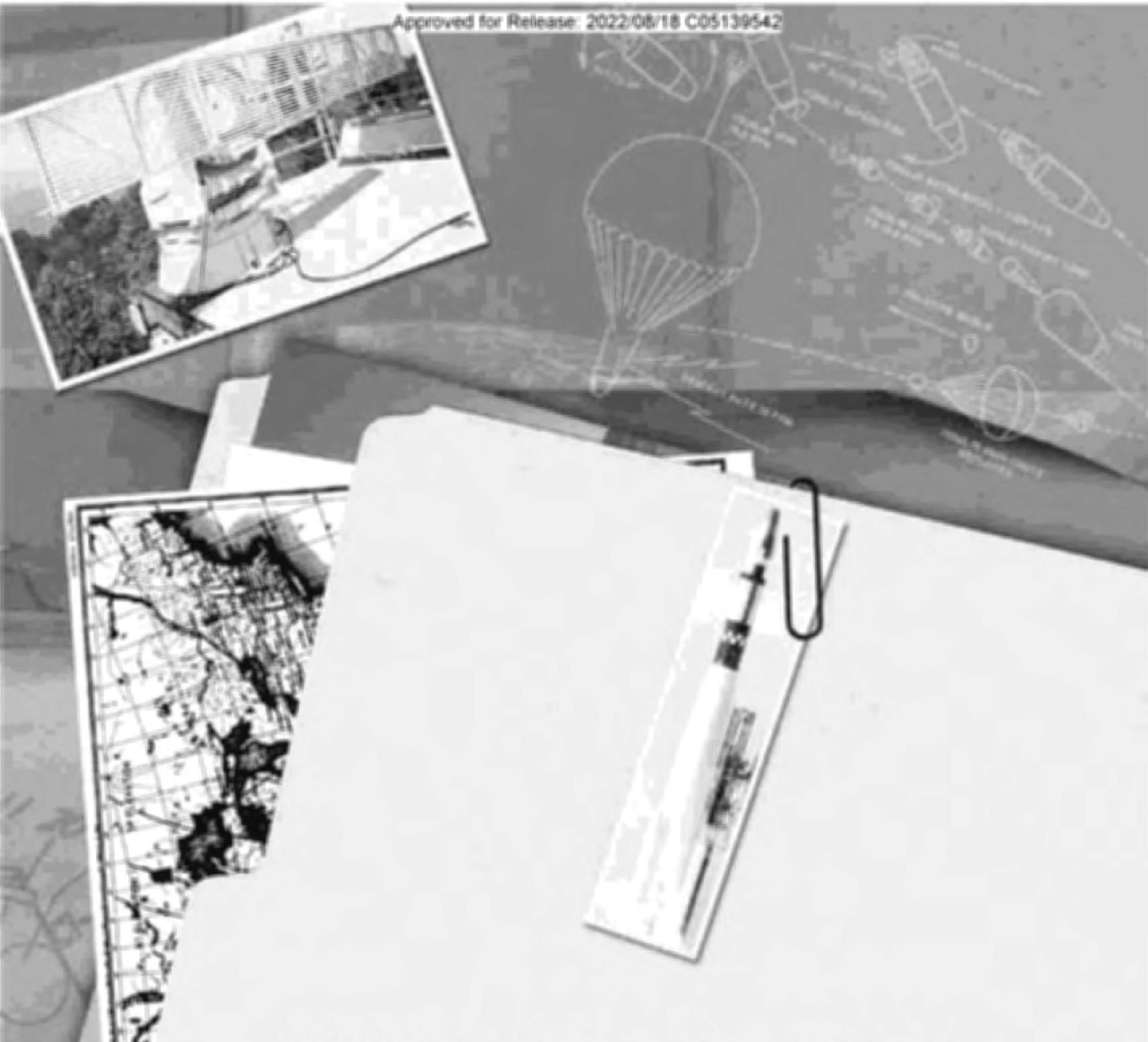

TRAILBLAZER 1964:
THE QUILL EXPERIMENTAL RADAR IMAGERY SATELLITE COMPENDIUM

Edited by James D. Outzen, Ph.D.

Approved for Release: 2022/08/18 C05139542

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RADAR IMAGERY SATELLITE COMPENDIUM

EDITED BY JAMES D. OUTZEN, PH.D.

CENTER FOR THE STUDY OF
NATIONAL RECONNAISSANCE

AUGUST 2012

Approved for Release: 2022/08/18 C05139542

CENTER FOR THE STUDY OF NATIONAL RECONNAISSANCE

The Center for the Study of National Reconnaissance (CSNR) is an independent National Reconnaissance Office (NRO) research body reporting to the NRO Deputy Director, Business Plans and Operations. Its primary objective is to ensure that the NRO leadership has the analytic framework and historical context to make effective policy and programmatic decisions. The CSNR accomplishes its mission by promoting the study, dialogue, and understanding of the discipline, practice, and history of national reconnaissance. The Center studies the past, analyzes the present, and searches for lessons-learned.

