SECTION 1

THE ERA BEFORE KENNEN/KH-11

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Forerunners of Near-Real-Time Imagery

Visionaries of the 1940s and early 1950s foretold the use of space vehicles for reconnaissance. Rand Corporation studies had established the specifications for a reconnaissance satellite that would return TV-like images to an Earth ground station—when the technology for the satellite, the images, and the ground station became available.

This period in history was dominated by the Cold War, and the Soviet Union was the United States' primary military focus. President Dwight D. Eisenhower had recently concluded the war in Korea when a 1953 report by James R. Killian, president of the Massachusetts Institute of Technology and Eisenhower's science adviser, warned that the United States was vulnerable to surprise attack. This perceived threat became a driving force behind US foreign and military policy in the mid-1950s. Charting these policies was made difficult first by the "bomber gap" and later by the "missile gap," two misperceptions caused by a lack of intelligence on what precisely was happening in the Soviet Union.

In 1954 and 1955 respectively, the United States embarked on a high-altitude aircraft reconnaissance program and a space reconnaissance effort. The Air Force had the primary responsibility for both programs. The aircraft initiative took off more quickly and dramatically, while the space initiative at first received conservative funding and a fairly low priority. By 1956, U-2 flights over denied territory were collecting imagery that was spotty but sufficient to help analysts reduce the bomber gap uncertainty and to provide data on the fledgling Soviet missile and space program. Meanwhile on the space side, the Air Force had made little progress on the Advanced Reconnaissance System, which it had established within an ongoing program bearing the codename Weapon System 117L. Instead, the Air Force's intercontinental ballistic missile (ICBM) programs such as Titan, Atlas, and Thor received priority in funding and facilities at that time.

Nonetheless, as part of the new space reconnaissance initiative, the Air Force began a technologically ambitious program—eventually named SAMOS—to build a constellation of satellites with such capabilities as film return and near-real-time (NRT) imagery readout and with a range of payloads for such tasks as infrared imaging, collecting signals intelligence (SIGINT), and conducting scientific research.

SAMOS' status took a dramatic turn in October 1957 when the Soviet Union successfully launched Sputnik. Suddenly space reconnaissance became equal to missile development in urgency.

Late in 1957, President Eisenhower made a decision to emphasize the film-return satellite segment of SAMOS and to separate it from the main program. This directive sharply cut the priority being given to developing an electronic readout capability, and much of the research critical to the successful development of near-real-time systems was put on hold.* At the same time, the President's directive gave birth to CORONA, a film-return system intended to provide wide-area photographic coverage of the Soviet Union.[1-1, 1-2]

CORONA/KH-4: The First Imagery From Space

CORONA, also known as KH-4, became the first successful space-based imaging program. CORONA was a joint Air Force and Central Intelligence Agency (CIA) project developed under the auspices of the National Reconnaissance Office (NRO).† The Air Force was to provide spacecraft development and launch services, and the CIA was to handle technical development, procurement, cover, and security. CORONA was given the unclassified or "white" world name of Discoverer, a name that many Americans recall, and a cover story of space environmental studies and biomedical studies that included live animal specimens.

During 1959 and 1960 there were 12 consecutive failures to launch, orbit, and retrieve a Discoverer film capsule from space. Discoverer XIII carried a diagnostic payload in an attempt to gather data on why the previous missions had failed. It flew what was reported to be a perfect mission—launch, 17 orbits, and recovery in the Pacific Ocean—on 10 August 1960. Discoverer XIV, designated as Mission 9009, was launched a week later with a photographic payload. It flew a nominal one-day mission and ejected its film capsule, which was successfully recovered from the ocean.

The US space reconnaissance program had begun. It was 19 August 1960, ironically the same day that U-2 pilot Francis Gary Powers was being sentenced in Moscow for espionage. Eight of the Mission 9009 orbits were over the Sino-Soviet landmass. Discoverer XIV obtained coverage of 1.5 million square nautical miles (nm), more area than that imaged by of all the U-2 missions combined.‡

CORONA's more than 150 missions between 1959 and 1972 were amazingly successful. Imagery from CORONA, a low-resolution (25- to 6-foot) system, disproved the missile gap and contributed to the elimination of the bomber gap, both topics of governmental debate in the mid-1960s. For more details, see *The CORONA Story*, the first volume in the series of NRO histories of the US space reconnaissance programs.**[1-6]

* Within the Air Force, there was a basic conviction that CORONA was a stopgap and that readout SAMOS was the ultimate goal.[1-3] This was further reinforced by a comment by George B. Kistiakowsky, then science adviser to the President, who said, "They (Air Force Ballistic Missile Division) believe that 'readout' SAMOS is much more promising than 'recovery' SAMOS."[1-4]

† The NRO, established on 25 August 1960, by mid–1963 consisted of the space reconnaissance elements of the Secretary of the Air Force Special Projects (SAFSP), called Program A; the CIA, called Program B; the US Navy, called Program C; and air reconnaissance, called Program D.

‡ A few days later, on 26 August 1960, President Eisenhower signed a memorandum establishing the TALENT-KEYHOLE (TK) security system for satellite reconnaissance products.[1-5]

** CORONA KH-4 imagery was declassified by executive order on 23 February 1995 and made available to the scientific and academic communities.

GAMBIT/KH-8: Successful High-Resolution Photography From Space

On 12 July 1963, with the first flight of the high-resolution GAMBIT film-return satellite, the United States significantly improved its ability to resolve intelligence questions and problems. Tasked to photograph specific "point targets," GAMBIT was best known for the very-high-resolution photographs produced by its KH-7 and later KH-8 camera systems. By the time the program had run its course, it was routinely providing photography in the range of [redacted] ground resolution and achieving a best of [redacted] The program lasted through 54 spacecraft, the same number of missions, and more than two decades; the last GAMBIT mission was flown in 1984. The GAMBIT satellites were built by Lockheed Missiles and Space Company (LMSC) and carried General Electric (GE) payloads. The GAMBITs were launched on Titan IIs, modified ICBMs. For more information, see *The GAMBIT Story*, the second volume in the series of the NRO histories.[1-7]

HEXAGON/KH-9: Increased Area Coverage

While CORONA was enjoying a very successful lifetime, people associated with space reconnaissance realized that significant increases in area coverage and great improvements in resolution were needed. The United States and the Soviet Union were making progress in negotiations for controlling certain strategic arms. The needs for increased synoptic area coverage and medium resolution were identified as being critical to the arms control measures under consideration.

Launch weight capabilities and technology in camera systems had moved impressively forward in the middle to late 1960s. These advances resulted in an evolutionary imaging system known as HEXAGON, or the KH-9. Originally proposed by CIA in 1964 as project FULCRUM, it was described as having "CORONA-type coverage with GAMBIT-type (KH-7) resolution." HEXAGON was capable of missions more than 300 days long and eventually carried more than 300,000 feet of ultrathin base film. In contrast to the 25-foot resolution obtained on CORONA Mission 9009, HEXAGON's ground resolution was about 1.5 feet, and at those dramatically improved resolutions, area coverage also was significantly improved.

Where CORONA could image across a swath 150 nm wide, HEXAGON had the capability to image a swath 300 nm wide. Furthermore, HEXAGON's KH-9 camera system was revolutionary in terms of both its complexity and its size.

Starting in 1971 and extending over a period of 15 years, 19 HEXAGON spacecraft were flown in as many successful missions. The 20th and last mission in the series failed in April 1986 when the booster exploded a few seconds after liftoff. For more information on HEXAGON, see the third volume in the series of NRO histories, *The HEXAGON Story*.[1-8]

Film-Return Systems: Pluses and Minuses

When taken in context, CORONA, GAMBIT, and HEXAGON were all tremendously successful programs. They were to propel the United States into a position of unquestioned supremacy in space imagery reconnaissance. The Soviet Union, the only other country with a viable space reconnaissance capability even into the 1990s, remained technologically many years behind the United States. Space imagery reconnaissance provided the US Intelligence Community with invaluable data on denied areas of the world on a regular, predictable basis with ever-increasing levels of both coverage and resolution. See table1.1 for a comparison of the systems at KENNEN initial operating capability (IOC).

However, all film-return systems had similar shortcomings. Spacecraft were not continuously on orbit, and many world crises took place when no viewing satellite was operational. Even when spacecraft were flying, their revisit time to a precise geographic location was on the order of days—which was not adequate to support coverage of crises. Because of their low-Earth orbits, film-return systems required frequent orbit adjustments to prevent them from prematurely reentering Earth's atmosphere before the complete film payload had been used.* These orbit adjustments, or "drag makeups," consumed significant amounts of propellant—propellant that had to be carried into space as part of the launch vehicle. Consumables were traded for film payload, particularly in the early days, often resulting in fewer days on orbit. Film buckets had to be ejected; caught over the Pacific Ocean; transported to Rochester, New York, for processing; and then shipped to Washington, DC, for interpretation. The imagery was days to months old when it was received at the National Photographic Interpretation Center (NPIC) and other

Table 1-1. Comparison of GAMBIT, HEXAGON, and KENNEN Systems at KENNEN IOC

	GAMBIT KH-8	HEXAGON KH-9	KENNEN KH-11
Focal length	175 in/4.44 m	60 in/1.52 m	
Photo scale	1:27,000 to 1:54,000	1:100,000 to 1:54,000	
Film width	9.5 in/24.1 cm	6.6 in/16.8 cm	
Frame length	4 to 36 in/10 to 91 cm	31 to 126 in/79 to 320 cm	
NIIRS*	5 to 7	3 to 5	
Mission life†	60 days	160 days	

* National Image Interpretability Rating Scale.
† GAMBIT and HEXAGON were eventually capable of a longer life.

TCS-7728 NPIC (10/76)

* Nominal perigee over the Soviet Union was on the order of 100 nm for CORONA, 80 nm for GAMBIT and 90 nm for HEXAGON.

exploitation facilities. As a result, derived information was not timely for providing effective military, political, or economic intelligence. Before the advent of the Defense Meteorological Satellite Program (DMSP), a large percentage of the recovered imagery was cloud covered. As events were beginning to show, these constraints were becoming unacceptable.

Film-Return to NRT Systems: A Revolutionary Change

To understand the revolutionary role of [redacted] *its relationship to the predecesor imagery systems must be understood. The film-return systems [of the early 1960s and the 1970s] were inherently inefficient because of the inevitable delay in learning whether needed information had been collected when the shutter "clicked" in space. Verification always waited until after film recovery, days or weeks later.*

This lack of timeliness was a serious limitation. Over and over, imagery would be returned and evaluated, only to find that it contained time-sensitive information that had become available too late for effective follow-up, or in the cases of indications and warning, or crisis-related information, too late for action. These deficiencies were longstanding from the beginning of satellite imagery, but could not be met with early technology.

The documented requirements that were finally approved for a near-real-time satellite imagery system focused on needs for indications and warnings intelligence and crisis, but recognized that a system able to address those needs inevitably would have wide-ranging general purpose capabilities as well.

Roland S. Inlow

More, Better, Sooner: Drivers for NRT Imagery in the 1960s

From the earliest days of space reconnaissance development, the ultimate goal was to be able to send pictures rapidly to Earth. That, in fact, was the principal focus of SAMOS.

Although SAMOS progressed through a number of different system concepts and payload cameras, the technology necessary for the large-scale development of near-real-time readout was lacking.[1-9] Available boosters imposed serious payload weight limitations, stabilized spacecraft were only just becoming a reality, and state-of-the-art TV camera resolution was insufficient for intelligence purposes. In particular, the technical problems of transmitting large quantities of data from spacecraft to ground receiving stations were seemingly insurmountable, and the technology for converting the data to usable film for viewing still was unavailable.

By the mid-1960s, however, the Intelligence Community and its principal consumers, including the White House, were becoming increasingly strident in their demand for more timely information. The primary intelligence requirements driving this demand were indications and warning (I&W) and crisis management. Events through the middle and late 1960s provided convincing evidence that film-return satellite systems would not meet these growing intelligence needs.

Early Studies: An Oblique Beginning

In 1963 the Intelligence Community faced a potential threat to US satellites from an antisatellite missile system thought to be under development by the Soviet Union. In April 1963 the United States Intelligence Board (USIB) called for research leading to reduced vulnerability of US reconnaissance satellites. The Director of Central Intelligence (DCI), John A. McCone, convened a panel led by Dr. Edward M. Purcell of Harvard University to investigate problems being encountered in the CORONA program. McCone also asked the panel to consider the problem of satellite vulnerability.

The panel arrived at three tentative conclusions:

- Studies into reducing radar detectability and adding maneuvering capability should be undertaken.
- Research in real-time readout should continue.
- The concept of a fully covert satellite—including the ability to launch such a satellite from an aircraft—should be pressed.[1-10]

Within the CIA's Deputy Directorate of Science and Technology (DDS&T), the Office of Special Activities (OSA) began the study of a covert satellite that could avoid or resist detection.* The OSA engineers subsequently met with DDS&T managers in November 1963, and concluded that the crux of the matter was not the design of a covert satellite, but the feasibility of using satellites for crisis indications. Figure 1-1 shows those elements of CIA that have been involved in various aspects of ZAMAN/KENNEN [redacted] development, operation, and exploitation.

A task force of CIA experts from the System Analysis Staff (SAS) in the DDS&T and the Office of Current Intelligence (OCI) in the Deputy Directorate of Intelligence (DDI) examined the topic in the winter of 1963-64. The task force concluded that the types of overhead photography being provided by the CIA's CORONA and the Air Force's GAMBIT satellites were not available quickly enough for use

* The CIA identified its major elements as Deputy Directorates until the summer of 1965. After that, the Agency simply called them Directorates.

during a crisis situation. In what proved to be an accurate envisagement of future system requirements, the task force stated that in order to be effective tools for crisis resolution, reconnaissance systems would need to provide the following:

- Coverage of the primary targets of concern in the Soviet Union.
- Overhead photography.
- Ground resolution of 1.5 meters.
- Coverage of 250 targets daily.
- Frequent coverage of sampled targets.
  (That was more important than less frequent coverage of all targets.)
- A short timeline between collection and analysis (since the information was perishable).

The thrust of these conclusions was that the timeliness of photography available from existing systems was not adequate for crisis situations.[1-11]

ZOSTER: First NRT System Concept

The NRO approved three additional OSA studies into aspects of satellite detectability, and they were begun in December 1963. At a meeting in June 1964, OSA personnel involved in these studies also concluded that instead of a covert satellite, a near-real-time capability was needed.* By this time, a system concept for providing the necessary NRT capability had evolved. The concept, known by its codename ZOSTER, included a satellite in a 500-mile orbit providing moderate-resolution coverage of approximately 150 indicator targets per day. The data from the satellite was to be transmitted directly to [redacted] using [redacted] wideband telemetry links. When a crisis situation developed, the satellite would be brought down to a 100-mile orbit, where it would provide higher resolution photography of a still smaller number of targets.

The findings of these OSA studies and of the SAS/OCI task force were reported to the Director of the National Reconnaissance Office (DNRO), Brockway McMillan, on 15 July 1964. McMillan directed that the emphasis of future ZOSTER efforts be placed on "readout and rapid communication of high resolution pictures." Dr. Albert D. "Bud" Wheelon, the CIA's Deputy Director of Science and Technology (DDS&T), gave responsibility for ZOSTER to Jackson Maxey, who was also overseeing Project HEXAGON. Maxey responded by initiating four contracts for basic research into reusable photosensitive media, a demonstration of photosensitive mosaics using a videcon tube, a video-transmitted photo simulation study, and a guidance system technology study.

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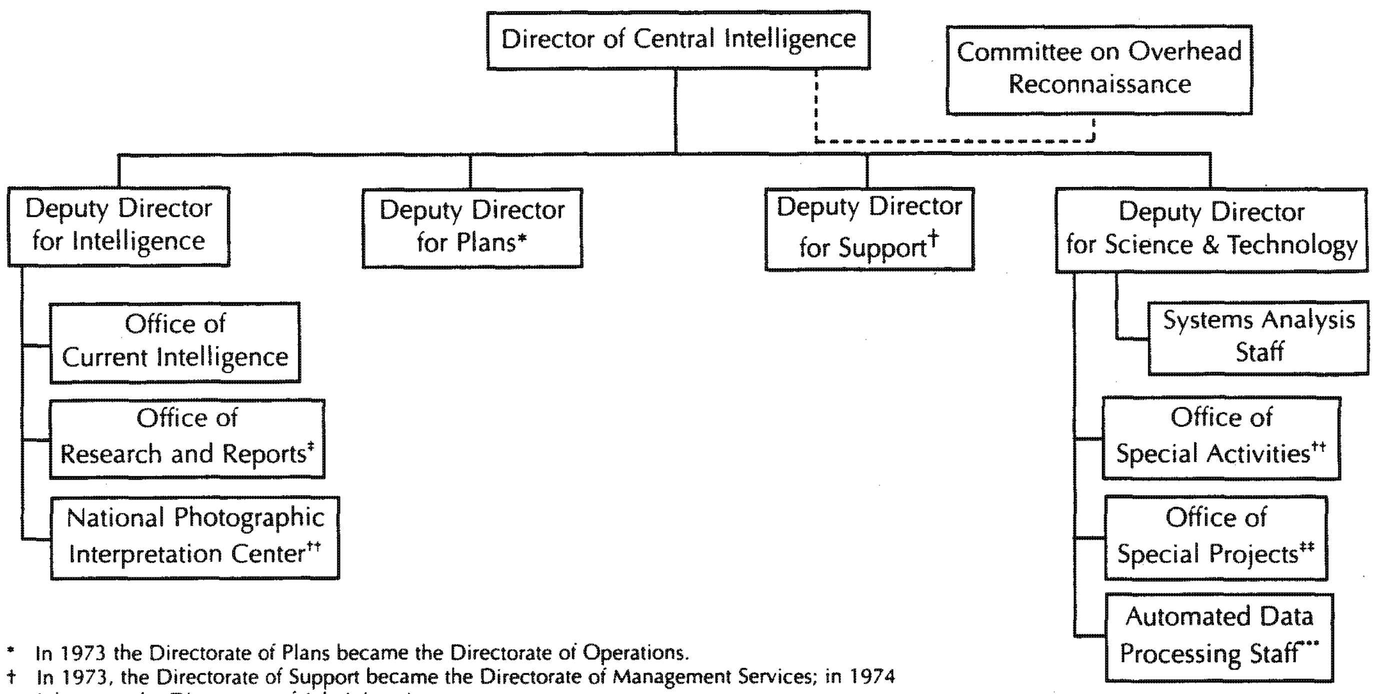
* It should be noted, however, that the initial USIB concern over satellite vulnerability had a lasting impact. At about the time of initial near-real-time system acquisition in 1972, Dr. Edward Teller reviewed the program and concluded [redacted] was necessary. This resulted in the decision to add [redacted]

Figure 1-1. CIA Elements Involved in ZAMAN (1960s)



* In 1973 the Directorate of Plans became the Directorate of Operations.
† In 1973, the Directorate of Support became the Directorate of Management Services; in 1974 it became the Directorate of Administration.
‡ In 1967 part of the Office of Research and Reports became the Office of Strategic Research.
** OSA was disbanded in 1975.
†† NPIC was moved to the DDS&T in 1973.
‡‡ Created in 1965, the OSP was renamed the Office of Development and Engineering in 1973.
*** The Automated Data Processing (ADP) Staff, established in the DS&T in 1963, later was called the Office of Computer Services. In 1973 the office was moved to the Directorate of Management and Support (DM&S); it later became the Office of Information Technology in the Directorate of Administration.

After eight months with no solid conclusions, Maxey reduced the effort to a development planning exercise, and in March 1965, he turned it over to Leslie C. (Les) Dirks' Design and Analysis Division.[1-12] Wheelon provided additional monies and very general guidance to Dirks, who then began the first of a series of advanced ZOSTER technology efforts.[1-13]

Albert D. Wheelon

Leslie C. Dirks

NRO Agreement Leads to CIA Office of Special Projects

On 13 August 1965, the Deputy Secretary of Defense, Cyrus R. Vance, and the DCI, Adm. William F. Raborn, Jr., signed an agreement concerning the NRO. The agreement formalized the membership of the National Reconnaissance Program (NRP) Executive Committee (ExCom) and gave it responsibility for allocating projects and funds.* The ExCom consisted of the Deputy Secretary of Defense, the DCI, and the Special Assistant to the President for Science and Technology. The ExCom also included the DNRO as a nonvoting member (figure 1-2).[1-14]

The NRO agreement addressed another issue as well. It officially identified the satellite responsibilities of Program B, the CIA's space reconnaissance element, something that earlier NRO memorandums had not done (figure 1-3).

Figure 1-4 shows the entities involved in national reconnaissance in late 1965. With the assignment of a positive role in the satellite reconnaissance program to CIA, a satellite group that was operating in the DDS&T under the title of Special Projects Staff was formally established as the Office of Special Projects (OSP). CIA [redacted] of 6 October 1965 announced the establishment of OSP,

* After the NRO was established in 1960, its organization and responsibilities were adjusted several times. This agreement became the more definitive and long-lasting document, defining the roles of the NRO's components and the mission of the organization as a whole.

Figure 1-2. NRP's Executive Committee (1965)

Deputy Secretary of Defense	Director of Central Intelligence	Special Assistant to the President for Science and Technology	Director of National Reconnaissance Office*

* Nonvoting member.

effective 15 September 1965, and named John J. Crowley as director and John N. McMahon as deputy director.[1-15] The advanced research activities of OSP were assigned to Les Dirks' division.

Dirks' Design and Analysis Division primarily emphasized intelligence requirements analyses, program definition studies, photographic satellite vulnerability analyses, and advanced technology programs in support of satellite systems development. Two areas of particular interest to Dirks' group were high-resolution photographic satellite systems with near-real-time recovery of imagery, and large precision mirrors for optical systems. [1-16]

Watch Committee: First Requirement for NRT Imagery

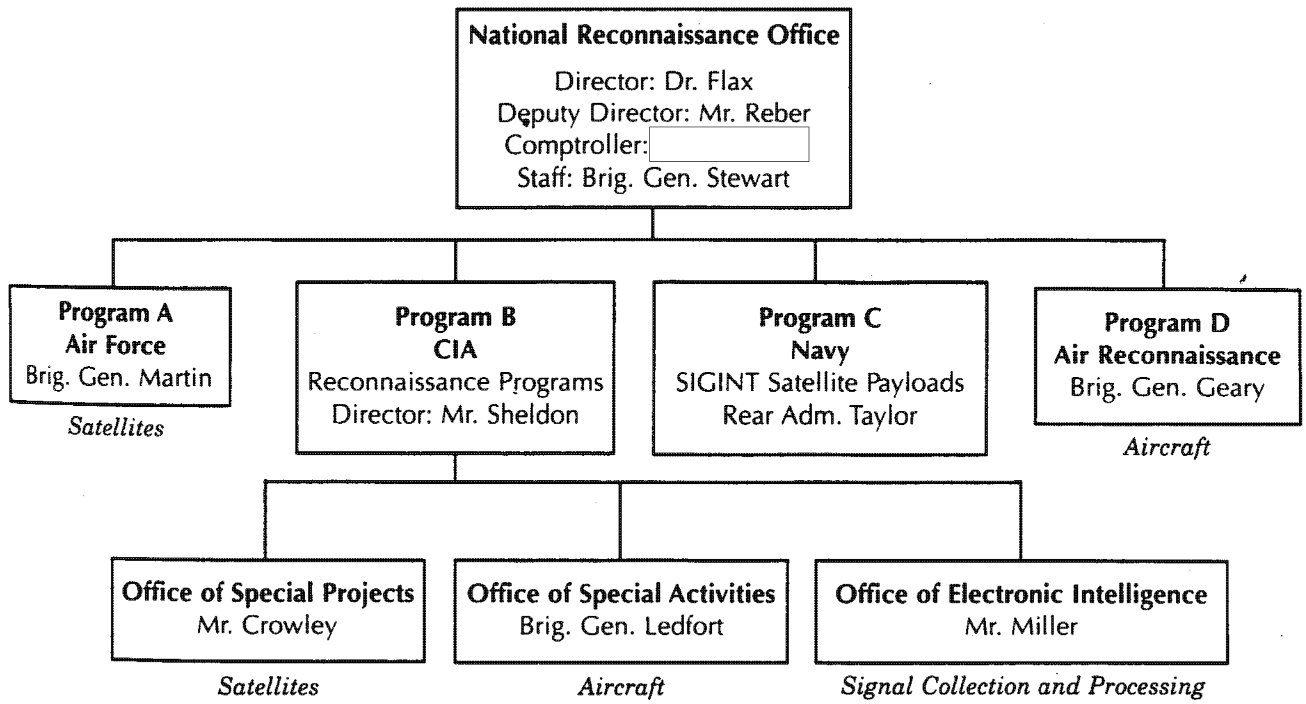
In late 1965, the USIB asked the NRO for a statement of quick-reaction capabilities (QRC) for dealing with international crisis situations. In January 1966, Dr. Alexander H. Flax, the new DNRO, responded to the request by noting that no current or planned satellite had the desirable QRC but that a greater emphasis would be placed on that type of satellite. In this same time period, the Committee on Overhead Reconnaissance (COMOR) was reviewing US photographic capabilities and assessing their limitations for supporting crisis situations. By January 1966, COMOR had concluded that:

> *. . . our requirement should be interpreted as calling for a system that can carry out the warning/indications and assist in satisfying routine, current intelligence, and special reconnaissance tasks.*

Later that month, COMOR asked the USIB's Watch Committee to review COMOR's position on the capability of then current photographic satellites for satisfying crisis management requirements.*[1-18]

* The Watch Committee had been established in the early 1950s to provide "the earliest possible warning to the US Government of any hostile action by the Soviet Union or its allies that might endanger the security of the United States." Between November 1963 and July 1967, the Watch Committee was chaired by Huntington D. Sheldon.[1-17]

