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*The first photographic reconnaissance satellite*

# CORONA

**Kenneth E. Greer**

When the U-2 began operating in the summer of 1956, it was expected to have a relatively short operational life in overflying the Soviet Union—perhaps no more than a year or two. That expectation was based not so much on the likelihood that the Soviets could develop the means of shooting it down, as on their ability to develop a radar surveillance network capable of tracking the U-2 reliably. With accurate tracking data in hand, the Soviets could file diplomatic protests with enough supporting evidence to generate political pressures to discontinue the overflights. As it turned out, the United States had underestimated the Soviet radars, which promptly acquired and continuously tracked the very first U-2 flight over Soviet territory. The Soviets filed a formal protest within days of the incident, and a standdown was ordered.

For nearly four years, the U-2 ranged over much of the world, but only sporadically over the Soviet Union. Soviet radar was so effective that each flight risked another protest, and another standdown. Clearly, some means had to be found to accelerate the initial operational capability for a less vulnerable successor to the U-2. Fortunately, by the time Francis Gary Powers was shot down near Sverdlovsk on 1 May 1960 (fortunate for the intelligence community, that is—not for Powers), an alternative means of carrying out photographic reconnaissance over the Soviet Union was approaching operational readiness. On 19 August 1960, just 110 days after the downing of the last U-2 overflight of the Soviet Union, the first successful air catch was made near Hawaii of a capsule of exposed film ejected from a photographic reconnaissance satellite that had completed seven passes over denied territory and 17 orbits of the earth. The feat was the culmination of four years of intensive and often frustrating effort to build, launch, orbit, and recover an intelligence product from a camera-carrying satellite.

At about the time the U-2 first began overflying the Soviet Union in 1956, the U.S. Air Force was embarking on the development of a strategic reconnaissance weapons system employing orbiting satellites in a variety of collection configurations. The program, which was designated WS-117L, had its origins in 1946 when a requirement was placed on the RAND Corporation for a study of the technical feasibility of orbiting artificial satellites. The first real breakthrough had come in 1953 when the USAF Scientific Advisory Board reported to the Air Staff that it was feasible to produce relatively small and light-weight thermonuclear warheads. As a result of that report, the ATLAS ICBM program was accorded the highest priority in the Air Force.

Since the propulsion required to place a satellite in orbit is of the same general order of magnitude as that required to launch an ICBM, the achievement of an ICBM-level of propulsion made it possible to begin thinking seriously of launching orbital satellites. Accordingly, General Operational Requirement No. 80 was levied in 1955 with the stated objective of providing continuous surveillance of pre-selected areas of the world to determine the status of a potential enemy's war-making capacity.

The Air Research and Development Command, which had inherited the RAND study program in 1953, assigned the satellite project to its Ballistic Missile Division. The development plan for WS-117L was approved in July 1956, and the program got under way in October 1956 with the awarding of a contract to the Lockheed Aircraft Corporation for the development and testing of the system under the program name PIED PIPER.

The planning for WS-117L contemplated a family of separate systems and subsystems employing satellites for the collection of photographic, electronic, and infrared intelligence. The program, which was scheduled to extend beyond 1965, was divided into three phases. Phase I, the THOR-boosted test series, was to begin in November 1958. Phase II, the ATLAS-boosted test series, was scheduled to begin in June 1959 with the objective of completing the transition from the testing phase to the operational phase and of proving the capability of the ATLAS booster to launch heavy loads into space. Phase III, the operational series, was to begin in March 1960 and was to consist of three progressively more sophisticated systems: the Pioneer version (photographic and electronic), the Advanced version (photographic and electronic), and the Surveillance version (photographic, electronic, and infrared). It was expected that operational control of WS-117L would be transferred to the Strategic Air Command with the initiation of Phase III.

It was an ambitious and complex program that was pioneering in technical fields about which little was known. Not surprisingly, it had become apparent by the end of 1957 that the program was running behind schedule. It also was in trouble from the standpoint of security. The U-2 program was carried out in secret from 1956 until May 1960. Its existence was no secret to the Soviets, of course, but they chose to let it remain a secret to the general public (and to most of the official community) rather than publicize it and thereby admit that they lacked the means of defending their air space against the high-flying U-2. WS-117L was undertaken as a classified project, but its very size and the number of people involved made it impossible to conceal the existence of the program for long. The press soon began speculating on the nature of the program, correctly identifying it as involving military reconnaissance satellites, and referring to it as BIG BROTHER and SPY IN THE SKY. The publicity was of concern, because the development of WS-117L was begun in a period when the international political climate was hostile to any form of overflight reconnaissance.

It was against this background that the President's Board of Consultants on Foreign Intelligence Activities submitted its semi-annual report to the President on 24 October 1957. The Board noted in its report that it was aware of two advanced reconnaissance systems that were under consideration. One was a study then in progress in the Central Intelligence Agency concerning the feasibility of a manned reconnaissance aircraft designed for greatly increased performance and reduced radar cross-section; the other was WS-117L. However, there appeared little prospect that either of these could produce operational systems earlier than mid-1959. The Board emphasized the need for an interim photo reconnaissance system and recommended that an early review be made of new developments in advanced reconnaissance systems to ensure that they were given adequate consideration and received proper handling in the light of then-existing and future intelligence requirements. The Executive Secretary of the National Security Council on 28 October notified the Secretary of Defense and the Director of Central Intelligence that the President had asked for a joint report from them on the status of the advanced systems. Secretary Quarles responded on behalf of himself and Mr. Dulles on 5 December with a recommendation that, because of the extreme sensitivity of the subject, details on the new systems be furnished through oral briefings.

As a consequence, there are no official records in CIA's Project CORONA files bearing dates between 5 December 1957 and 21 March 1958, but it is clear that major decisions were made and that important actions were undertaken during the period. In brief, it was decided that the photographic subsystem of WS-117L offering the best prospect of early success would be separated from WS-117L, designated Project CORONA, and placed under a joint CIA-Air Force management team—an approach that had been so successful in covertly developing and operating the U-2.

The nucleus of such a team was then constituted as the Development Projects Staff under the direction of Richard Bissell, who was Special Assistant to the DCI for Planning and Development. Bissell was designated as the senior CIA representative on the new venture, and his Air Force counterpart was Brigadier General Osmond Ritland, who, as Colonel Ritland, had served as Bissell's first deputy in the early days of the Development Projects Staff and later became Vice Commander of the Air Force Ballistic Missile Division.

Bissell recalls that he first learned of the new program and of the role intended for him in it "in an odd and informal way" from Dr. Edwin Land. Dr. Land had been deeply involved in the planning and development of the U-2 as a member of the Technological Capabilities Panel of the Office of Defense Mobilization. He continued an active interest in overhead reconnaissance and later headed the Land Panel, which was formed in May 1958 to advise on the development of OXCART, the aircraft planned as the successor to the U-2. Bissell also recalls that his early instructions were extremely vague: that the subsystem was to be split off from WS-117L, that it was to be placed under separate covert management, and that the pattern established for the development of the U-2 was to be followed. One of the instructions, however, was firm and precise: none of the funds for the new program were to come from monies authorized for already approved Air Force programs. This restriction, although seemingly clear at first glance, later led to disagreement over its interpretation. CORONA mangement expected that the boosters already approved for the THOR test series of WS-117L would simply be diverted to the CORONA program; this proved not to be so. As a consequence, CIA had to go back to the President with an admission that the original project proposal had understated the estimated cost and with a request for more money.

Roughly concurrent with the decision to place one of the WS-117L subsystems under covert management, the Department of Defense realigned its structure for the management of space activities. The Advanced Research Projects Agency (ARPA) was established on 7 February 1958 and was granted authority over all military space projects. The splitting off of CORONA from WS-117L was accomplished by a directive from ARPA on 28 February 1958, assigning responsibility for the WS-117L program to the Air Force and ordering that the proposed WS-117L interim reconnaissance system employing THOR boost be dropped.

The ARPA directive ostensibly cancelling the THOR-boosted interim reconnaissance satellite was followed by all of the notifications that would normally accompany the cancellation of a military program. The word was passed officially within the Air Force, and formal contract cancellations were sent out to the prospective suppliers. There was much furore when the cancellations went out: contractors were furious over the suddenness of the action; Air Force personnel were thunderstruck at the abandonment of the WS-117L photographic subsystem that seemed to have the best chance of early success. After the cancellation, very limited numbers of individuals in the Air Force and in the participating companies were cleared for Project CORONA and were informed of the procedures to be followed in the covert reactivation of the cancelled program.

Although CORONA was removed from WS-117L and placed under separate management as a covert activity, the original intent was to disguise its real purpose by concealing it as an experimental program within the first phase of WS-117L. This permitted overt procurement of the necessary boosters, second stages, and hardware associated with the biomedical cover launches. It also provided an explanation for the construction of launch and ground control facilities. Only the program peculiars associated with the true photographic reconnaissance mission had to be procured covertly.

After Bissell and Ritland had worked out the arrangements for the overt cancellation and covert reactivation of the program, they then began tackling the technical problems associated with the design configuration they had inherited from WS-117L. The subsystem in point contemplated the use of the THOR IRBM as the first stage booster and, as a second stage, Lockheed's modification of a rocket engine that had been developed by Bell Aircraft for take-off assist and auxiliary power applications in the B-58 HUSTLER bomber. It was referred to as the HUSTLER engine during the development phase of WS-117L but soon came to be known as the AGENA—the name it bears today.

One of the very early CORONA plans called for spin stabilization of the payload, with the camera scanning as the payload rotated. The contractors working on this subsystem design were Lockheed on the space vehicle, and Fairchild on the camera. The camera was to have a focal length of six inches, without image motion compensation. Ground resolution was expected to be poor with this short focal length, particularly if combined with the readout techniques envisaged by WS-117L.

Several important design decisions were implemented in this organizational period of CORONA. Recognizing the need for resolution to meet the intelligence objectives, it was concluded that physical film recovery offered the most promising approach for a usable photographic return in the interim time period. This resulted in the addition to the design of a recovery pod or capsule with General Electric selected as the recovery vehicle contractor. In retrospect, the decision on film recovery would prove to be one of the most important made in U.S. reconnaissance activities, in that all photo reconnaissance systems developed up to the current time have relied on physical recovery of film.

Another major decision for the new CORONA Program came in late March 1958, following a three-day conference in San Mateo, California, among representatives of CIA, Air Force Ballistic Missile Division, Lockheed, General Electric, and Fairchild. The discussion revealed that, while work was going forward, the design was far from complete. The senior Lockheed representative reported that they had investigated the possibility of building a satellite vehicle shaped like a football, a cigar, or a sphere. They had finally decided, for the original drawings at least, on a football-shaped pod slightly elongated at each end to correct the center of gravity. There was discussion of the need for immediate contractual arrangements with the various suppliers. Bissell remarked that he was "faced with the problem at present of being broke" and would need estimates from all the suppliers as soon as possible in order to obtain the necessary financing to get the program under way. The suppliers agreed to furnish the required estimates by the following week.

