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QUEST

THE HISTORY OF SPACEFLIGHT QUARTERLY

From U-2 to Corona: 50 Years Later

What We Officially Know

15 Years of Satellite Declassification

Critical Issues in the History and Historiography of U.S. National Reconnaissance

An Interview with

Lt. General Forrest McCartney

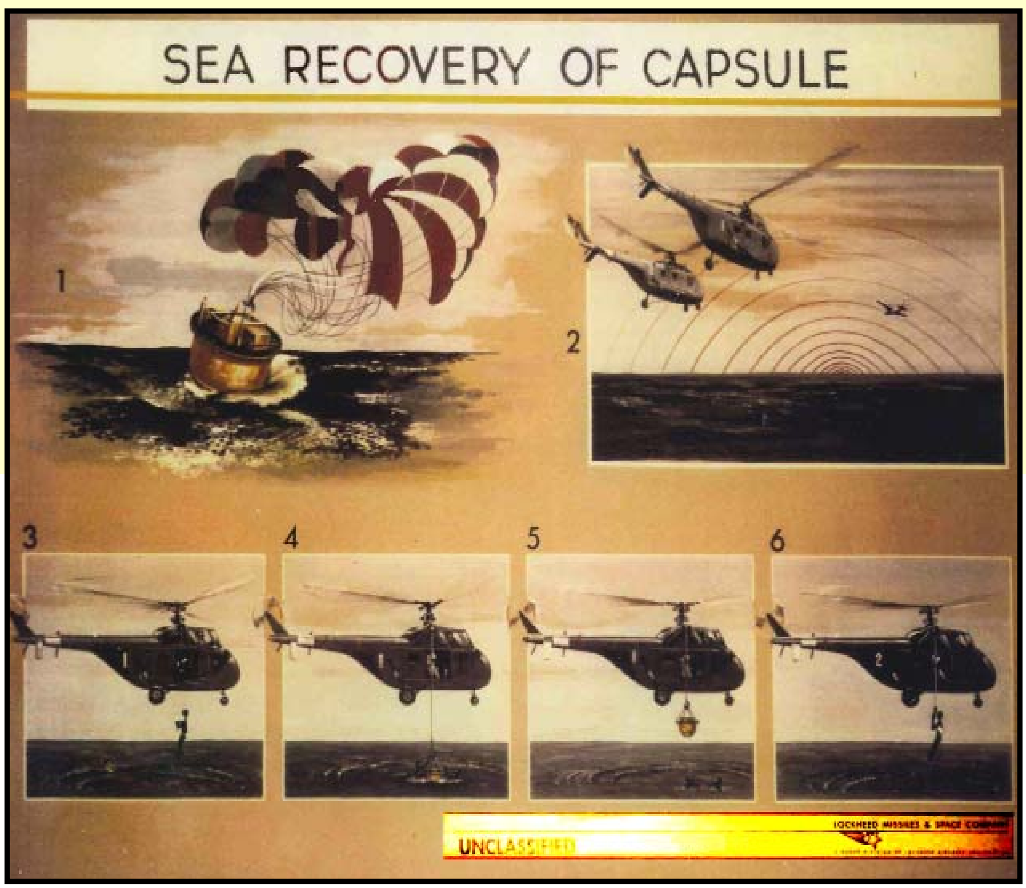
What Should Corona Photograph and How Often?

Eisenhower's Domestic Perspective on WS-117L

50 Years of Satellite Reconnaissance and the First Successful Film Capture from Corona

"We've spent thirty-five or forty billion dollars on the space program. And if nothing else had come of it except the knowledge we've gained from space photography, it would be worth ten times what the whole program cost. Because tonight we know how many missiles the enemy has and, it turned out, our guesses were way off. We were doing things we didn't need to do. We were building things we didn't need to build. We were harboring fears we didn't need to harbor."

President Lyndon B. Johnson, 1967



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Artist conception of a C-130 aircraft approaching a descending Corona capsule. Credit: NRO

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Bottom Left: Unidentified Corona launch from Vandenberg Air Force Base using a Thor booster. Credit: NRO

FEATURE

What We Officially Know:
Fifteen Years of Satellite Declassification

By Jeffery A. Charlston

Fifteen years ago *Quest* published an important two-part article on the first declassification of an American reconnaissance satellite program.[1] With considerable fanfare the Central Intelligence Agency's Center for the Study of Intelligence (CSI) had just introduced the world to the CORONA family of imagery satellites, and thus began lifting the veil of secrecy on space-based espionage. The National Reconnaissance Office (NRO), an organization whose very existence had been declassified fewer than three years earlier, supported and supplemented the CIA's May 1995 celebration.

In 1995 the NRO remained largely unknown to the general public. The organization had been secretly chartered by the CIA and Department of Defense in September 1961 to centralize management of CORONA and other overhead reconnaissance activities, remaining classified for the next 31 years. Details about satellite intelligence programs and the organization created to manage them have been gradually released during the last 15 years. What has slowly become evident is that, successful as they were, the first two generations of U.S. imagery satellites were compromises between available technology and an ultimate goal of near-real time intelligence production.

Declassification of U.S. reconnaissance satellites began with CIA Director Robert Gates' 1992 launch of an openness program and parallel expansion of CSI, the Agency's history office. By July 1993 CSI Director David Gries had convened an interagency working group to discuss the complex changes in regulations, revised security controls, and the Freedom of Information Act implications involved in the first detailed disclosure of American space-based espionage. This proved to be a formidable challenge.

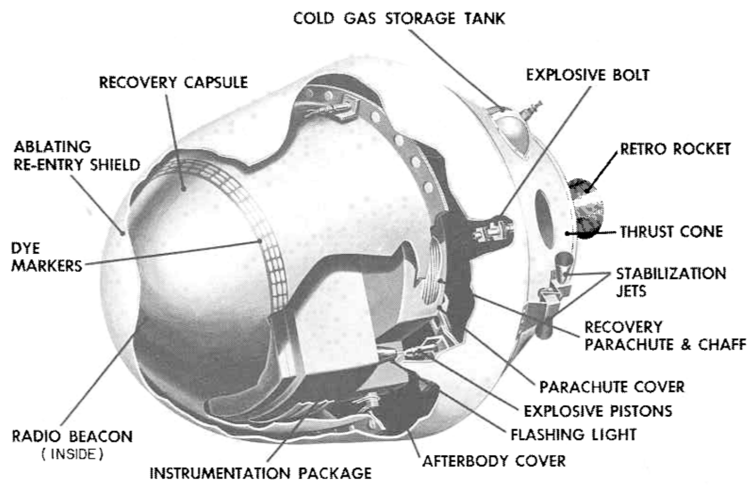
Relaxing the security surrounding even antiquated intelligence satellites required action from the White House. President William "Bill" Clinton's Executive Order (EO) 12951, issued on 22 February 1995, instructed the Director of Central Intelligence (DCI) to declassify imagery from "the space-based national intelligence reconnaissance systems known as the CORONA, ARGON, and LANYARD missions." While not specifically addressed by the president, compliance with his order also required the declassification of considerable information about the systems that collected the imagery. This presented the intelligence community with a number of challenges.

Even senior declassification analysts had no experience preparing records of satellite programs for public release, and the order to do so ultimately preceded the development of clear declassification guidance. The records in question contained "code words, cover details, financial information, and human or communications intelligence, or discussed targets in sensitive areas of the world" in addition to all the potentially sensitive technological complexities expected of rocket science. Government declassification programs as a whole remained in their infancy, not addressed by Clinton's EO 12958 until 17 April 1995. But the CIA and NRO successfully met their self-imposed deadline for initial public disclosure despite these significant organizational challenges.[2]

Most national security contributions of CORONA and the other orbital reconnaissance platforms remain classified. Indeed, the lack of such revelations and the slow pace of declassification in general often make it difficult to understand what, exactly, the government is still protecting. But the original declassification of CORONA included at least one indicator of these systems' worth. Senator John F. Kennedy campaigned for the presidency on a platform that decried the existence of a missile gap favoring the Soviet Union, placing the United States at a grave disadvantage in any standoff. Faced with a demand to withdraw from West Berlin shortly after assuming office, President Kennedy was able to call the Soviet bluff because CORONA had conclusively proven that the nuclear balance overwhelmingly favored America.[3]

Such revelations remain rare. The story of America's space-based espionage programs has, however, continued to emerge since CORONA's unveiling. The steady release of documents through the automatic declassification process and Systematic Declassification Reviews established by EO 12958, and Freedom of Information Act and Mandatory Declassification Reviews initiated at researcher request has allowed the public to learn more of the justification behind President Lyndon B. Johnson's 1967 assessment:

> *We've spent thirty-five or forty billion dollars on the space program. And if nothing else had come of it except the knowledge we've gained from space photography, it would be worth ten times what the whole program cost. Because tonight we know how many missiles the enemy has*



RE-ENTRY-RECOVERY VEHICLE Credit: NRO

and, it turned out, our guesses were way off. We were doing things we didn't need to do. We were building things we didn't need to build. We were harboring fears we didn't need to harbor.

