Highlight Article

CORONA: Success for Space Reconnaissance, A Look into the Cold War, and a Revolution for Intelligence[1]

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The Thirty-Fifth Anniversary CORONA Program Commemoration... *This article is being published as part of the CORONA Program's Thirty-Fifth Anniversary Commemoration, which will be celebrated at the Smithsonian's National Air & Space Museum on May 24, 1995. The celebration is being co-sponsored by the National Reconnaissance Office, the National Air and Space Museum, and the National Space Club. The Central Intelligence Agency, the United States Air Force, and the American Society for Photogrammetry and Remote Sensing are cooperating organizations.*

On 12 August 1960, Major Ralph J. Ford, USAF[3], sent a short, encrypted message to the Central Intelligence Agency in Washington, DC:

> *"Capsule recovered undamaged."*

This message reported on the first successful recovery of an object sent into space. The capsule was to be recovered by an aircraft in mid-air, but there had been a communication problem, and it splashed down in the Pacific Ocean some 330 nautical miles northwest of Hawaii. The capsule had to be retrieved by a Navy helicopter and was deposited on the deck of the surface recovery ship, Haiti Victory.

This recovery was a preview of what would become an exciting time for the US Intelligence Community. The capsule was the kind of satellite recovery vehicle (RV) that would play a pivotal role in the delivery of space reconnaissance imagery to the Intelligence Community over the next dozen years. This capsule, which was carried aboard Discoverer XIII, did not return reconnaissance film. It merely carried an American flag as part of a Discoverer diagnostic flight. (Figure 1 — President Eisenhower (center) Inspecting the American Flag From Discoverer XIII's Capsule During an August 15, 1960 White House Ceremony. Also shown with President Eisenhower are: Dudley C. Sharp, Secretary of the Air Force; Thomas Gates, Secretary of Defense; Gen Thomas D. White, Air Force Chief of Staff, and Col C. A. Mathison, Vice-Commander 6594th Test Wing. James Hagerty, Press Sec-

Figure 1. PRESIDENT EISENHOWER INSPECTING THE AMERICAN FLAG FROM DISCOVERER XIII.

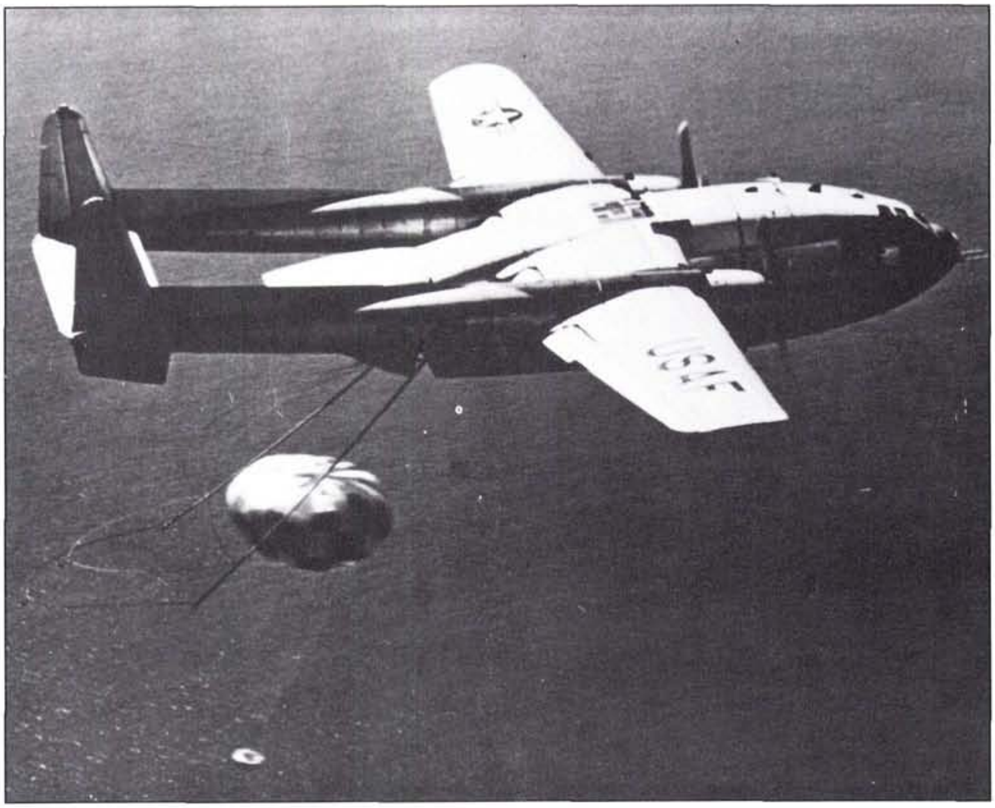

Figure 2. A US Air Force C-119 Recovering a Corona Capsule returned from Space.

retary, and Thomas Stephens, Appointments Secretary, are in the background. (Photograph provided courtesy of the National Park Service and the Dwight D. Eisenhower Presidential Library.) This recovery, however, was the beginning of the Intelligence Community's development of a space imaging capability that would transform a rudimentary remote sensing system into a sophisticated satellite reconnaissance capability. This capability would prove to be an invaluable source of foreign intelligence.

Maj. Ford's message must have been very welcomed to those in the Central Intelligence Agency (CIA) and US Air Force who had worked on the development of this highly classified program over the previous two years. The program had been a complex technical challenge with a difficult start. The first eight reconnaissance missions, which began launch operations in June 1959, did not produce any imagery. During these initial missions-and other subsequent missions during the early stages of the program-failures were the result of a variety of causes. There were launch problems (e.g., on one mission, the engines burned too long and caused the spacecraft to go into a higher than desired orbit); spacecraft component failures (e.g., on another mission, the three-axis stabilization system malfunctioned and caused the satellite to tumble); recovery mishaps (e.g., on yet another mission the RV parachute tore).

It wasn't until August 18, 1960—the date of the ninth attempted reconnaissance mission—that there would be success for the nations' first photo satellite reconnaissance program, a program that was known as CORONA[4]. When the RV for Mission 9009 was recovered in mid-air by a C-119, it became not only the first CORONA RV to return from space with reconnaissance film, but also the first object to return from space and be recovered in mid-air (Figure 2 — Over the next twelve years the Intelligence Community would develop photo satellite reconnaissance under project CORONA, a program that would have a unprecedented impact on intelligence collection and national security policy making. (See Appendix 1 for a mission summary of the early photosatellite reconnaissance programs.) With Discoverer XIV, and its CORONA Mission 9009, the age of space reconnaissance had begun.

August 18, 1960: A Point in Time — But a Mark in History

For the US Intelligence Community, August 18, 1960 marked the beginning of a revolution in acquiring foreign intelligence at a point in time when a new capability was most needed. Three months earlier, the Soviets had shot down U-2 mission 4154 while it was being flown by Francis Gary Powers. Some 4-1/2 hours into this May 1st mission, the Soviets detonated an SA-2 surface-to-air missile (SAM) behind the aircraft at 70,500 feet above Sverdlovskjust. This resulted in political embarrassment and diplomatic pressure that forced President Eisenhower to terminate all aerial reconnaissance missions over the Soviet Union. This left a significant gap in intelligence collection. The U-2 had been a key intelligence source in the collection of information about the perceived "missile gap" between the US and the Soviet Union. Ironically just 110 days after Powers was shotdown, CORONA was flying and imaging SA-2 sites and other targets throughout the Soviet Union. (See Figure 3 for a typical SA-2 site used by the Soviets for surface-to-air missile defense.)

This first successful CORONA flight, which acquired 3,000 feet of film and covered more than 1,650,000 square miles of Soviet territory, had made its mark in history. With this flight, the CORONA program already had acquired more overhead photographic coverage of the Soviet Union than all of the U-2 flights to that date. From a technological perspective, it was the first space program to recover an object from orbit and the first to deliver intelligence information from a satellite. It would go on to be the first program to employ multiple reentry vehicles, pass the 100 mission mark, and produce stereoscopic space imagery. Its most remarkable technological advance would be the improvement in its ground resolution from an initial 25 to 40-foot capability to an ultimate 6-foot resolution.

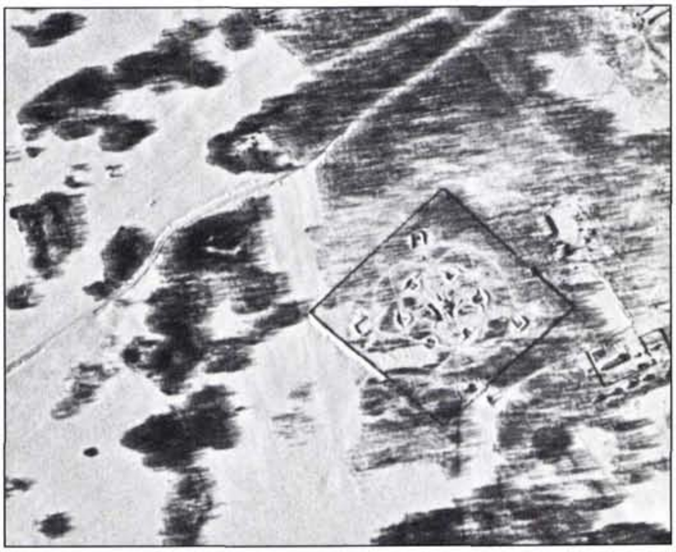

Figure 3. AN SA-2 LAUNCH SITE NEAR CHELYABINSK, USSR (MISSION 1106, FEBRUARY 8, 1969).

The Revolution in Overhead Reconnaissance

CORONA, along with ARGON, and LANYARD were the first three operational imaging satellite reconnaissance systems. CORONA—the most significant of the three from a national security perspective—operated from August 1960 to May 1972. It collected the bulk of imagery-both intelligence and mapping—during this period and is the main focus of this paper.

What Was CORONA?

CORONA, actually, is the program name for this first operational space reconnaissance project. President Dwight D. Eisenhower gave his formal endorsement for the project during a White House meeting in February 1958.[5] At this meeting, he was told about the project—a satellite imaging reconnaissance system that would take pictures from space as it passed over the Sino-Soviet bloc. The satellite periodically would deorbit a capsule with film, which would be sent to the CIA's National Photographic Interpretation Center for "exploitation" (i.e., imagery analysis).

Eisenhower's decision to endorse the plan was a bold attempt to counter the effects of the Iron Curtain and a daring step to challenge the unknown. The Iron Curtain had closed the West's view into the communist world, and this new space technology, while untested, offered this opportunity to the Intelligence Community.

The USSR had moved away from the West and had become a closed society with a penchant for controlling the flow of information both internally and externally. It was setting up satellite governments in occupied Europe and seeking to destabilize other governments in an effort to extend the communist power base. Nikita Khruschchev already had rejected Eisenhower's 1955 "Open Skies" proposal that was to be an essential basis for mutual arms control. Overlaying this context was a growing US public concern over a perceived "missile gap" with the Soviet Union. Consequently, US policymakers were under pressure to obtain timely, comprehensive, and accurate information about world events, especially events occurring in the USSR.

Reconnaissance attempts with high-flying aircraft and balloons only could provide limited useful information. The objective of the CORONA program was to use a space platform to acquire photographic intelligence to help satisfy a requirement for what was viewed as much-needed information. Engineering-wise it was based on theoretical concepts that yet were to be demonstrated using a technology that was based on neither confident data nor proven hardware. Questions that we take for granted today had yet to be answered: If you successfully launched a camera into orbit, would it work? If you took pictures from a satellite, could they see through the earth's atmosphere? Could you launch, control, and recover a spacecraft?

CORONA was managed jointly by the CIA and the US Air Force[6]. In the final project proposal that was submitted to General Goodpaster on April 16, 1958, the Advanced Research Projects Agency (ARPA) was designated as the funding source for development of the vehicle and as the agency to exercise general technical supervision over the project. The Air Force Ballistic Missile Division (BDM), served as ARPA's agent and performed detailed supervision of vehicle development. BDM provided ground facilities for launching, tracking, and recovery in collabora-

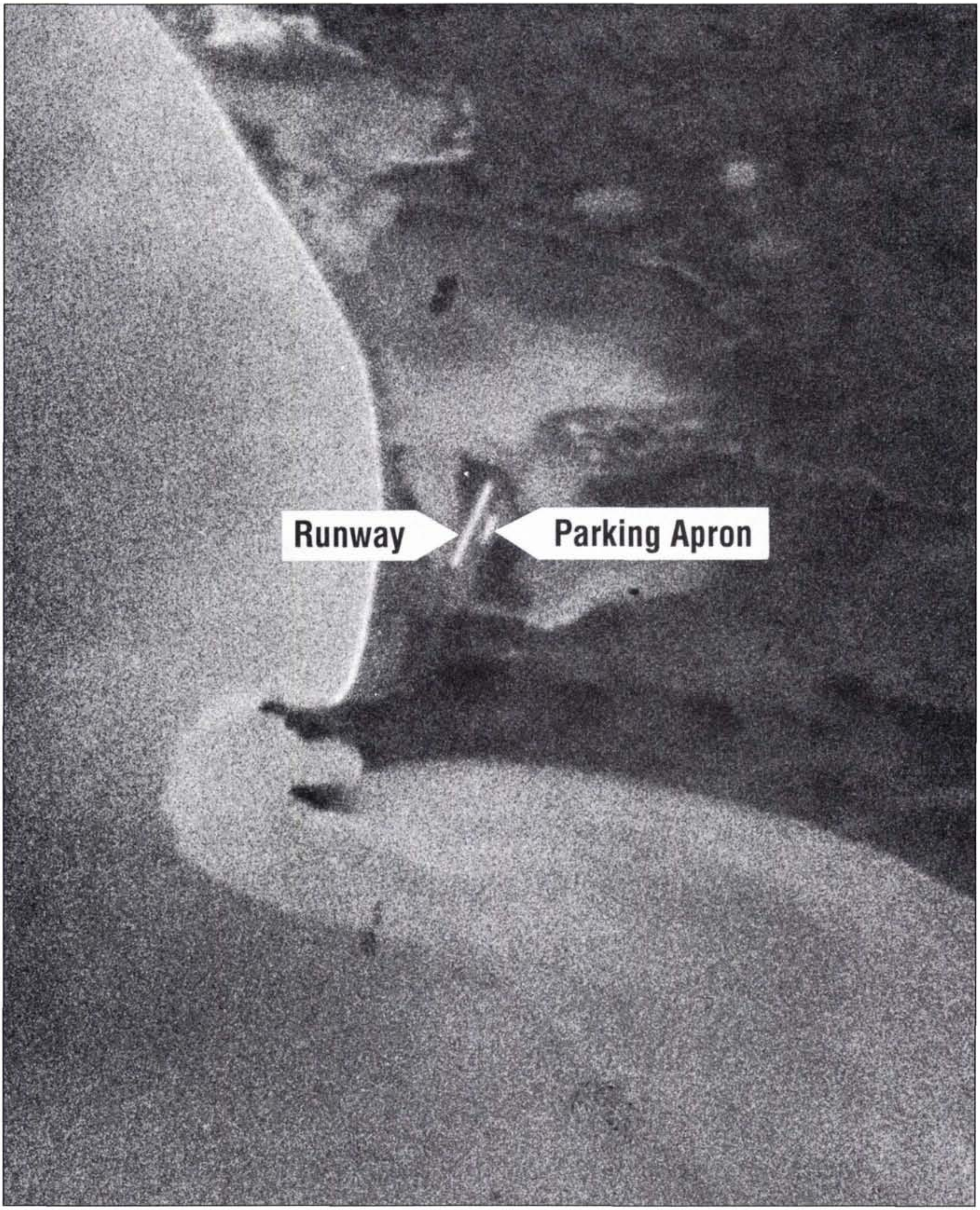

Figure 4. Mys Shmidta Air Field: CORONA's First Image of An Intelligence Target.