The project quickly began taking formal shape following that meeting. Within a span of about three weeks, approval of the program and of its financing was obtained, and the design of the payload configuration evolved into a concept quite different from the spin-stabilized pod. It was at this point in late March and early April 1958 that major complications had arisen in the technical design of the Fairchild camera. Interest shifted to a competitive design submitted by the Itek Corporation, a spin-off of Boston University. Itek proposed a longer focal length camera scanning within an earth-center stabilized pod. The Itek design was based on the principle of the Boston University Hyac camera. Bissell recalls that he personally decided in favor of the Itek design, but only after much agonizing evaluation. The decision was a difficult one to make because it involved moving from a proven method of space vehicle stabilization to one that was technically more difficult to accomplish. It did, however, standardize on the 3-axis stabilization being pursued on the WS-117L AGENA development, and which has been a part of all subsequent photo reconnaissance systems.

Bissell's first project proposal, which was completed on 9 April 1958, requested approval for concurrent development of both the Fairchild and the Itek systems, with the Fairchild configuration becoming operational first and the Itek configuration being developed as a follow-on system. Within two days, however, Bissell had made the final decision to abandon the Fairchild spin-stabilized configuration entirely. He rewrote the project proposal, taking note of the earlier configuration and giving his reasons for favoring the Itek approach (principally the better resolution attainable, the lower overall cost, and the greater potential for growth). The proposal was rewritten a second time, retaining the Itek configuration but raising the cost estimate from [redacted] to [redacted] Of the total estimated cost, [redacted] represented "a rather arbitrary allowance" for 12 each THOR boosters and Lockheed second stage vehicles, and was to be financed by ARPA through the Air Force. The remaining $7 million was for covert procurement by CIA of the pods containing the reconnaissance equipment and the recoverable film cassettes.

The final project proposal was forwarded to Brigadier General Andrew J. Goodpaster, the President's Staff Secretary, on 16 April 1958 after having been reviewed by Mr. Roy Johnson and Admiral John Clark of ARPA; Mr. Richard Horner, Assistant Secretary of the Air Force for Research and Development; Brigadier General Osmond Ritland, Vice Commander, Air Force Ballistic Missile Division; and Dr. James Killian, Special Assistant to the President for Science and Technology. The proposal was approved, although not in writing. The only original record of the President's approval reportedly was in the form of a handwritten note on the back of an envelope by General C. P. Cabell, the Deputy Director of Central Intelligence.

Although it may have been the original intent that CORONA would be administered in a manner essentially the same as that of the U-2 program, it actually began and evolved quite differently. It was a joint CIA-ARPA-Air Force effort, much as the U-2 was a joint CIA-Air Force effort, but it lacked the central direction that characterized the U-2 program. The project proposal described the anticipated administrative arrangements, but it fell short of clarifying the delineation of authorities. It noted that CORONA was being carried out under the authority of ARPA and CIA with the support and participation of the Air Force. CIA's role was further explained in terms of participating in supervision of the technical development, especially as regards the actual reconnaissance equipment, handling all covert procurement, and maintenance of cover and security. The work statement prepared for Lockheed, the prime contractor, on 25 April 1958 noted merely that technical direction of the program was the joint responsibility of several agencies of the Government.

The imprecise statements of who was to do what in connection with CORONA allowed for a range of interpretation. The vague assignments of responsibilities caused no appreciable difficulties in the early years of CORONA when the joint concern was primarily one of producing as promised, but they later (1963) became a source of severe friction between CIA and the Air Force over responsibility for conducting the program.

Bissell, the recognized leader of the early CORONA program, gave this description of how the early program was managed:

> The program was started in a marvelously informal manner. Ritland and I worked out the division of labor between the two organizations as we went along. Decisions were made jointly. There were so few people involved and their relations were so close that decisions could be and were made quickly and cleanly. We did not have the problem of having to make

compromises or of endless delays awaiting agreement. After we got fully organized and the contracts had been let, we began a system of management through monthly suppliers' meetings—as we had done with the U-2. Ritland and I sat at the end of the table, and I acted as chairman. The group included two or three people from each of the suppliers. We heard reports of progress and ventilated problems—especially those involving interfaces among contractors. The program was handled in an extraordinarily cooperative manner between the Air Force and CIA. Almost all of the people involved on the Government side were more interested in getting the job done than in claiming credit or gaining control.

The schedule of the program, as it had been presented to the CORONA group at its meeting in San Mateo in late March 1958, called for a "count-down" beginning about the first of July 1958 and extending for a period of 19 weeks. It was anticipated that the equipment would be assembled, tested, and the first vehicle launched during that 19-week period, which meant that the fabrication of the individual components would have had to be completed by 1 July 1958. By the time Bissell submitted his project proposal some three weeks later, it had become apparent that the earlier tentative scheduling was unrealistic. Bissell noted in his project proposal that it was not yet possible to establish a firm schedule of delivery dates, but that it appeared probable that the first firing could be attempted no later than June 1959.

It is pertinent to note here that there was no expectation in 1958 that CORONA would still be operating over a decade later. The CORONA program got under way initially as an interim, short-term, high-risk development to meet the intelligence community's requirements for area search photographic reconnaissance pending successful development of other, more sophisticated systems planned for WS-117L. The original CORONA proposal anticipated the acquisition of only 12 vehicles, noting that at a later date it might be desirable to consider whether the program should be extended—with or without further technological improvement.

Having settled on the desired configuration and having received Presidential approval of the program and its financing, the CORONA management team moved forward rapidly with the contractual arrangements. The team of contractors for CORONA differed from the team on the WS-117L subsystem as a consequence of selecting Itek's earth-center stabilized approach. Itek was brought in as one of the two major subcontractors to Lockheed (General Electric being the other). However, to soften the financial blow to Fairchild, Itek was made responsible for the design and development of the camera subsystem with Fairchild producing the camera under subcontract to Itek. This contractor team continued throughout the CORONA program, although later in the program, the relationship was changed to that of associate contractors. The contractor relationships on the CORONA program were as friendly and cooperative as any that could have been set up, and this team dedication to the success of the program is one of the primary reasons for the success the program enjoyed. The final contractors were selected on 25 April 1958 and a work statement was issued to Lockheed on that date. The contractors began systems design on 28 April and completed them and submitted them for first review on 14 May. The designs were frozen on 26 July.

[redacted]

Thus, by mid-1958, the program was well down the road—on the contractors' side—toward meeting the goal of a first launch no later than mid-1959. The Government side, however, was running into difficulties. The first problem was money, the second was cover, and the two were inextricably intertwined. The [redacted] cost estimate for the 12-vehicle program had assumed that the cost of the THOR boosters would be absorbed by the Air Force by diverting them from the cancelled WS-117L subsystem. That assumption proved to be incorrect. An additional [redacted] had to be found to pay for the 12 THORs. Further, it had been decided that an additional four launch vehicles would be required for testing of launch, orbit, and recovery procedures and that an additional three would be required for biomedical launches in support of the CORONA cover story. ARPA could not see its way clear to making Defense Department funds available merely for testing or for cover support when there were other DoD space programs with pressing needs for money. Consequently, CORONA management had to go back to the President for approval of a revised estimate.

By August 1958, it had also become apparent to the project's managers that the original, but as yet unannounced, cover story conceived for the future CORONA launchings (an experimental program within the first phase of WS-117L) was becoming increasingly untenable. WS-117L had by then become the subject of fairly widespread public speculation identifying it as a military reconnaissance program. It was feared that linking CORONA to WS-117L in any way would inevitably place the reconnaissance label on CORONA, and—given the hostility of the international political climate to overflight reconnaissance—there was the risk that the policy level of government might cancel the program if it should be so identified. Some other story would have to be contrived that would dissociate CORONA from WS-117L and at the same time account for multiple launchings of stabilized vehicles in low polar orbits and with payloads being recovered from orbit.

It was decided, therefore, to separate the WS-117L photo reconnaissance program into two distinct and ostensibly unrelated series: one identified as

DISCOVERER (CORONA – THOR boost) and the other as SENTRY (later known as SAMOS – ATLAS boost). A press release announcing the initiation of the DISCOVERER series was issued on 3 December 1958 identifying the initial launchings as tests of the vehicle itself and later launchings as explorations of environmental conditions in space. Biomedical specimens, including live animals, were to be carried into space and their recovery from orbit attempted.

The new CORONA cover concept, from which the press release stemmed, called for a total of five biomedical vehicles, and three of the five were committed to the schedule under launchings three, four, and seven. The first two were to carry mice and the third a primate. The two uncommitted vehicles were to be held in reserve in event of failure of the heavier primate vehicle. In further support of the cover plan, ARPA was to develop two radiometric payload packages designed specifically to study navigation of space vehicles and to obtain data useful in the development of an early warning system (the planned MIDAS infrared series). It might be noted here that only one of the three planned animal-carrying missions was actually attempted (as DISCOVERER III), and it was a failure. ARPA did develop the radiometric payload packages, and they were launched as DISCOVERERs XIX and XXI in late 1960 and early 1961.

The photo reconnaissance mission of CORONA necessitated a near-polar orbit, by launching either to the north or to the south. There are few otherwise suitable areas in the continental United States where this can be done without danger that debris from an early in-flight failure could fall into populated areas. Cooke Air Force Base* near California's Point Arguello met the requirement for downrange safety, because the trajectory of a southward launch from there would be over the Santa Barbara channel and the Pacific Ocean beyond. Cooke was a natural choice, because it was the site of the first Air Force operational missile training base and also housed the 672nd Strategic Missile Squadron (THOR). Two additional factors favored this as the launch area: the manufacturing facilities and skilled personnel required were in the near vicinity, and a southward launch would permit recovery in the Hawaii area by initiating the ejection/recovery sequence as the satellite passed over the Alaskan tracking facility.

Unlike the U-2 flights, launchings of satellites from U.S. soil simply could not be concealed from the public. Even a booster as small as the THOR (small, that is, in comparison with present-day space boosters) launches with a thunderous roar that can be heard for miles; the space vehicle transmits telemetry that can be intercepted; and the vehicle can be detected in orbit by radar skin-track. The fact of a launch could not be concealed, but maintenance of the cover story for the DISCOVERER series required that the launchings of the uniquely configured photographic payloads be closed to observation by unwitting personnel. Vandenberg was excellent as a launch site from many standpoints, but it had one feature that posed a severe handicap to screening the actual launches from unwanted observation: the heavily traveled Southern Pacific railroad passes through it. The early launches from Vandenberg had to

*Cooke AFB was renamed Vandenberg AFB in October 1958.

be timed for early afternoon,* and the Southern Pacific schedule broke this period into a series of launch windows, some of which were no more than a few minutes between trains. Throughout its existence, the CORONA program at Vandenberg was plagued by having to time the launches to occur during one of the intervals between passing trains.