The pages that follow summarize what the NRO has officially revealed about its satellite programs, using the most thorough declassified history of NRO activities and a publicly available version of the NRO's declassification guide. That history is Robert Perry's multivolume *A History of Satellite Reconnaissance*, completed more than 36 years ago with the support of the NRO's Program A. Presumably additional works, using more recent historical methodologies, still await declassification.[4] Considerable primary source information falling within the broad scope of the events described in this article is now available through the NRO. Several authors have labored to expand on these official declassifications through careful analysis of unofficial sources. David Waltrop's "Critical Issues in the History and Historiography of U.S. National Reconnaissance," appearing elsewhere in this issue, provides a summary of their efforts and those of the few official government historians that have published unclassified works of interest.

Genesis

America's spy satellites emerged from the military's post-World War II partnership with commercial enterprises, particularly a think tank established by the U.S. Army Air Force through the Douglas Aircraft Company. In 1946 Project RAND proposed a multistage satellite rocket in its very first report, *Preliminary Design of an Experimental World-Circling Spaceship*.[5] This concept developed into RAND's 1954 Project Feed Back Report, which recommended that the Air Force begin development of a reconnaissance satellite. Orbital reconnaissance appeared to offer one solution to the intelligence challenges of the growing Cold War.[6] The analysis proved convincing enough that the Air Force accepted the proposal, contracting Lockheed Missiles and Space Company to develop just such a vehicle in 1956.[7] Notably, Perry ascribes this decision to Air Force concern that the Navy might otherwise launch the first satellite.[8]

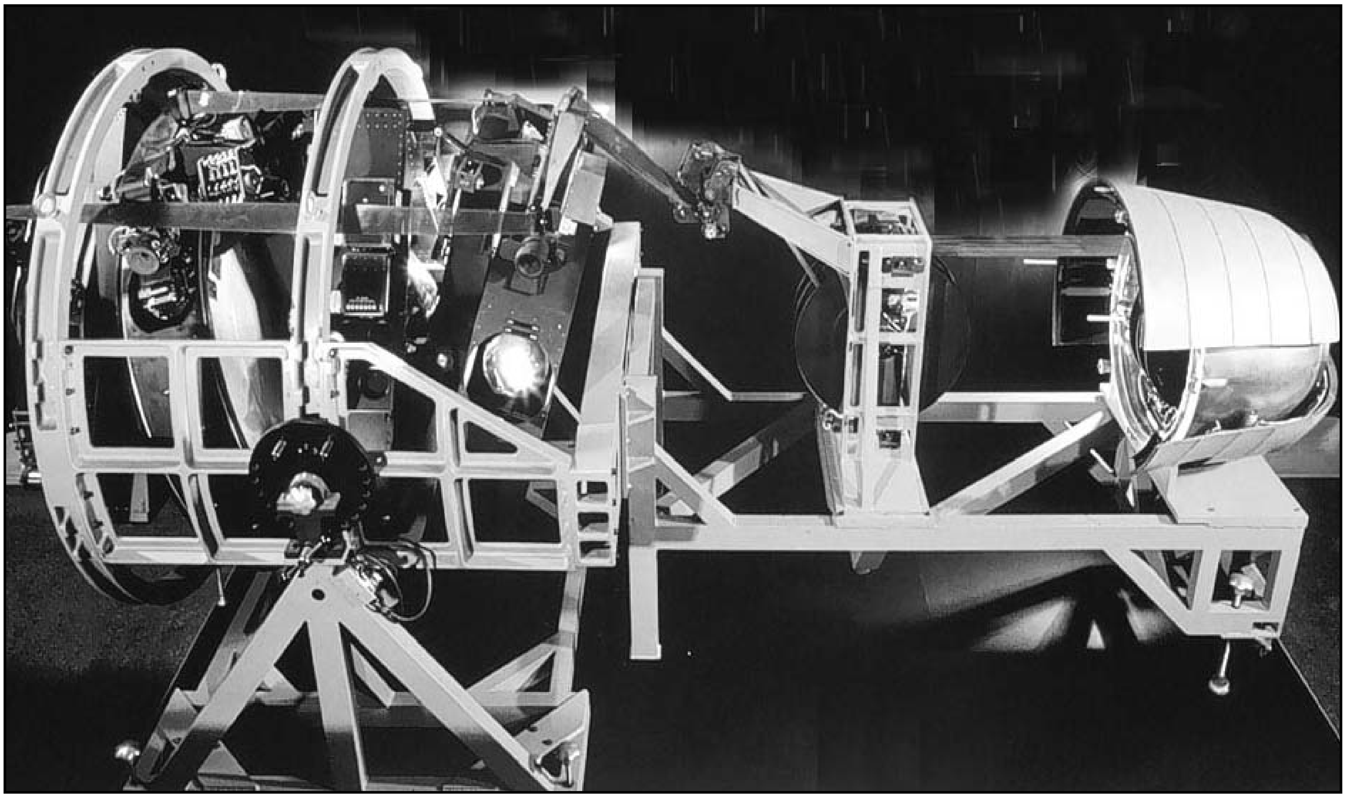
The pivotal Air Force effort had borne the undistinguished designation Weapons System (WS) 117L since the Air Research and Development Command translated the ongoing RAND studies into its own developmental program in January 1954. Focused more on theoretical possibilities and intelligence potential than the still-unknown engineering challenges that lay ahead, the program's concepts included the fundamentals for all subsequent reconnaissance satellites. Its approach included both electronic intelligence (ELINT) and imagery intelligence (IMINT) capabilities in a single family of systems. Despite its great promise, WS-117L also faced the immediate difficulty of a presidential administration emphasizing a "space for peace" position and strict limits on defense expenditures.[9]

Declassified documents clearly indicate that budgetary restraint did not prevent the program from achieving remarkable results. In addition to the nascent CORONA system, WS-117L eventually evolved two other elements. An infrared sensor system, intended to detect ballistic missile launches, was eventually designated as MIDAS (Missile Defense Alarm System). This system developed into the Defense Support Program (DSP), and then into the Space-Based Infrared System (SBIRS) that continues today.[10] CORONA's other sister within the WS-117L blanket was to be identified as SENTRY, later renamed SAMOS.[11]

The WS-117L elements destined to become SAMOS developed to contain two different types of payload: F, or "ferret," ELINT systems designated F-1 through F-4 and IMINT payloads designated E-1 through E-6. The ferret systems were intended to collect radar emissions and identify radar sites.[12] Relatively little additional information about the ferret systems has been released, but their intended mission appears to have been identical to that of America's first reconnaissance satellite.

GRAB and POPPY

Independently initiated by the Navy in 1958 and approved by President Dwight Eisenhower in 1959, fewer than 200 people knew the details of Project TATTLETALE's development. The satellite first launched into space on 22 June 1960 with a different name, riding with the Navy's TRANSIT II navigation satellite. This proved the Air Force's earlier concern justified, as a rival service preceded it into space with an intelligence mission. Identified to the public as the Galactic Radiation and Background



A reconstructed KH-4b Corona (Mural) camera, donated to the Smithsonian in 1995 by the NRO.
Credit: National Air and Space Museum

(GRAB) experiment, the small sphere included an unclassified experiment to measure solar radiation, named SOLRAD, together with the highly classified radar detector.[13]

From its polar orbit GRAB could monitor the entire globe revolving beneath it. Superficially the small satellite did not appear much different from the Soviet Union's original Sputnik. Its transmitter, however, was more than the automated 1957 beacon. On detecting a Soviet air defense radar GRAB relayed a corresponding signal to one of a series of Earth Satellite Vehicle huts stationed around the globe.