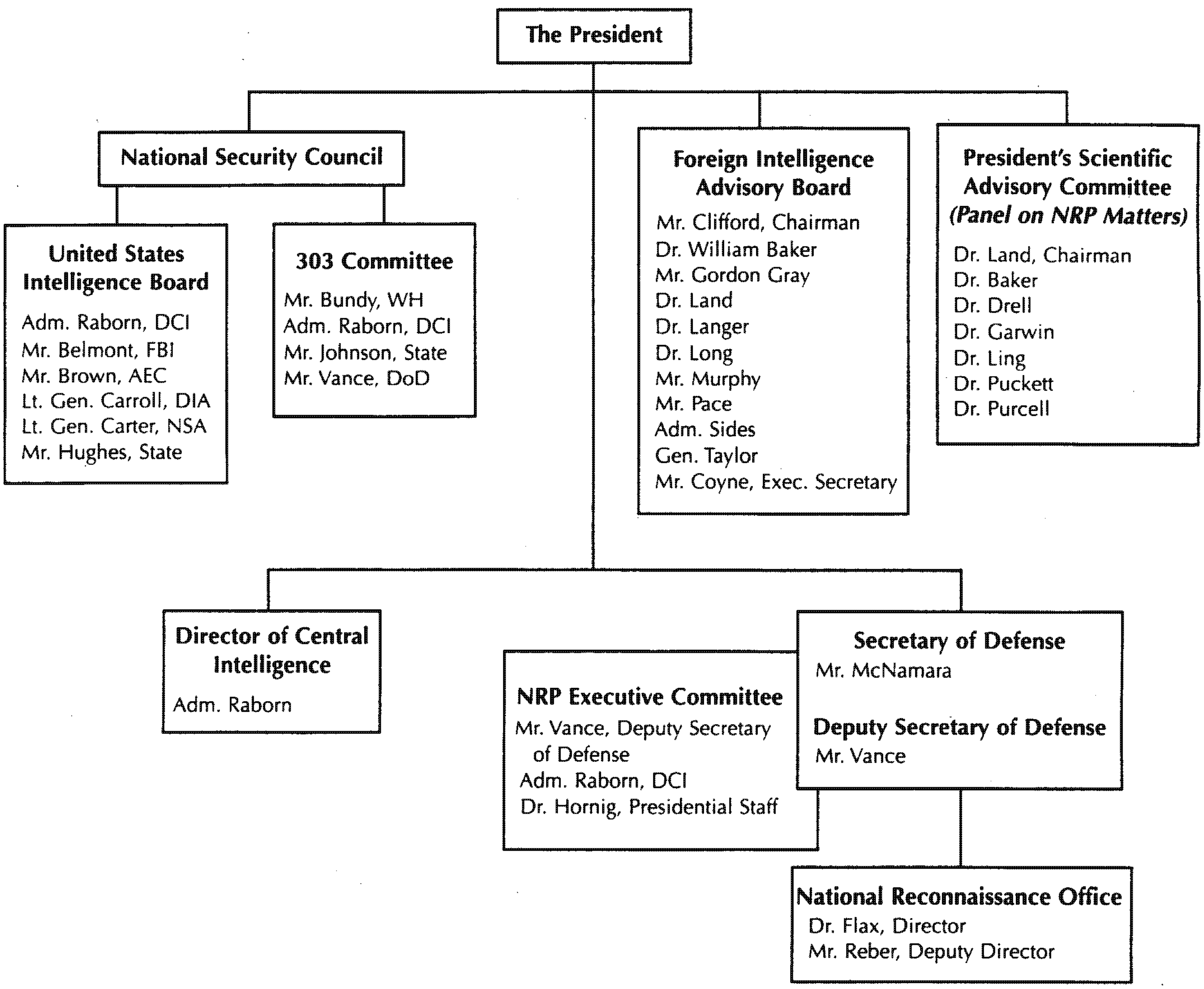
Figure 1-3. NRO and Supportive Components within CIA (October 1965)



The Watch Committee agreed that:

- Present satellite photographic systems did not satisfy the early warning crisis requirements.
- Essentially continuous real-time or near-real-time information was required in crisis situations.
- Interim measures such as multiple recovery buckets, recovery in proximity to the processing center, or readout accomplished aboard delivery aircraft could not improve the capabilities of current satellite photographic systems enough for them to serve as timely early warning tools.[1-19]

Figure 1-4. Entities Associated with National Reconnaissance Effort (1965)



ZOSTER: Early Technology Investments

Meanwhile, in response to the more definitive requirement, an expanded OSP ZOSTER study effort was under way, focused on advanced technological studies. Dirks recruited a number of key engineering personnel and proceeded with a series of small [redacted] contracts directed at the major technology stumbling blocks to near-real-time imagery systems. These advanced development efforts, led by engineering specialists [redacted] looked for alternatives to film for imaging, including storing the imagery and later transmitting it to Earth.[1-20]

Among the media investigated for capturing an image without film were several solid-state, photosensitive devices; a reusable plastic medium known as Xerox Frost; and videcon tubes (similar to those used in TV cameras). All of these came to be lumped under the rubric of electro-optical imaging (EOI). Fairchild Camera and Instrument Corporation and, subsequently, Motorola, began development of linear arrays of solid-state, photosensitive detectors. Xerox Corporation proposed a photosensitive plastic material called screened thermoplastic xerography (STX), which gave good promise for high-resolution photography. The other promising sensor, which had already demonstrated its ability to provide good resolution, was the RCA videcon: a photocathode tube operating over what were then wideband data links, both on the ground and from aircraft. Unfortunately, the largest videcon tubes in existence measured only 1 inch across, too small for space reconnaissance purposes. Work was initiated to develop tubes from 2 to 4 inches across.

Beyond those, a number of smaller contracts and in-house efforts were devoted to other sensors, such as the EG&G (Edgerton, Germeshausen & Grier) Corporation's avalanche diode and large area photocathode surfaces.

Methods also were studied for storing image data taken over the Soviet Union on board until a satellite passed over the continental United States. Available technology for recording TV signals at that time was bulky and required amounts of power too great for the onboard satellite recording of ZOSTER imagery. Considerable attention was given to tape recorders that had the demonstrated capability to record and play back several tens of megahertz of analog electronic signals. The ZOSTER need, however, was for hundreds of megabits of digital data. Advanced recorder technology research was started, principally at RCA and Ampex. These two companies, together with General Dynamics, Philco-Ford, and Eastman Kodak, also studied the requirement for recovery and reconstruction of the data on the ground. The results of these efforts indicated that compared to storing and recording data, transmitting wideband image data directly to the ground via a relay satellite (R/S) was more feasible and provided better [redacted] performance.

Transmitting large amounts of data from a satellite to the ground also required new technology.[1-21] A major effort in high-power and high-bandwidth traveling wave tube (TWT) amplifiers (TWTAs) was initiated in conjunction with the Air Force.

During this same period, modest efforts were directed to optics, spacecraft attitude control, image reconstruction from solid-state detectors, programmable satellite computers, and overall system concepts including ground station requirements.

DDS&T on System Technology

The [redacted] system began as a response to an urgent national need. . . . [Film-return] space systems could play no role in emerging crises, where prompt information is vital.

The Cuban Missile Crisis had driven this point home to the people at CIA, and the requirement for a [redacted] imagery system was born.

There were three major technical challenges. The first problem was to take the photographs in a form that could be readily retransmitted. It was realized that film readout systems could not meet the capacity and reliability requirements.

The second challenge was data transmission. How to get the electrical signals from the satellite to [redacted]

The third challenge was to orient the spacecraft so that its telescope and eye would aim at the desired target.

Albert Wheelon

Another Player: Film Readout GAMBIT (FROG)

During the period when Program B was investigating EOI technologies, Program A was looking at ways to retain the KH-8 camera and transform the high-resolution GAMBIT satellite from a film-return system to a film readout system. The effort was appropriately named Film Readout GAMBIT, which was reduced to the acronym FROG.[1-22]

FROG employed the same technology developed in the E-1 and E-2 camera systems of the SAMOS project, a "bi-mat" technique that developed the exposed film onboard the satellite by pressing it against a web containing developer and fixer chemicals.* A line-scan light source and lens, photomultiplier tube, and video signal amplifier were used to optically scan the image and convert it to an analog signal for downlinking to the ground station.

An Eastman Kodak payload flown on the National Aeronautics and Space Administration's (NASA's) Lunar Orbiter program provided a successful demonstration of bi-mat processing and associated readout. The same technology also was employed on a SAMOS mission, but these results were somewhat discouraging. The experiment produced imagery with resolution in only the 100-foot range, and the data transmission rates were too low to permit significant numbers of images to

* This film was very similar to the Polaroid film developed by Dr. Edwin H. Land. When Land was informed of this new film and the fact that it might infringe on his patents, he said to take no legal action because pursuing this technology was in the national interest.[1-23]

be sent. Nevertheless, interest in the readout was kept alive through low-level research and development (R&D) efforts that steadily advanced the state of the art in key technological areas.[1-24]

In the fall of 1966, the Committee on Overhead Reconnaissance was briefed on the FROG concept by Col. Lew Allen of Program A and on EOI by Les Dirks of Program B. Two weeks after Allen briefed, COMOR Chairman William Tidwell, Jr., stated that FROG might be the [redacted] imaging system that the Intelligence Community was seeking. The following week, Dirks briefed the COMOR staff on his division's EOI work and explained the differences between the EOI and FROG concepts. He explained that the CIA system would not use film for imaging and would digitally store the data aboard the satellite. He further indicated there would be no degradation of the imagery such as that caused by using the bi-mat film and the scanning technique proposed for FROG.

Community Studies Sharpen the Focus

On 1 November 1966, Huntington D. Sheldon, special assistant to DCI Richard M. (Dick) Helms, urged that the USIB conduct a detailed study of the contribution [redacted] readout system would make to the United States' indications and warnings (I&W) capability and identify the resources required to develop such a system. Helms directed the establishment of an ad hoc group led by COMOR Chairman Tidwell. The resulting Tidwell study was completed on 16 August 1967. It cited the reasons for having a [redacted] system and examined the various technologies available. Among its conclusions were three basic performance requirements of an NRT system:

- Nadir resolution of 2.5 feet.
- Capability to sample target categories on a daily basis.
- Capability to deliver information to decisionmakers within a few hours of sensing.

The Tidwell study also concluded [redacted] the development of a visible imaging system should be accorded priority.[1-25]

A few months later, in January 1968, the Committee on Imagery Requirements and Exploitation (COMIREX) published more detailed indications and warning requirements for an overhead imaging reconnaissance system.* COMIREX envisioned a multipurpose reconnaissance system, which in addition to I&W missions, could perform area search and special surveillance missions.[1-26]

* In the summer of 1967, COMOR was abolished. Its successor, COMIREX, in the imagery area, was given both collection and exploitation responsibilities.

Helms sent the Tidwell report to DNRO Alexander Flax on 14 February 1968, together with a request that the NRO evaluate the report and determine the feasibility and approximate cost of a system to meet these objectives. The reply, received 13 months later on 12 March 1969, was signed by the new DNRO, Dr. John L. McLucas. The response was less than favorable, claiming that solid-state sensor technology was not sufficiently advanced to support such a system. McLucas acknowledged that several promising technical concepts had been identified, but urged caution in embracing any that called for considerable advances in the state of the art. He further stated that if expediting development of a readout system was an immediate imperative, such a system would have to be film readout.[1-27]

Throughout 1968, however, world events made the need for a [redacted] system even more apparent. On 20 August 1968, the Soviet Union invaded Czechoslovakia. President Lyndon B. Johnson was preparing for a summit meeting and the limited information available to him before the invasion pointed to little more than a Soviet warning to Czechoslovakia. The second film bucket from CORONA Mission 1104 was returned on 22 August 1968, and results did not reach policymakers until five days later. The film showed all the classic indicators of an impending invasion. Members of the Intelligence Community and the White House were impressed by the added value the film would have had if it had been available in near-real-time.

As a result of this demonstrated collection gap, there was increased pressure for a more responsive imagery system. At this same time, the Americans and Soviets were holding Strategic Arms Limitation Talks (SALT). The United States' agreement depended on its ability to accurately keep track of Soviet strategic arms. A Defense Department position paper prepared for the NRP's Executive Committee in late November 1968 took note of this situation and supported development of an indications and warning system, particularly if it provided one-day responsiveness to crises.[1-28]

Dirks' Blue Book: [redacted] Foreseen

Meanwhile, Les Dirks and his small government team had begun a broad advanced technology program for an electro-optical system that would lead to a near-real-time capability.

In the spring of 1968, with the advent of more formal requirements, Dirks decided it was time to review the status of electro-optical imaging technology and assess the performance of possible electro-optical imaging satellite reconnaissance systems. The performance analysis was conducted for both the indications and warning problem and the then current high-resolution surveillance requirements established by the USIB.*

* During the 1950s and most of the 1960s, indications and warning was the primary driving requirement for near-real-time information. However, in the middle to late 1960s, the need for information on crisis situations joined I&W as a driving requirement.

Richard M. Helms

John L. McLucas

The analysis concluded that two electro-optical satellites could meet the target coverage requirements for I&W, but wintertime coverage would be marginal.* The surveillance requirement was shown to be met with ease. In addition, because of continuous on-orbit capability there would be no major gap in access and coverage of desired targets.

In May 1968, Dirks summarized his team's efforts in a published report called *Application of Electro-Optical Technology to Satellite Reconnaissance.*[1-29] This 58-page report, popularly called the "Dirks Blue Book," foresaw the [redacted] Program with impressive clarity and comprehensiveness. It summarized the key technologies, forecast results, defined a system architecture, and even projected costs. Virtually all of the document proved accurate except the costs. This is not surprising, because initial cost projections for almost all new major systems prove to be considerably low, and Dirks was particularly optimistic in this regard.[1-30]

The Dirks Blue Book was the first report to describe in some detail the advantages and the capabilities of an electro-optical system. It noted that electro-optical system technologies under study had no inherent limitations to prevent accomplishment of the I&W mission. However, electro-optical systems could not compete with photographic payloads for the foreseeable future to perform large-area coverage missions.

* [redacted]

The report described major technology areas and subsystems in sufficient detail to determine where additional technology development and studies should be focused. It identified and discussed against general design requirements the major subsystems associated with the imaging satellite, the relay satellite, and the ground station. The major findings were as follows:

- Optics. The report found no fundamental problems associated with the design and acquisition of the large optical system required to meet the proposed performance objectives.

- Magnetic tape recorder. Recorder technology was well advanced. The report anticipated no basic feasibility or engineering problems in this subsystem area.

- Image recovery. The primary mode of image recovery involved relaying data from the imaging satellite through a geostationary relay satellite to a ground station located in the continental United States. Both digital modulation and frequency modulation (FM) techniques had been examined, and both appeared feasible. The antennas required for the imaging satellite and the relay satellite were in the 2- to 4-foot range and posed no particular problem. Antenna pointing from the imaging satellite to either the ground station or the relay satellite was quite straightforward. However, the pointing of the relay satellite antenna to the imaging satellite was a problem because of the limited attitude control accuracy of the relay satellite. A search and track mode on the high-gain antenna linking the relay to the imaging satellite would require new engineering developments.

- Attitude control system. The attitude control system configuration that [redacted]

- Relay satellite. The relay satellite required for this application was considered to be closely related to an evolving family of communications satellites and did not represent a new engineering challenge.

- Ground station. The ground station did not pose a new development problem except that considerable system development—specifically, the ability to reconstruct the received image in near-real-time—was required to take full advantage of the digital nature of the imagery.

- Image transducer. The report identified the image transducer (a device that converts light energy into electrical energy) as the only system element that represented a major development problem. Four different transducers were identified and two of them, return beam videcon and STX, were used for bounding the system performance. The four transducers were:

  — Return beam videcon. This was a four-tube array of RCA return-beam videcons. The tubes were operated at a resolution level of 60 line pairs per millimeter, resulting in a frame of a 3- by 3-nm area at 2-foot ground resolution. After exposure, the four videcons were read out in parallel at an information bandwidth of 8 MHz per videcon.

  — Screened thermoplastic xerography. The STX configuration used an 8- by 8-inch format size and did not require tape recorders because it contained an image storage capability. The STX could be handled in the form of either thin glass plates or a flexible belt. The operational sequence was to apply a surface charge to the STX material, expose the material, recharge the material, and develop the latent electrostatic image by heating the thin plastic layer. The image information could then be read out at any subsequent time with an optical scanner. After readout, the stored image could be erased by heating the plastic layer a second time.

  — Solid-state array. This was a linear array of solid-state detectors. The best performing solid-state array had been fabricated using phototransistors. Higher resolution arrays were built employing photodiodes (photoconductors), but they had not yet shown adequate sensitivity. Solid-state linear arrays were attractive because of their versatile construction (unlike vacuum tubes, the arrays did not have a fixed size and shape), high reliability, and large format possibilities. The small physical size and shape of the linear array permitted optical system designs not possible with other transducers. Solid-state arrays also provided an electrical output compatible with data transmission systems.

  — CBS image tube. A new image tube under development by CBS Laboratories, its design specifications were directed at the requirements of high-resolution reconnaissance. The CBS tube was an electrostatic device, similar to the videcon , that had the additional capability of storing a number of images in the form of electron charge distributions on a moving belt or drum. The image data could subsequently be read out with an electron beam. It was determined, however, that this tube would require several more years of development before being operationally usable.

The technology required for the remainder of the system was estimated to pose no serious feasibility problems, although several of the subsystems associated with the imaging satellite would require supporting engineering development programs.[1-31]

The Dirks report resulted in the formulation of a much more focused effort to develop an electro-optical imaging system. It also was the real beginning of the ZAMAN Program and had a profound impact on the definition and development of the EOI technologies. Table 1-2 shows the ensuing areas of development work and the primary contractors either involved or soon to be involved in them.

Dirks had, by that time, increased his advanced systems technology staff to about 10 people. Frederick K. (Fred) Evans and [redacted] had been on the team for more than a year supporting systems and communications studies. Edmund (Ed) Nowinski had been on the team for several months and began the critical analysis of image chain performance. Dirks recruited Charles R. (Charlie) Roth to bring space and program management experience into the group.

Dirks himself, however, continued to be the central figure. Nowinski subsequently described Dirks as the "quintessential systems engineer," "the technological role-hero of reconnaissance," and "a man who had no time for politics, hated bureaucracy, focused entirely on technical problems at hand, and welcomed on his team anyone who had a solution for one of his technical problems." Dirks' watchwords were "technical excellence."[1-32]

Transducers: A Major Challenge

The Blue Book identified the imaging focal plane as the major technological challenge in developing an electro-optical imaging system. An enormous amount of energy and considerable amounts of money were expended in pursuing the underlying transducer problem. The first of the competing imaging materials to be found lacking was the STX proposed by Xerox. Although the plastic material demonstrated good sensitivity in the laboratory, little progress was made toward repeatable quality and usable sizes of material. Since other technologies were showing greater promise with fewer risks, STX was dropped from further consideration.

As work on the RCA videcons progressed, it became apparent that this technology would at best be an interim solution. While the signal-to-noise characteristics of the tubes were adequate, progress leading to a format larger than the then current 1- to 2-inch format was slow, the videcons were large (about 2 feet long and a foot square), and the imaging time was unacceptably slow. It also became obvious that the RCA division doing the work was far more interested in commercial applications of the videcon technology. Work on this effort was gradually reduced and finally terminated as the solid-state devices matured.

The solid-state transducers gradually emerged as the technology of choice for electro-optical imaging. When the National Reconnaissance Program allocated additional monies to the effort in November 1968, the Office of Special Projects let

Table 1-2. ZAMAN Development Efforts

Solid-State Transducers*	Mirror Blanks	Primary Mirror	[redacted] Attitude Control System
Fairchild TRW Westinghouse	[redacted]		GE Bendix Sperry Honeywell†
Onboard Computer	**Image Processing**	**Laser Image Reconstructor**	**Wideband Data Transmission**
Control Data Corporation IBM North American Rockwell	E-Systems	Itek RCA	Hughes

* Motorola, RCA, and Xerox also took part in the early stage of the competition to develop imaging materials.
† Honeywell developed a test facility for the [redacted] built by the other three companies.

contracts with Fairchild, TRW, and Westinghouse Electric Corporation to design and build test arrays of solid-state detectors that could be used in laboratories and to test the image chain at the Image Processing Laboratory (IPL). Motorola, which had participated in the early development, dropped out of the competition.

Fairchild became the first contractor to produce a working solid-state device. Named the [redacted] it had two slightly offset rows of detectors and provided a solid line of image samples. The results were initially exciting because they confirmed earlier signal-to-noise and sensitivity calculations by the Dirks team. Soon after this initial breakthrough, however, Fairchild redirected its efforts toward the commercial computer market.

Consequently, the ZAMAN Program Office narrowed its attention to TRW and Westinghouse. Development support for other competing devices, including avalanche diodes and photocathode tubes, was discontinued.

Preliminary designs, specified by the Program Office, called for 70,000 to 100,000 detectors, with 25 to 100 detectors per chip, and groups of five to 10 chips making up modules. Each module would also hold the required amplifiers and related electrical components. The modules, in turn, would be assembled into imaging arrays.

The TRW phototransistor design involved highly sensitive phototransistors arrayed in chips. Twelve chips made up an element, and 1,500 elements made up a module. Although the TRW modules exhibited excellent mechanical and thermal design, they suffered from what became known as "popcorn noise." The Westinghouse photodiode device, packaged five chips to an element and 480 elements to a module, proved to be quieter than the TRW array but its design was judged to be not as good.

Frederick K. Evans ***Edmund Nowinski***

Both companies quickly achieved the construction of linear arrays and both laboratory and imaging experiments were encouraging. Data from these tests, together with NPIC assessments and work from the ZAMAN Program Office, were used to arrive at a sampling scheme that would permit the use of an achievable wideband data rate of [redacted] Production yield became a significant problem and each contractor was tasked to produce 250 chips.

Solid-State Transducers: The Way To Go

In October, the President's Foreign Intelligence Advisory Board (PFIAB) was briefed and, recognizing the importance of solid-state technology and its application to [redacted] readout satellites, it asked the Land Panel to assess the status of the technology and report back.*

The Land panel met with both contractors and government personnel on 18 December 1968. Dr. Edwin H. "Din" Land reported back to the PFIAB chairman, Dr. Donald F. Hornig:

* In early 1965, the President's Scientific Advisory Committee had set up the National Reconnaissance Panel and chartered it to maintain an overview of the National Reconnaissance Program, paying particular attention to the technical characteristics of intelligence requirements, the status of existing projects, and the adequacy of research and development programs.[1-33] The panel became better known as the Land Panel, after its chairman, Dr. Edwin Land. The panel's members at the time of this request were Dr. William O. Baker, Dr. Sidney D. Drell, Dr. Richard L. Garwin, Dr. Marvin L. Goldberger, Dr. Donald P. Ling, Dr. Allen E. Puckett, and Dr. Joseph F. Shea.

> *We have come away from that review convinced that the solid-state array represents both a feasible technology for real-time satellite reconnaissance and an approach which in the long run offers performance opportunities and flexibilities not likely to be available with any other foreseeable transducers. As a result, we urge that highest priority be given the technology and analysis work related to the solid-state applications and that FY 69 funds be provided to support the highest level of the effort that available contractors can absorb.*[1-34]

Results: The System Concept Takes Shape

Based in part on the Dirks Blue Book and on the results from the many technology investments made during the 1960s, the ZAMAN Program Group (ZPG) began to assemble parametric relationships between data rate, image quality, optics size, detector sensitivity, spacecraft dimensions, and cost.

Early on in the investigations it became clear that a large optical system would be required. While some believed that a primary mirror on the order of [redacted] in diameter was desirable, the largest space mirror built to date was the 72-inch primary mirror for the classified photographic payload for the Manned Orbiting Laboratory, which was given the BYEMAN codeword DORIAN.* Launch vehicle options and probable transducer characteristics led to in-depth optical system studies that predicted favorable results from a [redacted] mirror was selected because the larger the diameter, the better the resolution, and this was the largest diameter mirror that could fit into the launch vehicle.†

[redacted]

Despite dire predictions by some people—including Dr. Eugene Fubini, a former Deputy Director of Defense Research and Engineering (DDR&E) and senior adviser to the Secretary of Defense—that an inordinate amount of time would be needed to produce mirrors in accordance with the specifications (if, in fact, it could be done at all) [redacted] succeeded in short order.

* BYEMAN is the security system for protecting the technical characteristics of reconnaissance satellites.

† The last of the three fundamental rules for optical systems design: Make it as big as you can.[1-35]

[redacted]

While work on the optical system and the attitude control system was under way, attention was given to the challenge of a programmable onboard computer, a new concept for NRO spacecraft. Specifications were prepared that included the capabilities to store and execute preformatted and [redacted] commands, and to process inertial reference data from onboard sensors as well as ephemeris data from the ground. Bids were requested from CDC (Control Data Corporation), IBM (International Business Machines Corporation), and North American Rockwell. Rockwell was selected, and it set out to develop an engineering model to support subsequent system tests.

In May 1969, Dirks briefed [redacted] of E-Systems on his concept for the EOI system and asked if E-Systems was interested in participating. E-Systems had no previous experience in image data processing, but did have signal processing experience. [redacted] took a deep breath and agreed to get involved.

During the rest of 1969 and 1970, E-Systems was hard at work learning all that it could about image processing. Every aspect of the task was studied in depth in what became called the "Eagle Project," with two principal contributors being [redacted] The results were published in "Eagle Notes," which Charlie Roth came to call "Eagle Droppings." Dealing with a data rate of [redacted] looked like a large order. There were no signal generators in existence at the time that could perform at those rates, nor recorders that could handle the required amounts of data. E-Systems built its own signal generators and split the data stream [redacted] substreams. Because the initial KENNEN [redacted] that made some sense—and it worked. [1-37]

Another major technological challenge was the need for a laser image reconstructor (LIR) in the processing facility at the ground station. Development efforts that would precede the prototype were started at both Itek and RCA. [1-38]

Relay Satellite: Getting Data From There to Here

One of the important challenges of the near-real-time concept was the rapid transmission of the imagery data to the ground station, where it would be converted into interpretable imagery. While this was not deemed as difficult a technical problem as was developing the imaging transducer, it nonetheless proved to be a tough proposition. The state of the art in communications technology at that time was not adequate to handle the initial data rates envisioned for ZAMAN. Considerable new ground would have to be broken in this technology area.