The planned recovery sequence involved a series of maneuvers, each of which had to be executed to near-perfection or recovery would fail. Immediately after injection into orbit, the AGENA vehicle was yawed 180 degrees so that the recovery vehicle faced to the rear. This maneuver minimized the control gas which would be required for re-entry orientation at the end of the mission, and protected the heat shield from molecular heating, a subject of considerable concern at that time. (Later in the J-3 design when these concerns had diminished, the vehicle would be flown forward until re-entry.) When re-entry was to take place, the AGENA would then be pitched down through 60 degrees to position the satellite recovery vehicle (SRV) for retro-firing. Then the SRV would be separated from the AGENA and be spin-stabilized by firing the spin rockets to maintain it in the attitude given it by the AGENA. Next the retro-rocket would be fired, slowing down the SRV into a descent trajectory. Then the spin of the SRV would be slowed by firing the de-spin rockets. Next would come the separation of the retro-rocket thrust cone followed by the heat shield and the parachute cover. The drogue (or deceleration) chute would then deploy, and finally the main chute would open to lower the capsule gently into the recovery area. The primary recovery technique involved flying an airplane across the top of the descending parachute, catching the chute or its shrouds in a trapeze-like hook suspended beneath the airplane and then winching the recovery vehicle aboard. C-119 Aircraft were initially used with C-130 aircraft replacing them later in the program. The recovery vehicle was designed to float long enough, if the air catch failed, for a water recovery by helicopter launched from a surface ship.

While the vehicle was still in the construction stage, tests of the air recovery technique were conducted by the 6593rd Test Squadron—with disheartening results. Of 74 drops using personnel-type chutes, only 49 were recovered. Using one type of operational drop chute, only four were recovered out of 15 dropped, and an average of 1.5 aircraft passes were required for the hook-up. Eleven drops with another type of operational chute resulted in five recoveries and an average of two aircraft passes for the snatch. Part of the difficulty lay in weak chutes and rigging, and in crew inexperience. The most serious problem, however, was the fast drop rate of the chutes. Parachutes that were available to support the planned weight of the recovery vehicle had a sink rate of about 33 feet per second. What was required was a sink rate approaching 20 feet per second so that the aircraft would have time to make three or four passes if necessary for hook-up. Fortunately, by the time space hardware was ready for launching,

*The early THOR-AGENA combination limited film to enough for a 24-hour mission of 17 orbits, seven of which would cross denied territory. Requirements for daylight recovery and for daylight passage over denied areas with acceptable sun angles dictated the afternoon launch time.

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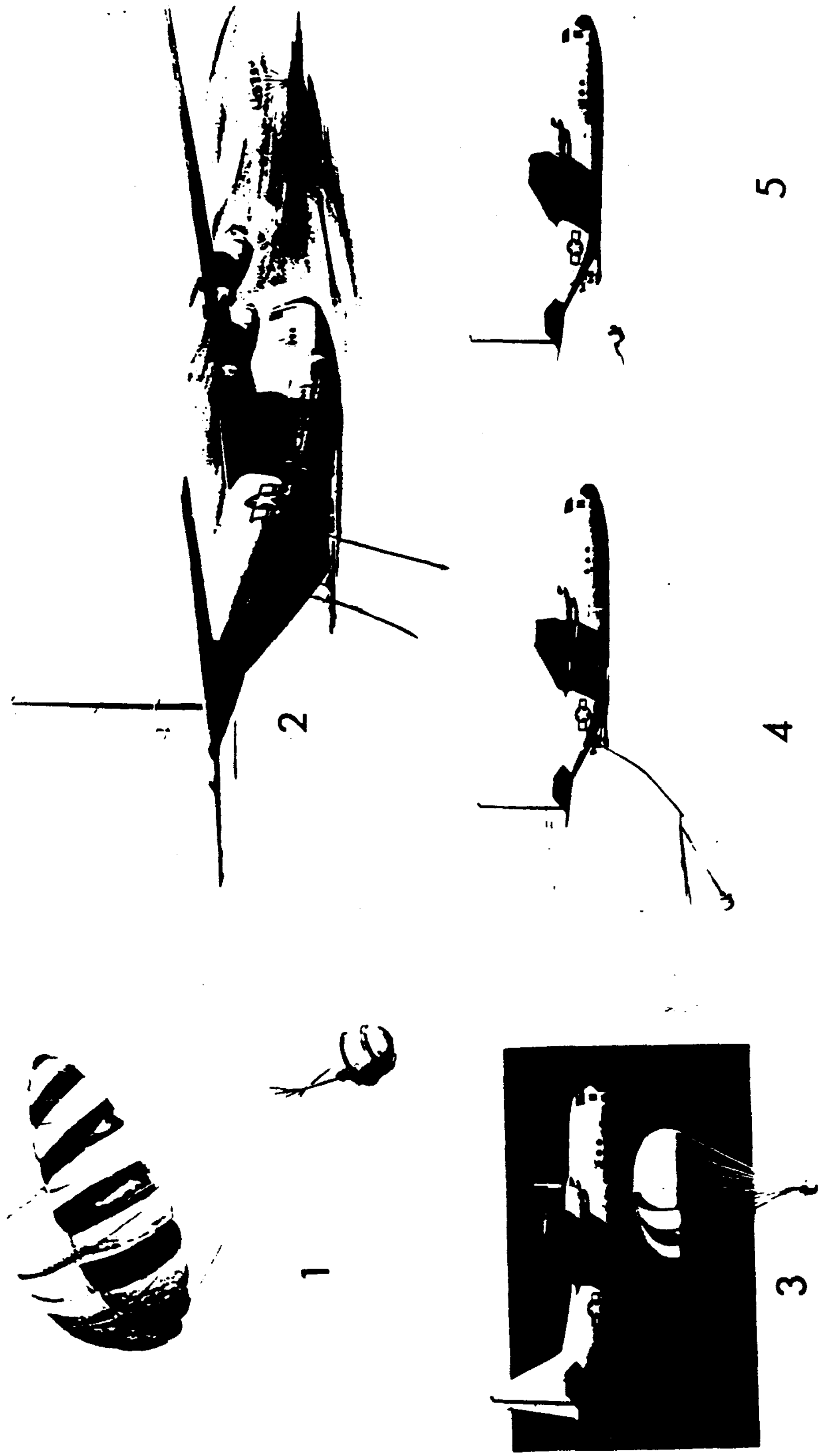
## AERIAL RECOVERY OF CAPSULE



a parachute had been developed with a sink rate slow enough to offer a reasonable chance of air recovery.

The launch facilities at Vandenberg AFB were complete, and the remote tracking and control facilities which had been developed for WS-117L were ready for the first flight test of a THOR-AGENA combination in January 1959. The count-down was started for a launch on the 21st; however, the attempt aborted at launch minus 60 minutes. When power was applied to test the AGENA hydraulic system, certain events took place that were supposed to occur in flight but not while the vehicle was still sitting on the launch pad. The explosive bolts connecting the AGENA to the THOR detonated, and the ullage rockets* fired. The AGENA settled into the fairing attaching it to the THOR and did not fall to the ground, but appreciable damage was done.

A program review conference was held in Palo Alto two days after the launch failure to examine the possible causes of the abort and to assess its impact on the planned CORONA launch schedule. Fortunately, the problem was quickly identified and easily corrected, and it was felt that the system was ready for test launches at the rate of about one per month.

At the review conference, General Electric surfaced a new problem having to do with the stability of the nose cone during re-entry. The cone was designed for a film load of 40 pounds, but the first missions would be able to carry only 20 pounds. GE reported that about three pounds of ballast would have to be carried in the forward end of the cone to restore stability. The program officers decided to add an instrument package as ballast, either for diagnostic purposes or for support of the biomedical cover story, thus converting what could have been dead weight into a net plus for the test program.

The test plan contemplated arriving at full operational capability at a relatively early date through sequential testing of the major components of the system—beginning with the THOR-AGENA combination alone, then adding the nose cone to test the ejection/re-entry/recovery sequence, and finally installing a camera for a full CORONA systems test. Just how much confidence the project planners had in the imminence of success cannot now be discovered; however, if the confidence factor was very high at the start, it must soon have begun to wane. Beginning in February 1959 and extending through June 1960 an even dozen launches were attempted, with eight of the vehicles carrying cameras, and all of them were failures; no film capsules were recovered from orbit. Of the eight camera-carrying vehicles, four failed to achieve orbit, three experienced camera or film failures, and the eighth was not recovered because of a malfunction of the re-entry body spin rockets. These summaries of the initial launch attempts illustrate the nature and dimensions of the problems for which solutions had to be found.

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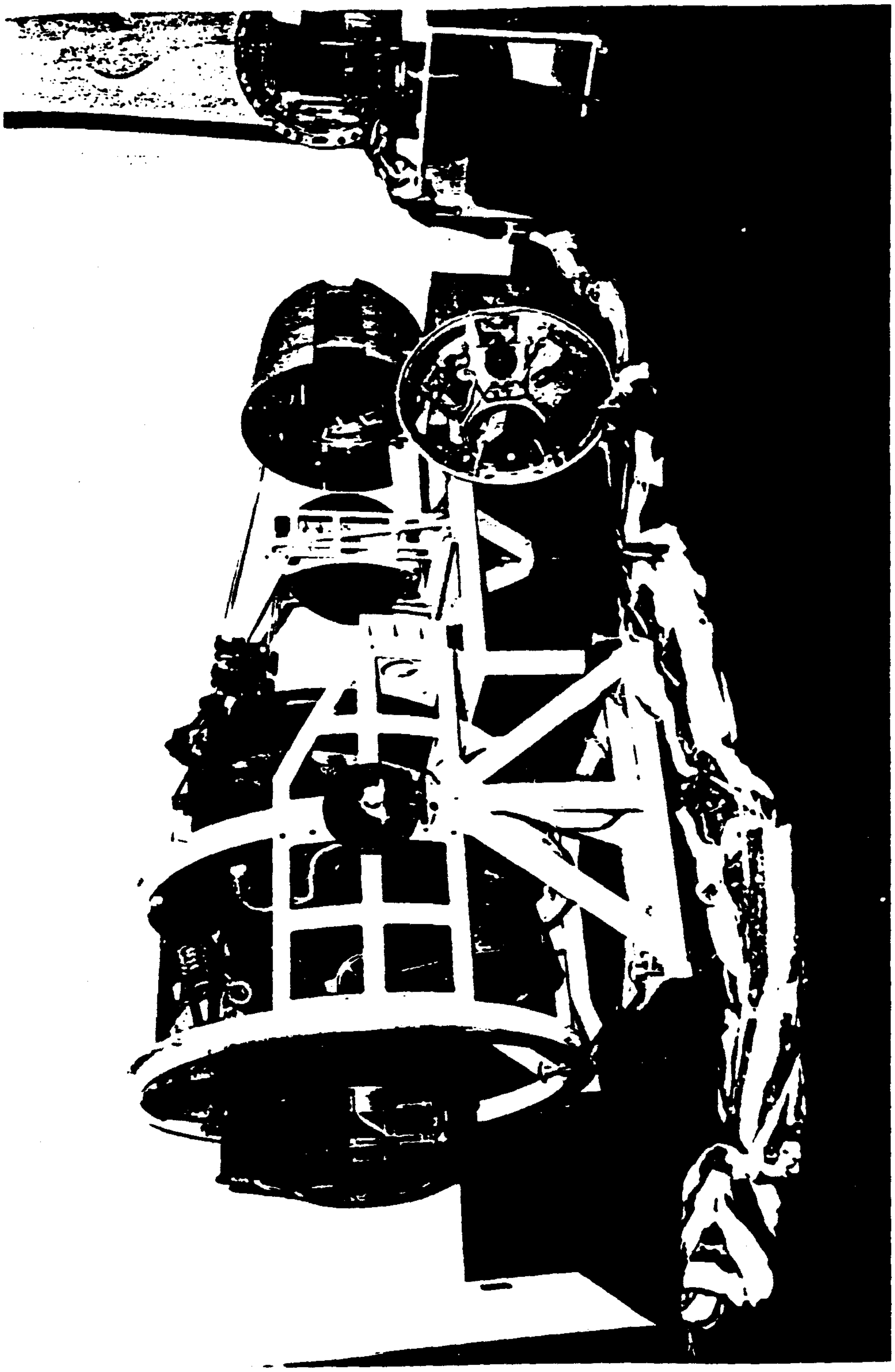
*Ullage rockets are small solid propellant rockets attached to the AGENA. These rockets are fired just prior to ignition of the AGENA engine after its separation from the THOR to insure that the liquid AGENA propellants are pushed against the bottom of the tanks so that proper flow into the pumps will occur.