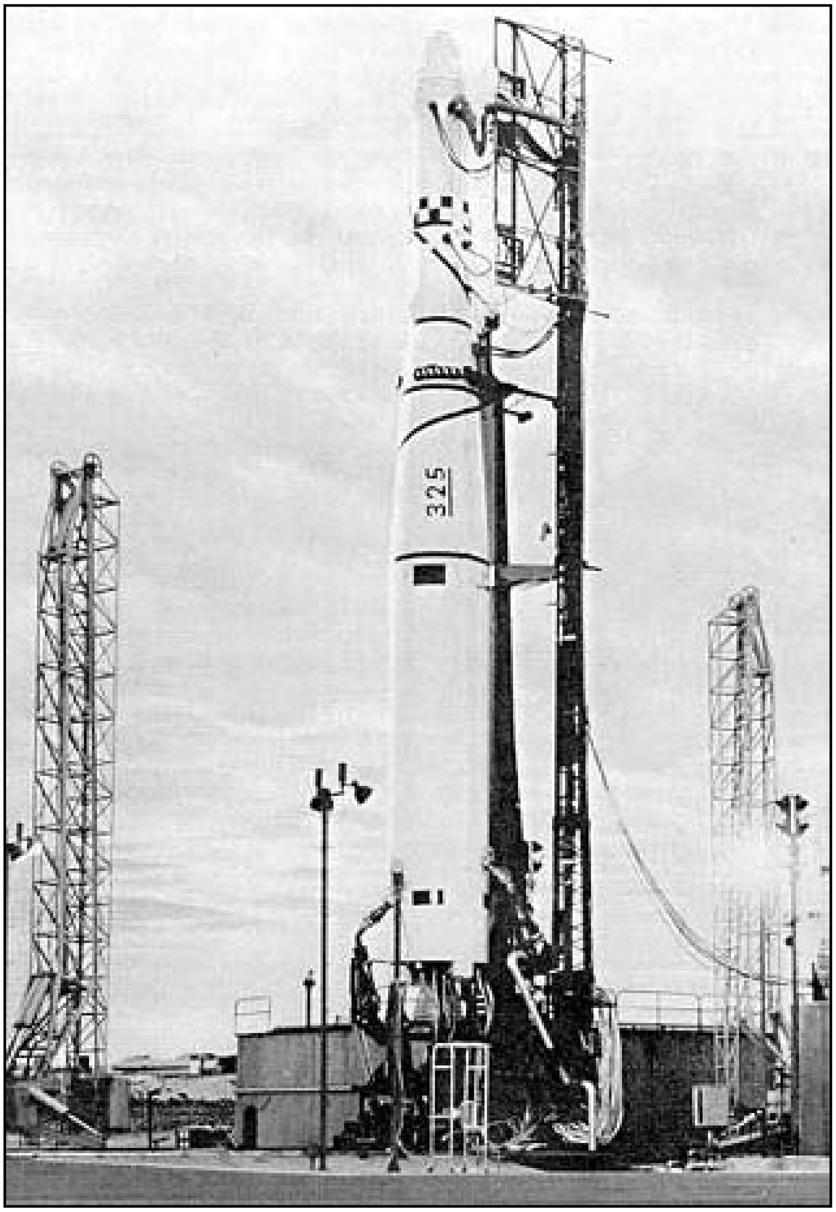
Those huts operated under the control of the Director of Naval Intelligence, coordinated by the NRO after its establishment. Their function, like GRAB's, proved deceptively simple. They recorded the ELINT satellite's signal onto magnetic tape and couriered that recording back to the Naval Research Laboratory, which in turn sent copies to the National Security Agency (NSA) and Strategic Air Command (SAC) for analysis. This allowed SAC to locate Soviet air defenses and refine the Single Integrated Operating Plan for any potential nuclear strike, and helped the NSA to detect Soviet use of radars suitable for ballistic missile defense.[14]

Only two of GRAB's five attempted missions between June 1960 and April 1962 are considered successful. GRAB soon developed into a successor program, POPPY, that collected radar emissions from both Soviet air defense radars and naval vessels. *POPPY 1* launched from Vandenberg Air Force Base on 13 December 1962, and the program continued until *POPPY 7* ceased operations in August 1977. [15]

Little else has been declassified about U.S. signals intelligence satellites. GRAB's existence remained classified until the intelligence community had time to adapt to the release of CORONA. The descendents of the SENTRY/SAMOS ferrets, GRAB, and POPPY still remain cloaked in secrecy.

WS-117L

The same cannot be said of the WS-117L imagery payloads. Sputnik's 1957 launch triggered rapid, well-documented adjustments in the various U.S. space efforts. These swept up the WS-117L program and, by the end of that year, led to a call for a reconnaissance system coordinating committee to sort out the competing interests and programs, and to address security concerns. WS-117L began as an unclassified Air Force designation, and much of the program was known, or at least detectable, to the public. A key element in the proposed new security arrangements was the long-discussed creation of a publicized scientific satellite effort to provide cover for a highly classified reconnaissance satellite program.[16] The Air Force effort certainly needed careful management, for various aerospace firms and government enterprises all advocated different approaches to the imagery mission, and so too the design of both the necessary camera and the vehicle that would carry it. This range of design options explains the gradual emergence of the six different WS-117L imagery program concepts, E-1 through E-6.



Thor Agena B with *Discoverer 36* on the launchpad 12 December 1961
Credit: NRO

Security concerns during this period led to another important development in March 1958. The CIA assumed responsibility for security arrangements, leading to the public cancellation of some WS-117L efforts and the creation of a highly classified CIA program called CORONA.[17] This decision, however, did not end WS-117L and its continued pursuit of the imagery collection designs still under direct control of the Air Force.

The core WS-117L design concepts, E-1 and E-2, sought to provide a near-real time imagery capability. That approach offered the ideal solution to the challenge of monitoring strategic events, and even military operations, from space. In principle a near-real time system would transmit images back to Earth almost as quickly as they could be collected, allowing for rapid processing and evaluation. With this capability decision makers and military planners would be able to follow critical events as they developed.

Early television cameras offered the available analog technology for this purpose. The challenges in harnessing that technology, however, proved immense. A low orbit, with its relatively short range to a photographic target, offered the best potential for collecting imagery intelligence from space. However, a satellite moving at orbital speeds that close to the ground would be in view of any given location for mere moments. Its camera would need to capture a useable image in that brief window, store it, and then transmit it to a receiving station in a similarly short period of time once in range.

Television camera technology available in the late 1950s proved far too slow and inadequate for this demanding challenge. WS-117L's E-1 and E-2 "film-readout" concepts approached the problem of gathering near-real time imagery with the best substitute available. A film-based camera would capture the image, overcoming the limited speed and resolution of available television cameras and providing a limited storage mechanism. The resulting film would be processed onboard the vehicle. On command a dedicated television camera would scan the film, a less demanding chore than directly examining ground targets, and relay the resulting image to Earth.

This concept proved unworkable with the relative speeds and time windows required for operation in low Earth orbit, particularly in light of the existing analog band width limitations. Near-real time imagery intelligence from space would have to wait on technological advances. The effort to solve this problem with available technology, however, did not go to waste. In the summer of 1963 NASA (National Aeronautics and Space Administration) announced its need for a lunar orbiting reconnaissance satellite. Eastman Kodak, the firm behind the E-1 camera, asked the NRO for permission to work with the Boeing Airplane Company. Together the two firms adapted the E-1 concept to work at lunar distances, and five SAMOS Lunar Orbiters mapped the Moon (August 1966–August 1967) in preparation for the planned Apollo missions.[18]

CORONA

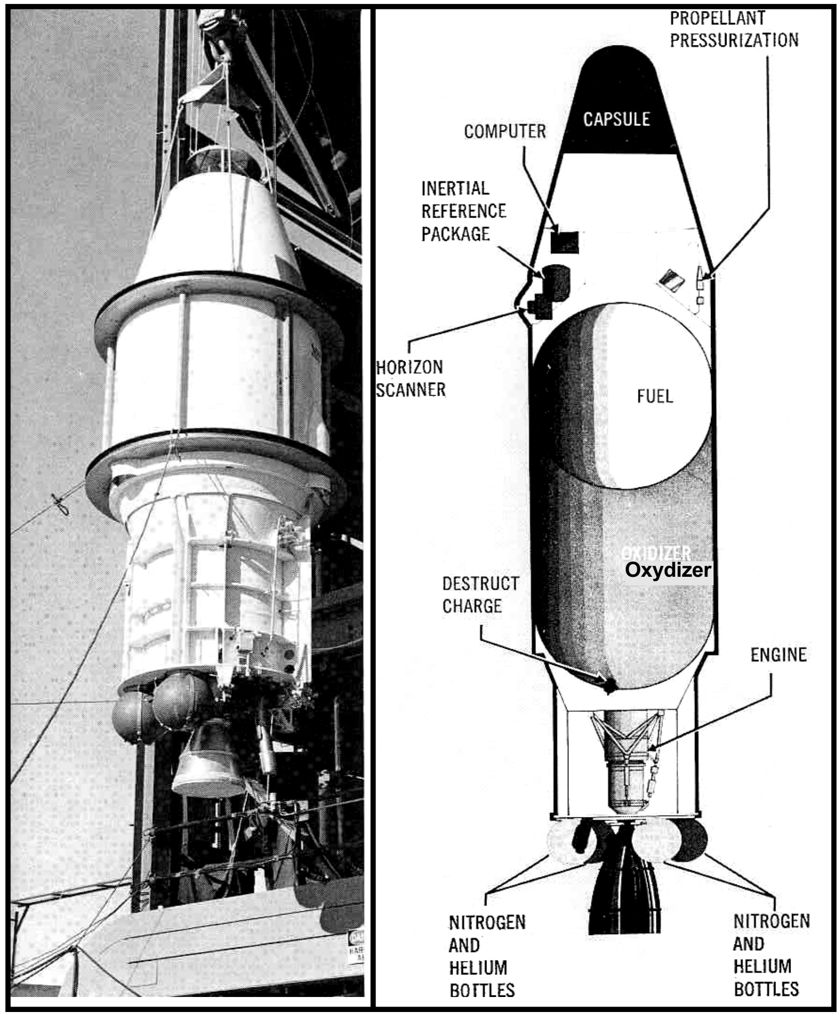
All of that lay well in the future as CORONA took shape after 1958 as a WS-117L project under the CIA's direction. WS-117L design alternatives included a film return option as a backup to the desired but challenging film readout approach. CORONA would employ that second-choice method, seeking to fill the need for satellite imagery until WS-117L produced a near-real time system. In place of the complex mechanisms required to process, scan, and transmit film images, the alternative approach used by CORONA simply stored the exposed film in a small reentry vehicle. This alternative sacrificed near-real time intelligence for far greater simplicity. But recovering the film on its reentry would require a large, and highly visible, effort. The public would therefore originally know the CORONA reentry vehicle as a biomedical bucket, part of a scientific program that provided an explanation while allowing the real mission to fade from public view.

