies of at least 18 meters in-track, 12 meters cross-track, and 6 meters vertical (one sigma values).

KH-9 panoramic photos are employed in those MC&G applications that require medium-high to medium resolution (2 to 20 feet). KH-9 panoramic photos provide medium-scale (about 1:110,000 to 1:180,000) coverage of large areas.

Uncertainties in the calibration, attitude, and orbit of the panoramic camera prevent the use of panoramic imagery as a single stand-alone system for compiling new maps. The compilation of new maps requires either KH-9 MCS photography or geodetic ground survey data for establishing a control network. Stereoscopic panoramic models are then fitted to this network to develop contour lines and fill in cultural details. Panoramic photos provide detail adequate for compiling or revising cultural features on maps, particularly at large scales but also at medium scales. It may also be used for revising small-scale maps in culturally developed areas. For revision of metrically accurate but culturally out-of-date maps, the panoramic photos are rectified and fitted to the map.

Imagery of 2 to 10 feet resolution provided by the KH-9 panoramic camera is also essential for determining radar reflectivity for 1:200,000 and 1:250,000 charts, and as a source of data for input into the Digital Radar Landmass Simulator.

4.3.3.3 DMA's Manpower and Equipment Review

The DMA is composed of a small headquarters consisting of 189 highly skilled professional and clerical people who direct the activities of about 7,500 people in three production centers. In addition, DMA is program manager for about 3,000 people assigned to the Military Departments but not under its direct control. To accomplish the DMA mission requires approximately a half billion dollars worth of resources. The total MC&G resources allocations are shown in Table 4-16.

TABLE 4-16

MC&G RESOURCE ALLOCATION

		Millions of Dollars
Facilities		100
Equipment		160
Annual Budget		246
	Subtotal	506
Non-DMA		58
	Total	564

The work force composition of the three production centers is shown in Table 4-17.

MC&G technology is extremely complex and requires the use of very precise and highly sophisticated equipment. Many processes require the application of automated digital and analytical plotting equipment unique to mapping. Equipment used in support of DMA's primary mission includes:

Stereocomparators for photogrammetric derivation of positional data;
Analytical stereoplotters for compilation of graphic and digital data;
Automated cartographic systems;
Scientific computers for geodetic, photogrammetric, and cartographic computations;
Lithographic reproduction equipment; and Photographic reproduction equipment.

TABLE 4-17

PRODUCTION CENTERS WORK FORCE COMPOSITION

SKILLS	COUNT
Professional/Scientific:	[redacted]
Cartographers	
Geodesists	
Mathematicians	
Aeronautical Information Specialists	
Physical Scientists	
Other	
Wage Board	
Other	

The total investment for equipment to exploit the panoramic and frame imagery is over 71 million dollars (Table 4-18). This investment has been made to insure that DMA could

TABLE 4-18

MAPPING, CHARTING AND GEODETIC EQUIPMENT INVENTORY DATA APRIL 1977

(MILLIONS OF DOLLARS)

CATEGORY	DMAAC	DMAHC	DMATC	TOTAL
Photogrammetic	[redacted]			
Photographic				
Cartographic				
Geodetic				
Lithographic				
Automatic Data Processing				
TOTAL				

meet the MC&G requirements levied by DoD military and intelligence community users. Cost effective MC&G applications have been established during the life time of the KH-9 systems. Such application may well apply to other NRP imagery in the future; however, there will be additional cost associated with the necessary research and development for complete implementation.

Top Secret

[redacted]

Top Secret

SOLID RETRO MOTOR
SPIN HOT GAS GENERATORS
PARACHUTE COVER
VHF ANTENNA
SEPARATION SPRING CARTRIDGES (4)
SPIN JETS
REENTRY HEAT SHIELD
RECOVERY ACCELE
SWITCH
HEAT SHIELD
MAIN BATTERY
PCM COMMUTATOR
PYRO BATTERY
SEQUENCER PANEL
ELECTRICAL HEATER
SS TAKE-UP ASSEMBLY
77"
PRIMARY SUPPLY
PRIMARY CAMERA
SECONDARY CUTTER
35 mm TWISTER
35 mm TAKE-UP
9½" PRIMARY TAKE-UP
5" TAKE-UP
5" SUPPLY
APTC
STORAGE LOOPER
SATELLITE RE-ENTRY VEHICLE (SRV)
SUPPLY/RECOVERY MODULE (SRM)
PROPULSION TR
SPIN-OFF CONNECT
MANUAL POWER SWITCH
RV/SBA FITTING
GUIDE TRUSS
+X
MAIN PARACHUTE
GUILLOTINE
SEPARATION PANEL
CIRCUIT INTERRUPTER SW
COURIER CONTROLLED MATERIAL
PROPERTY OF THE UNITED STATES GOVERNMENT
IF FOUND, DO NOT OP
CALL: 1-800
EASTMAN KODAK CO.
SPECIAL HANDLING