*DISCOVERER I*

The on-pad failure of 21 January was not assigned a number in the DISCOVERER series. DISCOVERER I was launched on 28 February 1959 with a light engineering payload as a test of THOR-AGENA performance. No recovery was planned. For a time there was uncertainty as to what had happened to it because no radio signals were received. At the time, it was believed to have obtained orbit with speculation that the protective nose cone over the antennas was ejected just before the AGENA fired and that the AGENA then rammed into the nose cone, damaging the antennas. Today, most people believe the DISCOVERER I landed somewhere near the South Pole.

*DISCOVERER II*

The second vehicle was launched on 13 April 1959. Orbit was officially announced about two hours later, along with a statement that the capsule carried a lightweight biomedical payload (as indeed it did). The Air Force reported on 15 April that plans to recover the capsule near Hawaii had been abandoned and that the capsule might descend somewhere in the Arctic. The announcement slightly understated the known facts. The capsule had ejected on the 17th orbit as planned, but a timing malfunction (actually a human programming error) had caused the ejection sequence to be initiated too early. The capsule was down, probably somewhere in the near-vicinity of the Spitsbergen Islands north of Norway. In fact, there were later reports that the falling capsule had actually been seen by Spitsbergen residents. The Air Force announced on the 16th that the Norwegian government had authorized a search for the capsule which would begin the following day. Planes scoured the area, and helicopters joined the search on the 20th. Nothing was found, however, and the search was abandoned on the 23rd. There was speculation at the time that the capsule might have been recovered by a Soviet search team,* and Norwegian Air Force reconnaissance yielded some indications to that effect.

*DISCOVERER III*

Much publicity attended the launching of DISCOVERER III: some of it planned and some uplanned (and unwanted). This was the first (and only) DISCOVERER flight to carry animals: four live black mice. Black mice were chosen in order to ascertain the possible hair-bleaching effects of cosmic rays. The mice were members of the C-57 strain, a particularly rugged breed. They had been "trained," along with 60 other mice, at the Air Force's Aeromedical Field Laboratory at Holloman AFB. They were seven to ten weeks old and

*The incident inspired a book by Alistair MacLean, *Ice Station Zebra*, and a 1968 movie of the same name, but the fictional version gave little cause for concern that some CORONA alumnus was serving as technical consultant. In the movie, a U.S. nuclear submarine is heading for the North Pole to rescue British meteorologists on a disintegrating ice floe. Special agents on board are after a missing capsule with coverage of all U.S. missile sites, snapped by a Soviet satellite equipped with a stolen U.S. camera. Enter Soviet paratroopers, second- and third-country spies, etc., etc., etc.

weighed slightly over an ounce apiece. A three-day food supply was provided, which consisted of a special formula containing peanuts, oatmeal, gelatin, orange juice, and water. Each mouse was placed in a small individual cage about twice its size, and each had a minuscule radio strapped to its back to monitor the effects of the space trip on heart action, respiration, and muscular activity.

The lift-off on 3 June 1959 was uneventful, but, instead of injecting approximately horizontally into orbit, the AGENA apparently fired downward, driving the vehicle into the Pacific Ocean and killing the mice. Looking back on the mission, the attempt to orbit the mice seems to have been jinxed from the very beginning.

Just before the first try at launch, telemetry indicated a lack of mouse activity. It was thought at first that the little fellows were merely asleep, so a technician was sent up in a cherry-picker to arouse them. He banged on the side of the vehicle and tried catcalls, but to no avail. When the capsule was opened, the mice were found to be dead. The cages had been sprayed with krylon to cover rough edges; the mice had found it tastier than their formula; and that was that.

### *"The Mouse That Poured"*

The second try at launch several days later, with a back-up mouse "crew," was a near-abort when the capsule life cell humidity sensor suddenly indicated 100 percent relative humidity. The panic button was pushed, and troubleshooters were sent up to check. They found that when the vehicle was in a vertical position the humidity sensor was directly beneath the cages, and it did not distinguish between plain water and urine. The wetness dried out after a while, all was forgiven, and the vehicle was launched—unhappily into the permanent 100 percent moisture environment of the Pacific Ocean.

Also, the timing of the launch was unfortunate. The monkeys, Able and Baker, had survived a 300-mile flight in a JUPITER nose cone on 29 May in connection with another, unrelated test program. However, Able died during minor surgery on 3 June to remove an electrode that had been implanted under his skin. (This was the date of the DISCOVERER III launch.) The British Society Against Cruel Sports made a formal protest to the U.S. Ambassador, and the press raised quite a stink about the fatal mice flight—comparing it unfavorably with the Russians' successful launching of the dog, Laika, in SPUTNIK II back in November 1957, and demanding that orbit and recovery procedures be perfected before attempting further launches of mice or monkeys.

### *DISCOVERERS IV-VIII*

DISCOVERER IV on 25 June 1959 was the first to carry a camera and thus the first true CORONA test, but the payload did not go into orbit. DISCOVERER V, again with a camera, attained orbit but the temperature inside the spacecraft was abnormally low and the camera failed on the first orbit. The recovery capsule was ejected at the proper time, but never showed up; early in 1960 it was discovered in a high near-polar orbit with an apogee of 1,058 miles. Failure of the spin rocket had caused the retro-rocket to accelerate rather than de-boost the package. DISCOVERER VI went into orbit six days later, but the camera failed on the second revolution, and the retro-rocket failed on the recovery attempt.*

DISCOVERER VII on 7 November did not go into orbit. DISCOVERER VIII on 20 November went into an eccentric orbit with an apogee of 913 miles, and the camera failed again. The recovery vehicle was ejected successfully, but the parachute failed to open.

It had become plain by the end of November 1959 that something (or, to be more precise, many things) had to be done to correct the multiple failures that were plaguing the CORONA system. Eight THOR-AGENA combinations and five cameras had been expended with nothing to show for the effort except accumulated knowledge of the system's weaknesses. The project technicians knew what was going wrong, but not always why. Through DISCOVERER VIII, the system had experienced these major failures:

One misfired on the launch pad.
Three failed to achieve orbit.
Two went into highly eccentric orbits.
One capsule ejected prematurely.
Two cameras operated briefly and then failed.
One camera failed entirely.
One experienced a retro-rocket malfunction.
One had very low spacecraft temperature.

A panel of consultants reviewed the various failures and their probable causes and concluded that what was needed most was "qualification, requalification, and multiple testing of component parts" before assembling them and sending them aloft. This called for more money. Accordingly, Bissell submitted a project amendment to the DDCI on 22 January 1960 asking approval of nearly [redacted] additional to cover the costs of the testing program. He apologized to General Cabell for submitting a request for funds to pay for work that was already under way: "Although such a sequence is regrettable, there has been con-

*One of these early launches tested a system for concealing the tell-tale payload doors from inquisitive eyes near the launch pad. The scheme was to cover them with paper, fastened over two lengths of piano wire with pingpong balls at the front end. The air flow at launch would use the pingpong balls and wire as "ripcords" to strip away the paper. The idea was tested on the side of a sports car simulating launch velocity as nearly as possible on the Bayshore Freeway late one evening. The test proved that the ripcords worked, and that Freeway patrolmen could overhaul a vehicle going only 90 m.p.h. Unfortunately, the ripcords malfunctioned on the next actual launch, and there was no consensus for another test round with the Freeway police.

siderable confusion in this program as to what the amount of the overruns would be and this has made it difficult to obtain approvals in an orderly fashion in advance."

As of the fall of 1959, major problems remained to be solved in achieving an acceptable orbit, in camera functioning, and in recovering the film capsule. These were the more serious of the specific failures that were occupying the attention of the technicians:

> The AGENA vehicle was designed for use with both the THOR and the ATLAS boosters. The ascent technique used by the AGENA vehicle was essentially the same in both combinations, but there were significant differences in the method of employing the booster. In the CORONA program, in order to conserve weight, the THOR booster followed a programmed trajectory using only its autopilot. Also, the THOR thrust was not cut off by command at a predetermined velocity (as in the ATLAS); instead, its fuel burned to near-exhaustion. This relatively inaccurate boosting profile, coupled with the low altitude of CORONA orbits, required great precision in the orbital injection. At a typical injection altitude of 120 miles, an angular error of plus or minus 1.1 degrees or a velocity deficit of as little as 100 feet per second would result in failure to complete the first orbit. This had happened repeatedly. Lasting relief from this problem lay some distance in the future: a more powerful AGENA was being developed, and the weight of instrumentation for measuring in-flight performance on the early flights would be reduced on later operational missions. The short-term remedy lay in a drastic weight-reduction program. This was carried out in part (literally, it is said) by attacking surplus metal with tin snips and files.
>
> The system was designed to operate without pressurization (again to conserve weight), and the acetate base film being used was tearing or breaking in the high vacuum existing in space and causing the camera to jam. A solution for this problem was found in substituting polyester for acetate base film. The importance to the reconnaissance programs of this achievement by Eastman Kodak in film technology cannot be overemphasized. It ranks on a level with the development of the film recovery capsule itself. The first orbital flight in which the camera was operated with polyester film was DISCOVERER XI (Mission 9008) in April 1960. Although recovery was not successful, one of the major space reconnaissance problems had been solved.
>
> The equipment was built to work best at an even and predetermined temperature. To save weight, only passive thermal control was provided. The spacecraft's internal temperature had varied on the flights thus far, and it was much lower than desired on one flight. An interim solution for this problem was found in varying the thermal painting of the vehicle skin.
>
> The spin and de-spin rockets used to stabilize the recovery vehicle during re-entry had a tendency to explode rather than merely to fire. Several had blown up in ground tests. A solution was found in substituting cold gas spin and de-spin rockets.