One critical problem remained. Substantial funding for WS-117L came through the Department of Defense's Advanced Research Projects Agency (ARPA), rather than the CIA. In fact WS-117L represented the largest single component of ARPA's budget in 1958. The research agency used the power of the purse to steer WS-117L toward scientific objectives, interfering with the CORONA program and continued pursuit of near-real time imagery technology. The original plan for CORONA called for ARPA to route money through the WS-117L program for the purchase and launch of 10 vehicles. Plans for CORONA as an intelligence mission quickly developed to require additional launches, even as ARPA struggled with NASA for control of the emerging human space program. WS-117L, and its publicly claimed scientific program, became a pawn in this bureaucratic contest as ARPA called for more funding and more launches of its own scientific satellite. Projected costs for the CORONA program escalated rapidly as a result. By late 1958 planning for the 1960 fiscal year brought these matters to a head.

December 1958 sealed CORONA's direction. The Air Force created the DISCOVERER project as an unclassified scientific program within the larger WS-117L effort, providing an explanation for the CIA's classified CORONA activities. ARPA would fund only 13 DISCOVERER flights, including eight CORONA launches, under this plan. Other aspects of WS-117L would now be publicly acknowledged as SENTRY, later renamed SAMOS, an admitted experiment in satellite reconnaissance. CORONA continued as a highly classified effort, largely disassociated from SENTRY/SAMOS and protected by DISCOVERER.

Of course DISCOVERER did not provide a perfect explanation for the unclassified activities conducted in its name. Limited launch facilities at Cape Canaveral provided a rationale for Air Force launches from Vandenberg Air Force Base, and Vandenberg's location in turn explained DISCOVERER's use of polar orbits as a matter of range safety. DISCOVERER's planned low orbit could be explained by claiming limited U.S. launch capabilities. For the few non-CORONA personnel who became aware of their presence in the DISCOVERER effort, the CORONA cameras were explained away as equipment for astronomical or vehicle stability observations.[19]

Actually getting DISCOVERER into space presented another challenge. Its first launch attempt, on 28 February 1959, failed outright. *Discoverer 2*'s reentry capsule landed on Spitzbergen Island, Norway. The capsule may well have been recovered by the Soviet



The USAF'S Agena spacecraft, built by Lockheed, has been used to oribt photo reconnaissance satellites since the program began. The photo shows an Agena-B being hoisted into position for firing tests. Credit: Lockheed Martin

Union. One of CORONA's personnel later served as technical advisor for the movie *Ice Station Zebra*; the plot of Alistar MacLean's book of that title bears some resemblance to the *Discoverer 2* mission.[20] Luckily the mission did not carry a CORONA camera. The missing capsule contained only "mechanical mice" intended to generate biomedical data.[21]

Discoverer 3, launched in June 1959, comically indicates the range of problems engineers encountered in the complex undertaking that disguised CORONA. Part of the DISCOVERER biomedical research cover for that mission included the launch of a number of mice. Unfortunately their cage was mounted directly above the return capsule's humidity sensor, and an unplanned exposure to mouse urine caused the sensor's reading to soar to 100 percent and so delay the launch. The rodent astronauts received only a short reprieve, however, before the vehicle launched and another problem caused it to crash into the Pacific Ocean.[22]

Including *Discoverer 0*'s explosion on the launch pad, neatly downplayed by the simple bureaucratic expedient of not designating the test firing with a formal DISCOVERER mission number, the program suffered 13 successive failures. Their causes were legion. On 19 February 1960 *Discoverer 10* had to be destroyed by the range safety officer shortly after launch, showering Vandenberg Air Force Base with debris in a particularly memorable event.[23] Other problems resulted in the failure to collect images, failure to return the capsule, failure to achieve orbit, and so on. *Grab 1*'s 22 June 1960 success as America's first operational intelligence satellite would have done little to cheer the few CORONA participants permitted knowledge of both programs.

By the summer of 1960 the United States needed an operational imagery satellite. On 1 May, CIA pilot Francis Gary Powers flew a final mission over the Soviet Union that ended in disaster. His U-2 aircraft, designed to penetrate Soviet airspace and return badly needed intelligence, had outlived its originally predicted operational lifespan and was now vulnerable to interception. Diplomatic fallout from Powers' resulting capture guaranteed that overflights of Soviet territory had ended. While GRAB could identify air defense radars, it could do nothing to identify nuclear threats or provide other vital strategic information. Continuing development of the Air Force's WS-117L SENTRY film-readout project, approaching its own initial flights and not yet shown to be unworkable, provided an apparent near-real time alternative to the CIA's struggling CORONA efforts.

Successful recovery of *Discoverer 13*'s film-return capsule following its 10 August 1960 launch provided a timely indication that the program was making headway against the long list of technological challenges it had encountered. The important mission did not carry a CORONA camera, instead concerning itself with telemetry instrumentation. This first successful return of an object from space concluded with the very public delivery of another cargo, a U.S. flag, to President Eisenhower. Those with knowledge of the CORONA program recognized that it also paved the way for the first operational photoreconnaissance mission in space.

On 17 August the Soviet Union convicted Powers of espionage, announcing the CIA pilot's 10-year sentence the following day. As the international community watched this very public blow to American intelligence collection unfold, on 18 August 1960 a new era secretly launched from Vandenberg Air Force Base. *Discoverer 14* was a full-fledged CORONA mission. Its camera would later be given the retroactive security designation of Keyhole (KH)-1.

Like the other CORONA missions, the *Discoverer 14* satellite was contained in and inseparable from an Agena booster. After achieving orbit the Agena platform maneuvered to direct the CORONA camera Earthward. Exposed film wound onto a spool in the reentry vehicle, or "bucket," for return to Earth. Ground stations could monitor and control the spacecraft, ordering the bucket to detach for reentry at mission's end. The reentry vehicle would then spin for stabilization and fire a small retro rocket, launching it back into the atmosphere. To complete this complex cycle the bucket had to separate from its heat shield and guidance package, deploy a parachute, and be caught in mid-air by a passing aircraft or hope for water recovery before sinking to the ocean depths. *Discoverer 14* met this demanding test of engineering skill.

During its brief first successful mission CORONA photographed more Soviet territory than all previous U-2 missions combined. Its f/5.0, 24-inch focal length KH-1 camera achieved a best resolution of approximately 40 feet, allowing intelligence analysts to count heavy bombers on Soviet airfields and garner other vital information. Among its other accomplishments, this single mission disproved the existence of any "missile gap" favoring the Soviet Union.

While useful, all of those involved in the CORONA effort knew that these initial results were just the beginning. Additional camera designs were already emerging from the WS-117L efforts, and would be flown onboard subsequent CORONA missions. *Discoverer 18*, launched on 7 December 1960, carried the first KH-2 camera in the next successful CORONA mission. The new camera system, with an achieved resolution of approximately 35 feet, confirmed the results of *Discoverer 14* and allowed the newly elected President John F. Kennedy to revise American defense policies and priorities.[24]

CORONA, and its film-return technology, proved their intelligence value as the WS-117L SENTRY/SAMOS effort continued to struggle with the challenges of the film-readout approach to near-real time reconnaissance. Further developmental efforts within the CORONA program focused on improved camera systems and capabilities as SAMOS approached cancellation and transfer of its E-1 technology to NASA. Managing these and other reconnaissance programs, however, presented a problem.