The CORONA Project was developed in the utmost secrecy.

tion with the US Navy. The CIA supervised technical development and classified procurement of the reconnaissance equipment. CIA also had overall responsibility for security.

The CORONA project was developed in utmost secrecy so that targeted nations would not be aware of what was being planned. Access was tightly controlled in the Executive Department, and very few in Congress were involved in the approval process, perhaps as few as three to five senior members. The CIA and Air Force were entering into a new field of intelligence; there was uncertainty over how foreign governments would react. Would there be a negative foreign reaction to the US collecting intelligence with overhead "spy" satellites? There already was a history of objections to aerial overflights. Would there be an attempt to develop countermeasures against these satellites? These early reconnaissance vehicles would only be able to discern objects about 50 to 100 feet on a side, making it relatively easy for a targeted nation to deploy countermeasures.

The CIA Project Director for CORONA was Richard M. Bissell, Jr. (the Special Assistant to the DCI for Planning and Development). Brig. Gen. Osmund Ritland (Deputy Commander of BDM) was in charge of Air Force CORONA support for Maj. Gen Bernard A. Schriever, the Commander, BDM. During the early days, these individuals implemented their program management in a very informal manner, with a high degree of cooperation between the Air Force and CIA components.

The cooperation and teamwork went beyond government components. It also was a joint effort between the government components and a team from industry. The industry team included Lockheed Missiles & Space Company, Itek Corporation, Fairchild Camera & Instrument Corporation, Eastman Kodak, General Electric, and Douglas Aircraft Company. Lockheed, which was under contract to both CIA and BMD, had broad responsibilities: (1) it served as the technical director and integrator of all equipment (other than the Thor booster); (2) it developed the orbiting upper stage; and (3) it integrated and led the test, launching, and on-orbit control operations. Itek, with Fairchild Camera & Instrument Corporation, developed the camera, and General Electric was the contractor for the recovery capsule. Douglas served as an associate contractor for the Thor boosters. Kodak supplied the film, and—over the years—worked with the government to assist in the development of film processing.

The first CORONA image of an intelligence target was acquired during Mission 9009 on 18 August. It was of a Soviet bomber base at Mys Shmidta, located on the extreme northeast coast of the Soviet Far East. (See Figure 4 for a 30X enlargement of this image.) This base was only 400 miles from Nome, Alaska and was a frequent target during subsequent CORONA missions. This image represents a ground resolution of approximately 25 feet, the best that could be expected during these early missions.

CORONA operated for little over a decade and acquired photographic coverage of at least 600 to

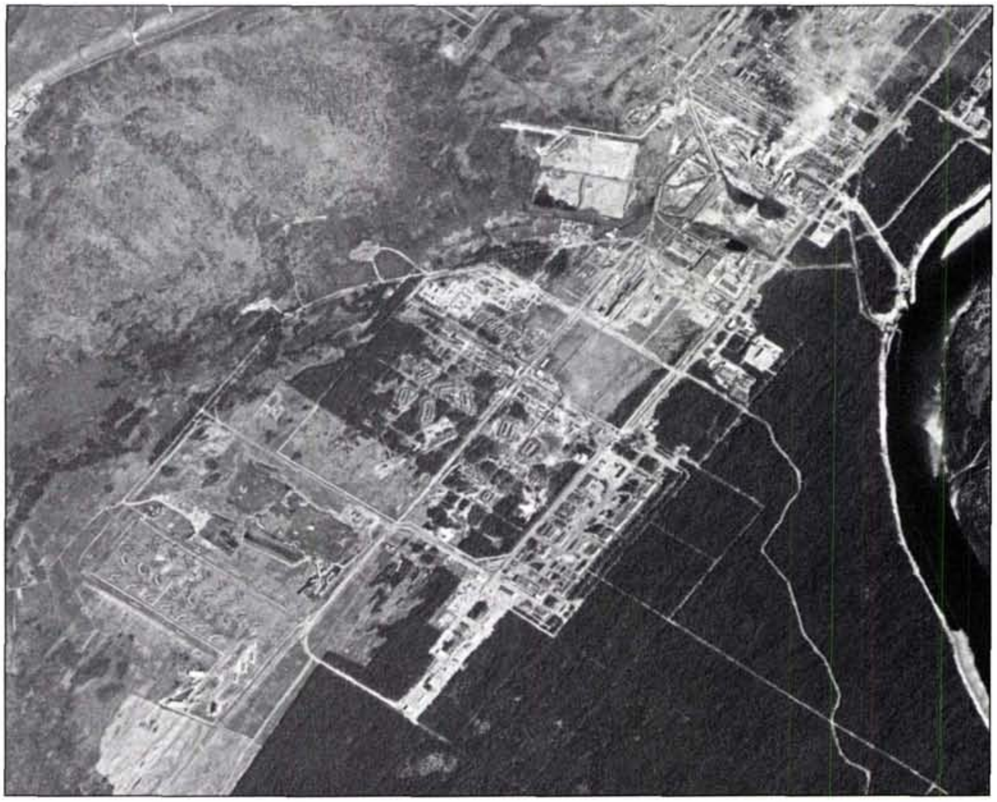

Figure 5. SOVIET SOLID ROCKET MOTOR PRODUCTION PLANT NEAR BIYSK.

750 million square nautical miles of the earth's surface. The early years of the program were marked by rapid changes. The CORONA program office made a series of modifications between August 1960 and August 1963 that resulted in taking a single camera system that could produce imagery of only limited resolution (25 feet to 40 feet) and quickly improved it to a twin panoramic camera system that could produce medium resolution imagery (6 to 10 feet). A one day mission had been extended to around nineteen-day missions. Figure 5 is an example of an about six-foot resolution image that was acquired during KH-4-B Mission 1115, 14 Sept. 1971. (See Appendix 2 for an operational overview of the CORONA reconnaissance program.

What about LANYARD and ARGON?

ARGON and LANYARD were the program names for two related space imaging capabilities of the 1960s. ARGON was a mapping system that was developed in parallel with CORONA, and LANYARD was an attempt to develop an intelligence capability with a higher resolution capability. (See Appendix 3 for an operational overview of the ARGON and LANYARD programs.)

ARGON flew 12 missions between February 17, 1961 and August 21, 1964. What would have been numbered CORONA mission 9014 was numbered ARGON Mission 9014A, the first successful mapping system launch. ARGON had a focal length of 3 inches. Project ARGON grew out of a requirement from the US Army Map Service for a reconnaissance satellite that could obtain precise geodetic data on the Soviet Union for pinpointing strategic targets. The program provided significant mapping and geodetic data on the Soviet Bloc in support of US military requirements. The White House approved ARGON as an independent mapping project on July 21, 1959. The project, however, was to be administered within the organizational framework of the CORONA program because of a fear that ARGON, as a satellite imaging system, might compete with CORONA for launching facilities and might complicate the security plans associated with the CORONA program. The earliest ARGON missions were flown independently, but the later missions were flown piggy back with CORONA cameras. There also was a second mapping camera with a 1.5 inch focal length. This camera also flew piggy back on CORONA missions.

LANYARD was a project designed to solve a significant information gap facing the Intelligence Community—the absence of high-resolution photographs of suspected ABM sites at Leningrad. Although LANYARD was expected to be a source of high-resolution intelligence imagery (i.e., 2 feet), it collected a best resolution of only six feet. Because of this, its single 1963 mission was considered to be only partially successful.

What are the "KH" Designators?

The Intelligence Community used two sets of terminology to refer to its photosatellite reconnaissance activities, one for the program manager and another for the users of the imagery. The program managers—i.e., the Air Force and CIA—referred to the satellites by their program names, i.e., "CORONA," "ARGON," and "LANYARD." The users of the imagery referred to the reconnaissance satellites and their imagery by the KEYHOLE (KH) designators that were assigned to the camera systems. CORONA's cameras were designated as the KH-1, KH-2, KH-3, and KH-4; ARGON's camera was designated as the KH-5; and LANYARD's camera was known as the KH-6 system.

Sometime after CORONA's KH-4 camera became operational, the designator, "KH-4," was expanded retroactively to include all of the initial CORONA missions that were flown as the KH-1, KH-2, and KH-3 systems. The two final modifications of the CORONA camera were designated as the "KH-4A" and "KH-4B."

In addition to the program names and KH designators, each camera system was assigned a numerical series to number its missions. The KH-1 through KH-4 missions (i.e., the "KH-4") were numbered in the 9000 series; the KH-4A missions were numbered in the 1000 series; and the KH-4B missions were numbered in the 1100 series.

What Were the Capabilities of CORONA's "KH" Camera Systems?[7]

The KH-1 and KH-2 cameras, which were manufactured by the Fairchild Camera Company, were basically the same cameras—70 degree scan, vertical-looking, reciprocating, panoramic cameras. They exposed the film by scanning at right angles to the line-of-flight. In the KH-1 configuration, image motion compensation (IMC) had a constant velocity, while for the KH-2, the image motion compensation changed continuously throughout each pass. In the engineering community, these two cameras also were known as the C and C Prime (C') models. Only five of the 20 KH-1 and KH-2 missions yielded usable photography. The failures resulted mostly from system problems, rather than camera malfunctions.

The KH-3 and follow-on CORONA cameras were manufactured by the Itek Corporation. The KH-3 camera (the C Triple Prime or C''' model) also was a 24" focal length, panoramic camera; however, there were five major design changes: (1) the structural design was modified to avoid the negative impact of thermal differentials to its components; (2) the camera controls were made more reliable; (3) the method of metering film and achieving and maintaining camera focus was improved; (4) the scan arm design was improved; and (5) a faster lens system was installed, which in turn permitted the use of slower, finer grain film. There are other changes

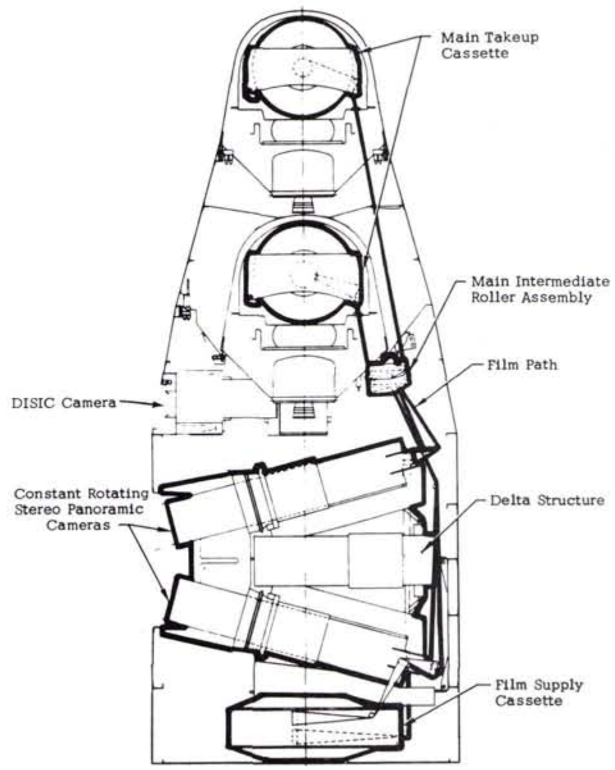

Figure 6a. LINE DRAWING OF MAJOR COMPONENTS OF THE KH-4B CAMERA.

that are noticeable to those who use the film. The width of the format was changed from 2.10 inches to 2.25 inches, and the timing pulses (to determine the scan velocities and image motion compensation velocities for a frame) are marked in the "image area," rather than in the border area of the format.

With Mission 9031, CORONA began to fly its dual KH-4 camera system (the Mural or "M" camera). It was the first camera system to provide stereoscopic imagery. This was an opportunity for the Intelligence Community to increase the information content by a factor of 2 1/2 times. The KH-4 system consisted of two KH-3 cameras on a common mount, one looking 15 degrees aft from the vertical and the other 15 degrees forward. This provided for a 30 degree convergent angle for stereo photography that permitted measuring vertical as well as horizontal dimensions on the Earth's surface. The cameras were mounted back-to-back and scanned in opposite directions. This tended to offset any operating imbalances and improve the overall system dynamic balance. The KH-4 also expanded mission life from three or four days to six or seven days.

The KH-4A camera was essentially the same system as the KH-4; however, it increased the film load and added a second film recovery bucket. This increased film load permitted missions of longer duration, which meant greater frequency of access to foreign targets and a higher probability of success in imaging targets without the impediment of cloud cover. As a result, the earlier mission capability of acquiring about 4,500,000 square miles of mono coverage was now expanded to some 18,000,000 square miles of stereo coverage.

The film load for earlier cameras was constrained by boost capacity. It wasn't until after the launch system was redesigned by adding three solid propellant rockets to the first-stage THOR that CORONA was able to substantially increase its boost capacity, thereby permitting a larger and heavier film load. The mission length for the KH-4A could be expanded to over 15 days, and—with the two buckets—the first could be recovered after half the film load had been exposed.