One of the most intractable problems, which was to persist for many months, was that of placing the satellite recovery vehicle (SRV) into a descent trajectory that would terminate in the recovery zone. This required ejecting the SRV from the AGENA at precisely the right time, and decelerating it by retro-rocket firing to the correct velocity and at a suitable angle. There was very little margin for error in this phase: each one-second error in ejection timing could shift the recovery point five miles; a retro-velocity vector error of more than ten degrees would cause the capsule to miss the recovery zone completely.

One might ask why the CORONA program officers persisted in the face of such adversity. The answer lay in the overwhelming intelligence needs of the period. The initial planning of CORONA began at a time when we did not know how many BEAR and BISON aircraft the Soviets had, whether they were introducing a new and far more advanced long range bomber than the BISON, or whether they had largely skipped the build-up of a manned bomber force in favor of missiles. There had been major changes in intelligence estimates of Soviet nuclear capabilities and of the scope of the Soviet missile program on the basis of the results of the relatively small number of U-2 missions approved for the summer of 1957. However, by 1959, the great "missile gap" controversy was very much in the fore. The Soviets had tested ICBM's at ranges of 5,000 miles, proving they had a capability of building and operating them. What was not known was where they were deploying them operationally, and in what numbers. In the preparation of the National Intelligence Estimate on guided missiles in the fall of 1959, the various intelligence agencies held widely diverse views on Soviet missile strength. Nineteen Sixty ushered in an election year in which the missile gap had become a grave political issue, and the President was scheduled to meet with Soviet leaders that spring without—it appeared—the benefit of hard intelligence data. The U-2 had improved our knowledge of the Soviet Union, but it could not provide area coverage and the answers to the critical questions, and it was increasingly becoming less an intelligence asset than a political liability. It was judged to be only a matter of time until one was shot down—with the program coming to an end as an almost certain consequence.

### *DISCOVERERS IX-XII*

A standdown was in effect in CORONA from 20 November 1959 until 4 February 1960 to allow time for intensive R&D efforts to identify and eliminate the causes of failure. On 4 February, DISCOVERER IX was launched and failed to achieve orbit.

The first recovery of film from a CORONA vehicle occurred with the launching of DISCOVERER X on 19 February 1960, but in a manner such that no one boasted of it. The THOR booster rocket began to fishtail not long after it left the launch pad and was destroyed by the range safety officer at 52 seconds after lift-off. The payload came down about a mile from Pad 5, was located by helicopter, and the recovery was made by a crew that rode to the scene by Jeep.*

DISCOVERERs VII through X carried only a quarter of a load of film (10 pounds) to permit the carrying of additional instrumentation for testing vehicle performance. DISCOVERER XI was launched on 15 April 1960 carrying a camera and 16 pounds of film. A reasonably good orbit was achieved (380 miles at apogee and 109.5 miles at perigee), and the camera operated satisfactorily.** All of the film was exposed and transferred into the recovery capsule. Unfortunately, the problem of the exploding spin rockets, which had been observed in ground tests, occurred during the recovery sequence, and the payload was lost.

Another standdown—a major one—was imposed following the failure of DISCOVERER XI. As of mid-April 1960, there had been 11 launches and one abort on pad. Seven of the launches achieved orbit, but no capsules had been recovered. DISCOVERER XII was planned as a diagnostic flight—without camera payload—heavily instrumented to determine precisely why recovery of capsules had failed previously. The vehicle was launched on 29 June 1960, but the AGENA failed to go into orbit.

### *DISCOVERER XIII—Partial Success*

The next flight, on August 1960, was launched as a repeat of the no-orbit DISCOVERER XII diagnostic flight, without camera and film. The vehicle was launched and successfully inserted into orbit. The recovery package was ejected on the 17th orbit, and retro-firing and descent were normal—except that the capsule came down well away from the planned impact point. The nominal impact area was approximately 250 miles south of Honolulu where C-119 and C-130 aircraft circled awaiting the capsule's descent. The splash-down occurred about 330 miles northwest of Hawaii. The airplanes were backed up by surface ships deployed in a recovery zone with a north-south axis of some 250 miles and an east-west axis extending about 550 miles to either side of the expected impact point. Although beyond the range of the airborne recovery aircraft, the DISCOVERER XIII capsule descended near enough to the staked-out zone to permit an attempt at water recovery. A ship reached the scene before the capsule sank

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*This was one of the few launch failures for the remarkable Douglas team which prepared the THOR boosters at Vandenberg Air Force Base. The early CORONA launches provided many exciting moments for the Douglas crew, however. Several of the crew were holdovers from the V-2 "broomlighters," who on V-2 launch days would actually ignite reluctant rocket engines with kerosene-soaked brooms. At Vandenberg AFB they did not have to resort to this tactic, but they were required on numerous occasions to return to the launch pad as late as T minus 15 seconds to unfreeze valves with the touch of a sledgehammer. Other members of the blockhouse crew would marvel as the "Douglas Daredevils" would race their vehicles in reverse the entire way from the launch pad to the blockhouse, arriving just as ignition would begin.

**This was the first mission on which the camera operated successfully throughout the mission, primarily because of the change from acetate base to polyester base film.

and fished it out of the ocean. Much of the credit for the success was attributed to the inauguration (on the unsuccessful DISCOVERER XII launch) of the cold gas spin and de-spin system.

For the first time ever, man had orbited an object in space and recovered it. This American space "first" beat the Russians by just nine days. The Soviets had tried to recover SPUTNIK IV the previous May but failed when the recovery capsule ejected into a higher orbit. They did succeed in de-orbiting and recovering SPUTNIK V carrying the dogs, Belka and Strelka, on 20 August 1960.

Arrangements were made for extensive publicity concerning this success in recovering an object from orbit—in large measure to support the cover story of DISCOVERER/CORONA as being an experimental space series. News photos were released of the lift-off from Vandenberg, of the capsule floating in the ocean, and of the recovery ship *Haiti Victory*. President Eisenhower displayed the capsule and the flag it had carried to the press, and it was later placed on exhibit in the Smithsonian Institution for public viewing.

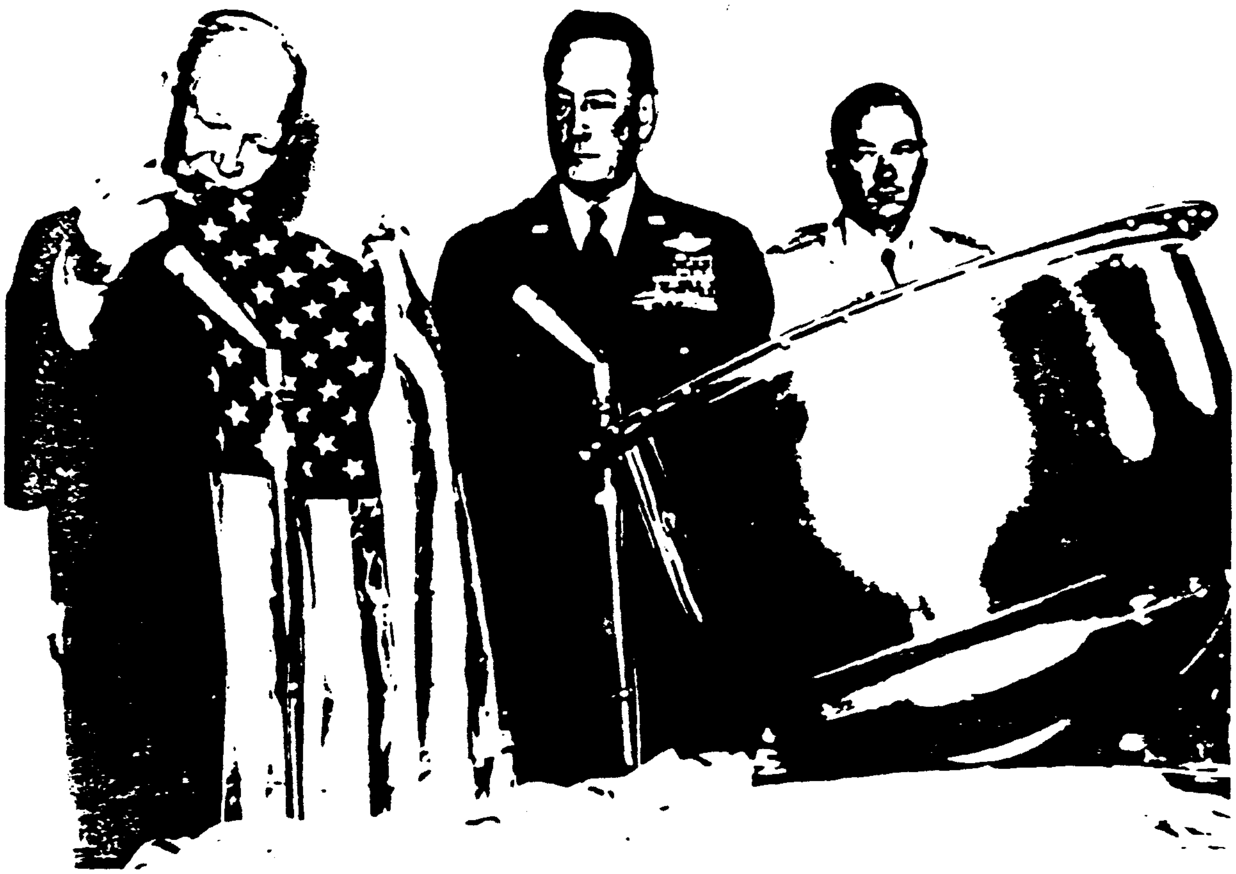
In anticipation of the first recovery being a reconnaissance mission, a plan had been developed under which the capsule would be switched in transit through Sunnyvale. Since DISCOVERER XIII was a diagnostic flight, the project office was spared the necessity of executing a clandestine switch of capsules prior to shipment to Washington, and the President and Smithsonian received the actual hardware from the first recovery.

We have all watched television coverage of the U.S. man-in-space programs with the recovery of astronauts and capsules after splash-down in the ocean. A helicopter flies from the recovery ship to the floating capsule and drops swimmers to attach a line to the capsule. After the astronauts are removed, the helicopter hoists the capsule from the water and carries it to the recovery ship. What most of us don't realize is that the recovery technique was developed for and perfected by the CORONA program as a back-up in event of failure of the air catch.

### *DISCOVERER XIV—Full Success*

Success! ! ! DISCOVERER XIV was launched on 18 August 1960, one week after the successful water recovery of the DISCOVERER XIII capsule. The vehicle carried a camera and a 20-pound load of film. The camera operated satisfactorily, and the full load of film was exposed and transferred to the recovery capsule. The AGENA did not initially position itself in orbit so as to permit the recovery sequence to occur. It was on the verge of tumbling during the first few orbits, and an excessive quantity of gas had to be used in correcting the situation. Fortunately, vehicle attitude became stabilized about midway through the scheduled flight period, thus relieving the earlier fear that recovery would be impossible. The satellite recovery vehicle was ejected on the 17th pass, and the film capsule was recovered by air snatch.