National Reconnaissance Office

On 25 August 1960 the National Security Council assigned responsibility for the SAMOS program to the Secretary of the Air Force. Six days later management of the SAMOS program was formalized, with a project office on the west coast and an office directed by the Under Secretary of the Air Force, the Office of Missile and Satellite Systems (SAF/MSS), in Washington. This provided the SAMOS director with easy access to the Air Force's senior leaders, and to the White House at need. But the new arrangement only affected this aspect of the original WS-117L effort.

The Navy continued to pursue the GRAB/POPPY electronic intelligence program, just as the CIA administered CORONA. Both of those efforts also required close cooperation with the Air Force and the rest of the defense and intelligence communities. The need for formalized central management of these programs had become clear. In response the Central Intelligence Agency and Department of Defense established the National Reconnaissance Program on 6 September 1961.

The program would centralize management of American strategic reconnaissance programs, both the satellite efforts and the U-2, A-12, and SR-71 reconnaissance aircraft. To direct this effort a highly classified National Reconnaissance Office, originally codirected by Under Secretary of the Air Force Dr. Joseph Charyk and CIA Deputy Director (Plans) Dr. Richard M. Bissel, would operate out of the Pentagon.

Until its September 1992 declassification the NRO remained little more than a rumor in public. Its internal structure solidified after the last unsuccessful GRAB launch, and subsequent transfer of the NRL's intelligence satellite activities to NRO control. The Navy's ELINT satellites became NRO Program C, joining the Air Force's Program A satellite efforts, the CIA's Program B satellites, and the miscellaneous aircraft and drones of Program D.

ARGON, LANYARD, MURAL

The final variant of the original CORONA satellite launched for the first time shortly before the NRO assumed its management role. On 30 August 1961 *Discoverer 29* left Vandenberg Air Force Base carrying the KH-3 camera. This new model offered minor enhancements, but successors had already emerged from the original WS-117L design concepts. When the final KH-3 launch failed on 24 January 1962, the CORONA KH-1, KH-2, and KH-3 had launched 26 times, with 11 successful recoveries.[25]

Analysis would improve if photo interpreters could perceive a third dimension. This could be accomplished with stereo imagery, and stereo capability soon emerged as a desired goal for the CORONA program. Engineers worked to combine two KH-3 cameras into a single payload for a modified Agena booster. Pointed forward and aft of the spacecraft to provide overlapping coverage from different angles, the two cameras could generate stereo images. The system would be known as MURAL, the KH-4.

Stereo systems presented significant engineering challenges, however, and KH-4 did not launch in sequence. The first KH-5, or ARGON, system flew even before KH-3, but its 17 Feb 1961 launch was the first of several failures. The NRO's history of CORONA summarizes the situation nicely after the first 26 DISCOVERER missions (including *Discoverer 0*): "Although the ratio of CORONA successes to failures seemed appallingly bad by later standards of reconnaissance program achievement ... ARGON was a disaster."[26] Of 12 attempted ARGON launches 1961–1964, only 5 resulted in successful recoveries.

MURAL became the workhorse of the CORONA family after its first, successful mission on 30 August 1961. Subsequent versions of the KH-4 camera, KH-4a and KH-4b, doubled the original KH-4's 80-pound film supply by adding an additional return bucket and eventually achieved resolution of five–six feet. KH-4a accounted for 52 systems, returning 94 buckets, 1963–1969. Its somewhat larger sibling, KH-4b, returned 32 buckets in 17 launches between 1967–1972.

The differences between the KH-4 variants appear fairly minor at first glance. All three cameras used f3.5, 24-inch focal length lenses. KH-4a doubled its film capacity by adding an extra return bucket and larger film supply. This, however, did more than lengthen its useful lifespan. A second bucket meant that analysts could, in dire need, request that a MURAL mission return the first bucket as soon as it captured necessary images without terminating all of the mission's collection potential. It also spread the cost of the MURAL payload, its Agena host, and their first stage booster over more images, yielding greater cost effectiveness for the National Reconnaissance Program. KH-4b added additional flexibility through adjustable exposure and filter control.

All of these CORONA variants suffered a similar, inherent limitation. They were designed to search large areas of terrain for items of interest. While their resolution was easily sufficient for most tasks, it left analysts longing for the ability to select more specific targets for higher resolution photography. The NRO's declassification guide contains one tantalizing summary of CORONA Mission 9056, launched in June 1963 with an experimental camera projected to obtain resolution up to a single foot. The experiment failed.[27]

LANYARD, the KH-6 camera system, offered another approach to higher resolution. It combined a variant of the SAMOS E-5 camera with CORONA's Agena booster.[28] Using a substantially enlarged Agena vehicle and the same 80-pound film load as the KH-4, the KH-6 attempted to aim its optics independently rather than maneuvering the entire spacecraft. A dedicated roll joint could direct the camera to zero, fifteen, or thirty degree angles, giving a potential targeting area some 192 nautical miles across along the spacecraft's flight path. The roll joint, however, could be used only 200 times on each mission, requiring three seconds to move each 15-degree increment and a total of 30 seconds to move from one extreme to the other.[29] LANYARD launched only three times, returning its film to Earth on two of those missions.

In total the CORONA family of systems returned approximately 800,000 images to Earth. Those images occupied some 2.1 million feet of film, stored in 39,000 separate reels. The KH-4b MURAL system achieved a resolution of six feet. When it worked, LANYARD's KH-6 system achieved a resolution of two feet. Over its operational lifetime the CORONA program developed to provide a reliable window into developments behind the Iron Curtain.

Limits

Despite its steadily growing list of accomplishments, it is clear that the intelligence community recognized the limitations of the CORONA family of systems by 1962. Their analysis is indicated by the various improvements attempted in the ARGON, LANYARD, and MURAL systems and the Mission 9056 experiment. CORONA suffered from its reliance on a limited film supply, the continuing need to physically return that film to Earth for analysis, and the limited resolution of its wide-angle photography.

The very nature of optical photography also posed problems for the CORONA systems. Limited use of infrared film presumably addressed CORONA's general dependence on daylight in addition to its other intelligence applications.[30] Cloud cover presented an even more imposing barrier to photography. With the system's lack of near-real time imagery, CORONA controllers had no way to assess cloud cover above a target area in the absence of detailed weather forecasts. Predictably, a lot of valuable satellite film obtained little more than pictures of Soviet cloud formations. On 21 June 1961 the Office of the Secretary of the Air Force for Special Projects, soon to become the NRO's Program A, began planning a solution in the form of the Defense Meteorological Satellite Program (DMSP).[31]

Intended to support CORONA, DMSP satellites began operations following the first successful launch on 23 August 1962. By October that weather satellite paid immense dividends, supporting aircraft reconnaissance flights during the Cuban Missile Crisis. The program continued long after CORONA missions ceased in 1972.

There has been considerable speculation about NRO efforts to overcome CORONA's weaknesses in subsequent satellite programs. The declassification processes established by President Clinton's Executive Orders 12951 and 12958 have yet to release anything about those systems rivaling the original 1995 CORONA revelations. Perhaps the 50th anniversaries of CORONA and the NRO, coupled with President Barack Obama's recent revision of Executive Order 12958, will trigger another major disclosure.[32] But the basic nature of America's second generation of imagery intelligence satellites can also be deduced from officially declassified materials.

Chief among them is the same multi-volume *History of Satellite Reconnaissance* that summarized the CORONA program. Volumes 3a and 3b of that history describe the emergence of systems intended to complement, and eventually replace, the CORONA family of satellites. Among those volumes many revelations is the fact that the final SAMOS imagery concept, E-6, was originally pursued in 1960 as a higher resolution replacement for the struggling CORONA program. Like the five other conceptual "E" payloads of WS-117L, E-6 ultimately proved unworkable.[33] But during that same hectic summer of 1960, before the NRO was established, one of its future directors initiated the development of a system that did successfully surpass CORONA's capabilities.