The reliability of the KH-4A camera was phenomenal. Out of 52 missions, only four involved some degree of significant camera malfunction. The KH-4A routinely acquired 10 foot resolution imagery and even acquired resolution as good as seven feet. (The KH-4A camera also was known as the "J" or "J-1" camera.)

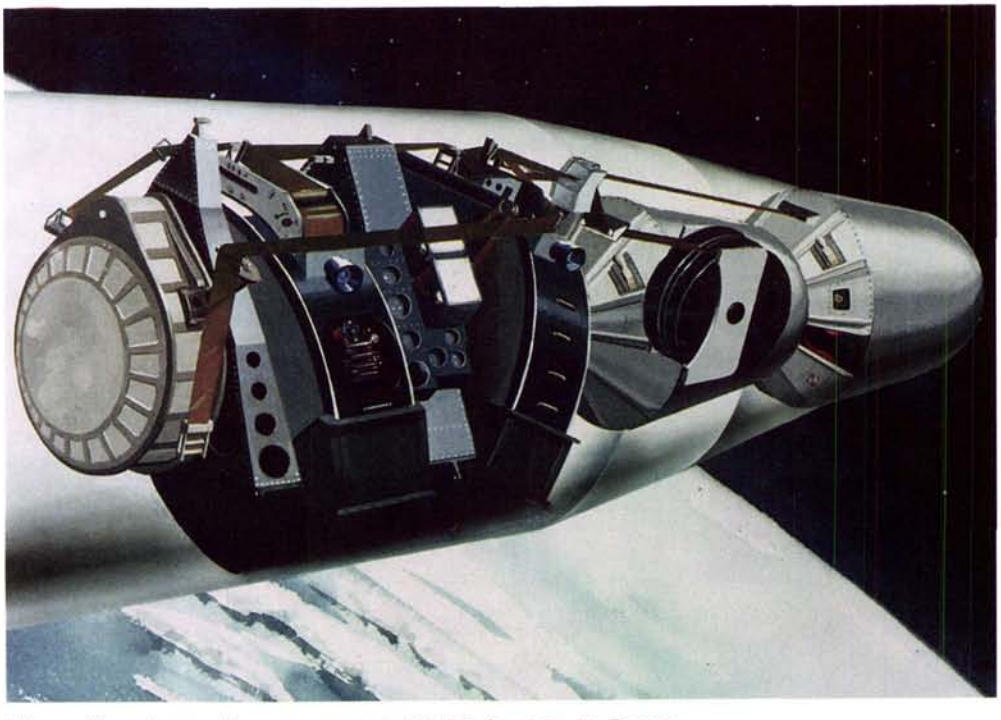

Figure 6b. ARTIST CONCEPT OF THE KH-4B CAMERA IN FLIGHT.

The KH-4B camera was developed to further

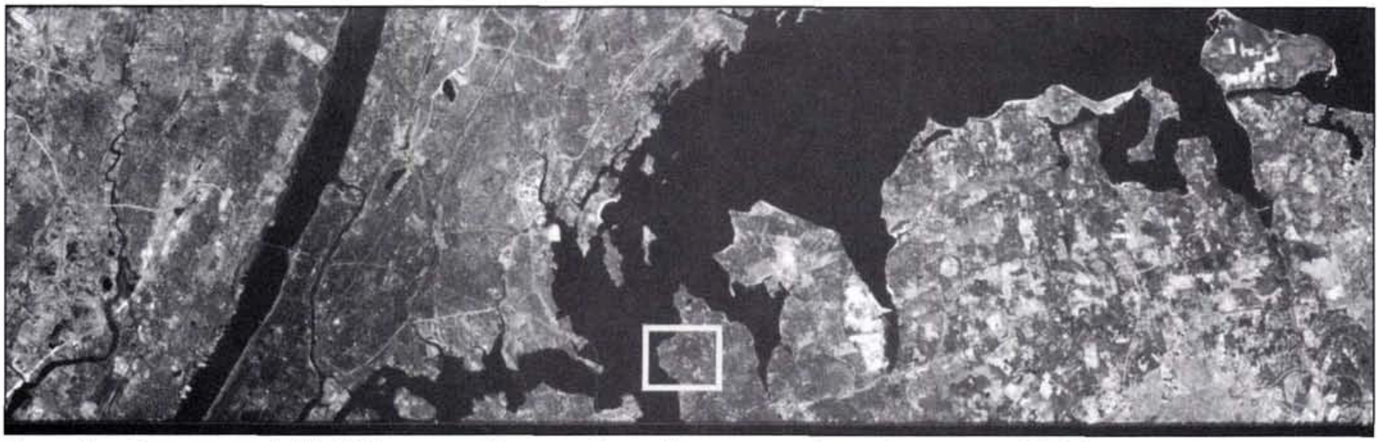

Figure 7a. Portion of a KH-4B Frame at Contact Scale Showing the Area Around the US Merchant Marine Academy On Long Island (Mission 1109, March 11, 1970).

improve resolution, as well as the flexibility of the camera system. Its primary purpose was to acquire extensive stereoscopic coverage with sufficient detail to permit intelligence analysts to monitor and evaluate intelligence targets. A secondary purpose was to provide photogrammetric control data with the required geometric accuracy to assist cartographers in constructing accurate terrain maps from the imagery collected by CORONA.

The KH-4B camera (also known as the "J-3" system) was a dual, 24-inch focal length, f/3.5 panoramic camera system. The system was oriented so that the forward camera in the vehicle was aft looking, and the aft camera was forwarding looking. With its increased photographic flexibility, the KH-4B could accommodate a variety of film types and operate more effectively under varying exposure conditions. Refinements in its camera cycle rate command controls allowed it to operate in orbits as low as 80 nautical miles, and it had a mission life of up to 19 days long. (See Figure 6 for illustrations of CORONA's KH-4B camera.)

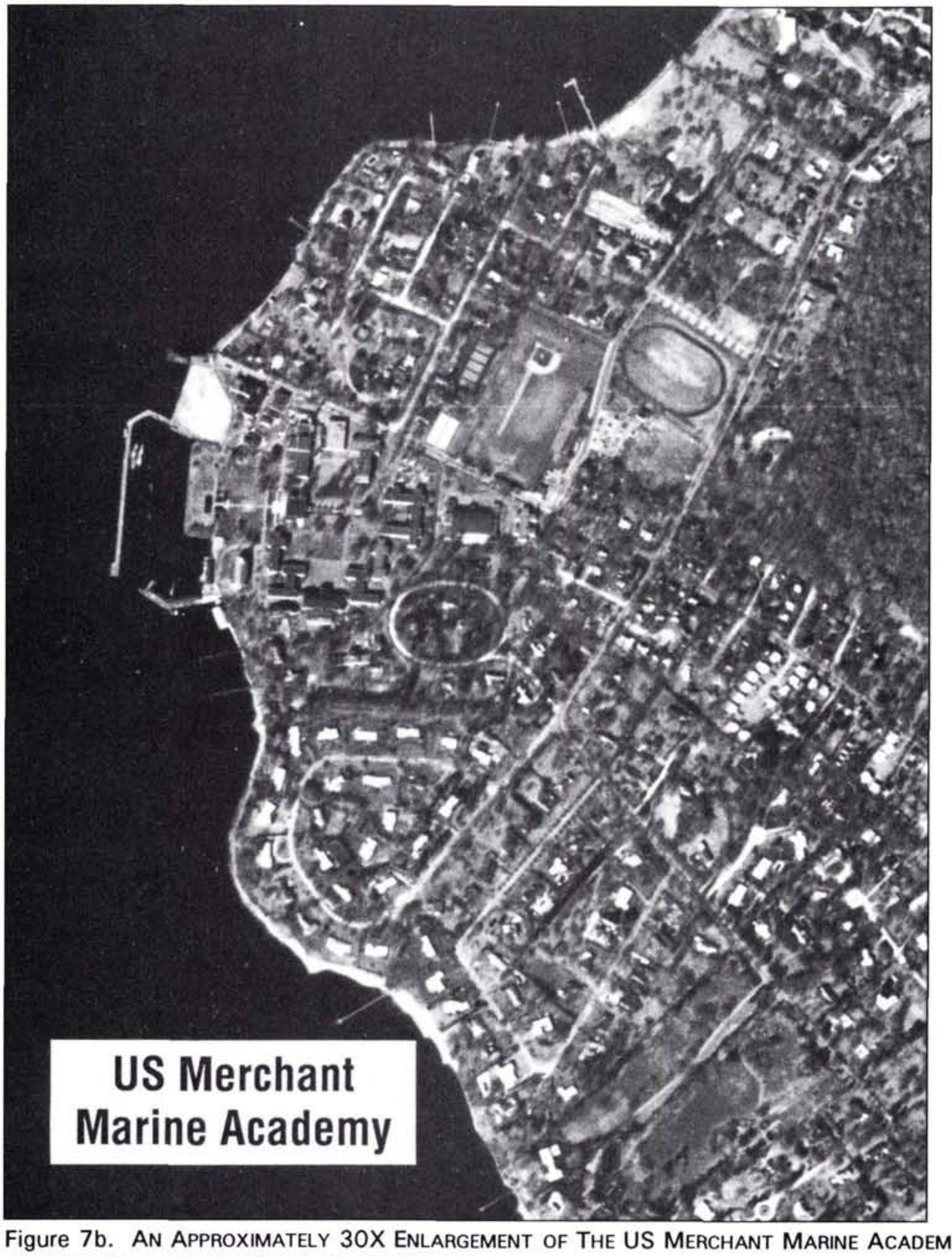

Figure 7b. An Approximately 30X Enlargement of The US Merchant Marine Academy at Kings Point On The Great Neck Peninsula.

The quality of CORONA's reconnaissance imagery improved significantly over the life of the program from the KH-1 to the KH-4B. The KH-4B camera, offered the best quality imagery, somewhat better than 6 feet (2 meters). In some cases its resolution was as good as 4.5 feet. Its usable format of 29.323" X 2.147" could be enlarged from a contact scale of 1:25,000 up to, in some cases, a scale of 1:7,500—nearly a 40X enlargement factor. CORONA was designed and operated for the collection of foreign intelligence; however, a very limited amount of domestic coverage was acquired for scaling and other engineering purposes. An example of this kind of more familiar domestic scene can be helpful, today, to demonstrate the scope of CORONA coverage, its quality, and its enlargement capability. The 1970 coverage of the US Merchant Marine Academy in Figure 7 illustrates this.

The KH-3, KH-4, KH-4A, and KH-B camera systems had one or more secondary cameras associated with them. There were horizon, stellar, and index cameras. The imagery acquired by the horizon camera was used to determine the attitude of the panoramic camera. (The KH-4B had two horizon cameras, associated with each panoramic camera.) The stellar camera acquired imagery that was used for very accurate determination of pitch, roll, and yaw during operational cycles. (The KH-4B had two stellar cameras, one pointed out either side with the optical axis 10 degrees above the horizontal.) The index (or "terrain") camera acquired vertical small-scale photography that was used for rapid correlation and indexing of the main panoramic imagery, and for the adjustment of attitude data between the stellar and main panoramic cameras. (The KH-4B had one index camera.) Figure 8 is a line drawing that shows the relationships of the KH-4B cameras. (See Appendices 4 through 6 for a summary of camera data on the early satellite reconnaissance systems.)

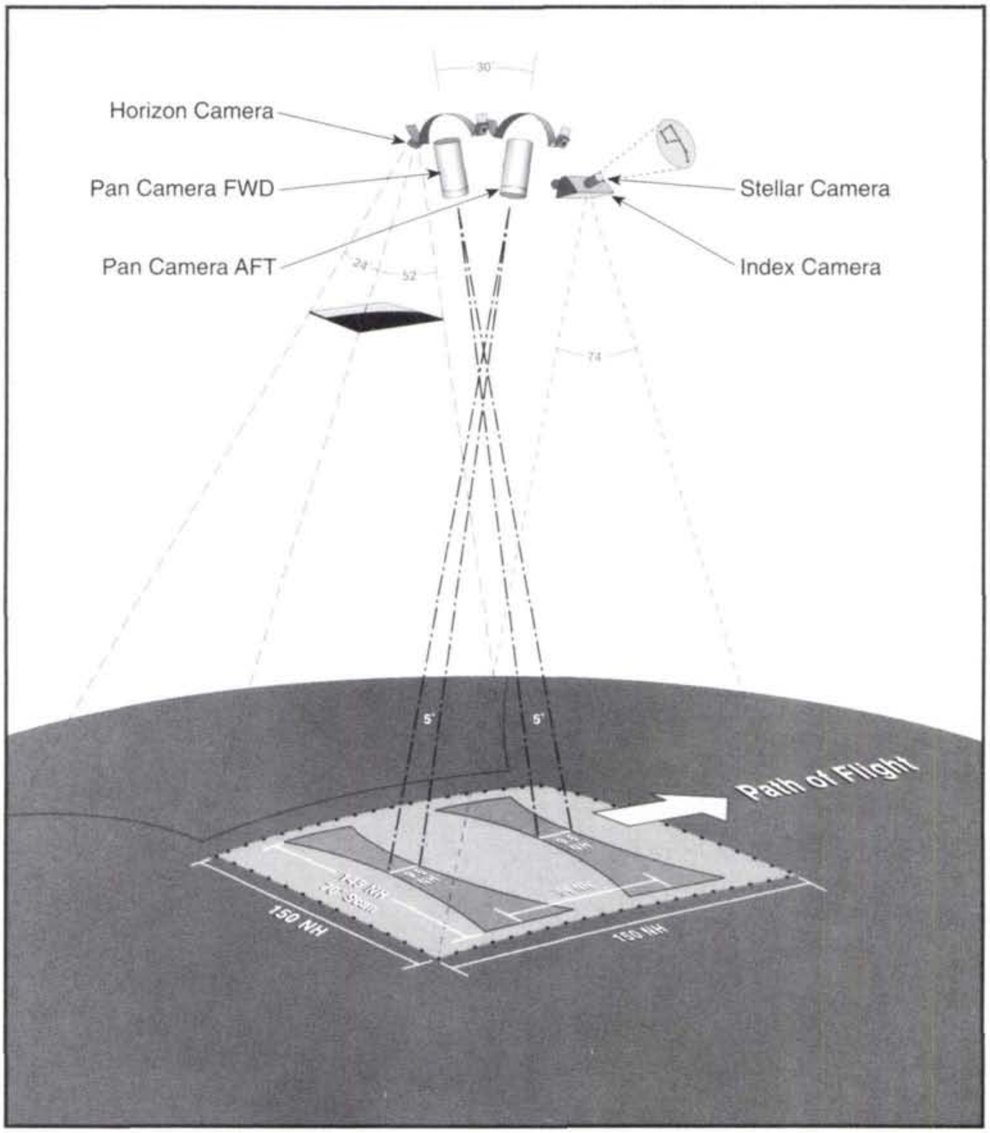

Figure 8. SCHEMATIC OF THE KH-4B CAMERA SYSTEM SHOWING THE RELATIONSHIPS OF THE CAMERAS IN REFERENCE TO THE EARTH'S SURFACE.