Challenges of the Relay Satellite

> ***In its day, the R/S was an ambitious undertaking. Components were not available to build the high frequency stages of the communications payload. . . . The satellite control systems were a challenge as well. To close the communications link . . . meant that the antenna gains had to be as high as possible. The antenna beam widths were narrow as a result, and the system required automatic pointing acquisition and tracking to*** [redacted]
>
> ***Anthony Iorillo***

There were two generic means of returning the digital imaging data to earth: storing it on the imaging satellite, either for future forwarding via a relay satellite or for subsequent transmission directly to the ground site; or establishing a relay system by which the data would always be transmitted [redacted] Quite early in the concept development of ZAMAN, it became apparent that the [redacted] satellite configuration was the preferred option. Dirks, however, did note that an engineering problem existed in achieving the required relay satellite–to-imaging satellite pointing accuracies. These were to be two vehicles moving through space in dissimilar orbits and at dissimilar altitudes, with a need for relatively high-gain, narrow-beam antennas. Dirks also noted that [redacted] was the ideal frequency for this link, but that component technology at this frequency was still undeveloped. He was to be proven correct in both cases.*[1-39]

CIA Study Confirms NRT Will Significantly Improve Intelligence

The amount of money being spent by the National Reconnaissance Program in 1969 was prodigious. Funding requirements included GAMBIT, HEXAGON, and several major overhead SIGINT systems, as well as technology development funds for FROG and ZAMAN. In addition, the Air Force, using its own monies and some

* [redacted]

NRP funds, was at work on Project DORIAN (the Manned Orbiting Laboratory [MOL]).* This caused President Johnson's Special Assistant, Walter. W. (Walt) Rostow, to ask at the PFIAB meeting on 10 January 1969 whether the reconnaissance effort was growing too large. DCI Richard Helms replied that in terms of national requirements he did not think so, and he noted the superiority of then current intelligence to that available before satellite reconnaissance. Edwin Land added that because the [redacted] readout system would be more selective, he did not believe that it would flood NPIC with too much imagery.

However, shortly after this meeting, the CIA Executive Director, Col. Lawrence (Red) White (US Army, Retired), ordered that a group be formed to examine the impacts of an NRT system on intelligence collection, processing, and production. Roland S. Inlow, then deputy director of the Office of Strategic Research (the CIA's military intelligence analysis group) and the Agency's member of COMIREX, was named to head the study.

The Inlow study set a precedent in that it included facets of intelligence never previously considered in the development of a reconnaissance system: computer-assisted targeting of the satellites, ground processing, image interpretation, analytical organizations, and dissemination of imagery and data to user organizations. In addition, while previous studies had been primarily focused on the I&W functions of NRT, the Inlow study broadened its scope to include crises and fast-breaking events, target surveillance, current intelligence, and the monitoring of strategic arms or disarmament.[†][1-41] This study used as a model essentially the EOI system that had been conceived and described by Les Dirks in the Blue Book.

The study came to this significant conclusion:

> *The potential value of a near-real-time system is sufficiently demonstrable at this time to warrant the issuance by the USIB of an initial statement of requirements and the prompt movement toward initial systems definition.*

In addition, the study report stated that:

- NRT would significantly improve current reporting, crisis reporting, event analysis, and some areas of indications and warning (particularly of tactical forces).

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* The Air Force was attempting another revolutionary approach to space reconnaissance with the MOL and its KH-10 camera. The MOL Program had many facets other than the classified or "black" photographic reconnaissance mission (DORIAN). It was to be a military man-in-space program, based largely on the Skylab spacecraft. General Electric was the prime contractor and Eastman Kodak was to provide the cameras.

† One result of the Inlow Study was the creation of CAMS (COMIREX Automated Management System) for coordinating and managing the collection of satellite tasking. A subsequent, expanded version of CAMS included the management of exploitation, reporting, and dissemination of both imagery and imagery-derived data.[1-40]

Edwin H. Land

Roland S. Inlow

- NRT would permit a more aggressive use of imagery in dealing with day-to-day analytical problems

- A major advantage of NRT would be an orderly and routine flow of imagery to support stable processing, analysis, and reporting throughout the Intelligence Community.

- System characteristics desired in an NRT system included:
  —Resolution comparable to that of GAMBIT and HEXAGON (2- to 3-foot resolution).
  —The capability to access all COMIREX targets at least three to four times per week.
  —A minimum area of 3 by 3 nm for an image footprint on the ground at nadir.
  —The capability of imaging [redacted] frames per day in stereo.

- The NRT system should be planned and executed in terms of a total system concept, not as separate pieces.

This last was a very important and far-reaching statement.

When the study was completed, Inlow briefed DCI Helms, who requested that senior agency personnel and then the USIB also be briefed. The briefing to USIB presented all sections of the study, including a description of the collection system. The system described was essentially the ZAMAN electro-optical system in early phases of technology development in Program B, the CIA component of the NRO. To the informed, this was a type of endorsement for the ZAMAN system. In fact, after the USIB briefing, Col. Lew Allen of the NRO staff went up to Inlow and in a congratulatory manner said, "Very cleverly done!" USIB endorsed the study, and in July approved and sent to the NRO a set of requirements for a near-real-time satellite imagery system.[1-42]

The study became the base requirement for the ZAMAN system. Dirks and his staff had provided significant input on the collection system and its potential capabilities against the intelligence problems evaluated in the report. Over the next several years, Dirks and Inlow had regular, informal meetings to exchange data on requirements and system developments, resulting in a system tuned to be more responsive to the Intelligence Community's needs.

Early Hughes Work: Data Transmission

Hughes Space and Communication Group started work in 1969 on an internal R&D program called WIDATS (Wide Band Data Transmission System) to investigate the problems of transmitting wideband data from satellite to satellite via [redacted] technology was in its infancy, a data rate of [redacted] was pushing the limit of digital components, and there were questions about just being able to acquire and track with [redacted]

The WIDATS program addressed some of these issues by constructing a breadboard system to demonstrate the transmission of wideband digitized signals in the laboratory. This program continued on into the early 1970s and became part of [redacted] which the Air Force had set up under the SAR (Special Access Required) classification. To understand the state of the art at that time, one must realize that just assembling equipment capable of measuring bit error rates at [redacted] was a considerable problem. Previous studies had identified technology areas critical to the program; these included the antenna, the [redacted] TWT, and the various [redacted] semiconductors. The Air Force proceeded to fund contracts in each of these areas, and it funded other system work as well.[1-43]

ExCom Approves Advanced Development for EOI

The USIB requirement for a near-real-time satellite system was discussed at an NRO Executive Committee meeting on 15 August 1969 at which competing technologies—film readout, electro-optical imaging, and tape storage—were debated at some length. DNRO John McLucas favored a two-year readout technology development program but urged that no specific approach be selected pending further advances in technology. Program B recommended that an EOI program be approved by the ExCom and established by January 1970, with sufficient funds allocated to begin system definition. Deputy Secretary of Defense David Packard offered a compromise that ultimately was accepted: a more rapid technology development program than offered by McLucas, with a task force appointed to report on the status of both electro-optical and tape storage technologies. The tape storage concept was a favorite of John S. Foster, Jr., the DoD's DDR&E, who believed it was less expensive and would require smaller optics than EOI but would give equivalent results. Moreover, because of Film Readout GAMBIT, NRO's Program A had studied this concept extensively.

By then the Manned Orbiting Laboratory had been canceled, and Packard asked whether a portion of the [redacted] we are moving real-time readout ahead." He summarized by saying that the ExCom should authorize pursuit of critical EOI technologies, authorize systems studies, and set up a task force to report progress to the ExCom.[1-45]

In response to Packard's recommendation, a task force—under the executive direction of Assistant Secretary of Defense Gardner Tucker and chaired by former Deputy DDR&E Eugene Fubini—was set up to advise the ExCom. The task force held its first meeting on 13 November 1969 and began deliberating the different technologies. The panel issued an interim report on 14 February 1970. The report, however, indicated serious technical problems and uncertainties connected with solid-state sensors and failed to endorse funding for studying solid-state technology at the system level. In addition it seriously questioned the ability to build a "practical" ground processor capable of handling data in [redacted] at more than [redacted][1-46]

CIA's Dirks wrote a rebuttal to the Fubini Panel's interim report on 27 February 1970. He was supported in his position by Dr. Richard L. (Dick) Garwin, who attended the Fubini Panel meetings and also was a member of the President's Scientific Advisory Committee's Land Panel. Garwin arranged a joint meeting between the Fubini and Land Panels on 18 March 1970. As a result of this meeting, Garwin convinced Fubini to sign a Joint Memorandum of Understanding, which altered the conclusions of the interim report and urged that funds be provided to undertake EOI system-level studies. This significant endorsement was critical to obtaining required NRO funds.[1-47]

[redacted]

Analysts Become Involved: Establishing Image Quality

During this time, a term new to the imagery world surfaced: ground sample distance (GSD). Simply put, GSD represents the distance on the ground covered by a single detector; it is the means of expressing the ground resolution of a sampling focal plane. The NRO imaging community set out to establish comparisons between GSD and the more familiar ground resolved distance (GRD) of the film systems and to adapt GSD to the National Image Interpretability Rating Scale used in imagery exploitation.* These actions were part of an extensive effort by the Design and Analysis Division to make GSD an acceptable measure of interpretability.

The ZAMAN Program Group, now led by Charlie Roth, established a working relationship with NPIC in order to include the interpreters' point of view and expertise in the process. NPIC personnel helped define a qualitative relationship between GSD and GRD, and establish GSD-related requirements as they applied to specific intelligence problems. Since NIIRS was already keyed to intelligence problems, the matching of GSD to the myriad intelligence problems was eased somewhat. Community intelligence analysts and imagery analysts were briefed in some detail, and they assisted in evaluating electro-optical imagery acquired over a wide variety of collection conditions, thus helping to define system engineering parameters. GSD credibility and the ultimate proving of the EOI concept were greatly assisted by correlating input from imagery analysts and all-source analysts with the performance of optics, transducers, communications links, laser image reconstructors, and film.[1-48]

Development Phase Almost Complete

By 1970, support for EOI from the Executive Branch, the NRO, the appropriate committees of Congress, the Land Panel, and the Intelligence Community was sufficient for the OSP to proceed with a development plan for an EOI system that would result in an initial operational capability (IOC) in the 1975 to 1976 time frame. The extensive technology investments and schedule laid out during the 1960s gave rise to a comprehensive plan.

The EOI system was partitioned into segments for development and acquisition purposes. Segments 1 through 4—systems integration (SI), the imaging satellite (I/S), the receive facility (R/F), and the operations facility (O/F)—were grouped as candidates for a single prime contractor. Segments 5 and 6—the processing facility (P/F) and optics subsystem (O/S)—were to be developed by directed associate

* NIIRS is a quasi-quantitative scale developed by imagery interpreters to measure how well they are able to identify specific features of interest in an image; it is used to measure image interpretability quality. Over time it has been quantified mathematically in terms of GSD; it can be specified in imaging requirements.

David Packard

Richard L. Garwin

contractors, while Segment 7—the relay segment (R/S)—was to be accomplished by the Air Force Space Division with ZAMAN Program direction. The site selection process for the ground station was also begun. Thus the stage was set to proceed to System Definition.

Advanced Development Phase: Looking Toward System Definition

On 26 February 1970, Carl E. Duckett, Deputy Director for Science and Technology, submitted to the DNRO a status report on the advanced development phase of the electro-optical imaging program. This report concluded that all of the technology programs under way in support of the EOI system had exceeded the goals set for that time period. In particular, the critical technology concerned with the development of the solid-state arrays had demonstrated satisfactory performance, not only in chip-level photoelectric testing, but in breadboard-level, actual-image testing.[1-49]

As a result of the success in the technology developments and of the Fubini and Garwin joint memorandum signed in April 1970, the DNRO approved an additional [redacted] along with authority to initiate a series of system design studies for both the imaging satellite and the processing facility. At that time the DNRO also stated his intention to review the status of the program in July 1970 and in consultation with the ExCom decide whether to proceed with the System Definition phase of the EOI Program.[1-50]

Carl E. Duckett

Harold L. Brownman

ZAMAN Program Office Established

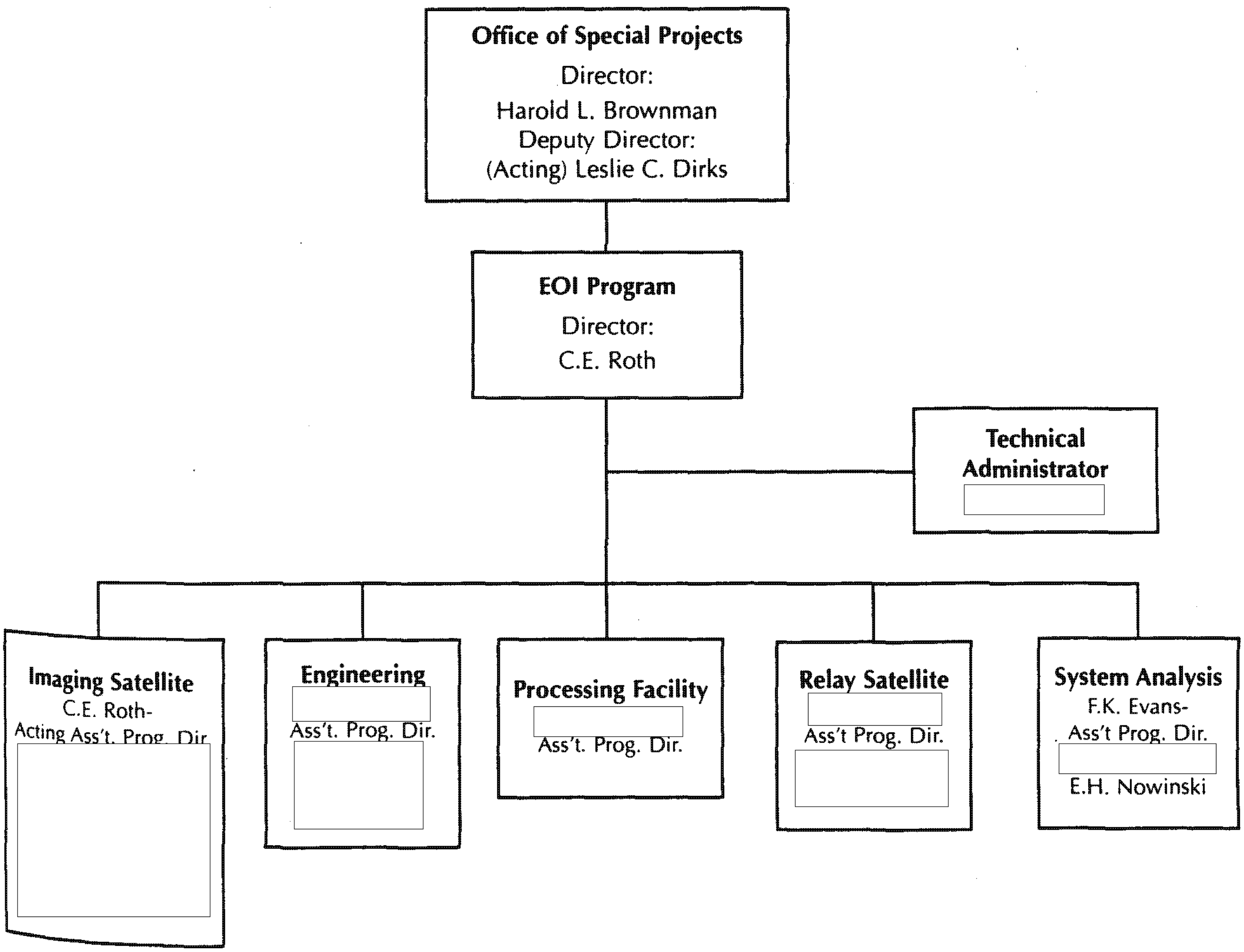
In July 1970, the Electro-Optical Imaging Program became a separate unit in the CIA's Office of Special Projects. Charlie Roth was named the ZAMAN project director, and the key people from the Design and Analysis Division who were involved in the program were assigned to the new EOI (as it was referred to in non-BYEMAN channels) unit.

Several changes in OSP leadership occurred in late 1970. At the end of August, Les Dirks became acting deputy director of OSP when John McMahon left to become the deputy director of the Office of ELINT (electronic intelligence). In November, OSP Director John Crowley announced his intention to retire, and DDS&T Duckett hired Harold L. Brownman from E-Systems as Crowley's successor. The resulting EOI organization is shown in figure 1-5. In May 1971, the "acting" was removed from Dirks' title and he officially became the deputy director of OSP.[1-51]

ZAMAN: The System Comes Together

By July 1970, the near-real-time Electro-Optical Imaging Program was well into an advanced development phase and preparations were under way to recommend moving into the system definition phase. Achieving the program objective—

Figure 1-5. EOI Organization



to develop a reconnaissance satellite system providing a continuous and responsive flow of imagery data to the Intelligence Community—would provide a major new capability with application to a broad range of strategic intelligence problems.

General system functional requirements had been developed and used as a guide for the technology activities and the system studies. The requirements had evolved as the result of continuous interaction between elements of the Intelligence Community. This effort was intended to define the most efficient and effective electro-optical imaging system configuration and operation to meet intelligence needs.

The [redacted] system concept at this time involved three major elements: the imaging satellite, a network of synchronous relay satellites, and supporting ground facilities—including a receive facility and an operations/processing facility—located in the continental United States. However, a range of system configuration concepts continued to be preserved as options until all major subsystems had been evaluated in a total systems environment.

The program plan was structured to complete the advanced development phase and then begin system definition phases I and II. This was to be followed by the system acquisition phase. Phase I of the system definition could begin as early as August 1970. Overall system-level design study activities were to be conducted during phase I in preparation for the competitive system definition phase II. Four contractors for the imaging satellite and three contractors for the processing facility were scheduled to conduct design studies during phase I. The imaging satellite contractors would be responsible for the imaging satellite, the receive facility, and the operations facility, as well as for the overall system integration task for the entire Electro-Optical Imaging Program (table 1-3).[1-52]

Imaging Satellite

During the last six months of 1969, the four imaging satellite contractors (Boeing , GE, LMSC, and North American Rockwell) carried out studies of subsystem areas to generate data as a guide for later development programs. The primary areas of investigation were:

- The structural, dynamic, and thermal interfaces between the spacecraft and the optics subsystem.
- The attitude control subsystem.
- The communications subsystem and the communications link.
- The plans for subsystem testing.

Boeing completed the structural/thermal study, which included interface discussions and design exchanges with [redacted] the optics subsystem contractor. The products of the study included a complete interface document, a mathematical model of both the satellite structure and the optics subsystem structure, considerations of reliability, and alignment requirements and preliminary designs meeting those requirements.

GE examined the overall attitude control system requirements with emphasis on the [redacted] the control laws, and the subsystem accuracy requirements. This study used the math model from the structural/thermal study to evaluate the overall control system design. In addition to the analysis and preliminary design work, three-axis air bearing tests were performed with [redacted] These tests evaluated the skewed, [redacted] They demonstrated the feasibility of meeting both the tracking and pointing accuracy requirements related to the solid-state array transducer.

Table 1-3. ZAMAN Advanced Development Phase

Number Segment	Term	Name	Competing Contractors
1	SI	Systems integration	Boeing*
2	I/S	Imaging satellite	GE*
3	R/F	Receive facility	LMSC*
4	O/F	Operation facility	North American Rockwell*
5	P/F	Processing facility	General Dynamics RCA E-Systems
6	O/S	Optics subsystem	[redacted]
7	R/S	Relay segment	SAMOS (USAF)
Subsystem			
		Tape recorder	RCA Ampex
		Onboard computer	CDC IBM Rockwell
		Transducers	TRW (phototransistor) Westinghouse
		Data transmission	Philco-Ford
		Traveling wave tubes	Hughes
		[redacted]	Sperry Bendix GE
		[redacted] evaluation laboratory	Honeywell
		Image reconstruction film	Eastman Kodak E-Systems‡
		Laser image reconstructor	Itek RCA

* Bid on segments 1 through 4.
[redacted] did not compete with [redacted] it pursued additional optical design and processing work.
‡ E-Systems provided input to [redacted] but did not develop film.

Lockheed performed a study of the entire communications link from the imaging satellite through the relay satellite to the receive facility. This study included an in-depth look at the communications system of the imaging satellite as well as an evaluation of the overall link budget. Products from this study provided data for the relay satellite functional requirements specification delivered to the Air Force's Space and Missile System Organization (SAMSO).

North American Rockwell submitted a detailed document outlining test procedures and examining the tradeoffs between tests at component, black box, and subsystem levels. Data from other programs such as NASA's Apollo were compiled and presented, identifying numbers of failures located at each step in the test process. These data provided inputs for adjustments to the overall program, determination of critical timelines, and indications of cost-effective procedures for testing and assurance of high reliability.

During the first six months of 1970, each of the four imaging satellite contractors was assigned EOI system configuration tasks including requirements analysis, performance analysis, and specific imaging satellite point design. The performance analysis centered on three primary characteristics: image quality, spacecraft maneuvering agility, and image quantity. Image quality was examined over ground sample distances from [redacted] to 18 inches, agility from the number of frames that could be achieved within a 50-mile radius [redacted] frames per target cluster), and image quantity from [redacted] frames per revolution and from [redacted] frames per day. Cost data were generated to provide estimates of nonrecurring developments, unit launch replacements, and operations.

Receive Facility

Receive facility design, installation concepts, and staff requirements as well as operations facility concepts were completed during early 1970. This work included analysis of the performance required, concepts of the hardware installations (such as antennas at the receive facility and computers in the operations facility (O/F), and preliminary designs of the link for data transmission between the receive facility and the operations facility. The imaging satellite and processing facility contractors met to assess those interfaces and define the requirements for data transmission between the O/F and processing facility. Cost estimates for design, development, and installation of the receive facility and operations facility were generated and combined with the estimates for the imaging satellite and the relay satellite. These were rolled into a total system cost over a 10-year period.[1-53]

Processing Facility

At the processing facility, imaging data transmitted directly from the receive facility would be used to produce hardcopy images. Processed telemetry data and other mission data would be obtained from the colocated operations facility. Provisions were made to handle the received data in both online and offline subsystems. The online subsystem was to process data to produce finished hardcopy ready for initial evaluation. The offline subsystem was to process data to meet special requirements and for final distribution. The processing facility was to be located in the [redacted][1-54]

In early 1970, the competing processing facility contractors (General Dynamics, RCA, and E-Systems) were asked to conduct overall processing facility configuration studies and parametric evaluations, and to draw up performance requirements and a family of point designs. The parametric studies evaluated the effect on equipment design and implementation of a range of operating requirements similar to those of the imaging satellite studies. Variations in data rate, calibration methods, data format, and sensor geometric characteristics were studied. Performance variables included processing time requirements, incorporation of transfer compensation, incorporation of corrections for geometric distortion, responses to special requests, archival storage requirements, and types and quantity of output. The outputs of these studies were used to develop preliminary designs and hardware implementation approaches for a complete processing facility. This included estimates of required space, facilities, and staffing for full-time operation.[1-55]

Relay Satellite System

The relay satellite system proceeded under the direction of SAMSO and was supported primarily with Air Force funds. Close coordination with SAMSO was maintained to integrate performance requirements for the relay with other elements of the EOI System. Sometime in 1970, it was decided that the non-NRO Air Force would build the ZAMAN relay satellites. This appears to have been largely a political decision. The case was made that the relay system could be built as an overt data relay system, increasing the unclassified, or white, Air Force budget and allowing the classified, or black, items in the budget to be more easily disguised. That also would allow the ZAMAN Program Office to tap the technical capability of the Air Force.[1-56]

Work on the relay satellite segment was carried out in three areas in FY 1970: in-house, with the assistance of Aerospace Corporation technical consultants; by the imaging satellite contractors; and by SAMSO, which had been assigned this responsibility in late 1969. The in-house effort included generation of a detailed requirements document including relay satellite system deployment, performance requirements, and overall link budgets. In addition to generation of basic data, the effort included reviews of communication and imaging satellite contractor studies, participation in radio frequency (RF) technology planning, and development and direction of SAMSO activities. The contractor activities included concepts for relay satellite segment configurations, deployment, and design requirements. The contractors also developed link budgets, assessed technology requirements, prepared preliminary deployment and replacement plans, and developed cost estimates. SAMSO activities during FY 1970 included two major areas: initiation of technology development contracts and completion of a competition for the concept definition phase for a relay satellite for the EOI system.[1-57]

Optics Subsystem

A major optics development program was begun at [redacted] after significant NRO monies for FY 1970 were reallocated to the ZAMAN EOI Program from the canceled Manned Orbiting Laboratory. An initial assessment of optical system requirements for solid-state transducers led to the selection of a [redacted]

[redacted] optical system. In addition, the overall configuration, structural concept, thermal subsystem, electrical and telemetry components, and system interfaces—including installation of the optics subsystem in the imaging satellite—were analyzed. A fabrication program demonstrated the feasibility of making the steep aspheric surfaces required by the [redacted] optical system.[1-58]

During this period, [redacted] continued its optical design and processing work and provided additional analyses of the lens formula, structural configuration, and thermal design for the optics subsystem.[1-59]

Tape Recorder Subsystem

A digital tape data recorder was required on board the imaging satellite both as a backup to the relay satellite system and to fill any gaps in [redacted] coverage that resulted from relay satellite positioning. Data recorders also were required at the receive facility for insurance recording and at the processing facility for buffering and archival recording. Both space and ground recorders were to be capable of recording digital data at a maximum rate of [redacted]

For the spaceborne requirement, two techniques were investigated: two-channel, rotary-head, transverse recording at RCA; and multichannel, fixed-head, longitudinal recording at Ampex. Preliminary results indicated that the rotary-head technique would require four recorders [redacted] whereas the fixed-head technique might require only one or two, depending on the two-dimensional bit-packing density that could be achieved. Because the longitudinal recorder had a very high number of tracks, the data rate in any given circuit was considerably lower than for the rotary recorder, leading to lower power requirements for the electronics portion of the longitudinal recorder.[1-60]

Flight Computer Subsystem

The onboard flight computer was required to receive, store, and execute commands; sample, check, and transmit housekeeping telemetry data; perform all attitude control calculations and executions; and determine antenna scanning and pointing operations. It required a very high reliability for the lifetime of the imaging satellite.* A series of studies in 1968 had concluded that further development of large scale integration (LSI) technology was needed. Program A funded the breadboard phase of development of a small, low-power computer. This program was based on plated-wire memory and LSI switching and logic, but did not include design or test efforts related to reliability and environmental requirements.