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Government Printing Office
732 North Capitol Street, NW
Washington, DC 20401-0001
http://www.gpo.gov

Published by

National Reconnaissance Office
Center for the Study of National Reconnaissance
14675 Lee Road
Chantilly, Virginia 20151-1715

Printed in the United States of America
ISBN: 978-1-937219-10-9

Approved for Release: 2022/08/18 C05139542

Approved for Release: 2022/08/18 C05139542

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TRAILBLAZER 1964:
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FOREWORD

In 1964, the National Reconnaissance Office (NRO)—in the secret world of its then highly classified Byeman Security Control System—conducted what has become known as the Quill experiment. This experiment resulted in another first for the NRO—the collection of radar imagery from space. This took place fourteen years before the National Aeronautics and Space Administration (NASA) conducted its 1978 short-term Seasat mission as a proof-of-concept for the use of radar remote sensing for ocean studies. The Quill experiment also took place almost 30 years before the emergence of regularized space borne radar imaging for the remote sensing community with missions such as the European Space Agency's ERS-1 in 1991 and the Canadian Space Agency's RADARSAT-1 in 1995.

In 1964 Quill was highly classified and remained so until programmatic declassification in 2012. Since the Secretary of Defense approved the declassification of the fact of the NRO in 1992, the NRO has initiated a growing number of programmatic declassifications. The first wave was during the ten-year period between 1995 and 2005 with the 1995 declassification of the Corona program, the 1998 declassification of the Grab Sigint satellite information, and the 2004 declassification of Poppy Sigint satellite information.

The declassification of the Quill experiment will mark the NRO's greatest declassification efforts, and one of the largest such efforts among U.S. intelligence agencies. In mid-2011, during the NRO's 50th anniversary commemoration, DNRO Carlson, significantly expanded the NRO's earlier declassification record. In June of 2011 he approved the comprehensive declassification of the Gambit-1, Gambit-3, and Hexagon film-return satellite reconnaissance programs. That decision included not only the declassification of documents, but also the declassification and transfer of program artifacts to the National Museum of the United States Air Force for public display. This 2012 declassification and release of Quill program documentation concludes that record 13-month period when the NRO conducted its single greatest declassification of what had been the most sensitive technical intelligence collection information of the Cold War and beyond. This compendium gives you an opportunity to read some of the leading edge of that formerly most sensitive national reconnaissance documentation in its original form.

The NRO's Quill project was a remarkable experiment for its time. It was an early trailblazer in the nation's national reconnaissance program. It was the first effort by the then newly formed NRO to obtain space imagery from a new type of sensor, the radar sensor. At the same time as it was undertaking the Quill effort, the NRO was improving the Corona photoreconnaissance satellites inherited from a joint collaboration between the Central Intelligence Agency and the United States Air Force, and developing a new high resolution photoreconnaissance satellite known as Gambit. These systems, along with early Sigint satellite systems would prove important to establishing the National Reconnaissance Office's reputation as a source of intelligence that could not be obtained by other intelligence collection means.

Quill, itself, is important to the NRO for a least five reasons. First, it demonstrated that radar imagery could be obtained from space, setting the foundation for future radar imagery satellite programs at the NRO. Second, Quill built upon the NRO's experiences with the Corona program, setting a precedent for the NRO to leverage its resources and technology across multiple programs. Third, Quill contributed to an early culture of success at the NRO where technological savvy was a prized asset, favoring timely and well-informed decisions rather than dependence on cumbersome bureaucratic processes. Fourth, Quill was an important developmental assignment for Major David Bradburn who would become an Air Force Major General, serve as staff director of the NRO headquarters staff, and lead the Air Force's program at the NRO known as Program A. Finally, Quill was a trailblazing program for inviting cooperation from intelligence organizations outside the NRO to assist in assessing and improving NRO programs.

The NRO Historian and Chief of the Historical Documentation and Research (HDR) Section of the Center for the Study of National Reconnaissance (CSNR), Dr. James Outzen, has assembled all of the available Quill documents and published them in this compendium, Trailblazer 1964: The Quill Experimental Radar Imagery Satellite Compendium. Dr. Outzen organized the compendium into six topical sections that help the reader understand not only the historical details of the program, but also the historical significance of the program. He begins the compendium with a comprehensive introduction that puts Quill into the geo-political context of the time and its relationship to the NRO's development of early satellite reconnaissance programs.

My expectation is that readers of this compendium will gain insight into this early experimental program. For those involved in experimental technology efforts, the Quill histories and documents in this compendium should reveal how determination, good technology development skills, and significant cooperation between several government organizations were all instrumental in carrying out a highly successful satellite experiment. For those with an interest in developing space radar imaging capabilities, this compendium can serve as a basic reference volume on the earliest effort to obtain and process radar returns into useable imagery intelligence. For those interested in how government organizations can succeed, the documents in this compendium can be used as a case study that demonstrates the importance of good personal relationships, a focus on using government processes to buttress innovation, and the essentialness of strong leadership in managing a program. Finally, for those interested in the history of the NRO, the material in this compendium reveals the early origins of several hallmarks of later NRO success including a strong program manager, both cooperation and tensions between the CIA and the Air Force, attentiveness to leveraging space technology to offer a new intelligence collection, and determination to overcome obstacles and minimize risks of program failure.

As you read this compendium, I challenge you to learn how the Quill experiment and the NRO opened the door for the U.S. Intelligence Community to obtain radar imagery from space.