KH-7

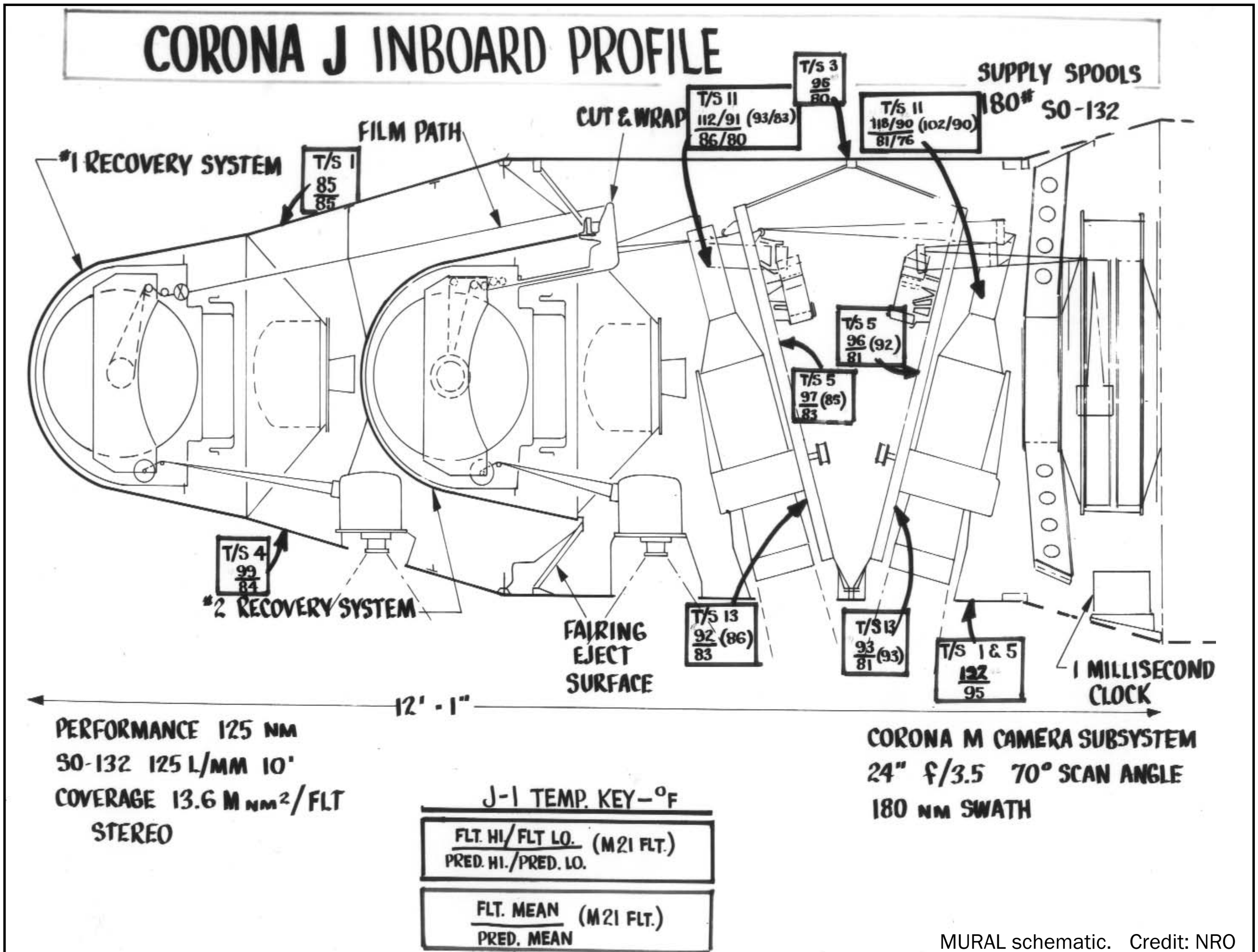
An unidentified firm proposed a new satellite camera to both future partners in the NRO, the CIA and the Air Force, in March 1960. The CIA's negative response may have reflected its commitment to the CORONA program. Air Force Undersecretary Charyk, however, proved interested in this film-return system. By early 1961 a covert Air Force effort to develop this system was firmly in place under his leadership.[34]

Like the Keyhole cameras of CORONA, the KH-7 employed an Agena booster, the Agena B, as its vehicle. The Atlas rocket would lift the Agena and its cargo from Earth, an effort orchestrated by the Air Force personnel of the NRO's Program A. During this early conceptual stage, with the experience of CORONA not yet acquired, the program's managers advocated landing the new system's payload to avert the potential crisis of a CORONA-style capsule falling into Soviet hands or onto foreign soil. By early 1962 it became clear that KH-7 would be different from all of its predecessors in one important way. Its required precision, for both targeting and basic procedures, meant that its operations would need to be designed on computer. The KH-7 system provided serious challenges to the rapidly evolving state of the art in satellite systems.[35]

Land recovery proved particularly troublesome, and was opposed by the director of Program A, Air Force Major General Robert E. Greer. The approach presented more complications than intercepting the CORONA capsule in mid-air, and the latter's success undoubtedly argued against the need for addressing them. In the summer of 1962 Greer secured Charyk's approval to reconsider the desirability of land recovery and investigate the use of a CORONA-style reentry capsule for mid-air retrieval of the KH-7's film payload. Using a slightly modified capsule from the operational program proved far simpler than developing a land recovery capability.

This use of CORONA technology would require the Air Force's Program A to coordinate with the CIA's Program B, underscoring the wisdom in the creation of the NRO that controlled both efforts. Negotiating the CIA's security concerns as technology and talented personnel moved from its successful program to the Air Force effort presented complexities of its own. But the young organization proved capable of executing its intended coordination function.[36]

General Greer established a simple measure of success for the first KH-7 flight: one good picture. Initial resolution could be sacrificed to achieve this demonstration, particularly as the CIA's



MURAL schematic. Credit: NRO

KH-6 LANYARD system, with its promised high resolution, emerged as a competitor to the Air Force project. Failure could not be tolerated. A single image with intelligence potential beyond that possible for KH-4, however, would be as useful as hundreds in proving that KH-7 could meet or surpass the promise of KH-6. In October 1962 Greer emphasized his goals for the project, directing its manager to stay on budget, stay on time, and deliver the necessary single photograph.[37]

The opportunity to do so was fast approaching on 11 May 1963. On that date a faulty fuel valve caused the loss of pressure in an Atlas booster's fuel tank as the launch crew rehearsed procedures. A full load of fuel and 13,000 gallons of liquid oxygen poured onto the launch pad but somehow failed to ignite. Without the tanks' supporting pressure, the Atlas collapsed under its own weight. The mission's Agena second stage was damaged. Although not those scheduled for the first launch, the Agena's KH-7 payload was damaged, its optics destroyed, and the rehearsal reentry vehicle proved too unreliable for use in an operational mission. The first KH-7 launch had to be delayed as program managers scrambled to adjust hardware assignments.[38]

On 12 July 1963 General Greer monitored the countdown from the Air Force Satellite Control Facility in Sunnyvale, California. As the first KH-7 lifted off from Vandenberg Air Force Base its exhaust briefly interrupted the electrical connections providing telemetry and television signals, giving remote observers the impression that the national reconnaissance program had suffered another expensive launch failure. Despite that impression and the spectacular results of the May rehearsal, this KH-7 did not repeat CORONA's troubled birth. The spacecraft achieved orbit, captured some quick photographs, and delivered its film back to a flying C-119 aircraft near Hawaii.

Greer had his one photo. When developed, the film achieved a best resolution of 3.5 feet. The average resolution for this first KH-7 flight was roughly 10 feet. The NRO's declassified history acknowledges the overall results of this flight as the best return from any reconnaissance satellite as of its January 1974 publication, with best resolution easily surpassing anything previously obtained.[39]

KH-7 proved to be an enormous success. While the CORONA family, primarily variants of the KH-4 camera system, continued to photograph vast sweeps of territory for waiting analysts, the new system offered more precision. Based on the same Agena vehicle and using very similar buckets, the two spacecraft must have appeared very similar. Their differences, however, insured that intelligence analysts could both detect activities of potential concern and examine them closely from the safety and neutrality of space.

As the first high resolution U.S. surveillance satellite, KH-7 flew a total of 38 missions between July 1963 and June 1967. Thirty-four of those missions returned their film to Earth, thirty of them bearing useable images. Collectively they represent 43,000 linear feet of film totaling approximately 19,000 individual frames. With a footprint on the ground of roughly 10 nautical miles by 12 nautical miles, and the ability to alter its 12 nautical mile wide images to lengths of 5–400 nautical miles, KH-7 photographed roughly 6.6 million square nautical miles during its operational life.