Studies indicated that a special-purpose computer with redundant functional modules that could be restructured by command would best satisfy the EOI requirement. To this end, a competitive design effort was planned with technology development supported only in those areas needed for the specific design. The development schedule allowed for evaluation of alternative designs by prototype testing. Specifications were prepared and bids requested from companies including

* The mean mission duration (MMD) of an EOI imaging satellite being planned in the late 1960s was expected to be between [redacted] as long as the life of imaging satellites being launched at that time.

CDC, IBM, and Rockwell. Rockwell submitted the winning proposal and began work to develop an engineering model to support subsequent system tests. Later Rockwell became the onboard computer supplier for system acquisition.[1-61]

Transducer Technology

In 1969 and early 1970, the engineering development program for solid-state transducers included fabrication and delivery to the Image Processing Laboratory of breadboard arrays and associated data processing electronics of both the TRW phototransistor array and the Westinghouse photodiode array. In addition, pilot production runs of photosensitive chips were made by both contractors and extensive test data were obtained and reported in their chip test data packages. Engineering studies, which were preparation for the start of a flight hardware design phase, had been conducted to provide essential interface data for candidate imaging satellite contractors, optics subsystem contractors, and communications subsystem contractors.[1-62]

Communication Technology Developments

Data transmission studies conducted during 1968 and 1969 indicated that if the essential communication technology was to be available, another development cycle would be required before an imaging satellite contractor was selected. Several major items continued into 1970, including a [redacted] antenna subsystem and a traveling wave tube amplifier. Philco-Ford built a 4-foot-diameter Cassegrain antenna in late 1970 that was constructed of a graphite-epoxy material having the high-dimensional stability required at [redacted] This demonstrated both the feasibility of the fabrication approach and the highly efficient performance required in an environment like space. In late 1969, a contract was negotiated with Hughes for the development of a breadboard 30-watt traveling wave tube. The design and performance goals established for the TWT were derived from earlier communications subsystem studies. This demonstrated operation of a [redacted] tube in a laboratory setup simulating a typical I/S communications subsystem. The TWT was delivered to Philco-Ford in early 1970, and installation was initiated immediately. All of the work in this area was conducted in close coordination with the SAMSO technology program.[1-63]

[redacted]

[redacted]

Image Reconstruction Film

Even as the space hardware was moving to some level of maturity, work was under way at Eastman Kodak to perfect a film specifically for use in the EOI laser image reconstructors at the ground station processing facility. It was most important that little qualitative data be lost in the process of exposing film to the laser spot. Eastman Kodak photoscientists labored long and hard to perfect a film with maximum resolution, or a high-modulation transfer function, at very short exposure times and in very high light levels. Kodak succeeded in this effort—with significant input from E-Systems—and the film for the final step in the image chain eventually was produced in the large quantities required.

Laser Image Reconstructors

The laser image reconstructors required a significant technological advance. Both Itek and RCA were examining the problem in detail. Although achieving either the high resolution or the high speed required was relatively simple, achieving the required combination was unprecedented. Digital-to-analog conversion at the necessary rates would require the development of exacting circuitry. Synchronizing the conversion to satisfy image quality requirements was to be the biggest challenge.[1-65]

Simulations Prove the ZAMAN System Concept

In 1969 and 1970, under the direction of Ed Nowinski and Fred Evans, significant emphasis was placed on simulation experiments to determine the image quality requirements across the complete EOI system image chain. Detailed experiments were performed that took into account the nature of sampled imagery and the impact of the sampling process upon the total information content of the final image product. Work in this field had been done by the television and communication industries; however, no significant data then available related to two-dimensional sampled image systems operating under low noise conditions.[1-66]

RCA's Advanced Technology Laboratory developed the basic simulation technique, which employed a relatively large-scale image scanner and reconstruction device as well as a general purpose computer with appropriate software. The input device scanned an illuminated, high-resolution transparency; modified the scanning beam to simulate the effect of the system modulation transfer function; and converted the resulting analog waveform into a discretely sampled digital image data matrix. This data matrix was then processed by a general purpose digital computer to impose on the raw data the effects of noise, encoding, compensation processing, calibration, and other special filtering. The processed digital data matrix was then reconverted by the reconstruction device into a continuous tone transparency suit-

suitable for viewing and interpretation. Thus, the entire end-to-end image chain was simulated, and it was limited only by the characteristics of the photographic input material.

Image simulations were run to include a wide range of scenes—including those of naval facilities, aircraft, buildings, and cars and other miscellaneous vehicles—over a range of transducer noise levels and ground sample distances. The ability of the EOI system to compensate for atmospheric haze and scene dynamic range was simulated in many scenes. This compensation capability provided an enormous improvement in image quality under poor acquisition conditions, something not shared by any film system.

A simulation effort was conducted to study the effect of the signal-to-noise ratio (SNR) on image quality for various values of GSD based on a fixed operating altitude and varying focal length and integration time. The assessment made it apparent that there were only small improvements in image quality [redacted] for the full range of GSD investigated. Moreover, significant data showed the sensitivity of image quality performance to the interaction of GSD and SNR. It was clear even to unsophisticated observers that an image [redacted] conveyed significantly more information per unit of ground area imaged than an image with a [redacted] The availability of simulated imagery settled a lot of disputes and enabled a "serve the customer" attitude to prevail.[1-67]

The image chain simulation determined the effects of the key system parameters on image quality performance. The results were used as input to system definition phases I and II and provided improved imaging performance specifications for the system acquisition phase. Results from the image chain simulation and from the Image Processing Laboratory were continually compared to ensure maximum feedback to the ongoing system design efforts.

A more advanced image chain simulation was initiated in early 1970. Image quality performance studies using this advanced simulation capability established performance specifications for the EOI system and its related subsystems. The image chain simulation incorporated a high-speed, high-accuracy film scanning device to scan large-scale, high-resolution photographic transparencies of representative targets to obtain a data stream equivalent to that expected from the transducers. This data was then digitally processed to simulate effects imposed by a range of variations in EOI system parameters. The image was then reconstructed, and the hardcopy was evaluated by photointerpreters to quantitatively assess the effects of the image formation and reconstruction processes on the image quality performance of the system.

Critical studies performed during this period included investigating data compression techniques for a range of image acquisition parameters and system operation modes, and defining transducer acceptance criteria. Effort was also devoted to evaluating digital processing techniques including trade-off studies between ground station data processing capabilities.[1-68]

A complementary activity termed the image chain analysis (ICA) was formulated at Eastman Kodak. The image chain was simulated on computer, and the results were used to determine appropriate ranges of parameters to use in controlling the physical simulations at the Image Processing Laboratory. The ICA also defined the "experiments" that were conducted using NPIC imagery analysts to provide inputs to the system requirements.[1-69]

Improvements to the Image Processing Laboratory were incorporated during the latter part of 1970. They included an improved image write-out device, an expanded digital processing capability, and modification of the data buffering hardware to accept data from the prototype arrays. The results from these tests supported the definition of transducer design specifications and acceptance criteria, and contributed to the processing facility performance requirements. These results were also correlated with those obtained from the ICA. Several hundred simulated images were produced to support the initial design specifications.[1-70]

System Definition Phase: We're Ready

In early July 1970, DDS&T Carl Duckett requested approval from the DNRO to initiate the system definition phase of the ZAMAN Electro-Optical Imaging Program. He noted that in April the DNRO had stated his intention to review the status of the program in July and, in consultation with ExCom, decide whether to proceed with the system definition phase of the EOI Program. Duckett pointed to the potentially difficult NRO budgetary problems that had developed for FY 1972, and indicated that alternative approaches to the first year of the acquisition phase of the program had been developed. Finally, he claimed the following:

- All the imaging satellite contractor studies were comprehensive; they provided an excellent database for the initiation of system definition. No significant problem areas were uncovered. A wide range of feasible configurations had been identified, and all of them were within the capabilities of subsystem hardware under development.

- All the contractors developed practical preliminary designs for a range of processing facility capabilities. No major problem areas had been identified, and the contractors concluded that the program status warranted initiation of system definition.

- Particularly notable progress had been made with the image chain simulation experiments using actual imagery. The experiments had demonstrated characteristics of various potential EOI system designs. A complete range of images had been generated, covering image quality characterized by GSDs [redacted] 24 inches.

These image chain simulation experiments confirmed that the original design point at a signal-to-noise ratio greater than 5:1 was a sound selection. More important, however, the studies confirmed the earlier analytical predictions that the solid-state array detectors would have imaging characteristics appreciably better than those of silver halide film.

These results from the image chain simulation tests, along with other experimental work, indicated that the earlier assumption that a 12-inch GSD would yield image quality equivalent to that of the earlier, initial GAMBIT system was extremely conservative. Indications were that an EOI system designed for a 12-inch GSD at a signal-to-noise ratio of 5:1 would yield imagery of interpretability comparable to that of the then current GAMBIT system.

This conclusion was particularly significant in light of the results of the imaging satellite system design studies. Those studies had shown that feasible system designs existed using solid-state arrays and [redacted] optics systems yielding a [redacted] GSD. Thus it was possible to contemplate an EOI system design providing image quality better than that of the GAMBIT system. Such an EOI system could replace GAMBIT. Alternatively, the performance requirements could be relaxed to an 18-inch (or perhaps even a 24-inch) GSD and the EOI system would still meet many of the USIB requirements for a readout system—at significantly reduced costs.

The Data Relay Satellite Program managed by the Air Force's SAMSO was coordinated and synchronized with the overall EOI Program plan. The SAMSO schedule ensured that the relay satellites would be ready five months before the first imaging satellite was to be launched. The Air Force had funded the necessary advanced development programs. SAMSO had completed a source selection and was preparing to initiate two parallel system-level design studies for data relay satellites. Thus, SAMSO also indicated the technology work and the results of the contract definition phase competition demonstrated the readiness to initiate system definition.

Duckett believed that no engineering feasibility questions were unresolved at that time. In addition, a successful and extremely valuable round of system-design studies had been completed, laying excellent groundwork for a system definition phase. He strongly recommended that a system definition phase be initiated in August 1970. The requisite contractor teams were assembled and had demonstrated their understanding of the total problem. In addition, the advanced development programs had proceeded to a point where meaningful systems design could be accomplished. Delays would cause diminishing returns and would postpone the eventual acquisition of an EOI System capability.[I-71]

On 17 July 1970, the ExCom met and made three significant imagery decisions. First, the committee decided to proceed immediately with the system definition phase of the EOI System. This phase was to be completed in time for the November 1971 ExCom meeting. At that time the ExCom would decide whether to proceed with system acquisition. Concurrent with the system definition phase, the Air Force was to proceed with development of the relay satellite. (This was the only element of the near-real-time package that was being handled overtly, outside the

National Reconnaissance Program). Second, the ExCom would continue to fund the tape storage camera (one of the competing technologies considered by the Fubini Panel) as a viable option for a near-real-time system. Third, the committee decided to terminate any major ongoing activity for development of a very-high-resolution imagery satellite system. The NRO's position was that the technology for a very-high-resolution imagery system existed and a system similar to DORIAN (KH-10) could be built at some future time if its cost was justified.[1-72]

System Definition Phase I Under Way

System definition phase I for ZAMAN was initiated on 17 August 1970. The four imaging satellite contractors, the three processing facility contractors, the two transducer contractors, and the optical contractor were required to generate data to allow the Program Office to make general budgetary recommendations regarding two different EOI configurations. On 28 August 1970 representatives from all 10 contractors (table 1-4) and SAMSO attended the phase I kickoff meeting held in Washington.[1-73]

Earlier in the summer, the Program Office had prepared a document to define the capabilities for an EOI system required to satisfy the needs of the Intelligence Community. It established the required system capabilities on which preliminary system and subsystem designs could be developed in the course of studies conducted during phase I of system definition. The document identified the intelligence objectives in terms of type of imagery required to satisfy strategic and technical intelligence tasks and system functional requirements for system configurations A and B.* The system definition contractors performed detailed and comprehensive studies of the overall EOI system design and performance for both configurations. The results indicated a general convergence toward quite similar designs and performance estimates on the part of each contractor.

The unique aspect of configuration A—and its fundamental difference from the previous EOI system configurations—was the orbit of the imaging satellites. [redacted]

* Configuration A provided the capability to achieve both the strategic and the technical intelligence objectives. Configuration B initially provided the capability to achieve only the strategic intelligence objectives. It was intended that configuration B would be deployed and then subsequently upgraded to configuration A by a second development effort.

Table 1-4. ZAMAN System Definition, Phase I

Number Segment	Term	Name	Competing Contractors
1	SI	Systems integration	Boeing *
2	I/S	Imaging satellite	GE*
3	R/F	Receive facility	LMSC*
4	O/F	Operation facility	North American Rockwell*
5	P/F	Processing facility	General Dynamics RCA E-Systems
6	O/S	Optics subsystem	[redacted]
7	R/S	Relay segment	SAMSO
Subsystem			
		Transducers	TRW (phototransistor) Westinghouse (photodiode)

* Bid on segments 1 through 4.

The performance of a typical configuration B was characterized by a GSD of 18 inches, near-global landmass coverage, and a lower data rate (resulting from the use of a single array). Strategic intelligence collection, the only intelligence objective evaluated, could be achieved by two imaging satellites operating in a 200-nm circular orbit.

A number of plans for the relay satellite were studied by both the Air Force's SAMSO and the CIA's Office of Special Projects to find a relay satellite configuration [redacted]

[redacted]

System Definition Phase II Approved

The first system definition phase was completed as planned and an NRP Executive Committee meeting was scheduled for 29 January 1971. The ExCom meeting was expected to answer such questions as "Should we go into phase II?" "If so, how fast should we proceed with it?" and "How does this decision affect alternative systems?"[1-75]

The discussion concerning a need for an interim system included data not only on FROG and a tape storage camera, but on other quick-response systems such as [redacted] The general characteristics of the latter three systems were as follows:

- [redacted]
- [redacted]
- [redacted]

At the January meeting of the ExCom, DNRO McLucas immediately raised the issue of cost. He said that the film readout system could be produced for half the cost of EOI and its Data Relay Satellite (DRS) Programs, which were estimated to cost about [redacted] over the next five years. McLucas believed that the EOI

* Johnston Atoll is southwest of the Hawaiian Islands in the Pacific Ocean.

system had more growth potential and had the possibility of replacing GAMBIT, one of the existing systems. He noted it could also have [redacted] strip photography capabilities. McLucas said he felt confident that EOI was a viable system that could do all the things required of it; however, he wanted to hold NRP costs at the then-present level. He recommended that studies on the backup systems be continued and that a decision on system acquisition be made in November.

Deputy Secretary of Defense Packard supported the EOI program but suggested that for funding and technical reasons they should extend the project timeline to an IOC in 1976. The issue was whether an interim system should be procured.

McLucas indicated his desire to discuss this subject because of the increasing interest in crisis reconnaissance in the community as substantiated by a recent letter from Secretary of State William P. Rogers to DCI Helms. McLucas noted that an interim system such as [redacted] would require funding from the EOI Program in the NRP budget, because that was the only money set aside for developments in this area. Packard noted that the difficult question was whether to continue with three approaches, namely EOI, film readout, and the tape storage camera. Film readout, he said, looked straightforward. As the ExCom discussed the budget, it noted that film readout system definition was budgeted for [redacted] in FY 1971 but would require [redacted] in FY 1972. In any case, an interim system would require funding to be obtained from some existing program.

The meeting then began to focus on the EOI Program. [redacted] the NRO comptroller, pointed out that the original plan was to go from four imaging satellite contractors at the end of phase I to two in phase II; however, Program B recommended continuing with three contractors for phase II. All of the principals concurred in the decision to retain the "third" contractor for phase II. Packard said the three contractors should be permitted to proceed on the imaging satellite for phase II, but this decision was subject to change. He also asked for a progress report in about two months, and Dr. Edward E. David, Jr., the science adviser to the President, and Helms endorsed the request.[1-77]

Another key item on the agenda of the ExCom meeting on 29 January was the Data Relay Satellite Program.* McLucas reminded everyone that when the white Air Force was given the relay program, everyone was convinced it could be multipurpose. Because there was now some uncertainty about its multipurpose use, Assistant Secretary of the Air Force Grant Hansen was reluctant to keep a dedicated relay satellite for EOI in a white Air Force budget and to go to Congress for its support. It was noted that if the data relay satellite was to be a dedicated program,

* The relay program was known in the unclassified world as the Data Relay Program.

the program should be a black program. McLucas noted that the Secretary of the Air Force, Robert C. Seamans, and the Air Force Chief of Staff, Gen. John D. Ryan, to name a few, would object to moving the program into the NRP. The points were made, however, that the EOI and relay programs were being kept in phase and that other functions could be combined with the DRS.[1-78]

Relay Satellite: [redacted] Orbit Preferred

In early 1971, a detailed requirements impact and implementation study for the relay satellite communications system was undertaken. The effort clearly showed that the advantages of the [redacted] configuration made it a preferable system solution. However, it was noted that [redacted] orbit would be acceptable for the relay satellite configuration. In neither of these approaches could a single spacecraft provide in three days the real-time global coverage that would be achieved by the two relay satellites [redacted]

> *. . . It was soon realized that a pair of relay satellites in* [redacted] *orbit would be vastly superior to a large number of ground station receiving the signals* [redacted]
>
> ***Albert Wheelon***

The [redacted] configuration for the relay satellites had the advantages of using space-proven, simpler equipment and less expensive boosters and eliminated the need of a "double hop")* The most significant impact on system equipment was the simplification of the communications link via the "single hop" approach and the resultant decrease in complexity and cost for the relay satellite segment (including boosters).

For downlink communications, [redacted] was preferred. It allowed the use of already available relay segment equipment, off-the-shelf receive facility equipment, and better link margins during low-elevation angle and heavy rainfall conditions. It also allowed a simpler dual feed arrangement on the imaging satellite to handle both the link with the relay satellite and the direct link with the receive facility.[1-79]

As a result of these significant findings, the *Relay Satellite Requirements Specification* document was revised in March 1971. The document was then provided for the initiation of the relay segment detailed definition phase on 29 March. This resulted in the relay staying on the same schedule as the imaging satellite and processing facility segments.[1-80]

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* Double hop refers to R/S-to-R/S crosslink, or transmitting the imagery data from the I/S to one R/S and then to the second R/S before downlinking it to the ground station.

System Definition Phase II Begins

The second phase of system definition was started on 1 February 1971 and was scheduled to be completed on 30 September 1971 (table 1-5). The overall plan was for the three contractors (LMSC, Boeing, and GE) to develop detailed designs for the imaging satellite, receive facility, and operations facility. The designs were to be sufficiently detailed—including equipment and interface specifications—to establish a complete system configuration.

The two processing facility contractors (E-Systems and General Dynamics) were to develop detailed designs for the processing facility. These designs were to include analyses, circuit and equipment descriptions, and interface documentation

Table 1-5. ZAMAN System Definition, Phase II

Number Segment	Term	Name	Competing Contractors
1	SI	Systems integration	Boeing *
2	I/S	Imaging satellite	GE*
3	R/F	Receive facility	LMSC*
4	O/F	Operation facility	
5	P/F	Processing facility	General Dynamics [redacted]
6	O/S	Optics subsystem	
7	R/S	Relay segment (contract definition phase)	Hughes TRW
Subsystem			
		Transducers‡	TRW (phototransistor)
		[redacted]	Westinghouse GE Sperry Bendix
		Image chain performance program	Eastman Kodak (image chain analysis) RCA (image processing laboratory)
		Traveling wave tubes	Hughes

* Bid on segments 1 through 4.
† [redacted] was responsible for the collimator and for finishing a 72-inch mirror [redacted]
‡ Contractor was to be selected four months after phase II began.
** Testing was to end in the autumn of 1971.

for the processing facility. Both sets of contractors were to identify all subsystems and subcontractor relationships. They also were to include a system design report and a system acquisition phase proposal.

The contractor for the solid-state transducer data processing system (TDPS) was scheduled to be selected for system acquisition in June 1971. This was to allow the selected contractor to proceed with the detailed design, fabrication, and assembly of an engineering model transducer. The modules containing the high-resolution detectors were to be assembled into four arrays. Because of the importance of this critical technology, the contractor not selected for system acquisition was to be funded to continue to carry out a basic technology program during FY 1972.[1-81]

Significant efforts also were to continue in the optics area. [redacted] continued the detailed optics subsystem design, the optics element fabrication, and the [redacted] system demonstration program to insure that the fabrication and testing techniques would be adequate for the requirements of the EOI Program. [redacted] was scheduled to complete and install a collimator with a [redacted] The collimator would be used to evaluate full-aperture tests of the optics subsystem and functional tests of the transducer subsystem. [redacted] also was to finish, on a computer automated optical surfacing machine, a 72-inch lightweight mirror with the [redacted] At that time, the equipment would be transferred to the imaging satellite contractor selected for system acquisition.

The image chain performance program, consisting of the [redacted] image chain analysis and work done at the RCA Image Processing Laboratory, continued through phase II. The fundamental objective of this analytical and empirical program was to continue to determine the functional relationships between image quality performance and the parameters of the key functional elements of the image chain. Determination of these relationships and application of data generated would permit meaningful trade-offs in the areas of system- and subsystem-level performance.[1-82, 1-83]

Relay Contract Definition Phase: Hughes Versus TRW

In the spring of 1971, the contract definition phase of the relay satellite segment began. Run by SAMSO under a Special Access Required security blanket, it was a two-contractor competition between Hughes and TRW. Knowledge of the imaging satellite was not officially available to the contractors; the imaging satellite was identified only as user A. The communications payload to support the I/S was called the [redacted]

The Air Force was still wrestling with combinations of communications payloads to include in the design. Under consideration were space ground link subsystem gear that permitted operations and relay of the data flowing in the Air Force Satellite Control System (and permitted transmission of commands to the Air Force base near Thule, Greenland, for relay to the imaging satellite if desired), and UHF (ultra-high-frequency) gear that was to be used for the SIOP (Single Integrated Operational Plan) forces, particularly for communications with the Strategic Air Command fleet.*

Initially, two proposals—reflecting two different payload configurations—were required. Immediately after contractors submitted these two proposals, however, the Air Force requested a third proposal that reflected the final relay satellite configuration. A new cost proposal, submitted in the fall of 1971, became the basis of the eventual development contract.[1-84]

Hughes was the directed subcontractor for all of the traveling wave tubes for both the imaging satellite and the relay satellite. Hughes, using its extensive experience in communications satellites, settled on a design concept early in the competition and set out to make it work. TRW, on the other hand, did an extensive series of trade studies that proved very useful and of ultimate value to the government. TRW did not arrive at a firm design until late in the competitive phase.

The Hughes design was a spin-stabilized satellite in which the upper portion of the satellite (containing the antennas) was despun while the lower portion rotated for stabilization. Hughes had been very successful in using this design for commercial satellites. The TRW design was a three-axis stabilized platform.[1-85]

Requirements: Near-Real-Time and an Interim System

On 22 April 1971, with the DNRO in attendance, the US Intelligence Board met and considered a memorandum called *Intelligence Requirements for Crisis-Response Satellite Imagery FY 1973-1975*, which had been issued by the Chairman of COMIREX. The memorandum was a result of this USIB charge from the previous November:

> *Recognizing potential crisis needs in the FY 1973 to FY 1975 period, the continuing limitations in timeliness of response which will exist until a near-real-time system is available, and that throughout the intervening period supplementing airborne systems will be the only means of performing additional photographic reconnaissance as special needs arise, COMIREX and the NRO should further examine the possibilities of interim satellite systems to satisfy limited needs in the context of the relative trade-off between benefits and costs and report [their] findings to the USIB.*

* SIOP was the National Command Authority's (NCA) plan for fighting a nuclear war.

The USIB discussed the subject in detail, and throughout the discussions, expressed concern over the lack of an adequate intelligence response to crisis situations. The Board noted that it had considered this problem in detail in July 1969, in discussions and studies related to the near-real-time imagery satellite system requirements, and subsequently in its periodic guidance for the NRO. Board members noted that the near-real-time system requirement was designed primarily to satisfy longstanding needs for improved indications and warning and crisis intelligence, and secondarily to fill other, multipurpose roles. A near-real-time system having the characteristics enumerated in the Board's requirements clearly would have powerful crisis-response capabilities. However, because it would not be operational until after FY 1975, the Board had instructed COMIREX and the NRO to further examine the possibilities for interim crisis-response capabilities as outlined above.

The Board agreed that the then-current imagery satellite program had limited flexibility and crisis responsiveness in relation to the requirements that might be put on the Intelligence Community until the NRT system was available. Nonetheless, the problem of dealing with this hinged on the availability of resources. The Board concluded that the interim system proposals that it had reviewed in late 1970, while offering valuable limited-purpose additional capabilities, did not appear to warrant a redirection of resources from then-present NRO programs. The Board recognized this continuing dilemma and directed COMIREX and NRO to further examine the possibilities of interim satellite systems in terms of their benefits and costs.