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

Approved for Release: 2022/08/18 C05139542

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The United States has declassified four major photo reconnaissance programs—Corona, Gambit, Gambit-3, and Hexagon, as well as the smaller Argon and Lanyard programs. For the major programs, the Central Intelligence Agency (CIA) and the National Reconnaissance Office (NRO) have issued compendiums of key documentation. We have chosen to continue this practice with the Quill experimental radar imagery satellite launched successfully in 1964. In this compendium, Trailblazer 1964: The Quill Experimental Radar Imagery Satellite Compendium, you will find all the documentation that currently exists relating to the Quill program, including two histories and 28 other documents.

Unlike the larger photoreconnaissance programs that the NRO previously declassified, Quill was an experimental program. The NRO only launched one Quill satellite vehicle, for a short duration mission. Consequently, the documentary base is significantly smaller than the other declassified programs. It also appears that much of the documentation associated with Quill has been destroyed as the program receded into the historical background and the NRO's radar imagery capability emerged as regular sources of classified intelligence.

I have grouped the documents thematically for this publication. The first grouping consists of two histories completed on Quill. Mr. Robert L. Perry wrote the first history. Perry was the first historian to carefully document early NRO satellite reconnaissance programs as well as the management of the organization. Perry's Quill history is important for keeping Quill from being forgotten as the NRO later developed new, sustained radar imagery capabilities. Perry carefully documented the Quill program and, like his other historical work, his history of Quill is well-written and demonstrates strong historical tradecraft. Dr. Robert L. Butterworth would later produce a Quill history that draws heavily from Perry's Quill history, but also includes more historical context, examples of Quill imagery, drawings and figures, and additional historical facts. I have edited these histories, removing redacted items and substituting new language to make the histories easier to read.

I have grouped the first set of Quill documents to include those related to the development of the program. In that grouping I include documents that address the reason for developing the Quill experiment, security questions surrounding Quill and other national reconnaissance programs underway at the time, the program management approach for Quill, and other details on Quill's development.

In the next grouping I placed documents produced as part of the main contractors'—Lockheed Missile and Space Company as well as Goodyear Aerospace Corporation—efforts to conduct engineering and program assessments. These five volumes constitute the largest number of pages in the document collection. They contain not only engineering and programmatic details, but also historical summaries of the program. The volumes provide other historically interesting details such as photographs, engineering drawings, and data tables.

Although Quill was originally proposed as an "offensive" collection system for assessing bomb damage after the use of U.S. military assets, by the time the NRO launched the satellite, program managers and intelligence community officials were curious about other potential intelligence uses. Consequently, the then Director of the NRO, Dr. Brockway McMillan, worked with the CIA to produce an assessment of Quill imagery and radar technology for expanded intelligence uses. I have grouped evaluation documentation that explores potential uses of radar imagery technology beyond bomb damage assessment.

The final documentation grouping addresses the question of whether or not to maintain Quill security under the "Byeman Control System," which was then the primary security control system to restrict need-to-know about the NRO and its operations. With the decision to retire Quill from Byeman controls came the retirement of Quill, while at the same time the potential for new intelligence from radar imagery became a more debated issue in the intelligence community.

I have only included printed excerpts of the long engineering and performance analysis reports, as well as two longer evaluation reports. The full versions of these documents are contained in a disk located at the back of this book. I have also included the redacted versions of the Perry and Butterworth histories for those interested in where material was redacted.

Like any project, the development of this compendium would not have happened without the good work of several organizations and people. Those include the NRO's Information Review and Release Team headed by Mr. Steve Glenn. Steve and his team members found, reviewed, and prepared for release the 28 documents found in this volume. Dr. Robert A. McDonald, Director of the Center for the Study of National Reconnaissance (CSNR) provided significant support for this project,

as well as his usual wisdom and insight. The CSNR is fortunate to have a staff of publication specialists whose talents are manifest in this publication. Many hands support a project such as this, and I am grateful for them all.

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

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INTRODUCTION

After the Iron Curtain descended between Eastern Europe and the West immediately after World War II, western allies were faced with finding ways to peer over that curtain and determine the intents and capabilities of their adversaries on the other side. The Soviet Union, China, and other communist states were mostly closed to observation. Citizens in those countries were restricted from traveling, and hence sharing insight into conditions in their daily lives with outsiders. Formal government communications were difficult to intercept and decode. Even common information sources in the West, like telephone directories, were uncommon in these denied areas, making intelligence collection difficult. At the same time, the Soviet Union was demonstrating seemingly remarkable technological capabilities such as the successful testing of nuclear weapons, the development of strategic military systems that could potentially deliver nuclear weapons to the United States, and the ability to leverage space as a platform for aiding the communist cause. Amid this environment, there was a growing imperative to gain insight into the Soviet Union and other denied areas.

EARLY COLD WAR RECONNAISSANCE

Following World War II, the United States had an available or in development arsenal of air, ground, and sea based weapons systems. Some of these were turned into platforms for gaining intelligence from the expanded denied areas under control of eastern bloc adversaries. For example, variations of the P-2 and F-80 were modified for overflight reconnaissance missions that flew near the borders of the Soviet Union and other denied countries to gain intelligence. Later the RB-47 would serve as a platform for many overflights. This platform proved vulnerable to being shot down by U.S. adversaries, limiting its use to missions mostly along the periphery, but not over borders of countries closed to western allies. The United States would also attempt unique experimental platforms, like a high-altitude balloon know as Genetrix that carried a camera for taking pictures over denied areas.