Captain Harold E. Mitchell of the 6593rd Test Squadron, piloting a C-119 (flying boxcar) called Pelican 9, successfully hooked the descending capsule on



# First Recovery from Space

Dwight D. Eisenhower

his third pass.* Upon arrival at Hickham Air Force Base, Hawaii, with his prize. Captain Mitchell was decorated with the Distinguished Flying Cross, and members of his crew were awarded the Air Medal for their accomplishments.

The film was flown to the [redacted] processing facility in [redacted] for development and was then delivered to PIC (now known as NPIC) for readout and reporting. The resolution was substantially lower than that obtainable from the U-2, but the photography had intelligence value, and it covered areas of the USSR which the U-2 had never reached. This one satellite mission, in fact, yielded photo coverage of a greater area than the total produced by all of the U-2 missions over the Soviet Union. The only major deficiencies in the photography were plus and minus density bars running diagonally across the format. Some were due to minor light leaks, and others were the result of electrostatic discharge known as corona. These marks showed that the program security officer had had great insight when he named the program. There are two types of corona markings, a glow which caused the most difficulty, and a dendritic discharge which is more spectacular in appearance.

A press release announced the success of the mission but naturally made no mention of the *real* success: the delivery of photographic intelligence. The announcement noted that the satellite had been placed into an orbit with a 77.6 degree of inclination, an apogee of 502 miles, a perigee of 116 miles, and an orbital period of 94.5 minutes. A retro-rocket had slowed the capsule to re-entry velocity, and a parachute had been released at 60,000 feet. The capsule, which weighed 84 pounds at recovery, was caught at 8,500 feet by a C-119 airplane on its third pass over the falling parachute.

### *Progress and Problems*

The program officers did not take the success of DISCOVERER XIV to mean that their problems with the system were at an end, but many of the earlier difficulties had been surmounted. The orbital injection technique had been improved to a level at which vehicles were repeatedly put into orbit with injection angle errors of less than four-tenths of a degree. The timing of the initiation of the recovery sequence had been so refined that ejection of the DISCOVERER XI SRV occurred within five seconds of the planned time. Parachute deceleration and air catch of the capsule had been accomplished repeatedly with test capsules dropped from high-altitude balloons. The last two cameras placed in orbit had operated well.

There were other critical problems, however, that remained to be solved. Foremost among them at the time was that of consistently achieving the correct retro-velocity and angle of re-entry of the recovery vehicle. The DISCOVERER

*Mitchell had been patrolling the primary recovery zone for DISCOVERER XIII, which was fished from the water by a recovery ship after Mitchell's plane missed it. The Air Force, pride stung, assigned Mitchell to the boondocks some 500 miles downrange for DISCOVERER XIV. The capsule overshot the prime recovery area, where three aircraft were chasing the wrong radar blip. When Mitchell first tried to report his catch, he was told to keep off the air in order not to interfere with the recovery operation.

First Aerial Recovery

*with best regards —*

XIV capsule was the only one thus far that had descended in the designated impact zone. This was a problem that was to receive major attention during the next few weeks.

Four more cameras were launched within the next four months, with one success and three failures. DISCOVERER XV was sent aloft on 13 September. The vehicle was successfully inserted into orbit, and the camera functioned properly. However, the recovery vehicle re-entered at the wrong pitch attitude, causing the capsule to come down outside the recovery zone and demonstrating that the technicians' concern over the retro-firing sequence was well founded. The capsule was located, but it sank before a recovery ship could reach it. DISCOVERER XVI was launched on 26 October, but the AGENA failed to go into orbit because of a malfunction of a timing device.

The first ten camera-equipped vehicles carried what was known as the C camera: a single, vertical-looking, reciprocating, panoramic camera that exposed the film by scanning at a right angle to the line of flight. DISCOVERER XVI carried the first of a new series of cameras known as the C Prime (C′). The C′ differed only slightly from the original C configuration and was essentially little more than a follow-on procurement of the C camera.

The DISCOVERER XVII mission was launched on 12 November and went the full route through successful air catch—except for one mishap: the film broke after 1.7 feet of the acetate base leader had fed through the camera. There is an inconsistency in the records on this and the succeeding mission. The press release concerning this mission announced that the AGENA B, a more powerful second-stage engine, was used for the first time; the project files record the first use of the B vehicle on the following mission. In either event, it was the first of the two-day missions. The capsule was recovered on the 31st orbit.

DISCOVERER XVIII was launched on 10 December 1960 carrying 39 pounds of film. Orbit was achieved, and the camera worked well, exposing the entire film load. The recovery vehicle was ejected on revolution number 48 after three days in orbit, and the capsule was retrieved by air snatch. This was the first successful mission employing the C′ camera and the AGENA B second stage. There was fogging on the first, second, and last frame of each photo pass due to mirror light leaks, but image quality was otherwise as good as the best from DISCOVERER XIV.

### *CORONA in 1961*

Of the next ten launches, extending through 3 August 1961, only four were CORONA missions. DISCOVERERs XIX and XXI carried radiometric payloads in support of the CORONA cover story, and they were not intended to be recovered. DISCOVERER XXI included an experiment that was to be of major significance in the later development of CORONA and other space programs: the AGENA engine was successfully restarted in space.

There was another "first" during these 1961 launches. When the film was removed from one of the capsules, the quality assurance inspector found three objects that should not have been there: two quarters and a buffalo nickel. Early capsules had contained a flag, so that there would be one to present to President Eisenhower after the first successful recovery. This had apparently inspired program personnel at Vandenberg to make their own payload additions during flight preparation. The Washington program office sent a sharply worded message to the West Coast project office charging it with responsibility for ensuring that the practice of souvenir-launching be stopped. (Years later NASA would find itself in the same position after the Apollo moon flights.)

DISCOVERER XX was the first of a dozen launches extending over a period of three years carrying mapping cameras, a program sponsored by the U.S. Army, which the President had approved for inclusion within the CORONA project. The purpose of the mapping program, which was known as ARGON, was to obtain precise geodetic fixes and an extension of existing datum planes within the Soviet Union. DISCOVERER XX was a bust on a number of counts: the camera failed; there were no shutter firings; and the orbital programmer malfunctioned. This last-named failure led to an important change in control procedures for CORONA. On this and all prior flights the recovery sequence was initiated automatically by an ejection command cut into the program tape. The program timer failed temporarily on orbit 31 of this mission, causing the entire sequence to be about one-half cycle out of phase. The automatic initiation of the recovery sequence was eliminated from the program tape on subsequent missions. Thereafter, the positive issuance of an injection command was required.

Of the four CORONA missions attempted between December 1960 and August 1961, two did not go into orbit as a consequence of AGENA failures, and two were qualified successes. DISCOVERER XXV was launched on 16 June and exposed its full load of film. The air catch failed, but the back-up water recovery was successful. The camera failed on revolution 22 of DISCOVERER XXVI, which was launched on 7 July, but about three-quarters of the film was exposed and was recovered by air catch.

Going into August 1961, a total of 17 camera-carrying CORONA missions had been attempted, and usable photography had been recovered from only four of them. These four successful missions, however, had yielded plottable coverage of some 13 million square miles, or nearly half of the total area of interest.

*Camera Improvements*

The first substantial upgrading of the CORONA camera system came with the introduction in August 1961 of the C Triple Prime (C''') camera. The original C camera was a scanning panoramic camera in which the camera cycling rate and the velocity-over-height ratio were constant and were selected before launching. Image motion compensation was fixed mechanically to the velocity-over-height ratio. A brief explanation of these terms may be helpful in understanding the nature of the problems with which the camera designers had to cope.

> A means must be provided for matching the number of film exposures in a given period of time (camera cycling rate) with the varying ratio between vehicle altitude and velocity on orbit (velocity-over-height) so that

the ground area is photographed in a series of swaths with neither gaps nor excessive overlapping in the coverage.

If the subject moves just as a snapshot is taken with a hand-held camera, and if the camera shutter speed is not fast enough to "stop" the motion, the photographic image will be smeared. To a camera peering down from an orbiting CORONA space vehicle, the earth's surface appears to be passing beneath the camera at a speed of roughly five miles per second. A camera photographing the earth's surface from a satellite moving at that speed would yield smeared photography if some means were not provided for stopping the relative motion. The technique used in accomplishing this is known as image motion compensation.

The C Triple Prime was the first camera built totally by the Itek Corporation. The C''' was also a reciprocating camera with a rotating lens cell, which exposed the film during a segment of its rotation. The new camera had a larger aperture lens, an improved film transport mechanism, and a greater flexibility in command of camera and vehicle operations—especially as regards control of the velocity-over-height factor. The larger aperture lens permitted use of slower film emulsions, which, combined with the improved resolving power of the lens itself, offered the prospect of resolution approximately twice as good as the C and C' cameras.

The first C''' camera system with a 39-pound film load was launched on 30 August 1961. The mission was a success, with the full film load being transferred and with ejection and recovery occurring on the 32nd orbit. All frames of the photography however, were out of focus. The cause was identified and was corrected by redesigning the scan head. Seven more missions were launched during the last four months of 1961, three with the C' camera and four with the C'''. Six of them attained orbit, and the cameras operated satisfactorily on all six. Film was recovered from four of the missions. The last of the four, which carried a C''' camera system, was rated the best mission to date. It also had a cover assignment to carry out: the injection of a secondary satellite, dubbed OSCAR (orbital satellite carrying amateur radio), into a separate orbit. OSCAR was a small radio satellite broadcasting a signal on 145 megacycles for pick-up by amateurs as an aid in the study of radio propagation phenomena.

Slowly but surely the bugs were being worked out, but it seemed that just as one was laid to rest another arose to take its place. Perhaps what was actually happening was that various sets of problems existed simultaneously, but the importance of some of them was masked by others. The elimination of a particular problem made it possible to recognize the significance of another. The recent successes had resulted largely from correcting weaknesses in the payload portion of the system. At the same time, difficulties in the AGENA vehicle began to surface. Of the last seven missions in 1961, four experienced on-orbit difficulties with the AGENA power supply or control gas system.

Power system components for general use in satellite systems were designed, developed, and tested in the CORONA program. Foremost among those components were the static electronic inverters used to convert direct current battery energy into the various alternating current voltages required by the other subsystems. Static inverters, which were first flown aboard CORONA vehicles, were considered essential, because they had half the weight and double the efficiency of their rotary counterparts. Unfortunately, they are rather temperamental gadgets. The history of inverter development had been marked by high failure rates in system checkouts on the ground. Despite the lessons that had been learned and the improvements in circuit design that resulted from them, the recent on-orbit power failures demonstrated a need for further research and development.