CORONA's imaging capability improved during the life of the program not only because of Itek's work with the camera systems, but also because of Kodak's work with the film. During the earliest part of the program, CORONA cameras used an acetate base film that often would crumble and jam during operation. To eliminate this problem, Kodak developed the capability to coat high resolution emulsion onto a polyester base. Kodak further improved CORONA's mission performance by producing thinner film, which permitted the camera system to carry more film during each mission. This, in turn, increased mission duration and provided more coverage at a lower cost per image.

Buckets of Gold for National Security

Not only was CORONA a revolution in the technology of space, but it also represented a revolution in the way intelligence was gathered and reported to senior national security decisionmakers. With CORONA, decisionmakers would be subjected to a different kind of intelligence that required more technical analysis by a specialized field of photographic interpreters. Policymakers also would find themselves wanting to see and touch the "photographic evidence" from these analyses. CORONA had moved US intelligence into the highly technical age of space operations and imagery analysis. And it paid off! Its gold-plated buckets that returned the film from space proved to be a gold mine for the Intelligence Community.

What Did CORONA Contribute?

CORONA's first successful mission on 8 August 1960 opened this new era in overhead reconnaissance. Even though the U-2 aircraft—CORONA's strategic reconnaissance predecessor—made a total of 24-foot deep-penetration overflights into the USSR, it only covered one million square miles of the Soviet Union. With only one tenth of the potential target area covered by May 1960, there were vast areas of the USSR that never had been seen by US reconnaissance sensors. CORONA filled that gap with its acquisition of about 510 million square nautical miles of the Earth's surface.

CORONA's purpose, of course, was to support arms control and associated military and intelligence interests. Accordingly, some 487 million square nautical miles of coverage, or about 95% of its total coverage was directed at acquiring imagery of foreign areas. The domestic coverage that was acquired in support of engineering and domestic mapping programs was limited to only about 5% of the total coverage.

During early missions, emphasis was placed on acquiring coverage of the Soviet Union. Later, coverage of other foreign areas was expanded. The map in Figure 10 portrays the typical coverage of the Eurasian land mass. It specifically shows the extensive area covered by the KH-4A during only four days of Mission 1017 in March 1965. Impressive, when compared with the U-2's total coverage. The map does not indicate which areas were cloud covered, but on most missions, about 50 percent of the imagery was obscured by clouds. (See Appendix 7 for a table that summarizes the area coverage of the early satellite reconnaissance systems.)

Coverage of domestic scenes was limited because it was acquired for narrow purposes, initially in support of engineering studies. For example, imagery of known domestic areas would be acquired, and measurements of image features would be taken. These measurements would then be compared with the known ground truth. In later years, additional limited domestic imagery was acquired to support domestic mapping programs.

What Was the National Security Impact?

As a preview of what space reconnaissance would be able to do in future decades, CORONA made a startling impact on the missile gap debate and opened the doors to monitoring arms control and nuclear proliferation. CORONA's vast contribution in this area becomes evident by looking at examples of the kinds of intelligence it provided over its operational life.

Exposing the Missile Gap Myth

The potential contribution of the CORONA program —and the future value of the KH-4 camera—became apparent after recovery of the first photo reconnaissance product from Discoverer XIV on August 19, 1960. Photo interpreters were able to demonstrate with KH-4 imagery that

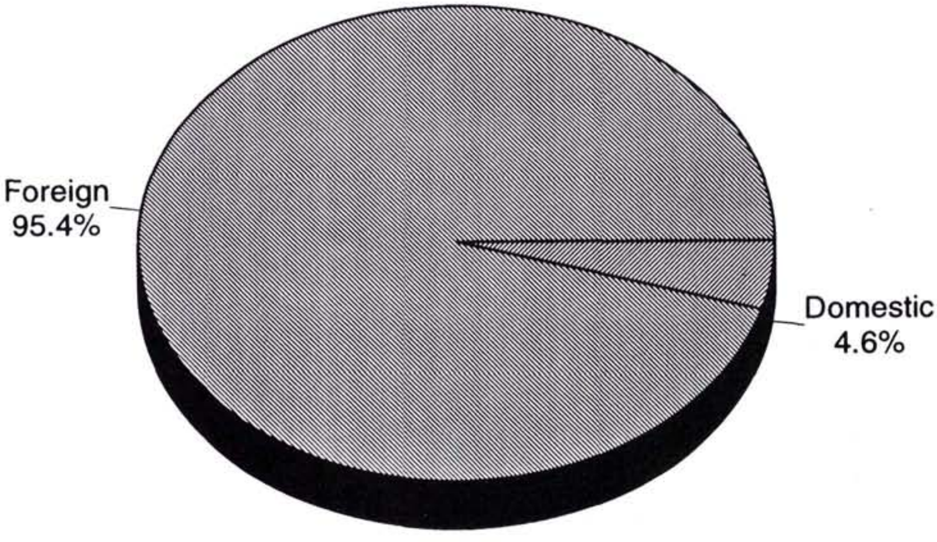

Figure 9. CORONA's Worldwide Coverage.

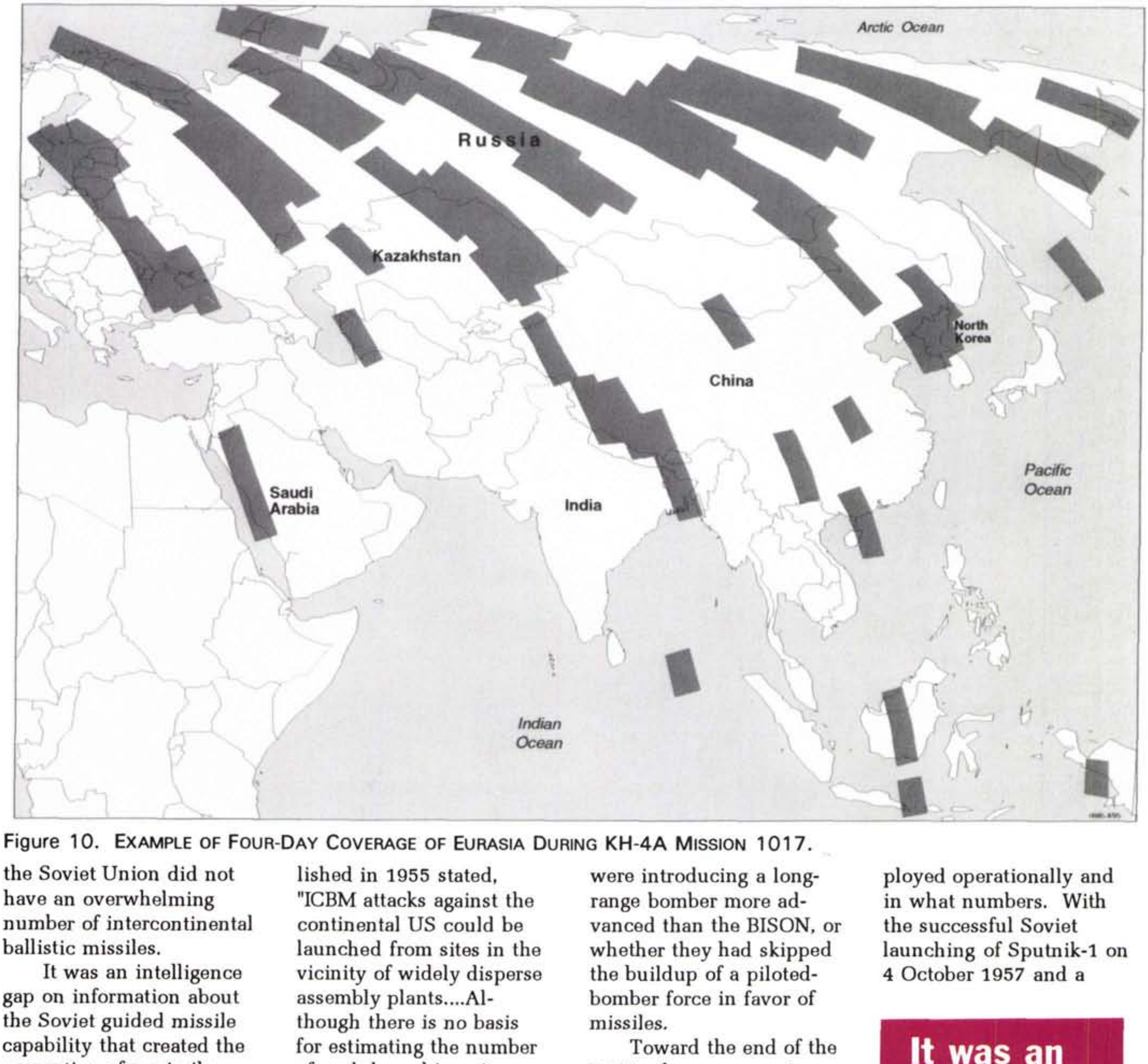

Figure 10. EXAMPLE OF FOUR-DAY COVERAGE OF EURASIA DURING KH-4A MISSION 1017.

the Soviet Union did not have an overwhelming number of intercontinental ballistic missiles.

It was an intelligence gap on information about the Soviet guided missile capability that created the perception of a missile gap. In the mid-1950s, one National Intelligence Estimate reported, "It is well within Soviet capabilities to develop numerous...types of missiles within the period of this estimate, but we have at present no information as to which of these various types the USSR may be developing on a priority basis." (CIA, 1954. pp. 8-9). Another estimate published in 1955 stated, "ICBM attacks against the continental US could be launched from sites in the vicinity of widely disperse assembly plants....Although there is no basis for estimating the number of such launching sites which might be available in 1965, we believe ICBMs could be launched in an initial attack against many US targets." (CIA, 1955, p. 2). Later in the 1950s, the Intelligence Community had gaps in information about the Soviet long-range bomber force. It was not known how many BEAR and BISON heavy bombers were operational and whether the Soviets were introducing a long-range bomber more advanced than the BISON, or whether they had skipped the buildup of a piloted-bomber force in favor of missiles.

Toward the end of the 1950s, there were major changes in estimates on the scope of the Soviet missile program based on the limited photography that was available from the relatively small number of U-2 missions. The Soviets had tested ICBMs at ranges of 5,000 miles, demonstrating that they had the capability to build and fly them. What was not known was where those missiles were being deployed operationally and in what numbers. With the successful Soviet launching of Sputnik-1 on 4 October 1957 and a

It was an intelligence gap on information...that created the perception of a missile gap.

Senate investigation into the US "missile lag" by the Preparedness Subcommittee, the purported "missile gap" had become a major controversy. By 1959 members of the Community held widely diverse views on the Soviet missile question. While the U-2 had improved the knowledge of the Soviet Union, it could not provide broad area coverage or answers to these questions.

A series of Soviet announcements fueled growing US concerns over what appeared to be a growing "missile-gap." The first, in August 1957, announced the successful test of an intercontinental ballistic missile. Then, in October 1957 the Soviets announced the successful orbiting of the world's first artificial earth satellite, Sputnik. This was followed by three other announcements: in November the Soviets announced that they orbited a dog and television camera; on 4 Dec. 1958, a Soviet delegate to the Geneva Conference on Surprise Attack stated that Soviet ICBMs were in mass production; and on 9 Dec. 1958, Premier Nikita Khrushchev claimed that the Soviet Union had an ICBM capability of carrying a 5-megaton nuclear warhead 8,000 miles. By the end of 1959 there was widespread concern within the US policy circles that the Soviets Union was producing a missile arsenal that would be much larger than that of the US (Licklider, 1970; Freedman, 1986, pp. 69-70).

This concern over an apparent growing "missile-gap" was a major factor in a decision by President Eisenhower's to authorize U-2 flights over the Soviet Union. In July 1959, he authorized limited overflights of the Soviet Union. This was in spite of the fact that in March 1958, he had cancelled U-2 overflights in reaction to strong Soviet protests and a growing fear that the Soviets were developing a capability to shoot down the U-2. The U-2 imagery, however, was not able to fully resolve the issue, and it was finally early CORONA imagery that subsequently resolved the issue and made it clear there was no missile gap.

The newly available public evidence from CORONA[8] offers historians an opportunity to speculate on how this closely held intelligence information might have influenced the 1960 election if it had been declassified 34 years ago. CORONA film had been recovered and analyzed two months before the campaign ended. The evidence was in, and CORONA had demonstrated that the "missile gap" was an illusion. Earlier in the year John F. Kennedy had been campaigning on the issue of the missile gap, but Richard M. Nixon had denied it existed. Vice President Nixon, of course, was knowledgeable of the CORONA imagery, but because of its sensitivity, apparently felt constrained from making the CORONA evidence public. Even though Kennedy had been made aware of the analysis and stopped talking about the missile gap, some of his supporters did not. Nixon's indirect assertions that there was no missile gap had little impact during campaign debate.

The CORONA ... became the primary "National Technical Means" of verification for ... SALT.

Monitoring Arms Control

The CORONA program played a major role in supporting development of US arms control policy and became the primary "National Technical Means" of verification for the Strategic Arms Limitation Treaty (SALT). It was CORONA in June 1961 that acquired overhead imagery of the first deployed Soviet Intercontinental Ballistic Missile (ICBM) launch complex. This was at Yurya, 500 miles east of Moscow. CORONA monitored Soviet activity at this complex. While some locations were obvious launch sites, other locations were only suggestive of a future site (See Figure 11a). With continued observation by CORONA, it became clear to analysts by the next year that the Soviets were constructing an SS-7 ICBM launch site at this location. (See Figure 11b for this later coverage.) The SS-7 ICBM system subsequently was deactivated, and its launch facilities were destroyed as a result of the 1972 SALT I Interim Agreement on Strategic Missiles.