President Dwight D. Eisenhower recognized the need for gaining better intelligence on U.S. adversaries to prevent surprises like the Japanese attack on Pearl Harbor that initiated the U.S. entry into World War II. Eisenhower authorized the development of a plane that would fly at 70,000 feet, well above the anti-aircraft capabilities of adversaries at the time, and carry a specially designed camera for gaining good quality photographs of the denied areas. The plane was known as the U-2, developed under the direction of Central Intelligence Agency (CIA) by Lockheed Aircraft Corporation. The U-2 would provide useful intelligence, especially settling the question of whether or not the Soviets had an advantage in the number of long-range strategic bombers, by providing imagery that confirmed earlier estimates were overstated.

Eisenhower feared that, from the time that he approved the U-2, the plane would eventually be shot down as Soviet anti-aircraft capabilities improved. On May 1, 1960, Eisenhower's fears were confirmed with the downing of a U-2 piloted by Gary Powers over the Soviet Union. Anticipating this day, and the end of U-2 overflights of the Soviet Union, Eisenhower had approved the development of a photoreconnaissance satellite two years earlier, code-named Corona. By this time, the United States was trying to assess whether or not Soviet abilities to produce Intercontinental Ballistic Missiles (ICBM) exceeded those of the United States.

CORONA AND THE BEGINNING OF SATELLITE RECONNAISSANCE

The CIA and Air Force designed the Corona satellite to carry a camera for capturing imagery of broad areas of the Soviet Union and other denied areas. The image quality was to be good enough to determine the true Soviet capabilities for developing weapons like ICBMs. It would carry film, which after exposure, would be spooled into a capsule for safe return to the earth. The return capsule would be caught mid-air by Air Force recovery teams and returned to the United States for development, processing, and interpretation by intelligence analysts. The first twelve Corona missions failed for over an 18 month period for various reasons including failures of the launch vehicle, camera system, and space control vehicle. With mission 13, came success. Although this was a test mission, the launch, orbit control, and return capsule all functioned properly. With mission 14, Corona delivered the first imagery from space, and in a single mission surpassed the imaging capability of all previous U-2 missions combined. Corona would be launched a total of 145 times, ending service in 1972.

Although Corona proved to be a reliable source of imagery, it was designed to provide imagery of broad areas. This limited Corona's ability to provide highly detailed imagery that would reveal not only the location of targets, but also the details of those targets. In September, 1961, the Kennedy administration established the National Reconnaissance Office (NRO) to take charge of the Corona program as well as all reconnaissance satellite programs under development. One of those programs, run by the U.S. Air Force, was known as Samos. The Samos program included a number of variations of photoreconnaissance satellites including one like Corona that would return film, but with high resolution of specific targets, and another that would read film on-orbit and electronically transmit high resolution imagery back to the earth. From this foundation emerged a high resolution system known as Gambit that would dramatically increase the U.S. space-based imagery capabilities.

THE GAMBIT PHOTORECONNAISSANCE SATELLITE

The NRO launched the first Gambit satellite in July, 1963. The launch was successful, as was the recovery of film from space containing higher resolution imagery than Corona provided. Gambit would face a few early difficulties with space vehicle and camera system operation, but it would prove to be a highly reliable source of imagery over the length of the program. A second generation of the Gambit system would be launched three years later, known as Gambit-3 or Gambit-cubed. Eventually, the newer Gambit system would produce very high resolution imagery from space and carry two film return capsules to increase the time that the Gambit system could image from space. The Gambit satellites would prove an essential resource in understanding advances in Soviet nuclear capabilities, as well as other military capabilities of the Soviets and other adversaries.

THE NEED TO GO BEYOND CORONA AND GAMBIT

Despite the successes of the Corona and Gambit programs, they suffered some significant limitations. They could not obtain imagery at night or in poor weather conditions. Because both Corona and Gambit imagery was obtained via capsule returned from space, imagery from the systems could not be obtained quickly. The NRO was searching for solutions to those limitations. One of those was data transfer from orbit, which had proven successful with Sigint satellites such as Grab. The other was the use of radar returns for manipulation into imagery, which the Army and Air Force had proven as a successful imagery approach using airborne platforms. Radar returns could travel through bad weather and night. Joined with data downlinks from space, a radar imagery program could address some of the limitations of the Corona and Gambit systems.

QUILL

Quill was born under these conditions in 1962. The NRO originally developed Quill to test the concept of using a satellite to capture radar returns to create imagery of targets bombed by the Air Force as a result of military action. It was characterized by the Air Force as an “offensive” system to assess the effectiveness of military operations, rather than an intelligence system to gain insight into denied areas or the capabilities of U.S. adversaries.

The Air Force element at the NRO, known as Program A, developed the Quill program. Major David Bradburn was assigned as the program’s director. Bradburn turned to Goodyear Aerospace and another associate contractor, who were already working with Air Force on airborne radar imagery, to develop radar sensor and subsystems for the Quill satellite. Bradburn also turned to Lockheed Missiles and Space Company, which was already supporting the successful Corona program to manage the integration of the radar components onto a space vehicle and rocket system. Bradburn proposed Quill as an experimental satellite that would simply test the potential for deriving radar imagery from space. Program A eventually procured two complete systems, the first would be launched, and if successful, the second system would not.

Bradburn worked diligently with the companies on contract to develop the Quill system. They were able to modify a number of existing radar and space vehicle components to integrate the system, saving time and money. They encountered little bureaucratic resistance with the only major issue requiring resolution was how to protect the secrecy of Corona while drawing heavily on Corona system components for the program. Despite original hopes to launch Quill in the spring of 1964, the NRO did not launch it until December 21, 1964.