The subsequent study supported the conclusion reached by the Board in November 1970: interim systems would offer valuable additional capabilities. At that time it was concluded that the candidate systems reviewed did not appear to warrant a major redirection of resources from then present NRO programs, and it was judged that the NRO was directing its available resources against the highest priority objectives in the proper order. As a result of the study, consideration was given to the development of interim system capabilities by means of additional resources, if possible, or by adjustments that would have minimum impact on other programs. In case significant trade-offs within present programs would need to be considered, the NRO was directed to assess and report the relative impact on other NRO programs of a decision to proceed with an interim system.[1-86]

The task group that conducted the study also examined a number of other historical examples that were judged to represent different classes of time-dominated critical situations. These included:

- A standdown of the Soviet Long-Range Air Force in August 1969.
- The Jordanian crisis of 1970.
- A Soviet military exercise, Dvina, held in 1970.
- The Suez cease-fire of 1970.
- The hypothetical DIA scenario of North Korean preparations for an invasion of South Korea.

In addition to these situations, the study group assessed in less detail a large number of other critical situations that had occurred in the previous 10 years and that would have been apparent on imagery. The intent of this exercise was to delineate the imagery needs related to fast-breaking situations of major importance to the United States.

The study noted the value of imagery in 1962 during the Cuban Missile Crisis. Also, it emphasized that imagery data on the invasion of Czechoslovakia were recorded but were not available for several days.

During the discussion the Director of NSA, Adm. Noel Gayler, commented that the study seemed to him to be somewhat out of balance with regard to other collection systems. Gayler then stressed his belief that the Board needed to take a balanced view and to consider carefully the impact of any interim system if it were to be pursued at the expense of the other collection systems. He said that the then-current budget situation was such that obtaining additional resources was most unlikely and that he did not think that an interim system could be achieved without damaging other programs.

Gayler commented at some length on the very great and unique value of photographs, but noted that the state of the art was such that there was little promise, within a reasonable time frame, of achieving photography or other imagery at night, during bad weather, or during periods of cloud cover. In contrast, SIGINT satellites were not handicapped by these factors. Gayler also noted that while photos had limited predictive value, that was an area where SIGINT often made its greatest contributions. He expressed his great concern that the resources required for an interim crisis-response system plus a near-real-time system might severely hamper the SIGINT satellite programs.

The study report concluded that timely satellite imagery could play an important role in intelligence and policy analyses related to all categories of situations that arose—from threats of nuclear exchange to natural disasters.[1-87]

Reaching a National Accord: The Parties Weigh In

Between April and September 1971, opinions on what the nation's next satellite reconnaissance system should be came in from the Intelligence Community, the executive branch, and Congress. Neither before nor since then has a reconnaissance system received that kind of attention.

The parties involved in assessing and advocating the different options included the DCI and the Secretary of Defense, the NRP's ExCom, USIB, COMIREX, PFIAB, the Land Panel, and the chairman of the Senate Appropriations Committee. Eventually the President himself decided the issue.

OMB: The President Wants It Sooner

On 22 April 1971, the day before the ExCom had planned to review phase II of system definition for the ZAMAN EOI system, George P. Schultz, director of the Office of Management and Budget, sent a letter to Deputy Secretary of Defense Packard. Schultz said the following in regard to the ExCom meeting:

> *I should like to emphasize the President's interest in an NRT or crisis capability system. It would be desirable if such a system could be operational at an early date and at a reasonable cost. I hope that you will give serious consideration to the procurement within NRP resources of such a system so that it could have appreciable utility during the President's administration.*[1-88]

The ExCom met the following day, with two imagery issues on the agenda:

- Should the NRO acquire an interim photographic reconnaissance system for crisis-response before the introduction of the EOI system? If so, should the funds be obtained within the current NRP?

- What EOI configuration(s) should be pursued, and at what rate should the program proceed?

In fact, however, acquiring an interim capability had become a given because of USIB's emphasis on it over the preceding several months; the early suggestion of Presidential support in previous ExCom meetings; strong support by Secretary of State William Rogers; and, most importantly, the letter of 22 April stating President Richard M. Nixon's interest in a near-real-time or crisis capability during his administration.

At Packard's request, DNRO McLucas introduced the subject and reviewed a large number of approaches for crisis and interim reconnaissance. In summarizing, he reduced them to three different approaches:

- Continue to launch GAMBITs and HEXAGONs and phase into EOI without acquiring an interim system.
- In addition, acquire FROG.
- In addition, acquire [redacted]

[redacted] was a less expensive alternative, but it offered less than FROG, which had the advantages of being both an interim and a fallback system for EOI. However, FROG was more of a budgetary problem.

The overall NRP budget had peaked in 1968 at about [redacted] and had been declining since then. For FY 1972, it was proposed to increase to slightly more than [redacted] Intelligence customers wanted to have the near-real-time capability. In addition, their other requirements tended to push the total budget toward [redacted]

Gen. Donald V. Bennett, the Director of DIA, commented on the requirement for some kind of interim system and put a high priority on resolution and area coverage. He also felt that the interim solution should have growth potential such that it might become a candidate for the final solution. In his opinion, only FROG and [redacted] satisfied the several characteristics desired. Of the two, he favored FROG. At a later time he could see the possibility of competing EOI and FROG. Robert Froehlke, the Assistant Secretary of Defense for Intelligence, agreed with General Bennett's conclusion on eliminating all systems but [redacted] and FROG.

At that point, Packard said he wanted to change the emphasis in the discussion. He said he was frankly very much impressed with the progress made on the EOI system. The EOI team had done an excellent job, and Packard did not want any decision made to acquire an interim system irrespective of any impact on EOI. He said he fully supported the development of EOI, and it was the ultimate system the United States wanted. The ExCom should make that decision and not make a decision to acquire an interim system on the basis of coming back later to compare one against the other. Packard felt that providing an extra year in the schedule would help in acquiring the system, so he wanted to make a firm commitment to EOI. The advantage he saw to acquiring FROG was that it could be a low-risk backup program to EOI while providing an interim capability. Although FROG was more expensive than [redacted] it provided more capability. However, Packard wanted to make it very clear to those working on EOI that the ExCom was fully behind them.

Edward David, the President's science adviser, indicated that in the near term, the film readout system, FROG, seemed to be the correct approach. Acquiring FROG minimized risk and maximized capability. He felt costs were quite within bounds and hoped by the end of the year more options would be available for examination; David felt the entire program was "very exciting."

Near-Real-Time Was Not First Choice

When it came time for the government to choose in 1971, the initial decision was against the electro-optical system. There were intense rivalries in addition to sincere, technically disparate views that entered into this decision.... Our arguments proved sufficiently compelling for Kissinger to overrule the original recommendation and to support the deployment of the [EOI] one, and he so convinced President Nixon.

Sidney Drell

The ExCom then voted, with the following results:

- FROG would be acquired as the interim photographic reconnaissance system for crisis reconnaissance. The impact on the NRP total funding was to be minimized.

- The date of first launch of the EOI system would be delayed one year to early 1976.
- The [redacted] was to be included in the EOI system.

The ExCom then directed the DNRO to produce firm bids and costs, and a schedule for FROG—together with a new plan including costs and schedule for EOI—in about six weeks. The DNRO was directed to indicate the impact of these program changes on the total NRP budget.

The DNRO also was to include the area coverage configuration in the further development of EOI. This resulted in a modified transducer data processing subsystem design [redacted]

On 11 May 1971, David reviewed the ExCom minutes and emphasized that Schultz's letter expressed the view that the near-real-time/crisis capability should have appreciable utility—not merely a capability—during President Nixon's administration. He supported taking an imaginative view of what the EOI system might become in view of an additional year. David also said,

> *Regarding the decision on the [redacted] I believe it expresses a need for substantial [redacted] capability and implies, I hope, a direction of effort and not necessarily a stopping place with present concepts.*[1-90]

ExCom Decides on FROG Now, EOI Later

Three days after the 23 April ExCom meeting, DNRO McLucas sent out the following messages, one to Program A and one to Program B:

Program A

For:	***Gen. Allen***
Info for:	***Mr. Duckett and Mr. Brownman***
From:	***Dr. McLucas***
Subj:	***Film Readout GAMBIT (FROG)***

Our ExCom decided on 23 Apr 71 to acquire FROG for a crisis reconnaissance and interim system. I request that you submit to me before 1 July 71 bids together with a five-year budget

Program B

For:	***Mr. Duckett and Mr. Brownman***
Info for:	***Gen. Allen***
From:	***Dr. McLucas***
Subj:	***EOI***

Our ExCom, while supporting the acquisition of EOI as the new photographic reconnaissance system, has decided to impose a year's delay in first launch to early 1976. I request that

and schedule. It is expected that first flight will occur 30 months after contract initiation.[1-91]

you submit to me a viable program based on a budget o[redacted] in FY 72 and not exceed [redacted] in FY 73 as given in mix 4 of the ExCom agenda material. [1-92]

As a result of the ExCom decision, two different sequences of actions and events began to unfold. First, SAFSP, Program A's office for FROG, began to immediately communicate with the imagery user community to get far more specific requirements. By early May, meetings were held to discuss processing, distribution, and feedback cycles for FROG. Over the next three months, COMIREX spent considerable time developing guidance on processing and distribution of FROG photography. Finally, after several drafts, on 20 August 1971 COMIREX provided preliminary guidance to the NRO.[1-93] The FROG Program Office also began to develop a five-year budget and to prepare its contractors for the initiation of system definition. The contractors were held in this "marking time" status until the final decision was made in September.[1-94]

By early May 1971, Program B—DDS&T Duckett, OSP Director Brownman, and OSP Deputy Director Dirks—had examined the impact of funding both FROG and EOI and concluded that the FROG system "will take almost as long in development (as EOI) and cost considerably more than presently estimated." They were clearly disappointed and concerned that funding both systems, with an earlier IOC for the interim crisis system (FROG), could easily cause the EOI system to be delayed for the foreseeable future or even to be canceled. Their concern was whether the nation could afford and would support two systems with similar gross capabilities. This was one of two major issues concerning FROG and EOI over the next four months. The other primary issue was the system capabilities and their potential for enhancements.

PFIAB Members Express Concern About EOI Delay

Edwin Land, a strong supporter of the EOI technology and a PFIAB member, had the opportunity to express his concern to President Nixon. The PFIAB met with the President in the course of its regular meeting on 4 June. Land expressed his concern that a decision to purchase a Film Readout GAMBIT to meet the crisis coverage requirement might, because of a budget squeeze, seriously delay or even defer development of the EOI System, ZAMAN.

In presenting this matter to the President, Land pointed out that quantum advances in the development of US overhead reconnaissance capabilities had been possible only with strong Presidential backing because the financial risks were more than the executive-branch agencies could or should assume. Land characterized FROG as a cautious step and ZAMAN as a quantum jump that would give the United States an unquestioned technological lead in this field. Land was supported by another PFIAB member, Dr. Bill Baker, who stated that neither he nor Land were as much concerned about immediate planning as they were over the potential loss of the long-term commitment to ZAMAN.

Adm. George W. Anderson, Jr., the PFIAB chairman, informed Deputy Secretary of Defense Packard of the exchange with the President and then said, "In view of budgetary cutbacks, the reservations raised by Dr. Land with respect to our ability to have both appear deserving of careful study."[1-95]

One week later, the Land Panel met at the request of the President's science adviser, Edward David, to review the near-real-time photoreconnaissance program (EOI-FROG). The panel meeting was supplemented by further discussions and visits. On 24 July 1971, Dick Garwin, acting for Land, sent the Land Panel's report to David.[1-96, 1-97] Two days later, David sent the report to both Packard and Helms.[1-98]

Senate Appropriations Chairman Supports ZAMAN

During the week of 14 June 1971, William Woodruff, Special Assistant to Senator Allen J. Ellender, the chairman of the Senate Appropriations Committee, discussed with the senator the question of whether both Film Readout GAMBIT and the ZAMAN electro-optical imaging systems were needed. Packard learned of questions that arose from this discussion and decided to send a letter to Senator Ellender expressing the need for a fully coordinated position. He drafted a letter that indicated the need for and Presidential support for FROG IOC in 1974 and EOI IOC in 1976.[1-99]

There is ample evidence that nearly everyone who knew of or was responsible for the system, both inside and outside the government, believed that EOI was the imaging technology of the future. Virtually no one argued that the effort should not be pursued. The principal attraction of FROG was its projected cost (about $450 million, compared to [redacted] for ZAMAN) and its anticipated availability two years earlier than ZAMAN. While all of the key players agreed EOI was the future, there was considerable uncertainty on exactly how soon this new technology could be brought on line. There were questions about the confidence they could have in the projected cost data on ZAMAN. NRO experiences in the late 1960s and early 1970s indicated that new systems (such as HEXAGON) cost significantly more than initially estimated. Others countered this criticism by noting that the major reason for cost "overrun" was changing the requirements.[1-100]

This uncertainty in the technology and the cost shifted the emphasis toward near-real-time ZAMAN program. There was a considerable body of belief both in the NRO—particularly in Program B—and among advisers such as the Land Panel that building and flying FROG would so dilute funding for ZAMAN as to presage its eventual demise.

On Monday, 21 June 1971, Woodruff called DDS&T Duckett, told him of the information being provided him by the Pentagon (Program A), and asked Duckett to privately brief Senator Ellender on the two systems. Duckett gathered his briefing boards and drove to Capitol Hill, where he spent several hours that afternoon explaining the differences between the two systems to Woodruff and Ellender.

In promoting its FROG program, the Air Force had stressed the fact that it was an "upgrade" of the GAMBIT-3 KH-8 camera, which already was famous for obtaining the highest-resolution overhead photography then available. Many senators and high-level officials believed the end product of the FROG system would be as good as then current KH-8 photography. Duckett had to correct this erroneous perception. His major argument was that because the FROG system would use Polaroid-type film, it would lack the fine resolution of standard satellite film and would be substantially poorer than the current GAMBIT-3 product. Also, Duckett pointed out that the flying-spot scanner, a device developed for the ill-fated SAMOS program in the late 1950s, would further reduce the resolution of the imagery, so that the reconstituted imagery at the ground site probably would be poorer than existing CORONA KH-4 photography.*

The EOI system, on the other hand, would use neither film nor a flying-spot scanner. Instead, each microminiature solid-state sensor would sense the light coming from a discrete point on the Earth and produce a photocurrent directly proportional to the amount of light sensed. Having neither film nor moving parts, the EOI device promised greater resolution as well as a much longer life on orbit.

At the time of this unusual meeting, Senator Ellender was the oldest man in the Senate; he would celebrate his 81st birthday in three months' time. He had been a senator since 1937 and was the power to be reckoned with when it came to appropriations. Ever since Carl Duckett had become DDS&T in late 1966, he had made an effort to cultivate Senator Ellender and his assistant, William Woodruff; Duckett had personally kept both men briefed on the various systems under development within his Directorate. Duckett also played on the fact that both he and Ellender were from the South.

During his briefing, Duckett reminded the elderly solon that he, Senator Ellender, had approved the EOI development the previous year and had suggested changes in the program that had been duly made. Duckett congratulated the Senator for his vision in backing the ZAMAN effort. Ellender was highly impressed and even flattered by the time Duckett completed his briefing, and the Senator directed Woodruff to write a letter stating that the Senate Appropriations Committee was going to support "my new system."[1-101]

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* SAMOS, the program from which CORONA had been spun off, had been an attempt in the late 1950s and early 1960s to build a constellation of satellites with a wide range of reconnaissance capabilities. Although SAMOS progressed through several system concepts and payload cameras, the necessary technology was not in reach at that time, and the program was canceled.

[redacted]

Duckett's success was evident within a week. When Senator Ellender's letter reached Deputy Defense Secretary Packard and DCI Helms, it said that the Senate Appropriations Committee would approve funding of only one of the two programs and added that the Committee hoped it would be CIA's EOI program. The Ellender letter had a definite effect on subsequent discussion of the matter. During a conversation after a meeting of the National Security Council on 30 June 1971, Packard told Duckett, "It might indeed be a good idea to drop FROG and proceed with EOI since that would allow Senator Ellender to feel that he had won a point, which might in turn take some of the pressure off other defense intelligence programs."[1-102]

Duckett's View: ZAMAN Technological Issues Understood

At the 15 July 1971 meeting of the ExCom, Duckett pointed out, "We will soon have put [redacted] into this program. This will significantly reduce our risk in committing to a development program."[1-103] As a result of these efforts, the OSP engineers and their contractor team had found means for overcoming numerous technical problems, including the following:

- Demonstrating the capability of solid-state transducers to reproduce usable imagery.
- Developing a transmitter to handle high data rates at ultra-high frequencies with low power-consumption levels.
- Designing an antenna able to withstand extreme temperature gradients.
- [redacted]
- Initiating plans for the largest mirror [redacted]
- Directing various contractor efforts to design high-density digital tape recorders and tape coatings for making a permanent record of the imaging data.

As a result, the team—government and partners in industry—believed it had a good grasp of the major technological issues that might be encountered.[1-104]

Kissinger Steps In, Requests Outside View

When Dr. Henry A. Kissinger, the assistant to the President for national security affairs, learned about the Senate Appropriations Committee's concern over the Nixon Administration's decision to proceed with both FROG and EOI and about Senator Ellender's letter recommending funding only one system, he realized the

FROG-EOI issue was still very much alive. Kissinger had his chief of staff, K. Wayne Smith, get in touch with DDS&T Duckett on 28 July 1971 to find out whether an impartial person from outside the government could give Kissinger a tutorial to help him fully understand the near-real-time imaging problem. Duckett told Smith that IBM's Dick Garwin and Stanford University's Dr. Sidney D. (Sid) Drell, both members of Land's National Reconnaissance Panel, were very knowledgeable on the subject.

The very next day, Thursday, 29 July 1971, when Duckett convened a meeting of the CIA's Strategic Intelligence Panel, he spoke to member Drell about Kissinger's request for a briefing. Drell said he would contact Garwin and arrange a time when the two men together could brief Kissinger. Without informing Secretary of Defense Melvin R. Laird or DNRO McLucas, they came to Washington in late August and gave Kissinger a detailed briefing on the near-real-time imaging problem.[1-105]

ZAMAN Has Potential To Replace GAMBIT, But HEXAGON Is a Problem

As a result of the April 1971 ExCom meeting, the Deputy Director of the NRO asked Program B to examine extending EOI capabilities [redacted]

OSP Director Harold Brownman responded on 13 July 1971 with a memorandum stating that the EOI design then in system definition had the capability to replace the GAMBIT system. In addition, it would provide a substantial increase in the volume of high-quality imagery for technical intelligence problems over that provided by GAMBIT.

On the other hand, neither the EOI design nor any of its foreseeable derivations could come close to providing the capacity necessary to perform the search functions of HEXAGON. Brownman noted that technology programs were under way to exploit that possibility but that he could see no likelihood of their coming to fruition for three to five years. However, he indicated, when they did, the search capability could be integrated into the [redacted] EOI system.

[redacted]

The Land Panel Report: Go For EOI

The National Reconnaissance Panel, better known as the Land Panel, issued a key report on 14 July 1971, offering its judgments as to the relative merits of the competing EOI and FROG programs. Among the key conclusions drawn by the Panel and documented in its report were the following:

- EOI would have a best nadir ground sample distance of [redacted] with a [redacted] mission duration. FROG would have a best nadir ground resolved distance of 24 inches, but could be operated for a limited time at an altitude of 85 miles, which would provide a GRD of 12 inches.

- At a [redacted] ZAMAN images were judged clearly superior to the best GAMBIT images, while at an [redacted] they were judged somewhat inferior to the best of GAMBIT. (At that time, GAMBIT usually was said to have an [redacted])

- EOI would have many more accesses at a GSD below 12 inches than did GAMBIT at GRD of 14 inches; therefore, EOI could replace GAMBIT. EOI could provide multiple views of the same structure from a range of angles on a single pass, while, FROG, which was limited to roll only, could not.

- Near nadir, FROG would have very little capability to monitor lines of communication (LOC). At large obliquity, FROG would have greater LOC coverage, but at a substantial sacrifice in resolution. EOI, even in its original framing mode, could acquire coverage of a minimum of 60 miles per pass. In the stripping mode, it could cover some 450 miles of typical LOC.

- [redacted]

- While EOI had demonstrated the performance of the developmental items that had been exposed to critical appraisal for at least the last two years, certain tasks remained to be accomplished, including:
  — Achieving adequate thermal control of the detector array.
  — Choosing the optimum means of continuously calibrating each detector.
  — [redacted]

Henry A. Kissinger

Sidney D. Drell

Land Panel's Impact

> *. . . the Land Panel's most important role was assessing the development technologies of electro-optical imaging, forecasting the extent and pace of their development, supporting the work of Les Dirks and his colleagues to advance our technical and production capabilities for large arrays of electro-optical sensors, and eventually convincing the officials in Washington that this technology was the direction to go for* [redacted] *imagery.*
>
> ***Sidney Drell***

The Panel was confident that this work could be performed successfully on the required time scale.

On the other hand, FROG would require the development or adaptation of many techniques and pieces of equipment new to the program and to the contractors. These included bi-mat processing with one-year life, which would involve precise thermal control; a laser scanner–film guide; roll joint modifications; zero-g propellant; and flexible solar cell arrays.

These capabilities appeared to be achievable, but the Panel members' past experience with analogous development programs indicated that there was a substantial risk in successfully achieving all these capabilities on schedule.

The Panel concluded that the risk associated with FROG on the stated schedule was likely to be greater than that associated with EOI on the schedule that delayed IOC by one year. The Panel believed that the EOI design would not benefit from the operational experience of FROG because such experience would not be available to any significant extent until mid-1975, and delaying the EOI procurement until then would postpone EOI operation to 1978 or 1979.

Their comparisons showed that the performance of FROG would be substantially inferior to that of EOI. FROG would be operated only as an interim program, and the longer EOI was delayed, the longer the United States would be denied the much superior EOI product. The panel felt that the development of the EOI system was inevitable. The question, they said, was not whether the United States would spend $675 million to build FROG to fly by the end of 1973 or [redacted] to fly EOI by the end of 1974, but whether having an inferior product one year sooner and risking the resulting delay of the superior capability was worth $675 million more. The panel also noted that the EOI system had substantial growth potential that could be accommodated in subsequent improvements such as [redacted]

The Panel believed that recent decisions had been based on two misconceptions: that EOI and FROG were sufficiently similar in performance that the two were alternates, and that the risk in developing FROG was substantially less than that in building EOI. Members of the panel who signed the report were: Chairman Edwin Land, William Baker, Sidney Drell, Richard Garwin, Marvin Goldberger, Donald Ling, Allen Puckett, and Joseph Shea.

Various officials reacted in several ways to the publication of the Land Panel report. It is evident that Packard was not convinced that the optimism of the Panel was well founded. He apparently still harbored doubts as to the maturity of key technologies in ZAMAN and wanted to proceed slowly in the development of the EOI program. It is equally likely that Packard was being urged by some in the Department of Defense (DoD) to move in the direction of acquiring an interim readout capability. The idea that some [redacted] imagery in the short term was better than a lot of [redacted] imagery in the long term was certainly prevalent at that time.

As a result of these differences of opinion, a memo prepared by the President's Science Adviser, Edward David, for the signatures of DCI Helms and Deputy Defense Secretary Packard, laid the decision between FROG and EOI squarely in the lap of President Nixon. It provided four options:

- Procure FROG now for launch in early 1974, and delay EOI for two years so that the first EOI satellite would be launched in 1978.
- Procure FROG now for launch in early 1974, and procure EOI in December 1971 for launch in 1976.

- Procure only EOI, for launch in 1976.
- Procure only EOI in a shorter time frame by undertaking a riskier, "crash" program.[1-108]

Dr. Garwin: Dr. Kissinger, Make a Firm, Irrevocable Decision!

Meanwhile, in the summer of 1971, during a Land Panel meeting, Garwin noted that he and Drell were to see Kissinger regarding EOI.[1-109] On 11 August, after reviewing NRO documents and meeting with the NRO Staff, Garwin, in response to a request for advice to Kissinger and Wayne Smith, personally typed a memorandum that he made clear contained only his advice to them. Included in the memorandum were the following points:

- "I am satisfied that there are viable alternatives for limited interim systems more desirable than those actively considered recently [redacted] and HEXAGON 11-Pack).

- "My bureaucratic judgment is that no true interim system decision can be made until a firm and essentially irrevocable commitment has been made to acquire EOI (ZAMAN) on the time scale proposed and with the budget as stated.

- "True interim system preferences: I do not regard systems like FROG or a possible film-read-out HEXAGON as interim systems. FROG is too expensive and too capable for an interim system and not good enough for the continuing need."

In closing the memo, Garwin stated, "I speak for no one but myself, and no one speaks for me in this matter."[1-110]

DCI: Mr. President, Don't Delay EOI and Don't Buy FROG!

On 9 August 1971, DCI Helms sent a memorandum to the President, succinctly summarizing the situation in the following manner:

> *Since 1969, the Executive Committee of the National Reconnaissance Program has been proceeding with a deliberate, well funded program leading to development of the EOI system. In April of this year, when we received an indication from Mr. Schultz that you wanted a readout capability within your administration, we tentatively selected FROG, the most capable but also most costly of the interim possibilities, to be built along with EOI. Subsequently, our own concern about the overall size of the budget and direct opposition from Senator Ellender have combined to make it apparent that this*

plan is fiscally impractical. Thus, we are still seeking a solution to what we understand to be your desire for an earlier capability, and since there is a range of possibilities with varying degrees of utility and cost, we are submitting the issue to you for decision.

Crucial to this whole issue are the estimates about when various systems could be ready and what they would cost. Both FROG and EOI would require substantial development and both are liable to schedule slip and cost overrun. I am persuaded by the studies of Dr. Land and his Panel that on schedules of comparable urgency FROG and EOI are only a year or so apart.

The question that we are trying to answer is how much to pay in terms of money or other intelligence capabilities in order to improve our capacity for crisis reconnaissance during a one year period or so in 1974-1975. My conclusion is that closing this gap is not sufficiently important to pay the cost of the FROG program, a two year delay in the availability of the much more powerful EOI system, and the risk of deferring EOI indefinitely.