Detecting Nuclear Proliferation

CORONA played a role in monitoring nuclear proliferation. KH-3 Mission 9029 in December 1961 provided the first satellite coverage of a Chinese nuclear test site located near Lop Nor. In August 1994 the Director of Central Intelligence published a Special National Intelligence Estimate that assessed the likelihood that China would detonate its first nuclear device that year. CORONA imagery provided the Intelligence Community with convincing evidence that the Lop Nor facility was a nuclear test site and could be ready for use in about two months. In October, China conducted its first nuclear test. Figure 12 is CORONA coverage of Lop Nor on 20 October 1964, four days after this test.

Supporting the SS-9 Debate

By 1964, CORONA had confirmed that the Soviet Union was developing and deploying the SS-9 Intercontinental ballistic missiles. (See Figure 13 for 1964 coverage of the SS-9 ICBM Complex near Uzhur, southwest of Moscow.)

Confirmation of SS-9 deployment set the stage

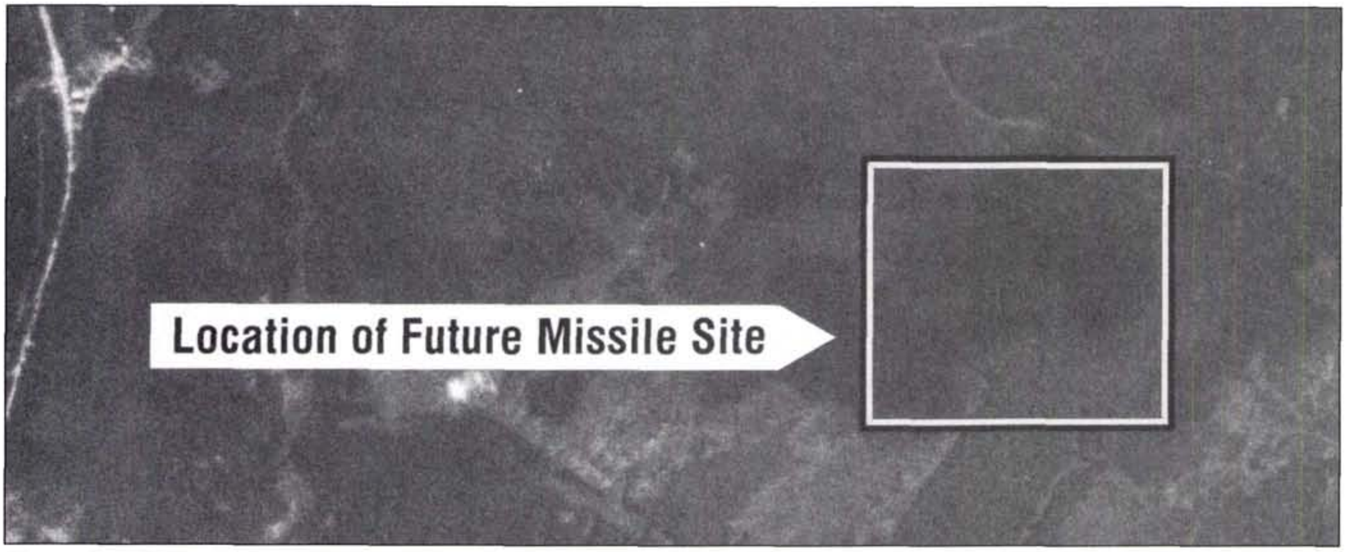

Figure 11a. YURYA ICBM COMPLEX SHOWING SITE OF FUTURE SS-7 LAUNCH SITE (MISSION 9017, JUNE 16, 1961).

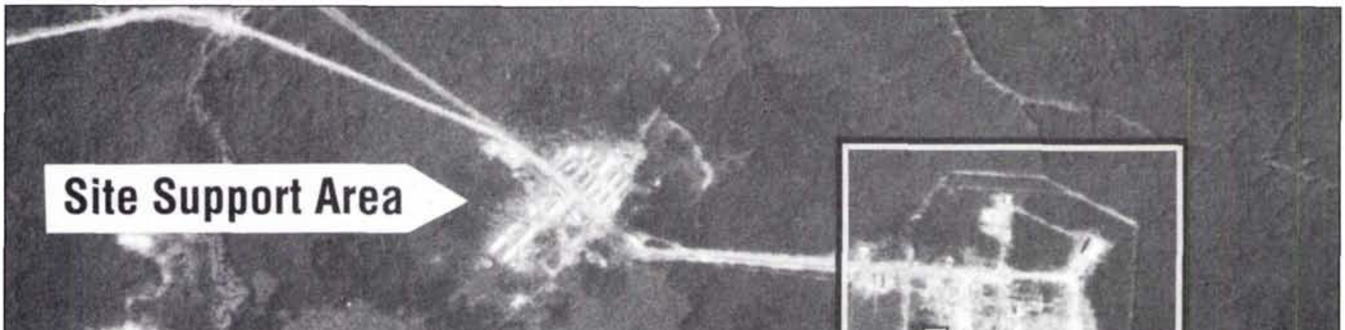

Figure 11b. YURYA ICBM COMPLEX SHOWING CONSTRUCTION OF AN SS-7 LAUNCH SITE (MISSION 9038, JUNE 28, 1962).

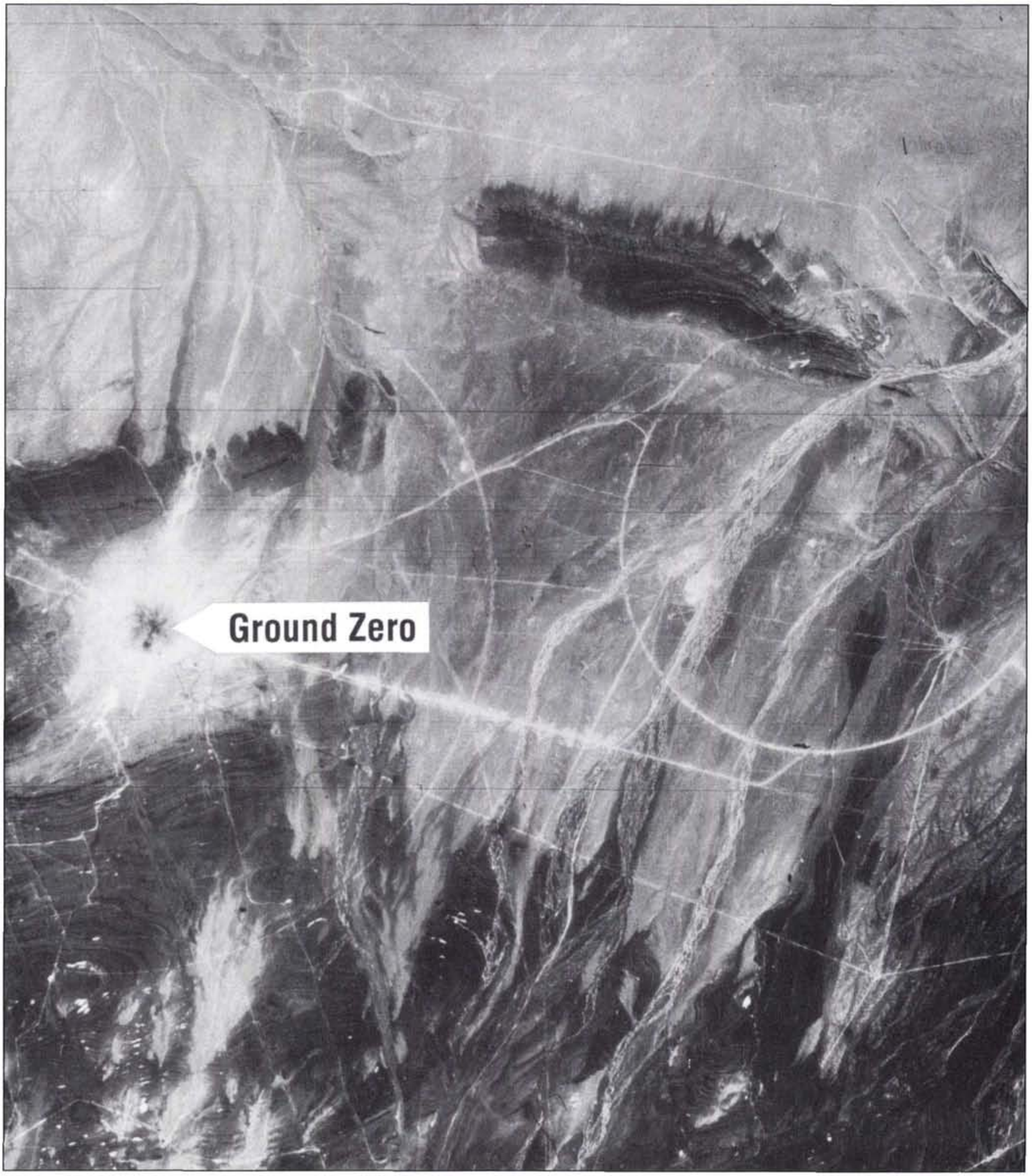

Figure 12. CHINESE NUCLEAR TEST SITE AT LOP NOR, SHOWING GROUND ZERO FOUR DAYS AFTER THE NUCLEAR TEST (MISSION 1012).

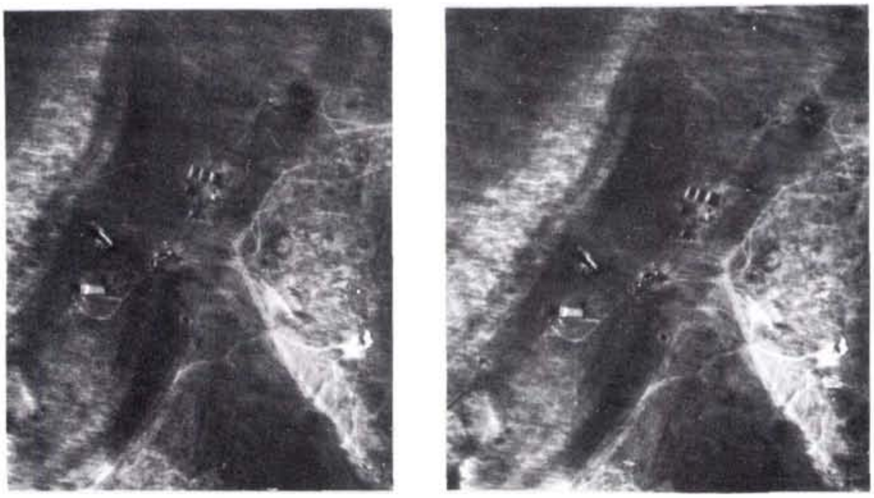

Figure 13. STEREO PAIR OF A SOVIET SS-9 ICBM LAUNCH SITE UNDER CONSTRUCTION NEAR UZHUR (MISSION 1014, NOV. 26, 1964).

for a major national security policy debate in Washington later in the 1960s. The SS-9 was generally considered to be a "mammoth" ICBM (10 stories high) with an ability to carry a payload of 10,000-15,000 pounds for a distance of 7,000 nautical miles. (By comparison, the US Minuteman only could carry one-tenth of the payload.) The Defense Department, CIA, and Congress became locked into an intense debate in 1968-69 about SS-9 deployment. The argument focused on whether the SS-9 was linked to an emerging multiple independently-targeted re-entry vehicle (MIRV) technology—a technology that could wipe out US defenses in a single blow. The policy question became one of whether this Soviet capability would require an American anti-ballistic missile (ABM) system (Lundberg, 1989). While the debate raged, satellite reconnaissance imagery played a key role in providing intelligence for the dialogue.

Images in Silver for Civil Remote Sensing Applications

The gold-plated buckets of film brought an invaluable product to the national security community. These silver halide records, which have been in the Intelligence Community's archives for 23 to 35 years, now offer a potential for making significant contributions to the civilian community. With the President Clinton's declassification decision on February 22, 1995, approximately 2,000,000 linear feet of reconnaissance film acquired by the CORONA, LANYARD, and ARGON programs is becoming available for use by the scientific and academic communities (McDonald, 1995).

What Is the Potential for Growing Environmental Problems?

What impact can this declassified space imagery have on the growing environmental challenges facing the US and world community? The imagery experts in the Intelligence Community believe that this imagery has the potential to contribute significantly to the analysis and understanding of global environmental processes.

Vice President Al Gore has long argued for this kind of capability to study environmental problems. In 1992, then Senator Gore pointed out the magnitude of the environmental problems facing the world today: "When considering a problem as large as the degradation of the global environment, it is easy to feel overwhelmed, utterly helpless to effect any change whatsoever. We must resist that response...if we cannot embrace the preservation of the earth as our new organizing principle, the very survival of our civilization will be in doubt. (Gore, 1992, pp. 366, 293)"

Gore has offered a model for addressing this environmental challenge, a Global Marshall Plan. The model is based on strategic goals that stress the importance of recognizing, and assessing progress toward making the changes that will be required (Gore, 1992, p. 305). This means gathering and measuring data, and Gore (1992, pp. 354, 357) has argued that we need to seek fundamental changes in how we gather information about the environment. While his "Mission to Planet Earth" would involve students collecting data, he also points to the unique value of Landsat space imagery that was collected over the past twenty years.

There is an information gap about the earth's surface when we turn to Landsat and other civilian space imagery. First, its record only goes back to 1972 when the first Landsat vehicle (know as Earth Resources Technology Satellite-1, ERTS-1, was launched (Elachi, 1987, p. 16). Second this Landsat imagery has spatial resolution that is limited to 30 meters.