KH-9

The KH-7 system provided the required high resolution supplement to CORONA's capabilities. It did not, however, address the limitations imposed by film capacity or all of these systems' continued reliance on film return, rather than film readout or other near-real time technologies. The other second generation system that the NRO has declassified, KH-9, sought to replace the CORONA system completely. Along the way its development became the longest, most expensive, and most successful project undertaken by the NRO as of 1973.[40]

By 1961 it had become apparent to the CIA that CORONA, intended as a stopgap system pending WS-117L's near-real time capability, held considerable growth potential. Consideration of an evolutionary successor began in parallel with development of CORONA's ARGON, LANYARD, and MURAL improvements. Sorting out the contending technologies, institutional interests, and operational requirements proved to be a substantial challenge for the young National Reconnaissance Program, however. Such issues were not fully resolved until 1970.[41]

A 1963 advisory panel established by DCI John McCone played a prominent role in this lengthy process. Harvard Nobel Laureate Edward M. Purcell chaired the group. The Purcell Panel recommended an emphasis on improving CORONA's capabilities, suggesting avenues of research for that purpose, and correspondingly recommending against any high priority development of a successor system. This finding contradicted earlier studies, possibly reflecting the contemporary difficulties of LANYARD and cancellations of E-1, E-2, E-5, and E-6 while CORONA continued successful operations. The Purcell Panel's members later joined the Land Panel, under Polaroid CEO Edwin "Din" Land, which became the president's principal advisory panel on reconnaissance systems from 1965 through 1972.[42]

The effort destined to produce the KH-9 faced a bureaucratic obstacle beyond the low priority the Purcell Panel initially assigned to developing a CORONA successor. A well documented conflict between NRO Director Brockway McMillian and CIA Deputy Director for Science and Technology Albert "Bud" Wheelon soured relations between the organization responsible for overseeing the National Reconnaissance Program and the CIA office that represented the program's most successful component. That personality conflict continued until the two men departed in 1965. One result was the August 1965 creation of a National Reconnaissance Program Executive Committee. The organization would collectively determine which new programs deserved funding, leaving the NRO Director responsible for execution of the committee's decisions.

Planning for CORONA's successor began in earnest under the new management system. Executive Committee decisions would determine the course of KH-9 development. Those decisions soon had to take into account the budgetary austerity of the later 1960s and satellite reconnaissance's importance in supporting the emerging Strategic Arms Limitation Treaty (SALT) process.

CORONA's continued success made a strong argument for continuing the program, now appearing ever more affordable in comparison with developing a new system. It became clear, however, that KH-9 offered greater utility than CORONA in monitoring crisis situations. By 1969 national policy assumed that the new system would be operational in 1972. The bureaucratic arrangements supporting this assumption had apparently grown as complex as the new system itself. The NRO's history remarks that "the acronyms" of the principle organizations involved in the system's operations "alone were enough to engage the attention of a trained philologist."[43]

Little information about the KH-9 system itself has been declassified, apart from that required to explain its declassified products. The system included a mapping camera subsystem that produced those images. That camera flew on 12 of the KH-9's 20 operational missions between March 1973 and October 1980, producing images used by the Defense Mapping Agency and U.S. Geological Survey, among other users, to produce 1:200,000 scale maps.

In the course of those 12 missions, the mapping camera used a CORONA-style bucket to return 29,000 individual frames totaling 48,000 linear feet of film. With a footprint of 70 nautical miles by 140 nautical miles, these images covered roughly 104 million square nautical miles in resolution between 20 and 30 feet. These images were largely declassified in 1997, but the nature and products of KH-9's other missions remain closely held.

Declassified information does, however, indicate that KH-9 remained a film return system. The work-around for the technological challenges that WS-117L's pursuit of near-real time imagery encountered remained in operation from KH-1's first flight on 18 August 1960 through the end of KH-9 operations in October 1980. The NRO has declassified the cancellation of the SAMOS film-readout approach to near-real time satellite photography and the transfer of that technology to NASA. How it ultimately achieved a near-real time capability remains classified.

Near Real Time

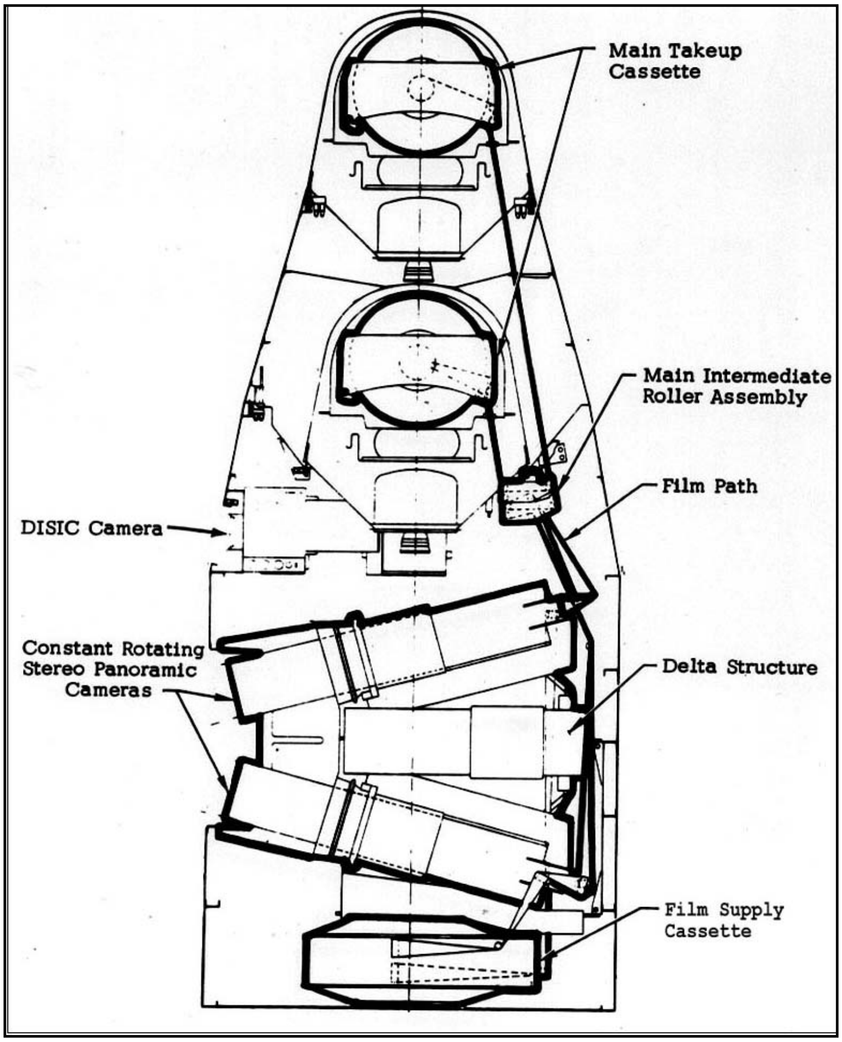
Twenty-three years separate WS-117L's January 1954 start from the first flight of the near-real time system that it sought to create. On 19 December 1976 the first U.S. near-real time imagery intelligence satellite launched into space. The camera it carried abandoned the film-readout concept, using an electro-optical technology developed by the NRO's Program B.[44] Program B, of course, was the CIA's institutional successor to the original CORONA effort that pursued an alternative to the stalled near-real time effort.

In July 2000 the NRO declassified limited information about its first electro-optical system, including the fact that President Gerald Ford declared it operational on 20 January 1977. The system's camera used charge-coupled device technology, the same basic technology utilized in today's digital photography. Such technology produces digital images as they are created, overcoming many of the weaknesses in the 1950s analog television technology available to WS-117L engineers and eliminating the need for the complex film-readout alternative that they pursued in SAMOS.[45]

Several factors had rendered the SAMOS system impractical for intelligence collection. Among them were its limited bandwidth and the brief time that a SAMOS satellite would be in view of any given ground station. Two decades of technological advances provided the solution.

In association with the declassification of its electro-optical capability, the NRO declassified the fact that it sponsors a relay satellite program. During the 1970s the Hughes Aircraft Corporation became prime contractor in the effort to develop a relay satellite that could operate with the near-real time

KH-4/MURAL profile. Courtesy: National Archives



electro-optical system. Hughes' Tony Iorillo led the design effort, later receiving the NRO's designation as a Pioneer of National Reconnaissance for this and other important contributions.[46]

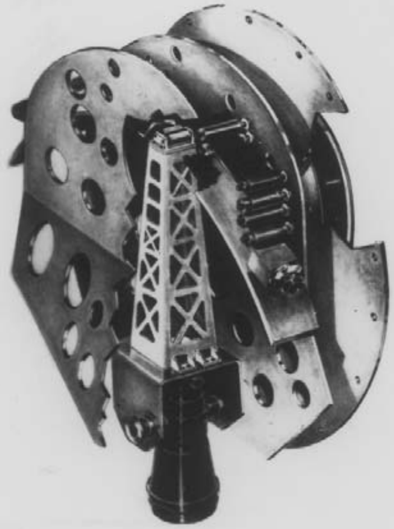
Iorillo's satellite solved the SAMOS problem. It orbited above the electro-optical satellite, spending long periods in view of both the continental U.S. and Soviet territory. The system worked perfectly when the electro-optical satellite began to transmit, relaying data at the rate of a hundred digital television channels. Instead of the far-flung network of control huts or receiving stations used for CORONA and intended for SENTRY/SAMOS, the relay satellite transmitted the electro-optical satellite's imagery directly to a ground station in the continental United States.[47]

Subsequent Revelations

The declassification process started by President Clinton's EOs 12951 and 12958 has slowly released additional information about U.S. spy satellites. Many details of the CORONA effort are available, and records of the GRAB and POPPY programs are beginning to emerge. But the American public still knows very little about its national reconnaissance program. A culture of extreme secrecy developed and reinforced itself for more than 30 years before even the existence of the NRO was declassified, presenting serious bureaucratic and personality challenges to the declassification process.