In summary, I share fully the desire to have a highly responsive photo satellite capability at the earliest time. I am, however, also concerned about improving our SALT monitoring ability and maintaining the economic viability of our overall photo reconnaissance program in the future. Because EOI will do these additional things and is technically ready to begin development, I would like to proceed with it as soon as possible. Because FROG will not do these additional things, I do not think it is worth the $600-700 million to develop and operate it over the next five years.

Helms then identified a range of options and recommended a preferable option that was similar to an option acceptable to Packard and David.[1-111]

Secretary of Defense: Mr. President, Buy Only an Orderly EOI Program

On 17 August 1971, Secretary of Defense Melvin Laird sent a memorandum on the readout satellite issue to the President. Laird noted that:

The Executive Committee (ExCom), which supervises our National Reconnaissance Program (NRP) has been examining the question of how best to achieve a readout capability which would provide daily return of photographic coverage from *space. . . . The Executive Committee agrees upon the development of the Electro-Optical Imaging System as the most capable and most useful such system. With an orderly development program and funding limited to about [redacted] per year, the EOI would be ready by about 1976. The committee concurs in this judgment and this is the course I strongly recommend.*

The Secretary also mentioned, however, that members of the committee disagreed on how best to achieve an earlier capability. Helms believed the EOI system could be available earlier with a higher funding level as suggested by the Land Panel. Packard did not believe this could be done and thought that the President should not be asked to count on it. Edward David shared Packard's doubts about having an EOI system earlier than 1976 and further believed it would be better to start with the Film Readout GAMBIT and plan to bring in the EOI system later. Helms believed there were better ways to obtain an earlier capability than with FROG.

This disagreement among the members of the ExCom was generated by the great uncertainties about how best to proceed with an interim system under a budget limitation.

The Secretary of Defense believed there were no compelling needs to have a [redacted] system by any specific date. Therefore in his memo he recommended proceeding on the EOI with an orderly program that would provide a capability in 1976 or perhaps somewhat earlier. He recommended against any of the other interim proposals considered by the ExCom. Laird then identified two options:

- Approve the EOI program with annual funding of [redacted] and an operational date of 1976.

- Approve an alternate program if an earlier operational date was desired, realizing that would require a higher level of funding: an additional $100 million or more per year.

Laird noted that if the second were selected, additional work would be required to prepare appropriate options.[1-112]

The President's Decision: Go For EOI, Stop Development on FROG

On 23 September 1971, Kissinger signed a very brief memo announcing that President Nixon had decided to proceed with the development of the EOI System figure 1-6.[1-113]

When the President approved that memo, he marked the end of FROG and the beginning of EOI's march toward an operational capability.*

President Richard M. Nixon

* OSP Director Harold Brownman made a very interesting and significant comment regarding this competition: "It was good—it caused everyone to stretch and achieve."[1-114]

THE WHITE HOUSE

WASHINGTON

~~TOP SECRET/BYEMAN~~

September 23, 1971

MEMORANDUM FOR

The Secretary of Defense
The Director, Office of Management and Budget
The Director, Central Intelligence
The President's Science Advisor
The Chairman, President's Foreign Intelligence Advisory Board

SUBJECT: Near-Real-Time Satellite Reconnaissance System

The President has carefully considered the various options presented to him regarding the development of a near-real-time satellite reconnaissance system. He has decided that the development of the Electro-Optical Imaging (EOI) system should be undertaken under a realistic funding program with a view towards achieving an operational capability in 1976. In addition, he has decided that there should be no further development of the Film Read-out (FROG) system.

Henry A. Kissinger

SECTION 2

KENNEN SYSTEM

Approved for Release: 2021/07/09 C05097836

KENNEN: The Development Phase

With President Nixon's decision to proceed with a near-real-time (NRT) space reconnaissance system, a major development program was begun. Over the next several years, activities included specific system development efforts, refinement of the importance and type of information to be collected, and integration of the parts of the system—imaging satellites (I/Ss), relay satellites (R/Ss), and ground station—into a single system.

ExCom Directs DNRO To Acquire EOI

On 23 November 1971, the Executive Committee (ExCom) of the National Reconnaissance Office (NRO) met to formalize the Nixon Administration's memorandum of 23 September approving the development of ZAMAN, the electro-optical imaging (EOI) system. The committee issued the following directive:

> *The DNRO will initiate acquisition of the EOI Program and assure that the schedule and budget established for the Relay Program are consistent with the EOI.*[2-1]

This decision resulted in the acquisition, development, and operation of the most ambitious and technically challenging program ever undertaken within the Intelligence Community. The system would consist of a constellation of imaging and relay satellites together with a ground station for the processing, initial analysis, and dissemination of the imagery.[2-2] The ZAMAN EOI program soon became the primary growth area of the National Reconnaissance Office's Program B, and received a larger share of the National Reconnaissance Program's (NRP's) budget than any previous effort had.

ZAMAN: Best Example of Pre-Acquisition Work

When the ExCom met in November, there was considerable discussion concerning the EOI program. Dr. John L. McLucas, the Director of the National Reconnaissance Office (DNRO), recalled the following comment made at the end of the Executive Session:

> *This program is the best example of doing the fundamental work behind a proposed system, followed by system studies and design competition. So we now are really ready to go ahead with systems acquisition.*[2-3]

Most of the remaining EOI discussion was concerned with the Five-Year Defense Plan (FYDP). It is interesting that the budget options being discussed were for a program costing around [redacted] The actual ZAMAN program approval was for [redacted] that was changed to [redacted] in the spring of 1972. Initially the first launch was scheduled for October 1976.[2-4, 2-5] The program stayed within budget, and a successful first launch took place in December 1976.

The Birth of a New BYEMAN System: KENNEN

On 24 November 1971, the day after the ExCom approved the EOI system acquisition, Dr. F. Robert Naka, Deputy Director of the NRO retired the ZAMAN codename and announced a new BYEMAN codename of KENNEN for the EOI Program.[2-6] The next few weeks were very busy for the NRO and the new KENNEN Program Office (KPO). On 7 December, McLucas completed the formal establishment of the program, assigning overall system acquisition and operations responsibility to NRO's Program B, the space reconnaissance element of the Central Intelligence Agency (CIA), and responsibility for launch vehicle procurement, integration, and launch operation to Program A, the space reconnaissance element of the Air Force. Responsibility for the communications relay satellite program was assigned to the Chief of Staff, US Air Force.[2-7]

Responding to the ExCom decision, CIA took steps to prepare the Intelligence Community for the new EOI system. Early on, members of the user community recognized that they could not effectively exploit the radical new collection capabilities of the EOI system unless they realigned and modified many of their daily procedures and information flows. The Community would have to identify and specify its information needs, establish their relative priorities, relate needs to specific targets, task the EOI system, observe system response, evaluate the degree of success and needs satisfaction, disseminate imagery and extracted information to consumers, and repeat the cycle in an orderly and effective manner.[2-8] On 29 November, a study group led by Richard J. Kerr and composed of representatives from the CIA's Directorates of Intelligence and Science and Technology was formed to investigate KENNEN's forthcoming impact on the Community's tasking, exploitation, and reporting requirements.*[2-9]

[redacted] KENNEN System Design: Early Decisions

During KENNEN's early development stage, a number of decisions affecting the system design and its capabilities were made to keep the program on schedule.

* Kerr, a CIA intelligence analyst, later became the Deputy Director of Central Intelligence.

What Impact Will This New System Have?

> *The Group worked closely with the program office, but its real constituency was the analysts and the collectors. The Group worked on every aspect of the imagery cycle—requirements, tasking, exploitation, dissemination, and use of imagery in all-source analysis. It even produced an animated film that was put together by a former Disney artist in Hollywood.*
>
> ***Richard Kerr***

The close relationship that developed between the KENNEN Program Director, Leslie C. (Les) Dirks, and the Chairman of the Committee on Imagery Requirements and Exploitation (COMIREX), Roland S. Inlow, ensured that agreement was reached in a minimum of time on such issues as:

- Selecting film format and product form.
- Excluding mapping, charting, and geodesy (MC&G) capabilities from the initial specifications.
- [redacted]
- Developing the COMIREX Automated Management System (CAMS) in-house rather than through contractors directed by the KENNEN Program Office (KPO).

Other Community-related problems and issues addressed by Inlow during this time period were:

- The difficulty in getting the user community to focus rigorously on readiness for the new system capabilities.
- [redacted]
- [redacted]
- Ground site processing and tasking functions and their relationship to off-site functions, including communications to the ground site and technological limitations.

- Factors affecting release of planning data and notification of new capabilities to the United Kingdom, Canada, Australia, and New Zealand.[2-10]

Anticipation

> *Although the Intelligence Community had plenty of time to prepare for the advent of the new system . . . I don't think anyone anticipated the impact that a near-real-time system would have on the community at large.*
>
> **John McMahon**

Sizing the Initial Target Deck. The initial COMIREX target deck was limited to [redacted] to minimize the number of targets that the collection planning and targeting (CPAT) software would have to consider on each imaging pass. A conscious effort was made to balance the specification of the user requirements with the EOI system's operational factors. The concept was that many low-priority targets could be moved into the target deck whenever the specific need for them to be imaged arose, but in the meantime, they would not overload the software with their presence day in and day out. This arrangement was controversial because a number of people in the Department of Defense (DoD) and DIA (Defense Intelligence Agency) argued strongly for having the entire set of world targets—all U&S Commands' targets to the tactical level, the Strategic Air Command's (SAC's) full strategic target list in detail, and so forth—a number far in excess of [redacted] at that time, in the operations software deck at all times.[2-11]

Advanced Technology: Security Concerns. Security for overhead imagery programs was historically provided through two separate channels: The BYEMAN system controlled access to technical and operational data, and the TALENT-KEYHOLE (TK) system protected the actual imagery and imagery-derived products, including intelligence reports. The BYEMAN system, controlled by the NRO, had strict need-to-know criteria and proliferation of accesses was a key concern. The TK system was managed for the Director of Central Intelligence (DCI) by the Chairman of COMIREX. Most Community users required only the TK access, which provided adequate system data to perform their planning and development tasks. The new KENNEN System placed considerable pressure on the existing TK system. KENNEN's near-real-time imaging capabilities would require additional time and people to plan for its effective utilization. [redacted] To solve these problems, a new security compartment, [redacted] was established within the TK System. [redacted] provided Community personnel directly concerned with KENNEN planning the information that they needed, but did not expose the program to everyone who had a TK clearance.

In the fall of 1972, the NRO prepared a document called *KENNEN System Description* and released it within the [redacted] channel, which used the new TK system designator KH-11.[2-12] This document provided a common reference for the imagery user community's long-range planning. It described in general terms various aspects of the KH-11 satellite reconnaissance system, including performance capabilities and the preliminary concept of the system tasking–response cycle.

DS&T Sheds HEXAGON Responsibilities

At the outset of KENNEN, responsibility for the HEXAGON (KH-9) payload and payload operations software was transferred from Program B, in the CIA's Directorate of Science and Technology (DS&T), to Program A, the Secretary of the Air Force Special Projects (SAFSP), which already had responsibility for the spacecraft and spacecraft-related operations. This transfer was noteworthy because many thought it was intended to partially offset SAFSP's loss of the Film Readout GAMBIT (FROG) Program. Others took the less political view that the purpose of the transfer was to allow the CIA Program Office to concentrate its resources on the new KENNEN Program. Whatever its underlying reason, the transfer served both purposes and was readily supported by both Program Offices. The transfer agreement was signed by these two organizations in March 1972, six months after President Richard M. Nixon had approved KENNEN.[2-13]

KENNEN Program: Disciplined Management Structure Evolved

The newly formed KPO soon published a *System Management Plan*, which was to serve as its primary management control for KENNEN development. The plan identified the key activities necessary to provide timely assessment of current system objectives, performance, cost, and schedule. The plan also established a Configuration Control Board (CCB), which provided formal control of the hardware, software, procedures, facilities, and other defining documents composing the system-level configuration of the KENNEN System.[2-14, 2-15] Changes to any hardware, software, or standing procedures—however major or minor—could not be made without CCB coordination and approval. This ensured that all affected elements of the Program took whatever necessary action the CCB directed.

System Segments Defined: KENNEN Program Gets Organized

Because of the tremendous complexity of the KENNEN Program and the many components that would have to be integrated for successful operation of the overall system, it was decided early on that the major components and tasks would be defined by "segments." The technical challenge of the KENNEN System was beyond the capacity of any single contractor; therefore, the defined segments were released to selected contractors on a competitive bid basis. There were exceptions in a few areas where the US government had a large investment in facilities and research.*

* For example, [redacted] was selected as the supplier of the optics subsystem and designated Segment 6.

During the development phase, 15 segments were identified; as the program evolved others were added. These initial segments are described in table 2-1.

Segment Accountability

> ***The hallmark of how this project was managed was accountability. We developed a government management organization where a single manager was accountable for an end item delivery and accountable for the cost, schedule, and performance of that end item. These people were called segment managers, and the end items called segments. The contractor relationships were similarly aligned, so that there was no doubt who was accountable for each piece of the program.***
>
> ***Robert Kohler***

KENNEN Acquisition: Let the Contest Begin

With the system segments properly defined, the KPO's efforts turned to system acquisition.

In December 1971, the Program Office published a final *System Requirements Document* (SRD), which established the minimum performance criteria for the new EOI system. A set of system specifications—which could be traced directly to the SRD—also was published, and so was a third set of documents, which set out the lower-level segment specifications. The segment specifications were detailed further in the work breakdown structure, which was to provide a critical management tool for the KENNEN Program Office during the subsequent development phase. All specifications, interface control documents (ICDs), and schedules were placed under Program Office configuration control and managed by the Program's Configuration Control Board.

During this process, the Intelligence Community, through COMIREX, provided inputs and guidance to ensure the SRD met the underlying collection requirements for indications and warning (I&W) and scientific and technical (S&T) intelligence.* Community requirements expressed in terms of number of images per day at a particular spread of ground sample distance (GSD) and signal-to-noise ratio (SNR) were translated to requirements for each of the segments. For the imaging satellite segment, for example, they appeared as requirements for power; spacecraft pointing agility; and performance of the optics, transducer, and communication subsystems.[2-16]

* COMIREX was under the aegis of the United States Intelligence Board (USIB) and was charged with documenting the coordinated national imagery requirements for the KENNEN Program Office.

Table 2-1. KENNEN Segments

Segment	Title	Description
1	Systems integration	Responsible for defining KENNEN System Requirements and ensuring their verification.
2	Imaging satellite (I/S)	Satellite vehicles deployed in low-altitude Earth orbits, and associated test and support equipment. [redacted] I/S is equipped with an electro-optical imaging capability consisting of a large-diameter [redacted] optical system; a sensor [redacted] and the subsystems necessary to support the acquisition, transformation, and transmission of the image and telemetry data.
3	Receive facility (R/F)	Two large-aperture [redacted] antennas enclosed in radomes, an S-band antenna, and an equipment room within the Operations Building with associated equipment, software, and personnel providing the single ground communications terminal between the spaceborne and ground-based KENNEN segments. It provides for the transfer of all received image data to the Processing Facility, all telemetry and tracking data to the Operations Facility, and all commands to the I/Ss and to the KENNEN System payload on the relay satellites.
4	Operations facility (O/F)	Computer hardware and software, equipment, and personnel located in the Operations Building required to perform the integrated operation and control of the KENNEN System. Performs collection planning and targeting, assembles and generates commands for all satellites, performs the reduction and analysis of all telemetry, prepares the necessary correlation data pertaining to the imagery acquired, and assesses overall system performance.
5*	Processing facility (P/F)	Equipment, computer hardware and software, and personnel located in the Operations Building required to record, process, and reconstruct the received digital image data into interpretable hardcopy imagery in near-real time.
6	Optics subsystem (O/S)	[redacted]
7	Relay satellite (R/S)	Satellites carrying KENNEN image data communications payload. Satellites are deployed in [redacted] Earth orbits so as to be in view of both the R/F and an I/S when the latter is actively acquiring imagery. R/S segment also consists of associated software, test, and support equipment.
8	KENNEN ground station (KGS)	Operations Building and all other dedicated ground facilities necessary for implementation of the KENNEN System.
9	Exploitation facility (E/F)	Located in the Operations Building, performs the initial phases of exploitation of KENNEN imagery.
10	Air Force Global Weather Central (AFGWC)	Provides planning and revolution-by-revolution weather forecasts to the Operations Facility in support of I/S imaging planning and operations.
11	Launch Vehicle Integration Office (LVIO)	Integrates all activities pertaining to the launch of the I/S [redacted] transfers, launch hardware, and launch operations.
12	Relay Program Office (RPO)-Satellite control facility (SCF)	Controls the R/S vehicles and all R/S payloads except for the KENNEN communications package.
13	Terrestrial communications (T/C)	Provides all ground communications links between the KGS and remote segments and facilities as required to support KENNEN System operations.
14	Relay program office-Western test range (WTR)	Performs all WTR support functions required for Segment 7 (R/S) and its launch vehicle.
15	Interface (I/F) segment	Provides selected imagery data in compressed form to the Defense Dissemination Program. The primary recipients of the imagery data are to be the Unified and Specified Commands.

*This segment was subsequently divided into two segments, segment 5 and segment 17. Segment 17, the photo processing facility (PP/F), reconstructs the digital data received from the digital processing facility (DP/F) into hardcopy images.

When all was ready, the contractors received their requirements packages—and the race was on.

Decisionmakers Well Informed; Reviewed Key Competitors Before Award

Senior government decisionmakers took an active interest in the KENNEN procurement and its impressive technical challenges. Toward the end of the competition, Deputy Secretary of Defense David Packard visited General Electric (GE), the Boeing Company, and Lockheed Missiles and Space Company (LMSC), which were competing for the imaging satellite; and Hughes Aircraft Company, which was competing for the relay satellite.[2-17, 2-18] Dr. Albert D. (Bud) Wheelon, then head of Hughes Space and Communications, recalls accompanying Packard to his plane.* As they got out of the car, Packard stopped, turned and put his hand on Wheelon's shoulder and asked, "Engineer to engineer—can we do it?" Wheelon replied, "It will be very challenging, but yes, I believe we can do it."[2-19]

Selection Process: Critical Decisions

Proposals for segments 1 through 4 were submitted on 30 September 1971 by GE, LMSC, and the Boeing Company. Proposals for segment 5 were submitted by E-Systems and General Dynamics.

The government source selection organization was fairly straightforward in composition. The source selection authority was Harold L. Brownman, the director of the CIA's Office of Special Projects (OSP). The Source Selection Evaluation Board (SSEB) was headed by Charles R. (Charlie) Roth, the KENNEN program manager. Panels consisting of representatives from the CIA, Air Force, DIA, DoD, and the Aerospace Corporation (for technical consultation) were constituted to evaluate technical, cost, and management volumes. The panel chairmen—together with the KPO's program manager, segment managers, security officer, and contracts officer—were members of the SSEB. Proposal evaluation was organized down to the work breakdown structure level in an effort to achieve both detailed and consistent results. Panel members and the SSEB held lengthy discussions in order to understand how their respective ratings had been reached. Cost realism was determined soley by the SSEB and the cost panel so that cost data could be withheld from all other evaluators.

The task of selecting the winners fell to Harold Brownman. [redacted] were very close in the SSEB scoring for segments 1 through 4. Brownman made a decision that was not anticipated. He concluded that no single corporation had the resources to perform successfully on all four segments. The SSEB had judged that while [redacted] was best suited to build the imaging satellite (I/S) [redacted] had submitted the best proposals for the system integration (SI), receive facility (R/F), and operations facility (O/F) segments. The surprise result was that Brownman split the award along

* Wheelon, after serving as the CIA's Deputy Director for Science and Technology from 1963 to 1966, had joined Hughes as a senior executive.

these lines. While this meant a small cost increase, overall program costs still fell within FYDP forecasts. [redacted] was selected over [redacted] as the processing facility (P/F) contractor. The ExCom and the DNRO concurred in Brownman's recommendations and commended the entire team for its outstanding work.[2-20]

Go-ahead for the Data Relay Satellite was planned for February 1972, with an acquisition program compatible with KENNEN projected schedules.[2-21]

KENNEN Budget Approved: Adequately Funded

DNRO McLucas and NRO Comptroller [redacted] authorized a budget that covered all segment costs as well as a funding reserve for engineering changes, which was unique for NRO programs. This reserve was to be used by KPO for unexpected problems, but would require [redacted] authorization on a line-by-line basis. A total program funding profile had been developed with the understanding that it could be modified as system definition proceeded and changes were made to the system configuration and the internal schedules. This profile resulted from both contractor input and government estimates, the government leads being [redacted] the KPO contracting officer, and Maj. Jimmie D. Hill (US Air Force, who headed the KPO budget staff).* Limits were placed on initial acquisition funding, and the reserve (engineering change line) was profiled to provide the largest amounts in years three and four of the development cycle. This engineering change line provided flexibility in program spending and kept segment overruns within the overall budget. The actual cost to first launch was [redacted]—amazingly close to the initial estimate.[2-22]

Selections: Not All Winners Are Ecstatic

By 1 December 1971, all of the necessary government decisions, including source selection, had been made and the approvals had been received. It was time for the initial contracts to be let and the winners notified (table 2-2).

The largest contract and the one considered the plum was for the imaging satellite (segment 2). [redacted] program manager, [redacted] received a telephone call from Charlie Roth, which set off a celebration in [redacted]

[redacted] was informed that it had been awarded the systems integration (segment 1), receive facility (segment 3), and operations facility (segment 4) contracts, but its team was initially disappointed because it had lost the contract for the imaging satellite. A contractor system integrator was a new concept in NRO programs, [redacted] was yet to realize the full extent of its win.[2-24]

[redacted] was selected as prime contractor for the processing facility (segment 5), which was another big win.

* Hill later became the Deputy Director of the National Reconnaissance Office.

Table 2-2. KENNEN Acquisition, Major Contractors

Number	Segment Term	Segment Name	Contractor
1	SI	Systems integration	[redacted]
2	I/S	Imaging satellite	
3	R/F	Receive facility	
4	O/F	Operations facility	
5	P/F	Processing facility	
(5)	DP/F	Digital processing facility	
(17)	PP/F	Photo processing facility	
6	O/S	Optics subsystem	
7	R/S	Relay segment	Hughes Aircraft

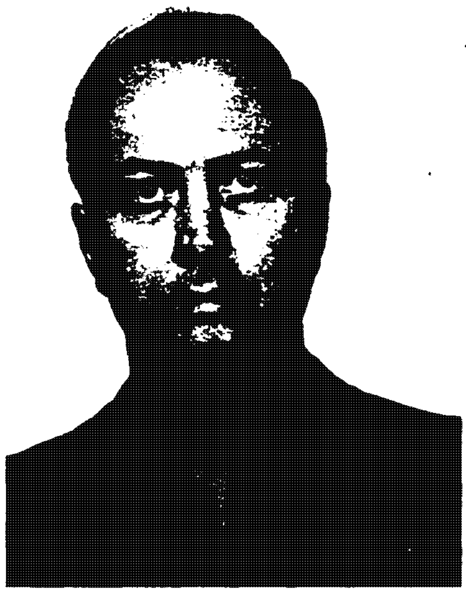
[redacted] was responsible for a collimator and for finishing a 72-inch mirror [redacted]

Some weeks later, in early 1972, Hughes Aircraft Company was selected as the prime contractor for the relay satellite (segment 7). Additional winners were [redacted] for the PP/F [redacted] subcontractor [redacted] for the I/S's communications subsystem and the antenna directional control assembly (ADCA); and [redacted] both as subcontractor to [redacted] for the [redacted] antenna and S-band antenna, [redacted] for the R/F's [redacted] antennas and communications hardware.

Building the System: The Hard Work Begins

After contract award, all KENNEN contractors, subcontractors, and suppliers began their work in earnest. The KENNEN System concept toward which all preparation had been directed is shown in figure 2-1. At the center of this system is the imaging satellite; its major assembly components and corresponding development contractors are identified in table 2-3.

By the spring of 1972, a coordinated EOI System schedule had been prepared. It contained the milestones for each of the major segments and called for an initial operational capability (IOC) by October 1976.[2-25] Much of the technology needed to build the KENNEN System was in hand, but an impressive number of technical challenges still remained to be met in the next four years. The following sections describe a few of these challenges along the road to a KENNEN System that was to prove remarkably successful.



Jimmie D. Hill

The [redacted] New Management Approach for I/S Development

[redacted] progressed toward the formal competitive phases of KENNEN, its management realized that the size and technical challenges of the program warranted special attention to program structure, management, and personnel. [redacted] Vice President and KENNEN Program Manager [redacted] won two important concessions from his top management:

- He could recruit specific individuals, even those considered critical to other programs, with the guarantee that in the event [redacted] did not win KENNEN, they were guaranteed other jobs within [redacted] without loss of salary or perquisites.

- He could "projectize"—issue policies and procedures specific to the KENNEN program—to the extent that he wished within [redacted] The only restriction was that the policies and procedures not violate existing federal policy or regulations.[2-26]

The ability to seek the most talented people within the company permitted [redacted] KENNEN management to build an exceptionally strong team. [redacted] himself later became general manager of [redacted] a position he held for 10 years, and he subsequently ended his career as [redacted] executive vice president. For KENNEN, [redacted] recruited as his deputy [redacted] who had been

Page Denied

Table 2-3. KENNEN Acquisition, Additional Contractors

Term	Subsystem	Contractor
ADCA	Antenna directional control assembly	[redacted]
	Communications antenna	
[redacted]		
	Image chain performance program	
OBC	Onboard computer	
SSA	Star sensor assembly	
TDPS	Transducer data processing subsystem*	
TWT	Traveling wave tubes	
TWTA	Traveling wave tube amplifier	
	Encryption/decryption system	

* Contractor was to be selected four months after phase II began.

a successful [redacted] program manager before becoming the assistant general manager [redacted] Research and Development Division. [redacted] joined the KENNEN team despite the fact that his new job would, in theory, be at a lower organizational level. [redacted] later succeeded [redacted] KENNEN program manager and eventually became general manager of the company's Advanced Systems Division.