The launch was highly successful. All the systems worked as planned. Quill was unique in that imagery would be derived from both film de-orbited from the space vehicle using a Corona return film return system, and a radar data downlink that would be processed to create imagery on the ground. The two sources would then be compared for effectiveness. The first launch and operation of the satellite was so successful, that a second launch was deferred indefinitely until the results of the Quill experiment could be fully evaluated.

RESULTS OF THE QUILL EXPERIMENT

The evaluations of the space vehicle, ground components, and other elements of the Quill experiment were completed by Lockheed, Goodyear, and the associate contractor by the spring of 1965. The companies provided rich details on the success of their efforts in their reports. A team led by the CIA's National Photographic Interpretation Center (NPIC) completed evaluation of the imagery obtained from Quill in the fall of 1965. The Quill imagery evaluation team concluded that radar imagery from space was a promising source of intelligence that could supplement imagery gained from Corona and Gambit. The team also noted that the resolution of the imagery would likely remain low and would not replace the other photoreconnaissance systems operated by the NRO.

The single launch of Quill satisfied the objective of determining whether or not radar imagery from space was possible. Consequently, no additional launches were undertaken. Eventually the unused hardware procured for Quill was used in other national reconnaissance programs. By 1968, the question of whether to maintain Quill in the strict security control system for national reconnaissance satellites, known as Byeman, was addressed by CIA who maintained the control system. By 1969, the CIA, in consultation with the NRO, determined that Quill no longer needed to be maintained in the Byeman system because of its experimental nature. For all intents and purposes, the notification of this decision served as the final closeout of the Quill program.

AFTER QUILL

After the Quill experiment, the NRO continued efforts to develop radar capabilities from space. Little can be written about those follow-on systems because they remain classified. In 2008, the NRO declassified the fact that the organization developed radar reconnaissance systems. These systems owe their heritage of success to the trailblazing path of the Quill experimental radar satellite.

As the NRO matured as an organization so did the uses of national reconnaissance systems. Rather than trying to only verify the number of strategic nuclear weapons systems such as long range bombers or ICBMs that were the focus of NRO systems in the 1960s, the Intelligence Community used those systems to verify nuclear arms limitation treaties in the 1970s, '80s, and '90s. The nation also used those systems for other purposes to sustain the national defense including better understanding military capabilities of adversaries beyond the major nuclear powers. The NRO built new and impressive reconnaissance systems such as the follow-on to the U-2, the SR-71 reconnaissance aircraft, and the amazing Hexagon satellite, which replaced Corona with significantly greater capacity.

The shift in national security priorities brought about two major changes that led to more openness about the nation's national reconnaissance systems. In 1978, President Jimmy Carter acknowledged for the first time that the United States used satellites for photoreconnaissance purposes in order to affirm abilities to verify future arms agreements with the Soviet Union. In 1992, the Cold War was won and the United States acknowledged for the first time that the NRO existed and was responsible for developing, launching, and operating the nation's reconnaissance satellites.

QUILL AS A TRAILBLAZER

At first glance it might seem odd to characterize Quill as a National Reconnaissance Trailblazer. The Quill program was an experimental program with a very short planned lifespan. Quill's program manager, Air Force Major David Bradburn planned only two launches—and only a second if the first failed. As it turned out, the first launch was successful by every measure and a second launch was therefore never undertaken. The question still lingers though, how could Quill be considered a trailblazer among the many national reconnaissance programs with long term sustained success?

Quill was a trailblazer. The program demonstrated that the NRO could take existing sensor technology, modify it for use in space, marry it with other specialized hardware for national reconnaissance programs, and demonstrate the potential for new intelligence collection. Quill blazed the trail in technologies that could collect images day or night and through cloud cover. Quill was also run by then Major David Bradburn, who would go on to become a senior leader of the NRO and major contributor to other successful program efforts at the NRO. The then young NRO needed a program that could be turned quickly from concept to operation and Quill blazed that trail, leaving a stronger, more confident NRO. It helped firm up many elements that would become the foundation of the NRO's culture of success. Quill set an early standard of success for future program development that established the NRO as one of the nation's premier acquisition organizations and critical source of one of a kind intelligence.

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

Approved for Release: 2022/08/18 C05139542

Quill: Radar in Orbit

In the first 20 years of reconnaissance satellite program activity in the United States, Quill was the only program that substantially conformed to initial cost, schedule, and performance estimates, and the only satellite program of any nature to proceed from start to finish with perfect records in launch, orbital operations, readout, and recovery.

Quill had its immediate origin in a proposal jointly concocted by Lockheed Missiles and Space Company and the Goodyear Aerospace Corporation early in 1962. Stimulated by rising interest in post-strike reconnaissance capabilities, those contractors suggested that synthetic aperture side-looking radar be installed in an Agena spacecraft for assessment of weapons effects in a post-nuclear-strike setting. The radar set was to be a modified version of one being built for the RF-110 (which subsequently reverted to its original RF-4 nomenclature). A Lockheed briefing team that included Goodyear representatives exposed the notion to a variety of interested audiences in the middle months of 1962. Air Force Undersecretary Joseph V. Charyk, who also headed the still-secret National Reconnaissance Office (NRO), was one of those who listened. Major General Robert E. Greer's Directorate of Special Projects (the West Coast element of the NRO) provided another audience.