### *The Last DISCOVERER*

The AGENA failed on DISCOVERER XXXVII, launched on 13 January 1962, and the payload did not go into orbit. It was the last mission to carry the C''' camera system, and with it the DISCOVERER series came to an end. After 37 launches or launch attempts, the cover story for DISCOVERER had simply worn out. With the improved record of success and the near-certainty of an even better record in the future, it seemed likely that there would be as many as a dozen and a half to two dozen launches per year for perhaps years to come. The cover story that DISCOVERER was an experimental series had ceased to be tenable, and no other cover story was available to account for the number of launches and their unique mission profiles. So, beginning with the 38th launch, CORONA missions were announced merely as being secret Air Force satellites. On 18 April 1962, the Air Force announced the issuance of a new directive classifying all information pertaining to military satellites and eliminating the DISCOVERER, SAMOS, and MIDAS series designations.

### *CORONA Goes Stereo*

The 1961 R&D effort was not confined to improving the performance of the existing system. A major development program was concurrently under way on a much better camera subsystem. A contract was awarded on 9 August 1961, retroactively effective to 20 March, for a new camera configuration to be known as MURAL. The MURAL camera system consisted essentially of two C''' cameras mounted with one pointing slightly forward and the other slightly backward. Two 40-pound rolls of film were carried in a double-spool film supply cassette. The two film webs were fed separately to the two cameras where they were panoramically exposed during segments of the lens cells' rotations and then were fed to a double-spool take-up cassette in the satellite recovery vehicle. The system was designed for a mission duration of up to four days.

The vertical-looking C, C', and C''' cameras had photographed the target area by sweeping across it in successive overlapping swaths. The MURAL concept involved photographing each swath area twice. The forward-looking camera first photographed the swath at an angle 15 degrees from the vertical. About a half-dozen frames later, the backward-looking camera photographed the same swatch at an angle also 15 degrees from the vertical. When the two resulting photographs of the same area or object were properly aligned in a stereo-microscope, the photography would appear to be three-dimensional. Simultaneous operation of both instruments was required for stereo photography. If either camera failed, photography could still be obtained from the other, but it could be viewed in only two dimensions.

The first MURAL camera system was launched as program flight number 38 on 27 February 1962. On the first M flight, an anomaly occurred during re-entry. The RV heat shield failed to separate and was recovered by the aircraft along with the capsule. This anomaly provided valuable diagnostic data on the re-entry effects, which served the program well in later years, when program stretchouts caused shelf life of the heat shields to be a major concern. The twenty-sixth and last in the MURAL series was launched on 21 December 1963. Twenty of the SRV's were recovered, 19 of them by air snatch. The one water recovery was of a capsule that splashed down a thousand miles from the nominal impact point. An interesting aspect of this recovery was that the capsule turned upside down in the water, causing loss of the beacon signals. It was located during the search by an alert observer who spotted the sun shining on the gold capsule. Of the six vehicles that failed, two malfunctioned in the launch sequence, one SRV failed to eject properly, and three capsules came down in the ocean and sank before they could be recovered. Twenty successes out of 26 tries appeared to be a remarkable record when viewed against the difficulties experienced only two years earlier.

The three capsules that sank came down in or near the recovery zone, indicating that the problems previously encountered in the reentry sequence had been solved. They were not supposed to sink so quickly, however. (One of them floated for less than three minutes.) To minimize the chance that a capsule might be retrieved by persons other than the American recovery crew, the capsules were designed to float for a period ranging originally from one to three days and then to sink. The duration of the flotation period was controlled by a capsule sink valve containing compressed salt, which would dissolve in sea water at a rate that could be predicted within rather broad limits. When the salt plug had dissolved, water entered the capsule, and it sank—ingenious but simple.

### *More Problems, More Answers*

Other significant improvements in the CORONA program were inaugurated during the lifetime of the MURAL system. One of them was an aid to photo-interpretation. In order to read out the photography, the photointerpreter must be able to determine for each frame the portion of the earth's surface that is imaged, the scale of the photography, and its geometry. In simplest terms, he must know where the vehicle was and how it was oriented in space at the precise time the picture was taken. Until 1962, the ground area covered by a particular frame of photography was identified by combining data provided on the orbital path of the vehicle with the time of camera firing. The orientation or attitude of the vehicle on orbit was determined from horizon photographs recorded at each end of every other frame from a pair of horizon cameras that were included in the CORONA camera system.

Beginning with the first of the MURAL flights, an index camera was incorporated into the photographic system, and a stellar camera was added a few missions later. The short focal length index camera took a small scale photograph of the area being covered on a much larger scale by successive sweeps of the pan cameras. The small scale photograph, used in conjunction with orbital data, simplified the problem of matching the pan photographs with the terrain. Photographs taken of stars by the stellar camera, in combination with those taken of the horizons by the horizon cameras, provided a more precise means of determining vehicle attitude on orbit.

The photography from program flight number 47, a MURAL mission launched on 27 July 1962, was marred by heavy corona and radiation fogging. The corona problem was a persistent one—disappearing for a time only to reappear later—and had become even more severe with the advent of the complicated film transport mechanisms of the MURAL camera. Corona marking was caused by sparking of static electricity from moving parts of the system, especially from the film rollers. The problem was eventually solved by modifications of the parts themselves and by rigid qualification testing of them. [redacted]

The boosting capacity of the first-stage THOR was substantially increased in early 1963 by strapping to the THOR a cluster of small solid-propellant rockets, which were jettisoned after firing. This Thrust Augmented THOR, or TAT as it came to be known, was first used for the launching of the heavier LANYARD camera system. LANYARD was developed within the CORONA program as a film recovery modification of one of the cameras designed for the SAMOS system and, with its longer focal length, was expected to yield better resolution than the CORONA cameras. It had a single lens cell capable of stereoscopic coverage by swinging a mirror through a 30-degree angle. Three flights were attempted, only one of which was partially successful. The camera had a serious lens focus problem, which was later traced to thermal factors and corrected. The LANYARD program was initiated as an interim system pending the completion of a high-resolution spotting system then under development. It was cancelled upon the success of the spotting system. The TAT booster itself was a significant success, permitting the later launching of heavier, more versatile CORONA systems.

### *The Two-Bucket System*

Program flight number 69, launched on 24 August 1963, introduced the first two-bucket configuration—the next major upgrading of the CORONA system.

(The film recovery capsule is commonly referred to as a bucket, although it more nearly resembles a round-bottomed kettle.) The new modification, which was known as the J-1 system, retained the MURAL stereoscopic camera concept but added a second film capsule and recovery vehicle. With two SRV's in the system, film capacity was increased to 160 pounds (versus the 20-pound capacity of the first few CORONA missions). The two-bucket system was designed to be deactivated or stored in orbit in a passive (zombie) mode for up to 21 days. This permitted the recovery of the first bucket after half of the film supply was exposed. The second bucket could begin filling immediately thereafter, or its start could be delayed for a few days. A major redesign of the command and control mechanisms was required to accommodate the more complicated mission profile of the two-bucket system.

As with each of the major modifications of CORONA, the J-1 program had a few early bugs. On the first mission, the shutter on the master horizon camera remained open about 1,000 times seriously fogging the adjacent panoramic photography, and the AGENA current inverter failed in mid-flight, making it impossible to recover the second bucket. Also, the J-1 system initially experienced a rather severe heat problem, which was solved by reducing the thermal sensitivity of the camera and by better control of vehicle skin temperature through shielding and varying the paint pattern.

Back in 1960 and 1961, the successful recovery of a CORONA film bucket was an "event." A mere two years later, with the advent of the J-1 system, success had become routine and a failure was an "event." By the end of 1966, 37 J-1 systems had been launched; 35 of them were put into orbit; and 64 buckets of film were recovered. There were *no* failures at recovery in the three years following 1966: 28 buckets were launched, and 28 buckets were recovered. Also, mission duration was greatly expanded during the lifetime of the J-1 system. A mission in June 1964 yielded four full days over target for each of the two buckets. Five full days of operation with each bucket was attained in January 1965. In April 1966, the first bucket was recovered after seven days on orbit. A 13-day mission life was achieved in August 1966, and this was increased to 15 days in June 1967.

The increased mission life and excellent record of recovery resulted from a number of successive improvements that were incorporated into the J-1 time period. Among them was a subsystem known as LIFEBOAT, a completely redundant and self-contained apparatus built into the AGENA that could be activated for recovering the SRV in event of an AGENA power failure (which still happened occasionally). Another improvement was the introduction of the new and more powerful THORAD booster. A third was the addition of a rocket orbit-adjust system. The CORONA vehicles were necessarily flown over the target areas with quite a low perigee in order to increase the scale of the photography, and this led to a relatively rapid decay of the orbit. The orbit-adjust system compensated for the decay. It consisted of a cluster of small rockets, known as drag make-up units, which were fired individually and at selected intervals. Each firing accelerated the vehicle slightly, boosting it back into approximately its original orbit.

### *A Maverick*

The CORONA camera system was to undergo one more major upgrading but we cannot leave the J-1 program without giving an account of one mission failure of truly magnificent proportions. Program flight number 78 (CORONA Mission Number 1005), a two-bucket J-1 system, was launched on 27 April 1964. Launch and insertion into orbit were uneventful. The master panoramic camera operated satisfactorily through the first bucket, but the slave panoramic camera failed after 350 cycles when the film broke. Then the AGENA power supply failed. Vandenberg transmitted a normal recovery enable command on southbound revolution number 47 on 30 April. The vehicle verified receipt of the command, but nothing happened. The recovery command was repeated from various control stations—in both the normal and back-up LIFEBOAT recovery modes—on 26 subsequent passes extending through 20 May. The space vehicle repeatedly verified that it had received the commands, but the ejection sequence did not occur. After 19 May, the vehicle no longer acknowledged receipt, and from 20 May on it was assumed that the space hardware of Mission 1005 was doomed to total incineration as the orbit decayed.

But Mission 1005, it later developed, had staged its own partial re-entry, stubborn to the end. At six minutes past midnight on 26 May, coinciding with northbound revolution No. 452 of Mission 1005, observers in Maracaibo, Venezuela saw five burning objects in the sky.

On 7 July, two farm workers found a battered golden object on a farm in lonely mountain terrain near La Fria in Tachira State, southwestern Venezuela, a couple of miles from the Colombian border. They reported it to their employer, Facundo Albarracin, who had them move it some 100 yards onto his own farm and then spread the news of his find in hopes of selling it. Albarracin got no offers from the limited market in Tachira, however—not even from the smugglers with access to Colombia—so he hacked and pried loose the radio transmitter and various pieces of the take-up assembly to use as household utensils or toys for the children.

Ultimately word of the find reached San Cristobal, the nearest town of any size. Among the curious who visited La Fria was a commercial photographer, Leonardo Davila, who telephoned the U.S. Embassy in Caracas on 1 August that he had photographed a space object. It was the first bucket from Mission 1005, with one full spool of well-charred film clearly visible.

A team of CORONA officers, ostensibly representing USAF, flew to Caracas to recover the remains. The capsule was lugged out by peasants to a point where the Venezuelan Defense Ministry could pick it up for flight to Caracas. There the CORONA officers bought the crumpled bucket from the Venezuelan government, and quietly dismissed the event as an unimportant NASA space experiment gone awry.