CORONA imagery has the potential to address the information gap. The majority of CORONA imagery predates the first

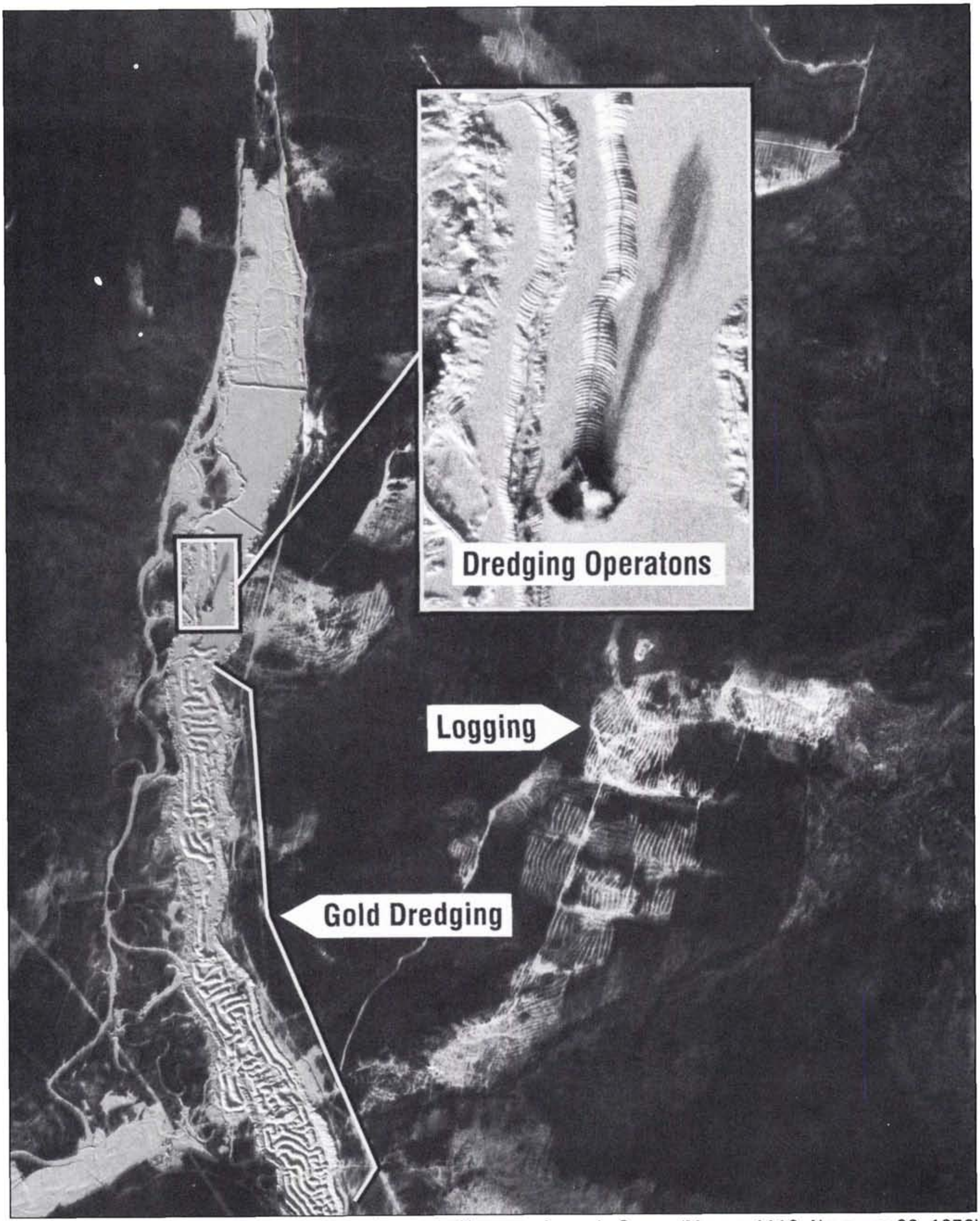

Figure 14. Coverage of Logging and Gold Dredging, North of Aldan in Siberia (Mission 1112, November 26, 1970).

ERTS launch and will extend the baseline for the systematic and comprehensive coverage of the Earth's surface by more than a decade. In many cases, there might be CORONA coverage of areas not acquired by early Landsat missions. CORONA imagery has the potential to provide environmental scientists with an opportunity to create an expanded baseline that will extend back to 1960. That will allow for a comprehensive assessment of geophysical changes that occurred on the Earth's surface during the decade of the 1960s.

In this way, CORONA imagery can significantly extend environmental timelines and fill gaps in the civil records. Changes in vegetative and desert boundaries, which may be sensitive indicators of global climate change, can be tracked over time by CORONA. The imagery can be used to monitor land use patterns, which is critical to assessing the environmental impact of population growth, urbanization, and industrialization. These archival data could be of high value in determining the often gradual changes in urban dimensions that significantly affect environmental quality.

The superior spatial resolution of CORONA imagery when compared with the civil remote sensing systems of the 1970s and 1980s can be used to complement information earlier obtained by the civil systems of the time. This CORONA imagery can help establish new ground truth, especially important in inaccessible regions. The imagery could be used to calibrate and re-interpret data obtained from the coarser resolution typical of early civil sensors. The CORONA imagery can provide more precise information related to: (1) natural resource management for resources such as oil, surface and ground water, fisheries, and minerals (2) land management for land types such as, forests, soil and arable land, deserts, and wetlands; and (3) biodiversity monitoring, such as monitoring the reported decline in the number of plant and animal species, a decline that has implications for human health and diet, as well as for the integrity of the overall ecosystem.

When used against these problems, this older reconnaissance imagery has the potential to meet Vice President Gore's objectives to recognize, measure, and assess our global changes that were occurring during the middle part of this century. Environmental scientists now will have new data points against which to recognize, measure, and assess global changes. They can apply these data points in their study of coastline erosion, wetlands degradation, deforestation, desertification, agricultural practices, and water use. These data, as related to biodiversity changes, could have implications for human health and diet, as well as overall ecosystem integrity.

What Does It Mean for Traditional Civilian Remote Sensing Tasks?

The CORONA imagery archive can offer imagery that civil users can employ to address traditional remote sensing and aerial survey problems. They can analyze the geometric features in CORONA's reconnaissance imagery just as they would analyze the shapes, forms, and patterns that are characteristic of the spatial features in conventional imagery. For geologic interpretation, linear features can suggest faulting and tectonic activities. For land use studies, geometric features can reveal human activities. For ocean studies, periodic patterns in the imagery can be used to analyze surface waves. For geomorphologic and hydrologic studies, features can be analyzed to disclose drainage patterns, which can be used to delineate geologic units, infer slope, and suggest structural control. For analysis of topography and vegetation cover, the variations in image tone can be examined (Elachi, 1987, pp 83-87).

The analysis of CORONA imagery, then, can provide new baselines for these traditional environmental assessments. For example, the analysis of imagery that depicts logging operations and mining activities (Figure 14) can provide new data on how humans impact on the environment.

Archaeologists and historians also should find CORONA imagery of interest. The applications of overhead imagery in these fields is well documented (McDonald, 1993). Such imagery can reveal features that are either invisible or distorted from the ground perspective. Traces of soil or crop marks on the earth's surface can be evidence of former human activity: lost roadways, buildings, ancient cities, or fortifications. One archeological example from the CORONA archives is the Roman fort at Lejjun, Jordan (Figure 15). CORONA imagery from 10 or 30 years ago can be be uniquely valuable for this kind of research. In some cases, the historical marks on the Earth's surface may no longer be visible from overhead because of decades of encroachment by modern human activities. The historical CORONA imagery, however, has preserved this evidence and is a permanent record of what was on the Earth's surface at that time.

These data ...could have implications for human health and diet, as well as overall ecosystem integrity.

In addition to the typical applications for black and white film,

Figure 15. Coverage of Roman Ruins At Lejjun, Jordan (Mission 1115, September 29, 1971).

Figure 16. EXAMPLE OF KH-4B INFRARED COVERAGE—VANDENBERG AFB AREA AT LOMPOC CALIFORNIA (MISSION 1104, AUGUST 28, 1968).

CORONA collected a very limited amount of infrared and color imagery that might have additional applications. Figure 16 is an example of infrared coverage that used SO180 infrared film, and Figure 17 is an example of color coverage that used high definition SO 121 aerial film.

CORONA color imagery might prove to be useful in establishing historical baselines in agriculture and forestry. Drury (1990, p. 127) has pointed out, "...one of the best measures of biological productivity on land is some kind of vegetation index based on the contrast in very-near infrared and red reflectance of plant structures compared with soils and rocks." The color imagery also might have potential for applications for photogeologic mapping associated with assessing the mineral and petroleum potential of the imaged areas.

Unfortunately there is very limited color coverage, and the resolution is relatively poor (approximately 20 to 30 feet). However, available color coverage can be used in conjunction with higher resolution black & white coverage to complement each other. Figure 18 is an example of how a color image can be matched with a black and white image of the same scene to make a stereo pair. This imagery shows an apparent mineralized area in the vicinity of an igneous intrusion and fault zone in China's Tsaidam Basin.

Opening a New World

As we can see from these examples, the soon to be available declassified imagery from the early satellite reconnaissance programs opens, for the civil remote sensing community's view, a formerly closed national security perspective. (See Figure 19 for a "CORONA

Figure 17. EXAMPLE OF KH-4B COLOR COVERAGE—CLINTON-SHERMAN AIR FORCE BASE, OKLAHOMA (MISSION 1105, NOVEMBER 20, 1968).

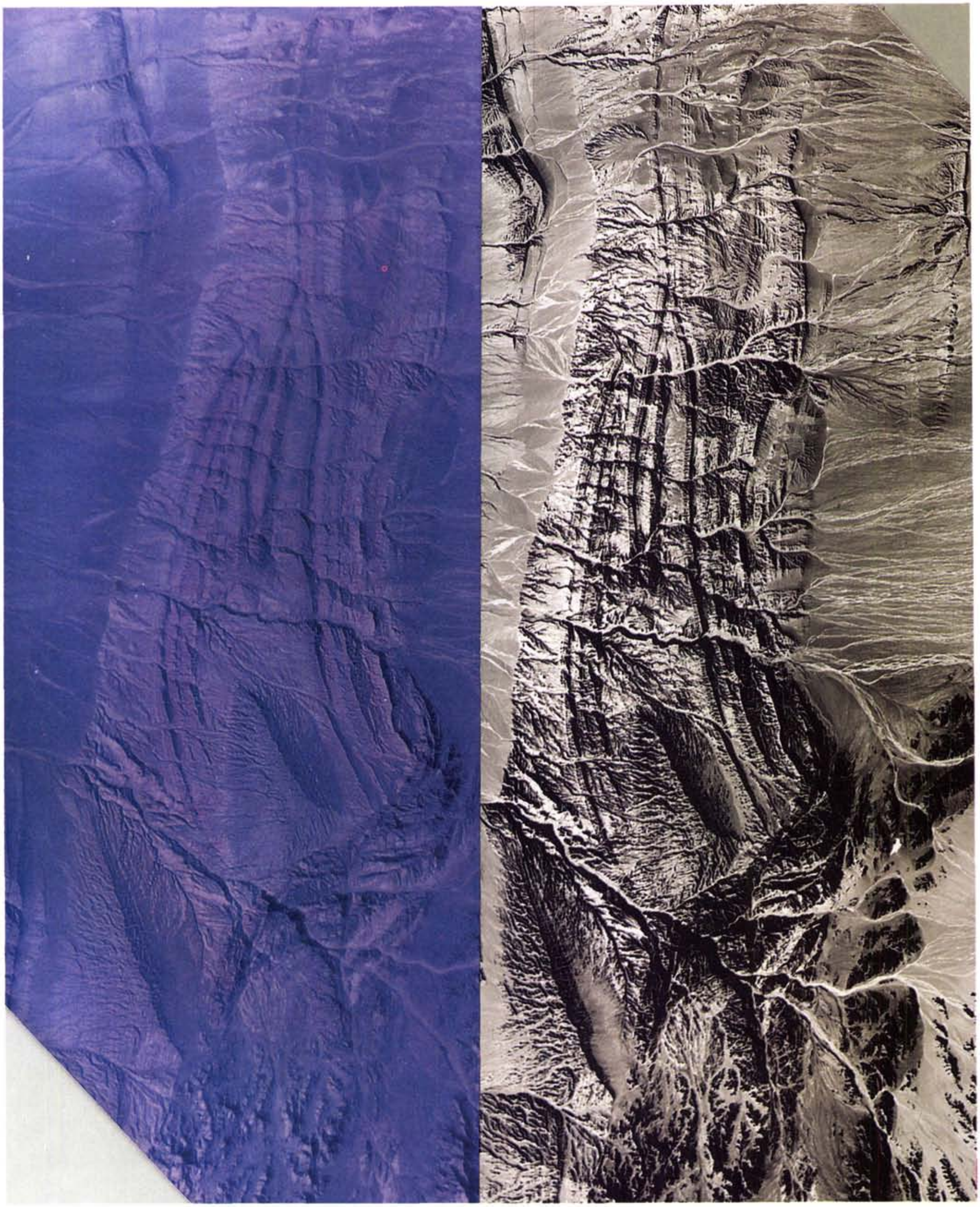

Figure 18. EXAMPLE OF MINERALIZED AREA IN TSAIDAM BASIN, CHINA—SHOWN IN A KH-4B STEREO PAIR (MISSION 1108, DECEMBER 21, 1969).

Figure 19. A New View of Washington For The Remote Sensing Community: The Pentagon As Imaged by CORONA (Mission 1101, September 25, 1967).

view" of the Pentagon, where KH-4 imagery was used in the 1960s and much of America's Cold War planning took place during that period.)

The potential uses, however, are not limited to traditional remote sensing applications such as geology and resource management, but can be expanded to those historians and political scientists who are students of the Cold War. These researchers will now have a unique source of information about the Cold War—information that has been captured in space and time from an overhead perspective. These researchers will be able to analyze the primary source of intelligence that was used by US national security policy makers as the basis for their decisions during the early period of the Cold War.

Conclusion

These early US satellite reconnaissance programs—which evolved into the present National Reconnaissance Program—were developed in response to the uncertainties and anxieties created by the Cold War. The Iron Curtain had closed off a Communist world that was seen as a growing nuclear threat. This world was a collection of political entities with suspicious societies. These totalitarian societies had disciplined, formidable, security structures that proved difficult for Western intelligence to penetrate (Helms, 1983).

Information was difficult to acquire by any means. President Eisenhower had terminated the GENETRIX balloon reconnaissance program in March 1956 in the face of Soviet protests. At the same time, the high altitude U-2 reconnaissance aircraft was only a temporary solution. It could only acquire a limited amount of imagery, and it was a risky business.