The idea of using orbiting radar for bomb damage assessment was scarcely novel in 1962. It had first been mentioned as part of Rand's initial studies of satellite feasibility and applications between 1948 and 1952, and had reappeared periodically during the next decade. Strategic Air Command (SAC) interest in satellite-based, post-strike reconnaissance pronounced for several years, was heightened by the 1961-1962 cancellation of the original photo-readout Samos satellite program (E-l and E-2), which until that time had been somewhat unrealistically counted on to provide retargeting data. In 1960 there was a brief flurry of interest in the idea of a combination bomb-damage-assessment and weather reconnaissance radar satellite, but like other ambitious proposals of the time it expired of funds starvation and technology shortcomings. Nevertheless, such discussion encouraged Lockheed to propose the near-term development of a radar-carrying, reconnaissance satellite that used on-the-shelf components.[1]

Greer, with Charyk's support, asked his Plans Chief, Captain Frank Gorman (USN) to examine capabilities and needs. Concurrently, a colonel on Greer's staff established a working relationship with the SAC's requirements group in the hope of clarifying SAC's post-strike reconnaissance requirements. He learned little that was new: SAC wanted a satellite-borne, post-strike, all-weather assessment capability in near-real-time. Gorman, after surveying the entire spectrum of requirements and capabilities, reached the initial conclusion that any system ". . . requiring reflected light cannot be considered a good solution to a problem where reaction time is paramount as is the situation for 'initial assessment.'" In Gorman's, judgment, the only effective technique would be one providing "all weather/light conditions" sensitivity. His recommendation to Greer: "A high-resolution radar development should be initiated immediately if an effective post-strike reconnaissance capability is to exist." And he concluded that readout was essential; physical recovery of payload, he argued, had been "a means of circumventing the bandwidth problem."[2] All of which was true, but in the absence of adaptable technology was also largely irrelevant.

Nevertheless, the several elements necessary to the establishment of a funded research and development effort that could lead by one route or another to an operational radar-in-orbit system were in being by the late summer of 1962. A requirement of sorts had been acknowledged, though no formal statement of national need for radar reconnaissance from orbit had yet emerged. The approach defined by Lockheed and Goodyear,* if it could be accepted at face value, represented a technologically achievable capability that could be acquired at a relatively modest cost. The ingredients of a system existed in the form of in-development items if not in operationally ready equipment.

In June 1962, Charyk directed that Greer's organization evaluate the possibility of adding special sensors "such as infrared and radar" to the payload of the heavy-lift Titan-III vehicle then being considered as a successor to the Atlas booster used for most space launches. The slight prospect that the Titan-III would actually be used in the satellite reconnaissance program for several years

* Other contractors had similar proposals, but all required some extended period of vehicle or sensor development.

prompted Greer to suggest consideration of a more direct approach. In October Charyk accepted Greer's views and formally authorized an evaluation of the Lockheed-Goodyear proposal based on use of a Thor booster and readily available Agena hardware.[3]

What began in the summer of 1962 as an evaluation became a source selection process. It had two aspects, one involving a normal competition for the development of a radar set, boosters, and readout equipment suited to extended operations, and the other an experiment using the Lockheed-Goodyear proposal as its base. Major David D. Bradburn, a member of the six-man study group†, suggested that the most direct and effective way of satisfying Charyk's request for an early demonstration of radar-in-orbit feasibility was to buy a few sets of on-the-shelf equipment, modify the hardware sufficiently to permit its operation under orbital conditions, and test the result in a real operation. The group's head, Colonel William G. King, Jr., was wholly in favor of that approach, but having recent and painful experience with optimistic contractor predictions that could not be translated into operational performance‡ decided to verify the alleged performance capabilities of the proposed system by checking with Air Force radar reconnaissance experts at Wright Field.

The entire six-man study team visited the Reconnaissance Laboratory, an element of the Aeronautical Systems Division at Wright-Patterson Air Force Base, early in October. The project officer for the AN/APS-73 radar assured his visitors that the set could do what had been promised for it and that no other item of available equipment could realistically be substituted. The question of what resolution could be expected was not as readily resolvable. The Laboratory's chief told Colonel King that if suitable "requirements" could be issued it would be possible to obtain comparison radar and photographic imagery of existing bomb craters at Frenchman's Flats (the Nevada test site) in four to six months. King, who planned to write his final report later that month, said mildly that he had a better idea. One of his team members knew the problem intimately, King said. His team member could adequately represent the study group in superintending an immediate effort, say in three or four days. He would fly aboard the photo airplane.

The Reconnaissance Laboratory's chief, after a moment's reflection, agreed that the test exercise could indeed be completed in three or four days. It was, and comparison photographs were being examined in Los Angeles the following week. They demonstrated that radar imagery could readily distinguish the principal features of bomb craters of various kinds, although the limitations of the test photography excluded any firm conclusions about the ground resolution obtainable from space by side-looking radar. "However," King's group eventually concluded, "it is obvious that craters and surface differences of the sizes identified in the accompanying photographs can easily be seen with a radar that has a ground resolution poorer than 50 feet."§

Having confirmed their preliminary judgment that radar in orbit could adequately perform bomb damage assessment (if it could be made to operate while in space), the study group had to confront the question of what to recommend to General Greer and ultimately to Undersecretary Charyk. Several contractors had provided copies of earlier unsolicited proposals and had briefed group members. In the end the study group settled on a recommended approach, which was characterized as ". . . not . . . the only feasible or best concept; . . . [but] merely . . . one concept having some plausibility—a basis from which the Board may proceed." The members were agreed that they would have satisfied the requirements of their charter if they provided (a) a conceptual foundation and operative recommendations for proceeding with a radar feasibility demonstration and (b) guidance for the conduct of further studies and analyses.