Challenges in Building the First NRT System

> *This program had a number of novel aspects and many would be several orders of magnitude more difficult than had been previously accomplished. It would collect a very large amount of data and transmit it securely to ground users at [a] high data rate with very low error incidence.*
>
> *The large spacecraft had to be highly agile and at the same time be able to point and move with exceptional accuracy.* [redacted]
>
> *Long life and flexibility were essential as the data gathered was of highest national importance and the venture costly.* [redacted]

A number of the other handpicked members of the original [redacted] KENNEN team also went on to higher level assignments. [redacted] who had been [redacted] chief engineer, became [redacted] deputy and then [redacted] program manager [redacted] He later became vice president and general manager of [redacted] division in [redacted] who originally was responsible for KENNEN system requirements and verification, became [redacted] KENNEN program manager, and was later promoted to vice president of the [redacted] and president of its [redacted] a member of the original team who, in an engineering capacity, made important contributions in the design of the critical attitude control system, rose to executive vice president of the parent [redacted][2-27]

Planning and Teamwork Paved the Way to Success

> ***The success of the program was largely aided by two aspects not usually found in government programs. One was the careful preparation in terms of complete system study and evaluation of options along with serious and significant development of critical hardware components before starting the acquisition phase. In other words, we were ready to proceed when so authorized.***
>
> [redacted]

[redacted] normally assigned program managers direct control over two functions: systems engineering, which tracked requirements and system performance; and program control, which managed business functions. Other important functions such as design engineering, reliability engineering, product assurance, manufacturing, and testing were organized in a matrix fashion with program teams in the appropriate discipline assigned from a large central engineering functional organization. The managers of these supporting functional organizations were directed by the [redacted] to cooperate with the KENNEN Program as the highest priority activity in the company. Because ineffective subcontractor management had led to cost and schedule overruns in some previous [redacted] programs, special [redacted] teams were made resident at subcontractors' plants.[2-28, 2-29]

KENNEN was also the first [redacted] program to "projectize" its software engineering team. The decision to allow the program to write its own policy and procedure documents permitted [redacted] KENNEN management to tailor its business approach with both its government customer and its subcontractors and suppliers. Corporate and government independent audits always found that program management's authority to "write its own ticket" had never been abused. Rather, some of these methods were incorporated in other [redacted] projects.[2-30]

The Imaging Satellite: A Large Telescope. [redacted] designed an imaging satellite consisting of a large [redacted] Many of these subsystems would be developed by subcontractors, some directed by the KENNEN Program Office. [redacted] job was to provide overall system engineering, to develop the satellite bus together with its test and support equipment, and to integrate the subsystems into a functioning whole.

[redacted] major challenge in building the imaging satellite would be the attitude control system (ACS). The maneuvering requirements on the [redacted] spacecraft were impressive. [redacted] a principal contributor to the ACS design, said that there was a concern at the outset whether they could achieve the required control.

Developing a Precision Pointing System

[redacted]

[redacted]

[redacted]

Another important [redacted] challenge was control of the antenna directional control assembly, the mechanism that [redacted] something never before attempted on a spacecraft. The ADCA was successfully developed by an [redacted] subcontractor. In all, 10 of the imaging satellite's subsystems required [redacted] and its subcontractors to solve problems never before accomplished in space. That they were successful beyond their expectation was borne out by the success of the first imaging satellite to fly.[2-31, 2-32]

[redacted] *SI, R/F, and O/F*

In the early 1960s, [redacted] was a major US spacecraft builder. [redacted] however, was in the forefront of the classified space program as the developer of the CORONA (KH-4) and GAMBIT (KH-8) spacecraft, as well as the later HEXAGON (KH-9) spacecraft. [redacted] became heavily involved in the Manned Orbiting Laboratory (MOL), known in the NRO world as DORIAN, but when MOL was canceled in June 1969, the company faced dire consequences. MOL was the largest US space program ever canceled, and [redacted] was the contractor most affected by the cancellation. [redacted] was forced to reduce its work force from 12,000 to 5,000 people in just one year. Subsequently, [redacted] to regain some footing in the photoreconnaissance programs by working with the Air Force on FROG, but the company viewed KENNEN as critical to its resurgence in the classified spacecraft arena.[2-33] [redacted] concluded that in order to win KENNEN, it must have a program manager who was well known, respected, and liked by CIA. [redacted] a retired Air Force Colonel who led the early [redacted] KENNEN team, fit this bill and was hired to lead the [redacted]

Upon award, [redacted] despite its disappointment at having lost the I/S award. As KENNEN SI, [redacted] provide KPO with the management and technical services required to integrate, monitor, and control the EOI program. Procedures were developed to monitor cost, schedule, and technical progress; to levy technical requirements and standards; to provide quick reactions and develop contingency operational directives; and to assess the readiness status of the system. The systems integrator would support formal preliminary and critical design reviews and be responsible for interface control documentation.[2-34]

Characterizing [redacted] at this time, [redacted] (who later became [redacted] said, "We were too vain to think that this couldn't be done."*[2-35] [redacted] had hired his former chief engineer at [redacted] to lead [redacted] task.[2-36] Within a few months, [redacted] vision and drive developed the systems integrator's role into a major one. Two other people who were key to the initial system integration effort and who have risen to top positions are [redacted] who succeeded [redacted] and became vice president of the system integration program; and [redacted] became director of the [redacted] system integration program. This embryonic effort in using a system integrator for [redacted] grew from [redacted] personnel at its inception to more than 300 by 1994, and the concept was successfully applied to other new programs.†

The first test of the new system integrator role occurred in February 1972, when Charlie Roth decided to place the system specifications under configuration control on 1 April 1973. Some of the affected development contractors thought that Roth "had lost his mind." [redacted] was among those who strongly supported the early implementation of the process of using interface control documents.[2-37] The results achieved proved conclusively that it was the correct decision. This management procedure resulted in firm control of the development of the system and underscored the needs to have a solid system engineering effort, to define and settle interfaces early, to never defer problems, and to have open communication between organizations. With this jump start, the role of the system integrator became more focused, and consequently the system integrator was a major force in the development of the KENNEN System.[2-38]

[redacted] to build the receive facility. Technical integration and management were performed at [redacted] was the major subcontractor, with responsibility for the communication hardware, the [redacted] antennas, and the S-band antenna. The R/F segment was structured to make maximum use of existing designs, which had proven operational performance and reliability. The dual antenna subsystem was assembled and tested at the ground facility.

All remaining equipment was assembled in the final configuration at [redacted] and tested before final installation and checkout at the ground station. [redacted] also provided operational maintenance and support of the R/F segment under [redacted] direction and control.

[redacted]

† By 1994 the [redacted] system integration contract allowed as many as 400 people; however, by that time, [redacted] organization had grown [redacted]

Of its three KENNEN segments, the operations facility proved [redacted] greatest challenge. [redacted] development with a single computer and three keypunch machines, operating in a batch processing mode. However, the software needed to operate the KENNEN System was much larger and more complex than anyone—government or contractor—had estimated. The initial version of the O/F software was to exceed 1 million lines of code, a figure never before approached on a single satellite program. The implications were not fully appreciated by [redacted] or the KENNEN Program Office, as will be seen later in this section.

The [redacted] *Processing Pixels*

[redacted] Texas, won the contract for the digital processing facility (DP/F). Major subcontractors were [redacted] New Jersey, for the laser image reconstructor (LIR) and [redacted] for the photo processing facility. The digital processing facility receives the digital data stream from the receive facility and transforms the data into imagery for the analysts. At no time has this been a simple task. There were many new engineering development challenges, including the needs to accommodate data rates of [redacted] per second, to develop a signal generator to operate at that rate, and to devise a method to record the [redacted] of data [redacted] Because available recorder technology could handle only [redacted] engineers split the data stream into [redacted] substreams, which corresponded to the initial ZAMAN focal plane design of [redacted]

A particularly thorny development problem for [redacted] turned out to be the laser image reconstructor shown in figure 2-2. [redacted] were the original LIR study competitors, and [redacted] was selected to develop the LIR as a directed subcontractor to [redacted] opinion, [redacted] was not organized to do this job, and it was having serious trouble with every component of the LIR. Eventually, [redacted] deliver the LIRs unassembled; then [redacted] assembled and checked out the LIRs before shipping them to the KENNEN Ground Station.

[redacted]

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Altogether, the LIR and associated DP/F interface equipment required significant advancements in available technology. Achieving either high resolution or high speed was relatively simple, but the combination was unprecedented. Digital-to-analog conversion at rates approaching [redacted] eight-bit conversions per second would require very unorthodox circuits. This and the aforementioned synchronization problem presented [redacted] with a number of formidable technical challenges, which it successfully overcame.[2-40]

As was the case with other KENNEN segments, software presented a significant problem to [redacted] processing was performed in dedicated, special-purpose hardware at an effective processing rate in excess of 7 billion operations per second, a respectable rate even in the modern supercomputer era. The software computed the processing parameters and controlled the processing hardware. The problem of simply coordinating this software turned out to be as difficult as that of coordinating the image data as it flowed from [redacted] separate processing chains. The acquisition geometry of the imaging satellite proved to be particularly challenging in trying to model the movements of the satellite, a step necessary to rectifying the imagery. The models developed by [redacted] for the DP/F were ultimately used in other softcopy exploitation systems including [redacted] IDEX (Imagery Digital Exploitation System).*[2-41, 2-42] A common KENNEN theme continued to hold true in the DP/F: "We underestimated the size and complexity of the task."

Developing the DP/F

> *The DP/F processing hardware . . . involved considerable innovation. During an image, there were nearly [redacted] image samples arriving at the input to the DP/F every second. Each sample required several hundred mathematical operations to convert it into a picture element (pixel) on the LIR film. Processing rates of this magnitude could be supported only by dedicated, special-purpose hardware. [However, reasons of reliability and cost spurred the use of commercially available hardware.] Some rather inventive techniques were necessary to support the processing requirements using components intended for quite different applications. Today we are completing the first DP/F in which the majority of the processing is performed in commercial supercomputers rather than in single-purpose hardware.*
>
> [redacted]

* Softcopy exploitation is the use of a computer and sophisticated image processing software to manipulate and enhance digital imagery for exploitation without the need for a photographic print. IDEX [redacted] are two softcopy exploitation systems.

[redacted]

At the time that Les Dirks had first approached [redacted] in 1969, the [redacted] division had about 800 employees and was on the decline. In 1993, it had nearly 5,000 employees. Two key contributors, [redacted] former senior executive vice president, and [redacted] retired vice president and assistant general manager, firmly believe that [redacted] role in KENNEN was chiefly responsible for this change. Other important contributors to this turnaround were [redacted] (in system analysis and algorithm development), [redacted] (managing hardware development), and [redacted] (managing software development).[2-43, 2-44]

The Hughes Aircraft Company Story: The Relay Satellite

The relay segment winner was the Hughes Aircraft Company, operating under the direction of the Relay Program Office of the US Air Force's Space and Missile System Organization (SAMSO). The relay satellites fly KENNEN System communications payloads [redacted] are deployed so as to be in view of both receive facility antennas and the imaging satellites during imaging operations. The relay satellites provide for the relay of commands to the imaging satellites and the relay of downlink tracking and telemetry data during both imaging and non-imaging periods.

The Relay Program would be unique in that its control was to be shared by two organizations. The spacecraft housekeeping functions, health, orbit, and attitude would be nominally controlled from a mission control center at the [redacted] while the KENNEN Ground Station, which would be located [redacted] was to control the KENNEN mission payload subsystem. Both facilities, however, were equipped to provide R/S command and control, and both could maintain attitude and state of health.

Anthony (Tony) Iorillo was the Hughes manager for the initial technology studies and system proposals for the relay segment. After Hughes was selected as the contractor for the relay satellite, it appointed [redacted] as the initial Relay Satellite Program manager. Hughes was organized as a classic matrix organization. That is, the company was organized into functional areas that supplied specific expertise to each of its programs. Each program office had total responsibility for performance and drew support from the many functional areas. The Relay Satellite Program operated in the same way, but drew its engineering resources principally from the technology, manufacturing, and quality control divisions.[2-45]

The Hughes program office was responsible for the administrative functions, system engineering, and system test. Because of security considerations, everyone was based in one work area, which facilitated teamwork and precluded a number of potential conflicts. With a few minor exceptions, the arrangement worked well. The design, manufacture, and test of the hardware for the relay satellite were the responsibility of the technology division, headed by [redacted] Key personnel were assigned to the program on a long-term basis and turnover was low. Strong working relationships were developed between the designers, system engineers, test engineers, and the Hughes program office.

This organization served Hughes and the government well. Several important factors contributed to its success. First, Hughes had a long history of working in this mode, so everyone was accustomed to it and, generally, the spirit of "let's get the job done" prevailed. Secondly, it was an exciting, challenging job and everyone recognized the importance of the program to national security. Third, there was very strong support from the top management in Hughes. Weekly meetings, presided over by either Bud Wheelon or [redacted] were held to review program status. The program office and all the functional organizations attended, and major problems were thoroughly aired and resolved as quickly as possible. The escalation of problems to this level seldom occurred, however, because most people worked very hard to avoid facing the senior-level management with an unsolved problem.[2-46]

Readying the Relay Satellites

> ***We had four years to complete the developments, get the satellite built, and launch two, nearly back to back. . . . Virtually every one of the new developments ran into serious difficulties along the way. However, working closely and well with the Air Force and Aerospace Corp., the program team worked through the problems and, in the end, launched the satellites exactly on time. The satellites worked very well and paved the way for the I/S deployment.***
>
> ***Anthony Iorillo***

[redacted] *Optics Subsystem: Building on a Legacy*

As the optical contractor on the [redacted] had developed a unique capability to manufacture and test optics as large as [redacted] in diameter. [redacted] supplier of mirror blanks, had contributed two other important new technologies: glass with an extremely low coefficient of thermal expansion; and technology to build this glass into very lightweight, large mirror blanks. [redacted] test facility, which housed the huge and very precise test chambers for mounting and testing optical system components, [redacted] At that time, no other company had comparable capabilities.

From the beginning of KENNEN, Les Dirks and Charlie Roth realized that the EOI optics subsystem must be given [redacted] The DNRO, who had previously invested in [redacted] directed this action. [redacted] had suffered several bad experiences as a subcontractor to aerospace firms and in particular as the camera subcontractor on the [redacted] vice president and general manager of [redacted], argued successfully that on KENNEN, [redacted] should be an associate contractor (which it had been on [redacted] as opposed to a subcontractor. [redacted] was strongly supported in this view by [redacted] assistant vice president and director of research and engineering for [redacted] was directly responsible for all [redacted] special program activity, including its very successful performance on [redacted] initial KENNEN team was formed under [redacted][2-47]

The KENNEN optics system, depicted in figure 2-3, consisted of a [redacted]

[redacted]

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[redacted] Transducers Require New Technology

The transducer data processing subsystem was the heart of the KENNEN onboard imaging payload. [redacted] KENNEN System [redacted] was eventually to [redacted] The resultant image, shown in figure 2-4, effectively became a logo for [redacted] The detectors and the accompanying electronics necessary to sweep the detectors and convert the return to a digital data stream were to require significant new technology advances. The [redacted] Many of the early [redacted] engineers came to the company directly from college or the military. They had not experienced failure on a project, and saw no reason why they could not succeed.[2-48]

[redacted]

Initially [redacted] worked with two candidate transducer devices, photodiodes and phototransistors, before settling on photodiodes (a simpler class of phototransistors) as the more promising. Both photodiodes and phototransistors convert photon energy to electrical energy. Photodiodes have a smaller pitch than the bulkier phototransistors and thus allow for a more dense array, which translates into higher resolution of the resulting imagery. [redacted] main competitor, concentrated on phototransistors.

[redacted]

The company also invented the self-scanning photodiode array, a mux (multiplex) reset switch that held all the photodiodes at their instant energy levels and then cycled through each diode in the array and multiplexed out their energy levels.

[redacted] attained a significant competitive advantage when it was first among the competitors [redacted][2-49]

[redacted]

[redacted]

Once [redacted] was selected to build the TDPS, the problems really began. The early production yield on the silicon devices was extremely low—at one point only one transducer in a thousand was usable. The assembly of the focal plane array was a particularly difficult and delicate operation. The faceplate had to be curved so that its radius matched the curvature of the focal surface on the optics subsystem. Assembling the modules containing the detectors took on the aspect of watchmaking. Further complicating this assembly task was the brittle nature of the silicon, which chipped very easily. It was almost one year before [redacted] produced a single usable chip for the imaging array. Although [redacted] had performed brilliant design work, some observers felt it was not organized to move into a disciplined, orderly manufacturing environment. To ensure that management problems did not exacerbate the tremendous manufacturing challenges that [redacted] faced, the KENNEN Program Office assigned [redacted] as the on-site contracting officer's technical representative. With close support from the KPO, [redacted] overcame sensor manufacturing challenges and successfully delivered the KENNEN TDPS on schedule.[2-50]

After building [redacted] the successful [redacted] maging array, [redacted] began work on charge coupled devices (CCDs). In 1974-75, [redacted] won a design phase award; subsequently it won a one-year contract to develop a CCD array. One of the big advantages of CCD technology was that it could include multiple stages of time delay integration (TDI). TDI permitted the building up, or summing, of the charge on the detectors, which led to an improvement in the quality and strength of the signal transmitted to Earth. It also made a scanning array act like a framing array, with accompanying improvements in image resolution and system flexibility. The state of the art in imaging detectors was being aggressively pushed at every turn.

[redacted]

Development of the star sensor assembly originally was awarded to [redacted] apparently had a faulty design, but that fact initially eluded the proposal evaluators. After [redacted] won the SSA contract and began work, the design fault began to manifest itself, raising concerns at both the KENNEN Program Office and the prime contractor [redacted] After trying for two years to resolve the problem, [redacted] concluded that [redacted] would not succeed, and [redacted] terminated the contract. Scientists at [redacted] Palo Alto laboratories who had studied the [redacted] design introduced a new design, and several companies were asked to submit proposals for its implementation. [redacted] a quality manufacturer with prior SSA experience, was selected and despite starting out two years behind, delivered workable star sensors on the KENNEN program's original schedule.

[redacted] *Onboard Computer: An NRO First*

Yet another unique piece of hardware on the imaging satellite was the onboard computer. The most important feature of this computer, built by [redacted] would be the ability to completely reprogram the computer in flight. While this capability may not have been of great importance in the design stage, it certainly became of paramount importance as KENNEN flew. KENNEN spacecraft frequently were recovered from potentially disastrous conditions because the computer commands could be changed and the databases altered. The now famous ability to operate successfully on only [redacted] was possible because of this capability. Any number of operational "work arounds" have been possible, thanks to this critical piece of technology. Other operational events that might not have been possible without a programmable computer on board the spacecraft are described later in this section.[2-53]

[redacted] *Communications System*

The crosslink between the imaging and relay satellites, including the data rates being forecast, was a technology area of considerable concern to all involved in the development of KENNEN. This simply had never been done before. The antenna directional control assembly, built by [redacted] contained the I/S-to-R/S crosslink communications electronics, built by [redacted] and was placed on the end of the spacecraft that normally does not point at Earth. The communications antenna, on an articulated joint, would keep the imaging satellite in continuous contact with the relay satellite once a link was established. [redacted] was the contractor responsible for the communications subassembly and antenna.[2-54]

It was critical that the crosslink work, as image data could be returned to Earth only across this path. A very conservative approach was taken in the crosslink design, resulting in a series of tightenings of the decibel design margin at each level of the architecture. This tightening of the specifications started with the systems integrator, [redacted] with successive contributions by the KENNEN Program Office, [redacted] systems engineering, and finally the [redacted] engineers responsible for the crosslink hardware development. Even [redacted] management tightened the decibel margin. All of these changes had to be approved by the Configuration Control Board and had to be justified by engineering analyses. The final approved specification sorely tasked the [redacted] engineers' talents to design and manufacture a crosslink to such tight specifications. Despite the enormity of the challenge, the I/S-to-R/S crosslink was established on the first try, apparently with so much extra margin that it quite likely would have connected on almost any signal strength. According to one anecdote, the two satellites linked up on signal leakage from the antennas, before the power was turned on.

A separate problem was cable wrap, a condition caused by antenna movements that led to cables wrapping around the gimbal and stopping movement. Software was developed to eliminate antenna pointing sequences that could cause this condition.[2-55]

Traveling Wave Tubes: The Key to Wideband Communications

The most difficult technical challenge in the data communications arena was the traveling wave tube amplifier, part of the wideband communication subsystem. TWTA is the primary component for transmitting the imaging data at [redacted] frequency from the imaging satellite to the relay satellite. The R/S then converts the signal to [redacted] frequency and transmits it to the KENNEN Ground Station, where the data is used to produce the acquired imagery.

While TWTA technology was neither new nor particularly difficult, the 100-watt power levels and [redacted] crosslink frequencies, together with the long life required for KENNEN, presented Hughes engineers new challenges. Hughes initially elected to have its Radar Group manufacture the power amplifiers, rather than establishing a separate production facility within the Space Group. This proved to be a mistake, as some 125 tubes were built without success. The Air Force brought in [redacted] to help with the problem, and it was discovered that the failures were caused by a step in the manufacturing process. The TWTA barrels were manufactured in segments, and in joining the segments small pockets of air were being trapped. The air pockets then diffused and became essentially scattered deflectors of the beam. Once the manufacturing problem was recognized, Hughes moved the manufacturing back to its Space Group and corrected the flaw in the glass molding technique. The tubes then met specifications, and a big hurdle was overcome.

The development and manufacture of the [redacted] devices, which had been anticipated to be a larger problem, went fairly smoothly. Ultimately, Hughes was successful in delivering the TWTAs on time.[2-56]

Controlling System Integrity: Interface Control Documents

The success of KENNEN development required maintaining tight control over the technical interfaces between KENNEN's many parts—a problem intensified by the significant technical challenges facing the individual engineering teams. Formal interface control documents for each of the major segments were instituted and proved to be an important management tool during KENNEN development. To test the interfaces, a series of "all-up" integrated system tests were to be conducted before the first launch to verify that all parts of KENNEN would "play" together.[2-57]

[redacted] Integrates the Imaging Satellite, Assures On-Orbit Success

In addition to the usual array of mockups and special test articles, there were two important I/S-like hardware articles that were to be built by [redacted] during the development phase of KENNEN. The earliest was a development test vehicle (DTV), which was intended to ensure that the vehicle positioning hardware and software worked properly. [redacted] All would play together for the first time as a part of the DTV. The subsystems did very well in concert at the DTV. Except for a minor rounding error in the software, which was quickly identified and corrected, the subsystems worked perfectly.

The other important piece of development hardware was the I/S qualification test vehicle (QTV), which provided a means for ground testing an all-up I/S flight vehicle in a stressed environment. The QTV passed its test without failure, and its [redacted] components that had been stressed during testing to a point that made their future operability questionable were replaced.

Before the first launch, all vehicle components and subsystems, as well as the total flight vehicle, would be required to pass a predetermined series of tests to ensure that they were properly designed and built. Component qualification and acceptance testing would be performed by each manufacturer in its facilities according to the requirements and methods approved by the prime contractor and the government. When KENNEN was launched from Vandenberg Air Force Base, the imaging satellite countdown would be performed by [redacted] engineers at the [redacted] facility, a few hundred miles away, through a high-capacity data link to the satellite on top of its Titan booster. Thus, the people who tested KENNEN would be involved right up through launch.[2-58]

Piece By Piece, Part By Part

The possibility that some major flaw had been overlooked was to be handled by a system [redacted] *[and] by detailed and [where possible] independent simulations to guide system design and choice. It worked out splendidly.*

Richard Garwin

Team Spirit Pays Dividends

In a number of significant cases, the team spirit fostered by Charlie Roth and Les Dirks paid immense dividends. The original design of KENNEN provided for the ability to send commands to the imaging satellite via the relay or directly from the ground station, but only via [redacted] which had a great deal of experience in building and operating satellites for the Air Force, perceived that having only one path for commanding would not be sufficient. [redacted] prevailed upon the KENNEN Program Office to add the capability to communicate with the I/S via S-band, either directly or through the [redacted] This would allow the ground station to perform state-of-health checks and to send commands through a path independent of the relays and not relying on the antennas at the ground station. During the first KENNEN mission, the imaging satellite went into protective mode—a state the satellite initiates autonomously that prevents mission termination because of onboard equipment malfunctions or receipt of illegal ground commands—31 times in its first year of operation. On many occasions, recovery from a potentially catastrophic situation was made possible by commands transmitted to the imaging satellite via the alternate S-band system.

Another example of clever contractor thinking concerned the optics subsystem. The original Dirks-Roth concept was to have [redacted] only build and configure the mirror. The company persuaded KENNEN Program Group (KPG) of the wisdom of building the entire optics subsystem at its facility in [redacted] then shipping it to [redacted] This allowed the optics subsystem to be tested at [redacted] shipped to [redacted] in a single container, and then slid into the spacecraft as a unit. This was also to prove valuable when an optics subsystem had to be removed and returned to the company for various reasons.

In both of these examples, a contractor recognized a system-level problem and suggested a solution that the government accepted—in large part because of the mutual trust that had developed between the two.[2-59]

Making the Program Work

The other area where this differed from many government programs was that the government and industry people worked as a team. When problems arose, as they inevitably would with anything this challenging, they were tackled with only the goal of getting good results. [redacted]

KENNEN Management Establishes Early Precedent of Competence

In a review of KENNEN in the autumn of 1973, the Science Panel of President Nixon's Scientific Advisory Committee gave very high marks to the "most competent management yet seen in a program of this type." In an accompanying memorandum to DCI William E. Colby, Science Panel chairman Adm. George W. Anderson, Jr., (Retired) spelled out several recommendations made by panel members, including protracted testing of system components wherever possible and forward buying of critical elements expected to be in short supply.