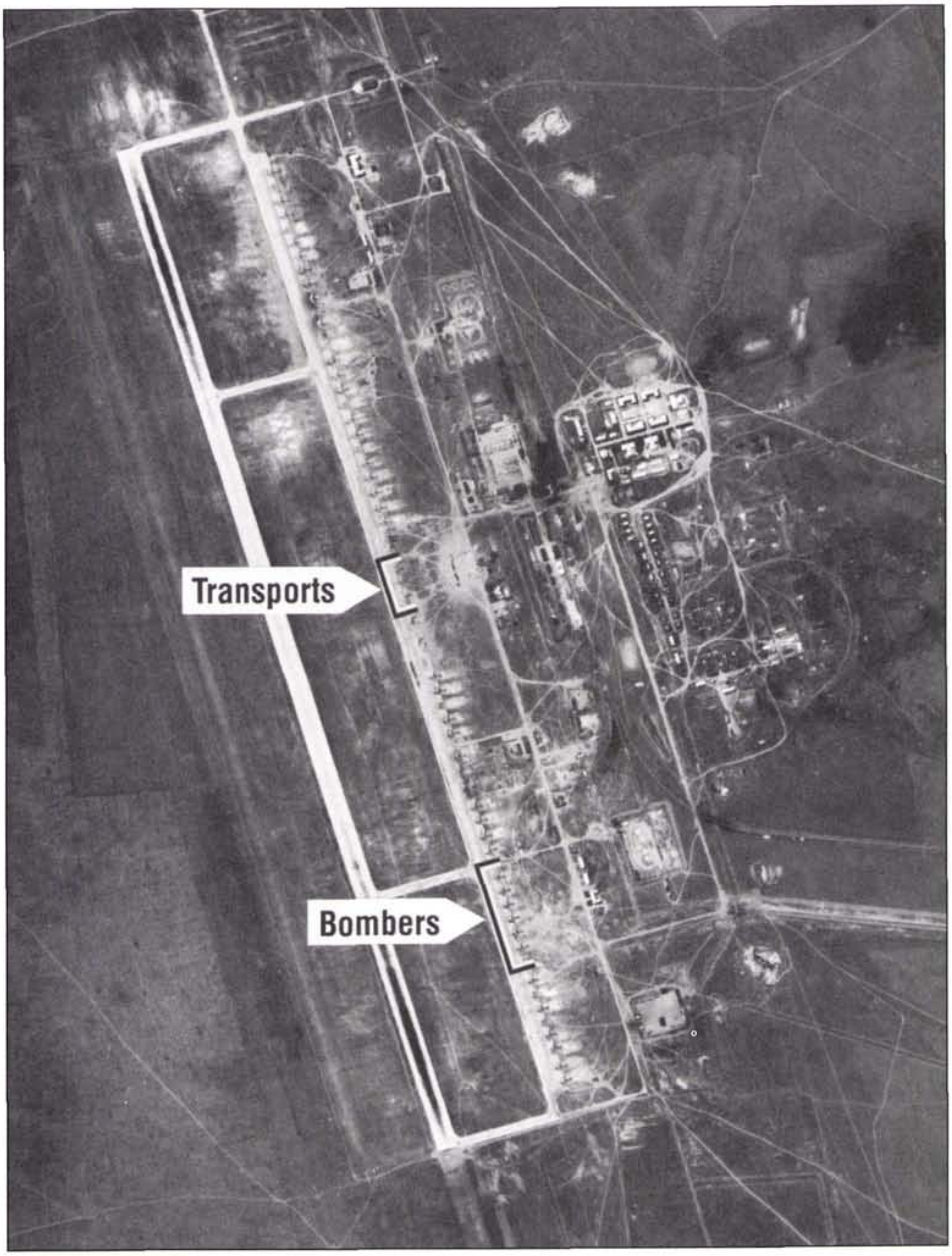

Figure 20. KH-4A Coverage of Dolon Air Field—Selected Heavy Bombers Compared With Selected Transport Aircraft (Mission 1036, August 20, 1966).

Former CIA General Counsel, Lawrence Houston (1995), recalled that the lack of information "was just appalling. We just didn't have it—any real information....We just didn't know what was going on....It was considered a key problem and... the frustration was, shall we say, absolute."

The technology of space reconnaissance changed all of this. CORONA, and its follow on programs, started a revolution in how the US collected, analyzed, and used foreign intelligence. CORONA was the beginning of what was to become an explosion of intelligence data that could provide concrete and visible evidence of foreign threats. "The intelligence side that received these pictures was absolutely fascinated by them" (Houston, 1995).

Satellite reconnaissance pictures could acquire a synoptic view of relatively large geographic areas and record this enormous amount of information on a small piece of film for subsequent detailed analysis. Intelligence analysts would now have an opportunity to see and count the strategic weapons that were a threat to the US. They could monitor the status of these weapons and follow their deployment. The pictures became concrete evidence of the threat and could give policy makers greater confidence in their planning decisions. August 1966 coverage of the Soviet Long-Range Aviation Airfield near Dolon, Kazakhstan is typical of the kind of intelligence that CORONA provided during the 1960s. This image (Figure 20) is of sufficient definition and quality to permit imagery analysts to distinguish between transport and bomber aircraft.

CORONA's technological development was in large part a result of Richard Bissell's vision that the assessment of global tensions during the Cold War required more than simple, accurate political intelligence. Such assessments needed accurate, factual information to determine the practical effects of tactical and strategic political moves. Bissell saw that the way to collect this kind of intelligence was by applying technology to the problem (Ranelagh, 1987).

CORONA was a daring technological challenge into unknown engineering. There was no evidence that an artificial satellite could be orbited when

Figure 21. THORAD BOOSTER LAUNCHING CORONA IN THE AGENA SPACECRAFT.

space reconnaissance was first seriously being thought of in the 1950s.

Even after the first Soviet Sputnik was launched in October 1957, there was no assurance that you could take pictures from space. Would the camera survive the ride into space? Could it operate in space? Could it see through the atmosphere? Could you recover the film? Would anything be visible on the film?

The success of the program was possible only because of ingenuity, perseverance, and a willingness to take risks by those involved in developing the program. There were at least twelve successive mission failures before the first successful film recovery during DISCOVERER XIV.

If this were today's program, would we tolerate this kind of failure rate? Only after learning from these failures were the developers able to go on to build the sophisticated and productive capability that CORONA was to become. More importantly, only with that perseverance and willingness to take risks was it possible to lay the foundation that has given the US the preeminence that it has in space reconnaissance today.

Most importantly, CORONA was the product of unique teamwork where government and industry personnel worked as one. "We had excellent people in those days...They'd just go ahead and get things done....We got cooperation on all fronts" (Houston, 1995). The CIA and the Air Force used a management approach that was truly a joint effort. Their approach could be the envy of those today who strive for the very high level of "joint" teamwork and cooperation that is expected within the Armed Forces by the Goldwater-Nichols DoD Reorganization Act of 1986 (Powell, 1993).

CORONA's organizational framework was simple, and its interactions were informal. The success of this management approach is reflected in the speed and efficiency with which decisions were made. For example, the President had endorsed the concept in February 1958. This was followed up by the Special Assistant to the DCI for Planning and Development (Richard M. Bissell, Jr) completing and forwarding a coordinated project outline to the Special Assistant to the President (BG Andrew J. Goodpaster) on April 16, 1958. It was for Presidential approval. Later the same day Goodpaster telephoned Bissell to confirm approval "at the highest level." By April 25, 1958—two months after concept approval by the President—the DCI approved funding for the photographic payload. Even this DCI approval memorandum (See Appendix 8) is an example of simplicity. With only three short paragraphs it commits seven million dollars to this daring joint Air Force/CIA project.

The final launch of CORONA was 23 years ago on May 25, 1972 (See Figure 21). But that was not the end of CORONA's impact. CORONA has a legacy that will live on, not only in the way its technology has influenced today's space and intelligence activities, but also in the new ways that its imagery might be used for future applications in remote sensing.

CORONA imagery clearly played a significant role by providing intelligence information during the Cold War. But CORONA imagery—which had been tightly controlled for more than 20 years—is being declassified and will become available to anyone—US or foreign—who might have an interest in the imagery. This previously restricted archive offers a unique source of data for a wide range of potential new users in the academic, scientific, and commercial sectors. There are potential applications in fields that are as diverse as: geology, history, political science, and resource management.

CORONA not only played a major role in answering key national security questions and revolutionizing the way the US collects intelligence, but it also contributed to advances in the overall US space program. For example, Itek's camera technology evolved into imaging capabilities for the Apollo lunar mapping program and the 1976 Mars Viking Lander. Also, Lockheed's exacting "rocket steering" that was necessary for precision imaging of ground targets evolved into a capability for accurate space maneuvering and docking.

The general methodologies and management infrastructures used by CORONA contractors also provided a framework that became the basis, in many cases, for developing future US space capabilities. "CORONA was the genesis for a web of technology that is still growing today, to include: Defense Support Program, Global Positioning System, Defense Meteorological Support Program...and today's generation of reconnaissance satellites" (Harris, 1995).

While CORONA and its follow-on space reconnaissance systems were secretly collecting space imagery in the classified world, the public saw MERCURY orbit the first American, John H. Glenn, Jr., in February of 1962; they saw APOLLO land Neil Armstrong on the moon in July of 1969; and, in late June 1995, they should see the docking of a US Space Shuttle with the Russian Mir space station to pick up NASA astronaut, Norman Thagard (*Washington Post*, 1995). We will have come full circle. A Cold War space technology has evolved into a capability that empowers the former Cold War rivals to peacefully join each other in the very space environment where CORONA operated.

CORONA's legacy also lives on in today's classified world of national security through the National Reconnaissance Program, which is managed by the National Reconnaissance Office (NRO). The NRO continues to collect reconnaissance imagery, but now in near-real-time to support post Cold War national security threats, such as weapons proliferation and military indication and warning. At the same time, the NRO collects imagery of cartographic interest for federal agencies involved in mapping, and imagery of natural disasters for federal agencies that respond to disasters.

Little did anyone know what the message "Capsule recovered undamaged" would lead to.

About the Author

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Footnotes

1. The information in this article is about events that occurred twenty-three to thirty-five years ago. As with most information from the past, there often are divergent recollections, contradictions in the records, and differing interpretations of the events. I based this article on the best information available to me at this time. I believe it to be an accurate reflection of CORONA and its contributions. The views in the article are mine and do not necessarily reflect the official position of the National Defense University, the Central Intelligence Agency, or any other component of the US Government.
2. I thank Peter M. Upton for his research assistance in preparing this article. I also thank Joseph A. Pavnica and Peggy Tuten for their assistance. In addition, I acknowledge A. Roy Burks, Joseph A Baclawski, Frederic C. E. Oder, James C. Fitzpatrick, Paul E. Worthman, and the many others who have provided valuable insight for my drafting much of the article.
3. Major Ford was assigned to the Air Force CORONA Office under the Air Force Ballistic Missile Division.
4. Prior to these attempted photo reconnaissance missions, Discoverer also had attempted five diagnostic missions, which were unsuccessful.
5. Dr. James Killian, the President's Science Advisor, and Dr. Edwin H. Land, the head of a CIA panel of technical consultants, discussed the proposal with the President and his Staff Secretary, then BGen Andrew J. Goodpaster.
6. By the mid 1960s, the CORONA management structure evolved into the National Reconnaissance Office (McDonald, 1995).
7. The ARGON and LANYARD "KH" cameras are not discussed in detail in this article. See Appendix 5 for summary data on the two "KH" cameras for these programs.
8. See McDonald (1995). Opening the Cold War Sky to the Public: Declassifying Satellite Reconnaissance Imagery. In *Photogrammetric Engineering & Remote Sensing*, Vol. 61, No. 4, April 1995.
9. This archive should be fully available for public use by mid-1996.
10. Checkerboard patterns can be indicative of cultivation fields, organized patterns in forest regions can reflect clear-cutting, and linear patterns can be indicative of highways and railways.
11. For details on this, see: McDonald (1995). Opening the Cold War Sky to the Public: Declassifying Satellite Reconnaissance Imagery. In *Photogrammetric Engineering & Remote Sensing*, Vol. 61, No. 4, April 1995.

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Appendix 1

MISSION SUMMARY (EARLY SATELLITE PHOTO RECONNAISSANCE)

Date	Mission	Designator	Success[1]	Remarks
1959				
25 Jun	9001	KH-1	no	Discoverer IV[2]; Agenda did not orbit.
13 Aug	9002	KH-1	no	Discoverer V; camera failed on Rev 1; RV not recovered.
19 Aug	9003	KH-1	no	Discoverer VI; camera failed on Rev 2; retrorocket malfunction; RV not recovered.
7 Nov	9004	KH-1	no	Discoverer VII; Agena failed to orbit.
20 Nov	9005	KH-1	no	Discoverer VIII; bad orbit; camera failure; no recovery.
1960				
4 Feb	9006	KH-1	no	Discoverer IX; Agena failed to orbit.
19 Feb	9007	KH-1	no	Discoverer X; Agena failed to orbit.
15 Apr	9008	KH-1	no	Discoverer XI; camera operated; spin rocket failure; no recovery.
29 Jun	*N/A*	*N/A*	*N/A*	*Discoverer XII diagnostic flight; Agena failed to orbit.*
10 Aug	*N/A*	*N/A*	*N/A*	*Discoverer XIII diagnostic flight Successful.*[3]
18 Aug	9009	KH-1	yes	Discoverer XIV; first successful KH-1 mission; first successful air recovery of object sent into space.
13 Sep	9010	KH-1	no	Discoverer XV; camera operated; wrong pitch attitude on reentry; no recovery.
26 Oct	9011	KH-2	no	Discoverer XVI; Agena failed to orbit.
12 Nov	90012	KH-2	no	Discoverer XVII; air catch; payload malfunction.
7 Dec	9013	KH-2	yes	Discoverer XVIII; first successful KH-2 mission; air catch.
20 Dec	*N/A*	*N/A*	*N/A*	*Discoverer XIX radiometric mission.*
1961				
17 Feb	9014A	KH-5	no	Discoverer XX; first ARGON flight; orbital programmer failed, camera failed, no recovery.
18 Feb	N/A	N/A	N/A	Discoverer XXI radiometric mission.
30 Mar	9015	KH-2	no	Discoverer XXII; Agena failure; no orbit.
8 Apr	9016A	KH-5	no	Discoverer XXIII; camera OK; no recovery.
8 Jun	9018A	KH-5	no	Discoverer XXIV; Agena failure, power & guidance failure; no recovery.
16 Jun	9017	KH-2	yes	Discoverer XXV; water landing.
7 Jul	9019	KH-2	partial	Discoverer XXVI; Camera failed on Rev 22; successful recovery.
21 Jul	9020A	KH-5	no	Discoverer XXVII; No orbit; Thor problem.
3 Aug	9021	KH-2	no	Discoverer XXVIII; No orbit; Agena guidance failure.
30 Aug	9023	KH-3	yes	Discoverer XXIX; lst KH-3 flight;. Air recovery.
12 Sep	9022	KH-2	yes	Discoverer XXX; Air recovery.
17 Sep	9024	KH-2	no	Discoverer XXXI; no recovery power failure.
13 Oct	9025	KH-3	yes	Discoverer XXXII; Air recovery.
23 Oct	9026	KH-2	no	Discoverer XXXIII; Agena failed to orbit.
5 Nov	9027	KH-3	no	Discoverer XXIV; no recovery.
15 Nov	9028	.KH-3	yes	Discoverer XXXV
12 Dec	9029	KH-3	yes	Discoverer XXXV
1962				
13 Jan	9030	KH-3	no	Discoverer XXXVII; Agena failed to orbit.
27 Feb	9031	KH-4	yes	Discoverer XXXVIII; first KH-4 flight; air recovery.
18 Apr	9032	KH-4	yes	air recovery
28 Apr	9033	KH-4	no	No recovery; failed to eject parachute.
15 May	9034A	KH-5	yes	
30 May	9035	KH-4	yes	
2 Jun	9036	KH-4	no	No recovery; torn parachute.
23 Jun	9037	KH-4	yes	
28 Jun	9038	KH-4	yes	
21 Jul	9039	KH-4	yes	
28 Jul	9040	KH-4	yes	
2 Aug	9041	KH-4	yes	
29 Aug	9044	KH-4	yes	