The final report said candidly, "we have assumed that our instructions limit us to showing the feasibility of developing satellite-borne radar capable of sensing information of sufficient intelligence value to allow some damage assessment. The more subtle problem of showing the feasibility of an overall post strike reconnaissance system must be fully analyzed concurrently with any radar demonstration."

The study program was intended to analyze the operational applications of high-resolution radar for bomb damage assessment in a post strike environment, assuming quick-reaction, all-weather capability for

† The study group, headed by Colonel W. G. King, Jr., included Lieutenant Colonel John Copley, Major Bradburn, Major Charles Redwine. and two others, all of Greer's staff. Three "advisors" also signed the final report, including Greer's legal specialist and Lieutenant Colonel Victor M. Genez of the SP Plans staff.

‡ King had managed the Samos E-I and E-2 programs, had been involved with satellite reconnaissance work since 1955, and was the final program manager for the wholly inadequate Snark missile.

§ The craters photographed ranged in diameter from a minimum of 80 feet to a maximum of 850 feet. Photographs were taken using a six-inch focal length T-II aerial camera loaded with Plux-X film, the combination providing a 20-lines-per-millimeter resolution at the film plane. The radar was an AN/APQ-55, with a six-foot, slotted roll, side-looking antenna, 45 kilowatts of power, and a frequency of 34.86 kilomegacycles. An electro-optical photo multiplier tube, an indium antimony infrared detector, and the radar operated as part of a development system being investigated by the Reconnaissance Laboratory. They were flown 2200 feet above the craters in a C-131 aircraft.

acquiring "the relatively coarse detail" obtainable from satellite-carried radar.¶

The feasibility demonstration was seen as a process that should be conducted quickly and with the minimum outlay of funds needed to assure success. Following the lines of Bradburn's suggestion the group urged testing off-the-shelf radar ". . . capable of providing information, which can be extrapolated (at minimum risk) into design information required for an operational radar . . ." The object of the demonstration would be to establish that ". . . physical phenomena do not exist which would preclude development of high resolution." To those ends, the study group recommended that an APS-73 model radar be integrated with a Thor booster, an Agena-D orbiting vehicle, a Corona recovery capsule, a readout system chosen from existing hardware,** an available ground processor, and the orbital control and communications net then being used by the National Reconnaissance Program. It was a somewhat less ambitious variant of the Lockheed-Goodyear approach, but devoid of operational objectives.

Concluding that only the equipment combination proposed by Lockheed and Goodyear could be made available for a timely demonstration, the study group recommended an immediate start of work using a sole-source procurement approach.†† The evaluation group concluded that a three-flight demonstration effort could be conducted at a specified cost, but that a ten percent contingency fee should be provided to protect against unforeseen development problems. (Should a five-flight program be approved, required funds would be more.)

Finally, the group recommended that an existing office house the feasibility demonstration and that Major Bradburn, "probably the most knowledgeable radar specialist at SAFSP," be named program manager.‡‡ In a statement that Bradburn was to emphasize frequently thereafter, the group observed that the orbital test program was ". . . the simplest and quickest approach to demonstrating the feasibility of the radar sensor," that quick completion of the test would make possible a decision on a later operational system, but that ". . . the launch vehicle and radar configuration proposed for orbital test are not considered adaptable for operational test." In so many words, the feasibility demonstration was to be that and nothing more; no consideration would be given to making the demonstration equipment the basis of an operational system.§§

The report of the study group, thereafter known as the "King Report," went to General Greer on 30 October. Its one-word title, "Quill," became the program's code name.¶¶ [5]

Greer approved the findings and recommended that Major Bradburn, the board's nominee for project leader, present them to Charyk for review. Three days after Bradburn's 7 November 1962 presentation, Charyk authorized him to begin work. Funding levels, as first approved, reflected the premises of the Lockheed-Goodyear proposal. Bradburn's plans called for five flight-qualified payloads, of which three were actually to be launched. Lockheed was to be assigned system engineering and technical direction responsibilities and responsibility for orbital vehicles, system integration and launch services. Goodyear Aircraft was to develop the

¶ Although the study group report did not explicitly so state, group members were convinced that the analysis should be performed outside the Special Projects directorate, preferably by the SAC. The participation of Rand Corporation specialists was explicitly proposed, however. In the event, the "studies and analysis" aspect of the total Quill program did not develop as the study group had proposed. Charyk never directed Greer's organization to do the analysis. Rand did perform some relevant research, but SAC continued to submit advocacy recommendations which, generally, were considered by senior defense officials to be insufficiently supported by objective analysis. The feasibility demonstration aspect of Quill became, by a process of inaction elsewhere, the dominant element of the program.