The story rated only a dozen lines in the *New York Times* of 5 August, but the local Venezuelan press had a field day. *Diario Catolico*, of San Cristobal, along with a lengthy report, published three pictures of the capsule showing the charred roll of film on the take-up spool. The *Daily Journal* handled the story in lighter vein with this parody of Longfellow:

> I shot an arrow into the air.
> It fell to earth I know not where.
> Cape Kennedy signalled: "Where is it at you are?"
> Responded the rocket: "La Fria, Tachira."

The CORONA technicians who examined the capsule after its arrival in the States concluded that the re-entry of the SRV was a result of normal orbit degeneration, with separation from the instrument fairing caused by re-entry forces. The thrust cone was sheared during separation but was retained by its harness long enough to act as a drogue chute, thus preventing the capsule from burning up during re-entry and stabilizing it for a hard, nose-down landing.

### *The Final Touches*

The final major modification of the CORONA system got under way in the spring of 1965, when about a dozen and a half of the two-bucket J-1 systems had been flown. The J-1 was performing superbly, but it had little potential for within-system growth. The new CORONA improvement program was begun with a series of meetings among representatives of Lockheed, General Electric, Itek, and the various CORONA program offices to examine ways of bettering the performance of the panoramic and stellar/index cameras, and of providing a more versatile command system. These were the resulting design goals established for a new panoramic camera:

- Improved photographic performance by removal of camera system oscillating members and reduction of vibration from other moving components.
- Improvement of the velocity-over-height match to reduce image smear.
- Improved photographic scale by accommodation of proper camera cycling rates at altitudes down to 80 n.m. (the minimum J-1 operating altitude was 100 n.m.).
- Elimination of camera failures caused by film pulling out of the guide rails (an occasional problem with the J-1 system).
- Improved exposure control through variable slit selection. (The J-1 system had a single exposure throughout the orbit resulting in poor performance at low sun angles.)
- Capability of handling alternate film types and split film loads. An in-flight changeable filter and film change detector was added for this purpose.
- Capability of handling ultra-thin base film (yielding a 50% increase in coverage with no increase in weight).

The panoramic camera that was developed to meet those design goals was known as the constant rotator. The predecessor C''' camera employed a com-

SRV being carried out of La Fría on foot by Campesinos

On location in La Fría, Táchira

Sold to the U. S. Air Force

bination of rotating lens cell and reciprocating camera members. In the constant rotator, the lens cell and the balance of the camera's optical system is mounted in a drum, and the entire drum assembly is continuously rotated, thus eliminating the reciprocating elements from the camera system. The film is exposed during a 70-degree angular segment of the drum's circular sweep. The capability of using ultra-thin base (UTB) film was one of the design goals, but the camera design was not to be constrained by requirements to accommodate the thinner film. UTB was successfully flown on several flights but ground test results showed a loss of reliability and attempts to use it in the contant rotator were eventully abandoned. In all other respects, however, the constant rotator was a resounding success. It yielded substantially better ground resolution in the photography. It also permitted versatility in operation far exceeding that available in the earlier cameras.

The stellar/index camera in use was a delicate instrument with a short (1.5") focal length and a history of erratic performance. The efforts at upgrading the performance of the stellar/index camera resulted in an instrument with a 3" focal length (like ARGON) and a dual-looking stellar element. The new camera had the jaw-breaking designation of Dual Improved Stellar Index Camera, commonly referred to by its acronym: DISIC.

The new payload system, which was designated the J-3, consisted of a pair of constant rotator panoramic cameras, a pair of horizon cameras, and a DISIC. The J-3 system naturally retained the stereo capability begun with the MURAL cameras and the two-bucket recovery concept of the J-1. Apart from the improved picture-taking capability of the hardware itself, the most significant advance of the J-3 was the flexibility it allowed in command and control of camera operations. Any conventional area search photographic reconnaissance system is film-limited. (When the film runs out, the mission is finished—assuming, of course, that other mission-limiting components of the system survive that long.) Consequently, the ultimate goal of all the CORONA improvement efforts was to pack the maximum of the best possible quality of photography of important intelligence targets into each roll of exposed film. The built-in flexibility of the J-3 system greatly increased the variety and degree of controls that could be applied to camera operations, thus substantially boosting the potential intelligence content of the photography.

The first J-3 system was launched on 15 September 1967, and it proved to be the one major modification with no bugs in it. In its nearly five years of operation, it yielded even better photographic intelligence and higher reliability than the remarkably successful predecessor J-1 system.

An early series of tests demonstrated the unusual flexibility of the J-3. It could not only accommodate a variety of film loads, including special camouflage-detection color and high-speed, high-resolution black and white; the camera also had two changeable filters and four changeable exposure slits on each camera.

These tests drew such interest throughout the intelligence community that a CORONA J-3 Ad Hoc Committee was formally convened by the Director of the National Reconnaissance Office on 4 December 1967, and formally constituted in February 1968. Its purpose was to analyze and evaluate the experiments conducted on these five test flights. Specific findings of the Committee included the recommendations that further testing of color films and techniques should be conducted, against specific intelligence requirements and that a special subcommittee of the Committee on Imagery Requirements and Exploitation (COMIREX) should be constituted to evaluate the utility of satellite color photography; and that a well-planned color collection program be worked out with the close cooperation of the system program offices, the Satellite Operations Center (SOC), the intelligence analysts, and the photo interpreters.

*In Retrospect*

Looking back on CORONA, it is not always easy to keep in mind that it was merely an assemblage of inanimate objects designed and put together to perform a mechanical task. The program began as a short-term interim system, suffered through adversity in its formative years, and then survived in glory throughout a decade. Those who were associated with the program or came to depend upon its product developed an affection for the beast that bordered on the personal. They suffered with it in failure and revelled in its successes.

The technological improvements engineered under CORONA advanced the system in eight years from a single panoramic camera system having a design goal of 20 to 25 feet ground resolution and an orbital life of one day, to a twin camera panoramic system producing stereo-photography at the same ground resolution; then to a dual recovery system with an improvement in ground resolution to approximately 7 to 10 feet, and doubling the film payload; and finally, to the J-3 system with a constant rotator camera, selectable exposure and filter controls, a planned orbital life of 18 to 20 days, and yielding nadir resolution of 5-7 feet.

The totality of CORONA's contributions to U.S. intelligence holdings on denied areas and to the U.S. space program in general is virtually unmeasurable. Its progress was marked by a series of notable firsts: the first to recover objects from orbit, the first to deliver intelligence information from a satellite, the first to produce stereoscopic satellite photography, the first to employ multiple re-entry vehicles, and the first satellite reconnaissance program to pass the 100-mission mark. By March 1964, CORONA had photographed 23 of the 25 Soviet ICBM complexes then in existence; three months later it had photographed all of them.

The value of CORONA to the U.S. intelligence effort is given dimension by this statement in a 1968 intelligence report: "No new ICBM complexes have been established in the USSR during the past year." So unequivocal a statement could be made only because of the confidence held by the analysts that if they were there, CORONA photography would have disclosed them.

CORONA coverage of the Middle East during the June 1967 war was of great value in estimating the relative military strengths of the opposing sides after the short combat period. Evidence of the extensive damage inflicted by the Israeli air attacks was produced by actual count of aircraft destroyed on the ground in Egypt, Syria, and Jordan. The claims of the Israelis might have been discounted as exaggerations but for this timely photographic proof.

In 1970, CORONA was called on to provide proof of Israeli-Egyptian claims with regard to cease-fire compliance or violation. CORONA Mission 1111, launched on 23 July 1970, successfully carried out the directions for this coverage, which brought the following praise from Dr. John McLucas, Under Secretary of the Air Force and Director, NRO, who said in a message to the Director of Special Projects, DD/S&T, on 25 August 1970:

> I extend my sincere thanks and a well done to you and your staff for your outstanding response to an urgent Intelligence Community requirement.
>
> The extension of . . . Mission 1111 to 19 days, without benefit of solar panels, and the change in the satellite orbit to permit photography of the Middle East on 10 August provided information which could not be obtained through any other means. This photography is being used as a baseline for determining compliance with the Suez cease-fire provisions.

CORONA's Decade of Glory is now history. The first, the longest, and the most successful of the nation's space recovery programs, CORONA explored and conquered the technological unknowns of space reconnaissance, lifted the curtain of secrecy that screened developments within the Soviet Union and Communist China, and opened the way for the even more sophisticated follow-on satellite reconnaissance systems. The 145th and final CORONA launch took place on 25 May 1972 with the final recovery on 31 May 1972. That was the 165th recovery in the CORONA program, more than the total of all of the other U.S. programs combined. CORONA provided photographic coverage of approximately 750,000,000 square nautical miles of the earth's surface. This dramatic achievement was surpassed only by intelligence derived from the photography.

In placing a value on the intelligence obtained by the U.S. through its photographic reconnaissance satellite programs between 1960 and 1970, a first consideration, on the positive side, would be that it had made it possible for the President in office to react more wisely to crucial international situations when armed with the knowledge provided by these programs. Conversely, it can be said that without the intelligence which this program furnished, we might have misguidedly been pressured into a World War III.

The intelligence collected by the reconnaissance programs makes a vital contribution to the National Intelligence Estimates upon which the defense of the U.S. and the strategic plans of the military services are based. Principal among those estimates are the ones which deal with the Soviet and Chinese Communist strategic weapons, space, and nuclear energy programs.

The intelligence from overhead reconnaissance counts heavily not only in planning our defense, but also in programming and budgeting for it. It helps to avoid the kind of floundering that occurred during the time of the projection of the "Missile Gap." Without the kind of intelligence which the CORONA program provided, the U.S. budget for the defense of our own territory, and for military assistance to our allies, would doubtless have been increased by billions.

The total cost for all CORONA activities of both the Air Force and the CIA over the 16-year period was [redacted]

The CORONA program was so efficiently managed that even the qualification models of each series were refurbished and flown. As a result, there was little hardware available at the termination of the program when it was suggested that a museum display should be set up to illustrate and to preserve this remarkable program. Using recovered hardware from the last flight, developmental models from the J-3 program, and photographic records from the memorable flights, a classified museum display was set up in Washington, D. C. In his speech dedicating the Museum, Mr. Richard Helms, the Director of Central Intelligence said:

> It was confidence in the ability of intelligence to monitor Soviet compliance with the commitments that enabled President Nixon to enter into the Strategic Arms Limitation Talks and to sign the Arms Limitation Treaty. Much, but by no means all, of the intelligence necessary to verify Soviet compliance with SALT will come from photoreconnaissance satellites. CORONA, the program which pioneered the way in satellite reconnaissance, deserves the place in history which we are preserving through this small Museum display.
>
> "A Decade of Glory," as the display is entitled, must for the present remain classified. We hope, however, that as the world grows to accept satellite reconnaissance, it can be transferred to the Smithsonian Institution. Then the American public can view this work, and then the men of CORONA, like the Wright Brothers, can be recognized for the role they played in the shaping of history.