MISSION SUMMARY (EARLY SATELLITE PHOTO RECONNAISSANCE) *cont'd*

Date	Mission	Designator	Success	Remarks
1962, cont'd.				
1 Sep	9042A	KH-5	yes	
17 Sep	9043	KH-4	yes	
29 Sep	9045	KH-4	yes	
9 Oct	9046A	KH-5	yes	
5 Nov[4]	9047	KH-4	yes	
24 Nov	9048	KH-4	yes	
4 Dec	9049	KH-4	yes	
1963				
14 Dec	9050	KH-4	yes	
8 Jan	9051	KH-4	yes	
28 Feb	9052	KH-4	no	Separation failure.
18 Mar	8001	KH-6	no	First KH-6 flight; no orbit; guidance failure (Agena).
1 Apr	9053	KH-4	yes	
26 Apr	9055A	KH-5	no	No orbit; attitude sensor problem.
18 May	8002	KH-6	no	Orbit achieved; Agena failed in flight.
13 Jun	9054	KH-4	yes	
26 Jun	9056	KH-4	yes	
18 Jul	9057	KH-4	yes	
31 Jul	8003	KH-6	partial	Camera failed after 32 hrs.
24 Aug	1001	KH-4A	partial	First KH-4A flight; 2 RV's; RV-2 Lost.
29 Aug	9058A	KH-5	yes	
23 Sep	1002	KH-4A	partial	RV-l recovered; RV-2 lost.
29 Oct	9059A	KH-5	yes	
9 Nov	9060	KH-4	no	Failure unstable launching.
27 Nov	9061	KH-4	no	Agena failed in flight; prevented recovery.
21 Dec	9062	KH-4	yes	Last KH-4 mission.
1964				
15 Feb	1004	KH-4A	yes	
24 Mar	1003	KH-4A	no	No orbit; Agena power failure.
27 Apr	1005	KH-4A	no	No on-orbit operation; Agena failure; RV impacted in Venezuela.
4 Jun	1006	KH-4A	yes	
13 Jun	9063A	KH-5	yes	
19 Jun	1007	KH-4A	yes	
10 Jul	1008	KH-4A	yes	
5 Aug	1009	KH-4A	yes	
21 Aug	9064A	KH-5	yes	
14 Sep	1010	KH-4A	yes	
5 Oct	1011	KH-4A	partial	No RV-2 recovery.
17 Oct	1012	KH-4A	yes	RV-2 water recovery because of bad weather.
2 Nov	1013	KH-4A	partial	Both cameras failed on Rev 52.
18 Nov	1014	KH-4A	yes	
19 Dec	1015	KH-4A	yes	
1965				
15 Jan	1016	KH-4A	yes	
25 Feb	1017	KH-4A	yes	
25 Mar	1018	KH-4A	yes	
29 Apr	1019	KH-4A	partial	No RV-2 recovery.
18 May	1021	KH-4A	yes	
9 Jun	1020	KH-4A	yes	Water recovery on RV-2.
19 Jul	1022	KH-4A	yes	
17 Aug	1023	KH-4A	partial	Forward camera failed.
2 Sep	N/A	no		Destroyed on launching by range safety.
22 Sep	1024	KH-4A	yes	
5 Oct	1025	KH-4A	yes	
28 Oct	1026	KH-4A	yes	
9 Dec	1027	KH-4A	yes	Control gas loss.
24 Dec	1028	KH-4A	yes	

Mission Summary (Early Satellite Photo Reconnaissance) *cont'd*

Date	Mission	Designator	Success	Remarks
1966				
2 Feb	1029	KH-4A	yes	
9 Mar	1030	KH-4A	yes	
7 Apr	1031	KH-4A	yes	
3 May	1032	KH-4A	no	Agena failed to separate from booster.
24 May	1033	KH-4A	yes	
21 Jun	1034	KH-4A	yes	
9 Aug	1036	KH-4A	yes	
20 Sep	1035	KH-4A	yes	
8 Nov	1037	KH-4A	yes	
1967				
14 Jan	1038	KH-4A	yes	
22 Feb	1039	KH-4A	yes	
30 Mar	1040	KH-4A	yes	
9 May	1041	KH-4A	yes	
16 Jun	1042	KH-4A	yes	Water pick-up on RV-2.
7 Aug	1043	KH-4A	yes	
15 Sep	1101	KH-4B	yes	First KH-4B mission.
2 Nov	1044	KH-4A	yes	
9 Dec	1102	KH-4B	yes	
1968				
2 Jan	1045	KH-4A	yes	
14 Mar	1046	KH-4A	yes	
1 May	1103	KH-4B	yes	
20 Jun	1047	KH-4A	yes	
7 Aug	1104	KH-4B	yes	
18 Sep	1048	KH-4A	partial	Forward camera failed.
3 Nov	1105	KH-4B	yes	
12 Dec	1049	KH-4A	yes	Degraded film.
1969				
5 Feb	1106	KH-4B	partial	Aft camera failed.
19 Mar	1050	KH-4A	partial	Terminated; Agena failure.
2 May	1051	KH-4A	yes	Degraded film.
24 Jul	1107	KH-4B	partial	Forward camera failed; RV-1 water recovery.
22 Sep	1052	KH-4A	yes	Last KH-4A mission.
4 Dec	1108	KH-4B	yes	
1970				
4 Mar	1109	KH-4B	yes	
20 May	1110	KH-4B	yes	
23 Jul	1111	KH-4B	yes	
18 Nov	1112	KH-4B	yes	
1971				
17 Feb	1113	KH-4B	no	Failure of Thor booster.
24 Mar	1114	KH-4B	yes	
10 Sep	1115	KH-4B	yes	
1972				
19 Apr	1116	KH-4B	yes	
25 May	1117	KH-4B	yes	Final CORONA mission.

[1] The assessment in this column is subjective.

[2] There were three Discoverer missions prior to CORONA mission 9001.

[3] This was the first successful diagnostic flight in the DISCOVERER series. Its mission ended with the first successful recovery of an object sent into space. The Recovery Vehicle (RV) capsule was recovered from the Pacific Ocean, and the RV currently is in the Smithsonian's National Air and Space Museum.

[4] On 26 October a non photo reconnaissance engineering mission was flown.

Appendix 2

OPERATIONAL OVERVIEW: CORONA RECONNAISSANCE PROGRAM

	KH-1	KH-2	KH-3	KH-4	KH-4A	KH-4B
Period of Operation	1959-60	1960-61	1961-62	1962-1963	1963-1969	1967-72
Number of RVs	1	1	1	1	2	2
Mission						
Series	9000	9000	9000	9000	1000	1100
Life	1 day	2-3 days	1-4 days	6-7 days	4-15 days	19 days
Altitude (nm)						
Perigee	103.5 (e[1])	136.0 (e)	117.0 (e)	114.0 (e)	u/a[2]	u/a
Apogee	441.0 (e)	380.0 (e)	125.0 (e)	224.0 (e)		
Avg Ops	u/a	u/a	u/a	110 (e)	100 (e)	81 (e)
Missions						
Total	10	10	6	26	52	17
Successful	1	4	4	21	49	16
Targets	USSR	Emphasis on USSR		Worldwide/emphasis on denied areas[3]		

[1] estimated

[2] unavailable

[3] Denied areas were generally considered to be Communist-controlled areas.

Appendix 3

OPERATIONAL OVERVIEW: ARGON & LANYARD

	Argon	*Lanyard*
Mission	geodetic positioning	intelligence target surveillance
Camera Designator	KH-5	KH-6
Period of Operation	May 1962-Aug 1964	Jul-Aug 1963
Number of RVs	1	1
Mission Series	9000A	8000
Altitude (Avg Ops)	174 nm	93 nm
Missions		
Total	12	1
Successful	6	1
Targets	worldwide	primarily Eurasia

Appendix 4

CAMERA DATA: CORONA

	KH-1	KH-2	KH-3	KH-4	KH-4A	KH-4B
Function	Intelligence	Intelligence	Intelligence	Intelligence	Intelligence	Intelligence
Model	C	C'	C'''	Mural	J-1	J-3
Type	mono	mono	mono	stereo	stereo	stereo
Scan <	70 degs	70 degs	70 degs	70 degs	70 degs	70 degs
Stereo<				30 degs	30 degs	30 degs
Shutter	u/a[1]	u/a	u/a	u/a	focal plane	focal plane
Lens	f/5 Tessar	f/5 Tessar	f/3.5 Petzval	f/3.5 Petzval	f/3.5 Petzval	f/3.5 Petzval
Focal Length	24"	24"	24"	24"	24"	24"
Resolution						
ground (e[2])	40'	25'	12'-25'	10'-25'	9'-25'	6'
film (e)	50-100l/mm	50-100l/mm	50-100l/mm	50-100l/mm	120 l/mm	160 l/mm
Coverage	u/a	u/a	u/a	u/a	10.6X144nm	8.6X117nm
Scale (contact)	u/a	u/a	u/a	1:300,000 (e)	1:305,000 (e)	1:247,500
Enlargement capability	u/a	u/a	u/a	20X (e)	40X	40X
max scale				1:12,000 (e)	1:7,500 (e)	1:7,500 to 1:12,000 (e)

CAMERA DATA: CORONA

	KH-1	KH-2	KH-3	KH-4	KH-4A	KH-4BFilm base
Film base	acetate	polyester	polyester	polyester	polyester	polyester
Film width	2.10"	2.10"	2.25"	2.25"	2.25"	2.25"
Image format	2.10" (e)	2.19" (e)	2.25X29.8"	2.18X29.8"	2.18X29.8"	2.18X29.8"
Film load	u/a	u/a	u/a	u/a		
camera					8,000'	8,000'
RV					16,000'	16,000'
mission					32,000'	32,000'

[1] unavailable

[2] estimate

Appendix 5

CAMERA DATA: ARGON & LANYARD

	Argon	Lanyard
Function	mapping (geodetic positioning)	intelligence (target surveillance)
Camera Designator	KH-5	KH-6
Type	frame	panoramic
Scan <	u/a[1]	22 deg
Focal Length	3 inches	66 inches
Resolution		
ground	460 ft	6 ft[2]
film	30 l/mm	160 l/mm
Coverage	300nm X 300 nm	7.5nm X 40nm
Scale (contact)	1:4,250,000 (e[3])	1:100,000
Enlargement		
capability	4X	40X
max scale	1:1,000,000 (e)	1:3,000 (e)
Film width	5 inches	5 inches
Image format	4.5" X 4.5"	4.5" X 25"
Film load mission	u/a	8,000 ft

[1] unavailable

[2] Design objective was two feet.

[3] estimated

Appendix 6

CAMERA DATA: COMPARISON OF MAPPING CAMERAS

	One Point Five Camera	Three Inch Camera
Focal Length	1.5 inches	3 inches
Type	frame	frame
Resolution		
ground (ft)	400-500 (e[1])	100-400 (e)
Coverage (miles)	166 X 166 (e)	140 X 140 (e)
Scale (contact)	1:4,880,000 (e)	1:1,980,000 to 1:4,250,000 (e)
Enlargement		
capability	4X-6X (e)	4X-8X (e)
max scale	1:750,000 to 1:1,000,000 (e)	1:250,000 (e)

[1] estimated

Appendix 7

AREA COVERAGE[1]

	Foreign	Domestic[2]	Worldwide
Intelligence[3]			
KH-1 to KH-4	106.936	5.628	112.564
KH-4A	195.625	10.295	205.920
KH-4B	183.731	7.563	191.294
KH-6	.450	(insignificant)	.450
Total	486.742	23.486	510.228
Mapping[4]			
KH-4A	26.784	1.504	28.288
KH-4B	26.992	1.692	28.634
KH-5	40.009	2.8	42.80
KH-6	(included with totals for KH-4A)		
Total	93.785	5.996	99.722

[1] Because of the variety of ways data have been recorded, and the different definitions of "coverage," all figures in this appendix are estimates. The estimates are based on the best avaliable data.

[2] Domestic totals prior to 1969 are estimates based on an average of about 5% of the total film being devoted to domestic coverage for engineering and related technical purposes.

[3] These figures reflect gross cloud-free coverage of land and adjacent water areas of the earth's surface. They are reported in millions of square nautical miles.

[4] These figures generally reflect the unique coverage acceptable for mapping. They are reported in millions of square nautical miles.

APPENDIX 8
TEXT OF DCI APPROVAL MEMORANDUM

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~~SECRET~~

DPS-0025
25 April 1959

MEMORANDUM FOR: The Comptroller

SUBJECT: Project CORONA

1. This is to advise that this date I have approved subject project in the amount of $7,000,000 for FY 1958.

2. You are directed by this memorandum to seek release of the above amount from the Agency Reserve for Contingencies as an unprogrammed requirement for which other funds are not currently available.

3. The Office of Special Assistant for Planning and Development has the responsibility for obtaining the required documentation to support the expenditure of these funds. This Office is also responsible for maintaining appropriate accounting records clearly setting forth the funds received and the expenditure thereof. Such supporting documentation and accounting records will be subject to audit by the Audit Staff of the Agency at the appropriate time.

(Signed)
ALLEN W. DULLES
Director

CONCUR: Richard M. Bissell, Jr.
Special Assistant to the Director
for Planning and Development

Lawrence R. Houston
General Counsel

28 Apr 1958

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