The Science Panel also warned Colby that changes in the program to effect economies "could lead to a disastrous compromise" and urged that he seek agreement with the Secretary of Defense to continue the then present program and level of funding for KENNEN through initial operational capability and to lock in funding for the relay satellite (funded out of the Air Force's "white" or unclassified budget) to preclude decisions on essentially unrelated programs from having an impact on KENNEN. Work on all of these observations and concerns was either already under way or subsequently begun.[2-60]

ExCom Approves Technology Program [redacted]

In November 1974, two years before the first KENNEN launch, the ExCom met and reviewed the National Reconnaissance Program. The ExCom approved the planned KENNEN procurement schedule, which [redacted]

The Data Encryption Saga: Data Rate Challenge

From the earliest days of the KENNEN Program, it was recognized that the amount of data to be returned to the ground would be more than anyone had previously been required to handle. Not only were communications circuits going to be advanced to a new level, the problem of how to deny this data to the enemies of the United States loomed large. Security provisions for the command and telemetry links were readily available using any of several systems from the National Security Agency. However, there simply were no encryption devices capable of handling the data rate required to field KENNEN imagery.

[redacted]

[redacted]

Several peripheral issues were worked, including verification that the [redacted] downlink would not be interfered with by "friendly" emitters, either existing or in the future. The National Bureau of Standards was enlisted to develop new hardware reference standards for equipment at [redacted] The bureau oversaw contracts at several companies to develop these standards so that testing could be verified at the required accuracy. [redacted]

The Ground Station: A Lot of Dirt Got Moved

Another in the long line of firsts in the KENNEN System was the planning for and construction of the ground station. While the SIGINT (signals intelligence) community had built ground terminals for its systems, the IMINT (imagery intelligence) community had never had to consider this sort of complication. There would now be no "film buckets" to recover, no long airplane rides to take the film to a processing facility, no cold nights in Rochester, no wild trips to DC, and no tons of film to load and move. All of this would be done in one place: the KENNEN Ground Station.

Once the realization set in that a complicated ground processing site would be an integral part of the program, the activity to make it a reality began. There were many questions to be answered, including what the ground station would look like, where it would be located, how it should be designed and built, and how it would be secured. These questions added up to a challenging set of problems for the KPO.

The KENNEN Ground Station was to be a facility far beyond anyone's experience. It would perform the usual satellite control functions for the imaging satellite, including commanding the imaging payload. The ground station also would command the relay satellite's communications payload. R/S health and status monitoring and control would be performed at the [redacted] Work at the ground station would not be limited to commanding and controlling the imaging and relay satellites. In addition the KGS would have a collection planning and tasking group, a communications facility, a receive facility for the wideband data, a photo processing facility, and huge computers for a large imagery analysis center. The KGS would also contain a Consumer Support Center (CSC) staffed by members of COMIREX and representatives of the user community.* Lastly, it would house a sizable exploitation and reporting contingent from the National Photographic Interpretation Center (NPIC). This activity—because of its sensitivity and classification—would necessitate a security cover story.

[redacted]

The Army Corps of Engineers was brought into the picture and appropriately briefed, and efforts were started to acquire the property. The Corps of Engineers acquired the land and began construction. [redacted] of the KENNEN Program Office supervised the principal contractor, [redacted] The architecture and engineering contractor was [redacted] Two final stumbling blocks in the approval process for the site were the requirements to insert the facility into the [redacted] Master Plan and to obtain approval from the [redacted] construction projects for conformity with standards appropriate for the [redacted]

* Although the CSC retained its acronym, in 1977 it changed its name from the Consumer Support Center to the Community Support Center.

[redacted] Once all of the preliminary steps were accomplished, ground was broken in the summer of 1973 by the two Charlies—Roth and [redacted]—who in keeping with [redacted] (figure 2-5). Construction was to proceed exceedingly well.

The KGS was completed in 17 months, one month ahead of schedule.* Originally identified as [redacted] it has since been known in semiunclassified terms as [redacted] These designations were primarily used for administrative and logistics support by personnel who did not have the BYEMAN clearance. The original building contained 228,500 square feet of floor space.[2-64]

[redacted]

[redacted]

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System Nears Completion

In late 1975, after more than four years of intensive effort on the part of the KENNEN Program Office, its contractors, and the Intelligence Community, the KENNEN System was ready to assume a preeminent role in gathering intelligence through overhead imagery. During the next several months, the KENNEN Ground Station was the site of significant checkout activities coordinated by the [redacted] a CIA employee from the Directorate of Administration. Almost immediately, many of the Program Office personnel and their contractors began installation and checkout of their equipment.

KENNEN/KH-11 Support for Military Users

After the KENNEN Program was approved for acquisition, a joint DIA-COMIREX-NRO simulation [redacted] was conducted to determine how best to incorporate Unified and Specified (U&S) Command requirements into KENNEN/KH-11 tasking [redacted] and to see how the large volume of imagery from the EOI system would affect interpretation resources [redacted]

[redacted]

* The imagery interface to the US military was generally through the TALENT KEYHOLE security system. Here, the KENNEN System was known by its TK designator, KH-11.

Designed Use v. Desired Use: DoD's Use of a National Security Reconnaissance System

It was apparent to even the casual observer that the KENNEN system had the potential to profoundly impact the way we planned, prepared for, and conducted operations within the Department of Defense. I was therefore both surprised and concerned with the apparent lack of knowledge regarding the KENNEN system and its capabilities within the Department of Defense . . . [From my perspective] there appeared to be no advocacy for the system with the DoD. Thus, while the system had great potential to support military operations, it was not optimized for that role

Edward Heinz

[redacted]

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Passing Imagery From the Pentagon to the Field: Another Perspective

> *DoD and the military services were not well prepared to receive and use information or imagery derived from near-real-time system. No provisions were included in the system design to insure that imagery requirements from military customers in remote locations could be levied on the system in a timely manner. . . . Many military applications require the imagery itself, not just derived information; thus the lack of a near-real-time dissemination system negatively impacted the utility of the imagery. . . . Regrettably, due to practical and political reasons, many of the problems identified above continued to plague the utility of the KENNEN system for long periods of time,* [redacted]
>
> ***Edward Heinz***

[redacted]

Informing the Community About KENNEN

Recognizing the importance of educating the Intelligence Community, the KPO in 1975 developed a detailed user community indoctrination package. The package addressed the two main users in the community, the imagery analyst and the intelligence analyst. For the imagery analyst, the emphasis was on image quality, format and titling, EOI image features, and unique KENNEN flexibilities such as replay. For the intelligence analyst, the package emphasized system operations, collection planning, targeting, system access, system timelines, and special targeting capabilities.

* The Office of Special Projects in the CIA's Directorate of Science and Technology had been renamed the Office of Development and Engineering in 1973.

This package was primarily for Washington-area users. Its major areas, shown in table 2-4, provided a brief overview of the KENNEN System attributes that are of interest to the user. Although the package did not substitute for user community training subsequently carried out by NPIC and COMIREX, it was an excellent prelude.[2-72]

Automating Requirements Leads to Birth of CAMS

The development of the KENNEN System required COMIREX to develop a new automated approach to requirements management. A new system was needed for two reasons: KENNEN represented a significant increase in the amount of imagery, with a corresponding increase in the work COMIREX would perform; and KENNEN could collect and return imagery continuously so that the management of community requirements would become a continuing process rather than the cyclic process associated with film-return systems.

Table 2-4. KENNEN Indoctrination Package

Section	Topic
KH-11 System User's Manual	Document similar in scope to the *KENNEN System Description Document*. It emphasized information necessary for the indoctrination of the user community elements and served as a reference manual. It covered such imagery and performance topics as: • Image chain [redacted] processing) • Concept of [redacted] • Digital data • Stereo • Tonal transfer and modulation transfer control/flexibility • Replay (flexibility and request procedures) • Image artifacts • System performance, tasking, and response • Access • Framing and stripping modes • Quantity and quality • Routine operations • Crisis operations • Community Interfaces to KGS (CSC, E/F, ExSubcom/ICRS Detachment)*†
Briefing Package	Contained essentially the same information as the *System User's Manual* and was assembled so that it could be used to brief both imagery analysts and intelligence analysts.
KH-11 Imagery Notebook	Contained simulated KENNEN imagery illustrating the various features unique to KENNEN. It was assembled so that the transparencies could be viewed on light tables.

* E/F: Exploitation Facility
† ExSubcom/ICRS: COMIREX's Exploitation Subcommittee and Imagery Collection Requirements Subcommittee.

The COMIREX Automated Management System (CAMS) was a natural, inevitable, and necessary result of the Intelligence Community's desire to take maximum advantage of KENNEN to support indications and warning and crisis management. The objective of CAMS was to provide automated assistance to the Intelligence Community for the effective management of collection, processing, exploitation, and film distribution not only for KENNEN, but also for GAMBIT, HEXAGON, and the aircraft collection systems.

CAMS was approved in August 1974 by DCI William Colby. Beginning in August 1974, the CIA's office of computer services, together with contractors and the COMIREX staff, worked on the CAMS development program. Development and interfaces with other systems were coordinated within the Intelligence Community through the COMIREX ADP (Automated Data Processing) Data Handling Coordinating Group. The KENNEN Program systems integrator, [redacted] reviewed the CAMS development program in March 1976 and assessed it as satisfying the requirements of the interface control documents.[2-73]

On 12 October 1976, as scheduled, CAMS became operational for use by [redacted] of the Intelligence Community who had completed the basic CAMS training course. CAMS supported the Intelligence Community 24 hours per day, seven days per week through a network of [redacted] A COMIREX Staff member designated as the database administrator (DBA) was directly responsible for the integrity of the database, standards for documentation and training, resource allocation priorities, computer outage procedures, security procedures, reports processing, special products, and user support. The DBA worked closely with the Data Base Management Unit, which was composed of four COMIREX staff members who maintained the operational integrity of the CAMS database and provided assistance to all users on routine matters.[2-74]

Schedule Uncertain: Ground Station Software Problems

Both [redacted] and the KPO sorely underestimated the complexity and magnitude of the KGS software. By early 1973, this problem began to manifest itself with software delivery delays. In mid-1974, the KPO began to give more attention to the growing software problem and [redacted] an additional computer to help speed development. [redacted] converted from a batch mode to a time-sharing processing mode to provide more computer support to the programmers. At the critical design review in November 1974, [redacted] the operations facility would not make the October 1976 launch date [redacted]

By early 1976, the government decided that it had to get the attention of higher level management at [redacted] While it was recognized that the software development problem was magnified because the KPO had not required more specific interfaces between the imaging satellite and the operations facility, time was running out. Launch clearly was going to slip from October 1976. The question was, how far?

Les Dirks, the director of the CIA's OD&E, Charlie Roth, Dirks' deputy; and Rutledge P. "Hap" Hazzard, the KENNEN Program Director, attended the next semi-annual award fee meeting for the operations facility late one week.* [redacted] given excellent ratings for its systems integration and receive facility segments. The operations facility, however, was a different story. Dirks announced [redacted] "For the O/F segment, you get zero award. Moreover, it is in such terrible disarray, I'm taking away the award fees for the other two segments." This action resulted in the loss [redacted] of several million dollars of award fees. The government then held out a carrot. [redacted] the operations facility in on the then current schedule (launch had already been slipped from October to November), it would be given back the fee for the SI and R/F segments.[2-75]

The government had gotten [redacted] On Sunday morning, [redacted] vice president and general manager of the [redacted] called [redacted] one of the senior members of [redacted] and asked him to come to [redacted] home to talk over a subject they could not discuss on a nonsecure telephone line. When [redacted] arrived [redacted] informed him that, [redacted] is clearing out his desk now, and tomorrow morning at 8:00 a.m., I am calling a staff meeting and announcing you as the EOI Program general manager." [redacted] soon found that the segment was [redacted] over budget, the final O/F software delivery was a year or more behind schedule, and significantly larger overruns were projected. Immediately, a "get well" plan was developed and implemented with government concurrence and support. At this point the O/F software loomed as a showstopper.[2-76]

Herculean Effort Results in Cohesive Team.

It was apparent that unless some capabilities were deferred, the ground station software would not be ready in time to support the scheduled launch date of the first imaging satellite. Robert J. (Bob) Kohler, chief of the KPG's System Analysis Staff (SAS), had established "tiger teams" to focus on specific problems. While principally focused on the difficulties of the I/S-O/F interface, these teams attacked other software and hardware issues as well. Approximately 150 additional software programmers, [redacted] were provided by the Program Office to help get the operations facility back on schedule. Further, in order to meet the scheduled launch date, the Program Office deferred selected capabilities, rescheduled O/F computer program configuration items (CPCIs), and moved system-level software testing to the ground station.

The KGS building had just been completed and was largely empty. Eighty-five [redacted] to test and install the O/F software. Initially, this effort was under the direction of [redacted] Subsequently, [redacted] managed the effort supported by Lead Engineers [redacted]

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* In September 1975, Roth was promoted to Deputy Director of OD&E and Hazzard was appointed Director of the KENNEN Program. Hazzard later became the Director of NPIC.

[redacted] The scramble to meet the launch schedule was under way. Software CPCIs had first arrived at the KGS at the end of 1975. The first half of 1976 was spent testing this software in preparation for the relay vehicle support, and it was found to be adequate for the launch of the first relay satellite, R/S-1, in June 1976. In the second half of 1976, these CPCI tests competed for resources with R/S initialization, operations training, and the launch of the second relay. Despite this contentious environment, the initialization of the second relay satellite, R/S-2, was completed in a timely and orderly manner. The KENNEN Readiness Board, however, determined that additional operator training and rehearsals were required before the first imaging satellite was launched.

While it was recognized that the original launch date for the first imaging satellite had been changed from 15 October to 12 November 1976 primarily because the operations facility was not ready, the later launch date would allow time to ensure that all critical elements were operative and to conduct a more rigorous training and exercise program at the KGS.[2-77] That the software was in place, tested, and functional after only a one-month delay of the first I/S launch was a testimony to the hard work and dedication of [redacted] KPG and its contractors, particularly [redacted] Moreover, the crisis had a major benefit: it caused a cohesive team of government and contractor personnel to be formed.[2-78]

KGS Organization is a Linchpin to Success

A key to KENNEN's success lay in the day-to-day operations at the KGS, where the whole system came together in a synergistic manner. This organization, within the KPG, [redacted] and its major contractors are shown in figures 2-7 and 2-15.[2-79] The Operations Division was responsible for coordinating collection and output product requirements within system constraints, and for scheduling all activities of the satellite systems and of the KGS. The Engineering Division was responsible for system performance assessment, engineering support, and maintenance and integrity of the system configuration for all hardware and software in the KGS. The Exploitation Division, which received direction from the Director of NPIC and from COMIREX, was responsible for the exploitation of the KENNEN imagery. The Support Division was responsible for the logistics, personnel and financial administration, registry, security, maintenance, and housekeeping functions at the KGS. The CSC served as the interface between the Intelligence Community requirements manager—COMIREX—and the Operations and Exploitation Divisions at the KGS.[2-80]

Satisfaction of national intelligence requirements, as channeled through the Operations and Exploitation Divisions, was the sole reason for the existence of the KGS and the ultimate reward to all those who had worked so long and so hard to bring the program to fruition. This close integration of the Intelligence Community with the system operator marked a first for this kind of on-site, day-to-day interaction for any of the NRO satellite programs.

Rutledge P. Hazzard

Exploitation 24 Hours Per Day

The KENNEN System required a totally new approach to photointerpretation and reporting. The KGS included an exploitation facility (E/F, KENNEN [redacted] with personnel, equipment, and computer hardware and software to accomplish the time-dominated exploitation of imagery acquired by KENNEN. The personnel were a detachment from NPIC and were designated as the Priority Exploitation Group (PEG). [redacted] was the first PEG chief, with Air Force Col. [redacted] as deputy chief. The E/F received computer and data processing support from NPIC's main building in southeast Washington via a terrestrial communications link.[2-81]

The exploitation processes were designed to provide information to satisfy high priority Intelligence Community requirements in a timely manner. Based on early studies of imagery flow and the time required to analyze the data, a new approach to exploitation was derived. The first-phase exploitation, which was to be conducted at the ground station, was divided into two levels: preliminary exploitation, to be completed within [redacted] of receipt of imagery, and current exploitation, [redacted][-82]

Preliminary exploitation was to be limited to images of targets in the categories of high current interest, crisis, indications and warning, and tipoff. The resulting reports were to be in cable message form and issued as required. Summary reports and non-time-critical reports would be released in subsequent cable messages at regular intervals. During this phase of exploitation, imagery analysts were required to answer specific time-dominated questions and report the results immediately. They were to scan all imagery to determine whether the designated targets had been imaged so that target accomplishment feedback data could be used in subsequent collection planning. Analysts were also to scan all remaining high-priority imagery and report any observed significant activity or new targets.[2-83]

Current exploitation dealt with target images requiring review daily but not immediately upon receipt of the film. Imagery analysts were required to provide a comprehensive review of all targets for which significant changes had been reported during preliminary exploitation, including those that had special exploitation requirements. Subsequently, analysts were to complete the search of all remaining imagery and perform preliminary exploitation of images of those targets received after 0700. Also during this period, the analysts were to report on cloud cover over the areas imaged for feedback to the KGS Operations Division.[2-84]

KENNEN System is Ready: The Goal Is To Take One Picture

During KENNEN's development period, two of Charlie Roth's "laws" became well known. The first one was, "Our task is to get a satellite up to take one picture," and the second was, "Our only focus is schedule, schedule, schedule." If anyone on the program, government or contractor, had any doubts on these matters, he soon left the program.

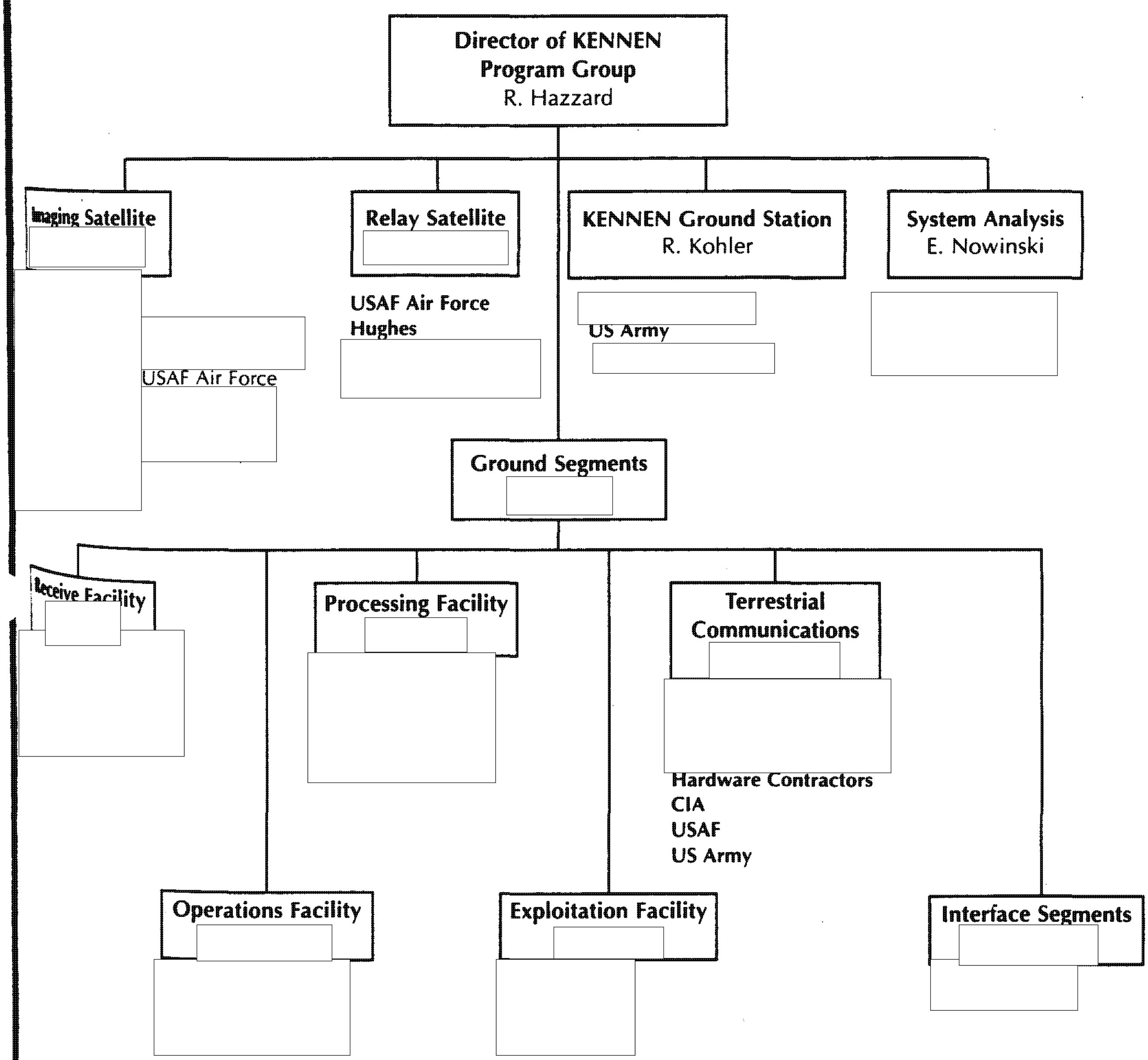
In keeping with his focus on successfully flying the first near-real-time imaging satellite, Charlie Roth designated one of his desk drawers for "Things to be considered after first launch," and filled the drawer with all the good ideas suggested by both his own and the contractor engineers. The concept was that nothing would impede the Program's ability to get the first imaging satellite into orbit—on schedule, at cost, and in accordance with the performance specified in the plan. All of the good ideas for improvement of the system would have to wait until that initial goal was achieved.

Although the goal of the KENNEN Program was more ambitious than taking one picture [redacted] the acquisition of the first KENNEN image was Charlie Roth's highest priority. As 1976 drew to a close, the long years of work were about to be tested with the launch of the first KENNEN imaging satellite.[2-85]

KENNEN: Only One of the System's Names

The NRO's electro-optical imaging satellite reconnaissance system was known by several names by different groups of people and at different times. The BYEMAN codename for the system was KENNEN; the TALENT KEYHOLE name was KH-11. [redacted] Similarly, each relay satellite was identified by an "F" number or an "R/S" number and then by a mission

Figure 2-7. KENNEN Program Group (Spring 1977)



Bold = Prime Contractor.
Italic = Subcontractor.

number after successful launch. The nicknames facilitated informal exchanges between contractors and ground station personnel. [redacted]

The Mission [redacted]

[redacted] Launched: The Dream Comes True

At 1817 Greenwich mean time (GMT) on 19 December 1976, the first KENNEN spacecraft was launched from Space Launch Complex site 4 East (SLC-4E) at Vandenberg Air Force Base.* Figure 2-8 shows a cutaway view of the KENNEN imaging satellite launched that day. The booster was a Titan III-D, the 100th in that series. The long-held dream of a near-real-time imaging reconnaissance system moved from idea to reality. To some, the hard work was finished. To many more, it was just beginning.

The launch into polar orbit, under the direction of Program A's [redacted] was completely nominal. Payload checkout was performed via remote data link with the [redacted]

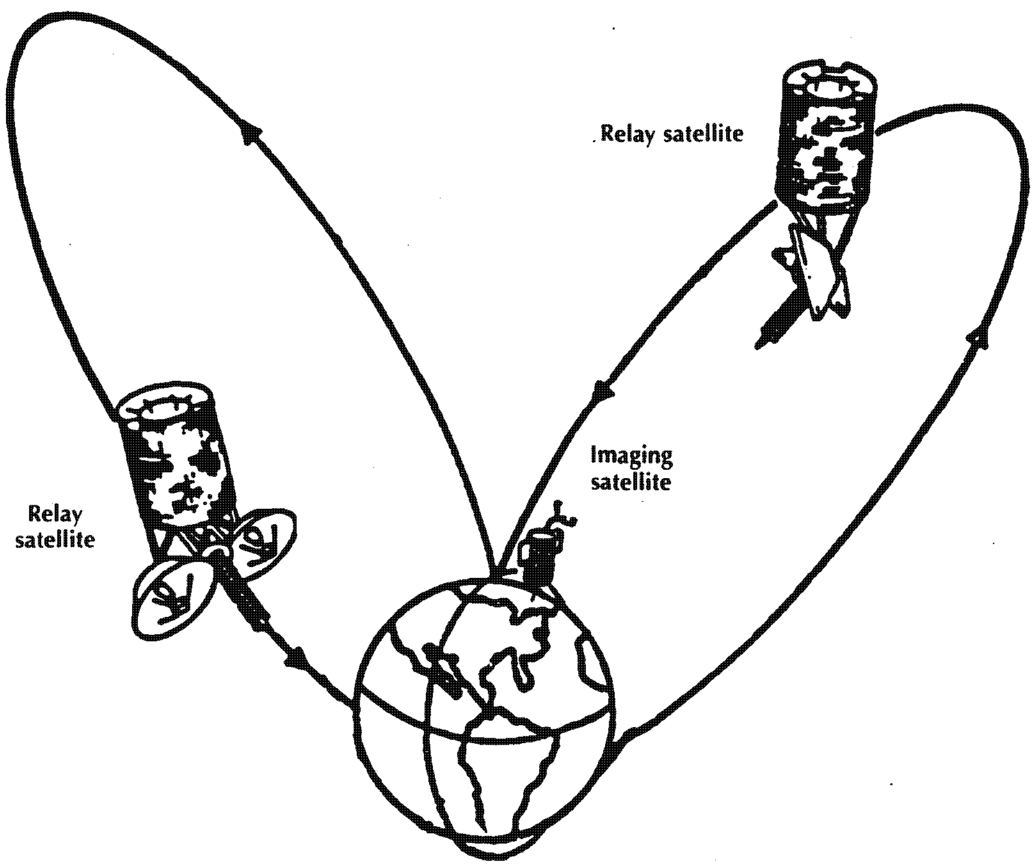
Figure 2-8. KENNEN Imaging Satellite

Imaging, Exploitation, Analysis, and Dissemination

Suddenly in 1976 the Intelligence Community was forced to deal with exploitation [redacted] of collection, and that, indeed, changed the tempo of exploitation, analysis, and dissemination.

John McMahon

Figure 2-9. KENNEN Initial Configuration (January 1977)



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