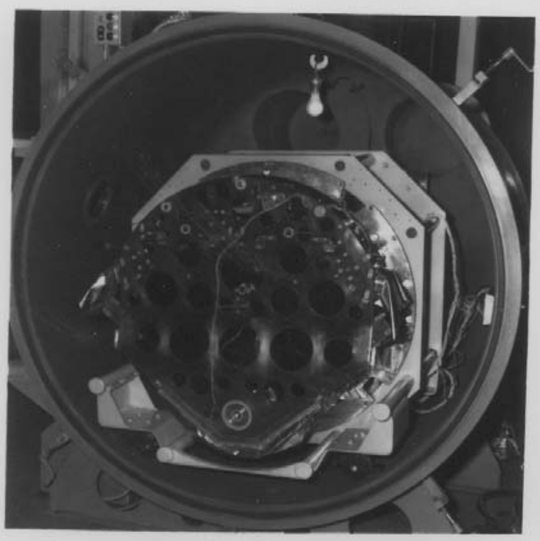
Still, we do know that the four original NRO program offices are no more. Program D ended in 1974 when the Air Force assumed responsibility for

THE FIRST SATELLITE CAMERA CONFIGURATION—C MODEL

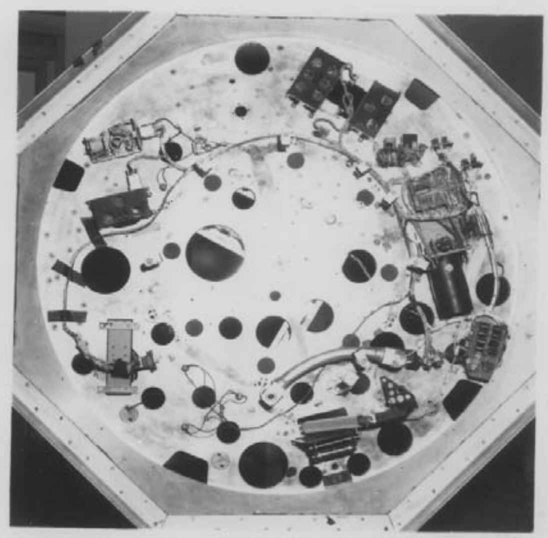


ARTIST'S VIEW OF CAMERA

ITEK'S F/5.0 24-INCH LENS



CAMERA IN VACUUM CHAMBER



REAR VIEW / FILM SPOOL SIDE OF CAMERA

all U-2, SR-71, and drone flights. The Air Force's Program A, CIA Program B, and Navy Program C continued until the NRO's reorganization and declassification under the leadership of Deputy Director, later acting Director, of the NRO Jimmie D. Hill. Restructured along functional lines, the NRO also consolidated its management offices into a Chantilly, Virginia, headquarters complex constructed in 1994.

In October 2008 the NRO acknowledged three other operating locations in the United States. These are the Aerospace Data Facilities at Fort Belvoir, Virginia; White Sands, New Mexico; and Buckley Air Force Base, Colorado. At the time it declassified these facilities the NRO also announced a presence at two overseas facilities, the Joint Defence Facility Pine Gap near Alice Springs, Australia, and Royal Air Force Menwith Hill Station, north of Leeds, in the United Kingdom.

With the 50th anniversary of the first GRAB launch now behind us, the 50th anniversary of the first successful CORONA mission at hand, and the 50th anniversary of the NRO itself not far off, it seems likely that the public will be learning more about America's reconnaissance satellites in the near future. Certainly the recent update to EO 12958, President Obama's EO 13526, sets a very high bar for continued classification of 50-year old information.

Hopefully one of the early results of any additional declassification decisions will be the release of more text from Robert Perry's crucial volumes, and at least the partial release of any similar works that the NRO's history program may have produced in the intervening 36 years.

About the Author

Dr. Jeffery Charlston is a history professor at the University of Maryland University College. He is also an employee of ManTech International, serving as the senior historian on NRO's Information Access and Release Team. All statements of fact, opinion, or analysis expressed in this article are those of the author. Nothing in the article should be construed as asserting or implying U.S. government endorsement of an article's factual statements and interpretations.

Notes

1. Dwayne Day, "CORONA: America's First Spy Satellite Program," *Quest* 4, no. 2 (summer 1995): 4–21; and *Quest* 4, no. 3 (winter 1995): 28–36.

2. Kevin Ruffer, "CORONA and the Intelligence Community: Declassification's Great Leap Forward," *Studies in Intelligence* 39, no. 5 (1996): 21–29.

3. Joseph Ansebuo, "CORONA: A Revolution in U.S. Intelligence Capabilities," *Aerospace Daily Focus* (9 June 1995).

4. Intelligence Community Directive 108, 29 August 2007, orders the NRO and other intelligence agencies to "establish and maintain a professional historical capability, consisting of formal history units as appropriate, to document, analyze, and advance an understanding of the history of the agency."

5. Douglas Aircraft Company, Project RAND report SM-11827, 2 May 1946.

6. See R. Cargill Hall and Clay Laurie, editors, *Early Cold War Overflights: Symposium Proceedings* (NRO: Office of the Historian, 2003). Two volumes.

7. Virginia Campbell, "How RAND Invented the Postwar World," *Invention and Technology* 20 (Summer 2004): 50–59.

8. Robert Perry, *A History of Satellite Reconnaissance: Volume 1, CORONA.* (NRO, 1973), 1. Declassified text available at www.nro.gov/foia/declass_initiatives .html.

9. Perry, *A History of Satellite Reconnaissance*, 6–7.

10. The MIDAS program was declassified in 1998.

11. NRO, Review and Redaction Guide for Automatic Declassification of 25-Year-Old Information (RRG), 2006 Edition, 146. Declassified text available at www.fas.org/irp/nro/declass.pdf. For a brief history of SAMOS, see R. Cargill Hall, *SAMOS to the Moon: The Clandestine Transfer of Reconnaissance Technology Between Federal Agencies.* Declassified text available at www.nro.gov/foia/ Samos%20to%the%20Moon.pdf.

12. RRG, 146–147.

13. RRG, 90.

14. RRG, 91.

15. RRG, 159–160.

16. *History of Satellite Reconnaissance,* vol. 1, 38–40.

17. *History of Satellite Reconnaissance,* vol. 1, 53–55.

18. R. Cargill Hall, "SAMOS to the Moon."

19. *History of Satellite Reconnaissance,* vol. 1, provides an extensive declassified account of program administration.

20. RRG, 155.

21. *History of Satellite Reconnaissance,* vol. 1, 90.

22. Robert Burns, "Lighter Side of Space Race: Troublesome Mice, Baffled Farmers," Washington: Associated Press, 24 May 1995.

23. *History of Satellite Reconnaissance,* vol. 1, 90–95, describes this series of failures in some detail.

24. *History of Satellite Reconnaissance*, vol. 1, 118–120.

25. See www.nrojr.gov/teamrecon/ resource-template.html for a convenient graphic summary of CORONA launches and platforms. Also, http://msl.jpl. nasa.gov/programs/corona.html provides a summary of all CORONA missions.

26. *History of Satellite Reconnaissance,* vol. 1, 127.

27. RRG, 23.

28. *History of Satellite Reconnaissance,* vol. 3a, 29.

29. RRG, 28–29.

30. RRG, 155.

31. R. Cargill Hall, *A History of the Military Polar Orbiting Meteorological Satellite Program* (NRO: Office of the Historian, 2001) provides a detailed history of this program.

32. Executive Order 13526, 29 December 2009.

33. *History of Satellite Reconnaissance*, vol. 3a, (NRO, Jan 1974), iii–iv.

34. *History of Satellite Reconnaissance,* vol. 3a, 2-9.

35. *History of Satellite Reconnaissance*, vol. 3a, 26, 30, 33–34.

36. *History of Satellite Reconnaissance*, vol. 3a, 37–47.

37. *History of Satellite Reconnaissance,* vol. 3a, 70.

38. *History of Satellite Reconnaissance,* vol. 3a, 81–83.

39. *History of Satellite Reconnaissance*, vol. 3a, 93–96.

40. *History of Satellite Reconnaissance,* vol. 3b, (NRO, November 1973), iii.

41. History of Satellite Reconnaissance, vol. 3a, 2.

42. *History of Satellite Reconnaissance*, vol. 3a, 8–10.

43. *History of Satellite Reconnaissance,* vol. 3a, 76–77, 97.

44. RRG, 54, 96.

45. RRG, 26.

46. RRG, 42, 101.

47. RRG, 42, 31.