** Relatively little was said about readout in the final report, which, however, included a general discussion of principles and techniques and an assessment of readout time requirements. As for feasibility, something of the group's views could be judged from the provision of a recovery capsule, an accessory that presumably would not find a place in any operational system. A brief but eloquent comment on the readout problem appeared toward the middle of the report: "Airborne and ground equipment to provide bandwidths of six megacycles (unreadable text in available copy) technically feasible. Their reliability leaves something to be desired." And, after a discussion which ended with the observation, "Our problem is not in sensing in detail, but . . . is retrieval of the information," the report suggested the "broad assumption" that ". . . information of a modest detail level which can be handled may be useful for an 'initial assessment.'" (Underlining in the original text.)

†† That somewhat unusual course—selecting contractors during an evaluation of program feasibility—was justified by Charyk's requirement for the quickest possible demonstration, which meant use of off-the-shelf equipment. The Agena-D was the only available orbital vehicle, the Thor the only appropriate booster previously mated to an Agena, and the APS-73 was "the nearest thing to an off-the- shelf item that could be used in the feasibility demonstration . . ." In the formal opinion of Greer's legal specialist, because only Goodyear made that radar ". . . it would be a gross waste of time and money to start another manufacturer building it in lieu of having Goodyear make the necessary minimum modifications in its existing product."[4]

‡‡ Quill, which was promised to be a short-term program of high technical interest, would be an attractive project to manage. Bradburn told King he was bored with his current assignment and asked, "Why don't you make me the project officer reporting to you. Then I will be able to do it quickly and cheaply and you can protect it from all the colonels who might want the job." King thought well of the idea.

§§ A post strike bomb damage assessment system as conceived then and later was assumed to involve requirements for multiple launches from hardened sites. The use of a Minuteman booster was generally believed to be a pre-requisite for operational utility that being the principal land-based ballistic missile in the U.S. inventory. The October 1962 study postulated five near-simultaneous launches, with five orbital radar systems making parallel-path passes over the principal Soviet targets. Obviously, a soft, liquid-fuel Thor was wholly inappropriate for such an operation, Agena could not be accommodated in a Minuteman silo and the APS-73 radar promised to have definition and resolution inappropriate for an operational application.

¶¶ Quill was suggested by Colonel Joseph W. Ruebel. At West Point, the term "Quill List" was used to identify the weekly listing of cadet demerits—the discipline list. To be "on Quill" was, therefore, a highly undesirable assignment. That was not the way the eventual Quill participants viewed their assignment, of course.

radar payloads.[***] Another organization had agreed to provide engineering consulting services for the radar experiment and to develop an optical correlator for final processing of radar data. General Electric Company was to build the reentry vehicle and Douglas Aircraft the thrust-augmented Thor boosters. The project goals included physical recovery and electronic data readout at a ground resolution of 100 feet or better. Real-time electronic readout over one United States station would be acceptable. The project—white name "P-40"—was to operate with a minimum of modification to all off-the-shelf systems, including the Goodyear radar, and was to be concluded as rapidly as possible. Time on orbit and data quantities were not considered critical items. However, Charyk wanted to be informed immediately if there was any question of meeting the 100-foot resolution requirement. He also insisted that contractors be clearly informed that the demonstration was of an experimental nature only and was not a device for acquiring operational radars or for starting the development of an operational system.

As Greer had suggested, Charyk directed that the demonstration project be conducted under a "black" cover. He authorized the notification of chosen contractors and the release of fiscal 1963 funds to cover initial costs. Additional funding would be provided for fiscal 1964.

Charyk also approved the conduct of more refined experimental work in advanced radar techniques. Designated "Phase Alpha," that aspect of the total project was to be separately classified "white" but with strict "need to know" security. Under Special Projects Office auspices, competitive proposals were to be issued, asking for design studies looking toward orbital tests and demonstration of the feasibility of radar sensors with electronic readout and storage capabilities (recovery was not an excluded option, however). Acceptable ground resolution was to be specified at 20 to 50 feet. All concerned expected Phase Alpha to take longer than the P-40 demonstration.[6]

On 14 November 1962, Bradburn advised the selected contractors that the Air Force proposed to accept their unsolicited proposal to test a radar satellite. Bradburn and others from the Special Projects directorate met with Lockheed, Goodyear, and another organization's representatives at Sunnyvale.[†††] A Lockheed representative had been asked to be ready to present again the proposal he had earlier made to King's group and to bring cognizant Goodyear people with him.

Bradburn informed the contractors that the Air Force was going to proceed with a minimum satellite radar demonstration, generally along the lines of the Lockheed-Goodyear proposal, but on an associate-contractor basis. Although Lockheed had favored a primary contractor-subcontractor framework, the Air Force had decided that direct access to the major contractors involved would limit schedule and cost overruns, and thereby enhance the probability of an early first flight. Lockheed, Goodyear and another organization would all have direct communication lines to Bradburn. Bradburn explained that he wanted to exploit existing contracts as much as possible, not only for administrative ease but also for purposes of maintaining security.

The project framework, as laid out by Bradburn, included procurement of five flight-qualified payloads to support three flights at two-month intervals with the first flight targeted for January 1964. The goal would be to obtain a high-resolution radar picture from a satellite (ground resolution of 100 feet or better with minimum time and with minimum modification of existing hardware.

An employee of the Aerophysics Division of Goodyear briefed the meeting on the radar system then being developed by Goodyear for the RF-110 aircraft. Capable of producing 50-foot ground resolution, the basic radar covered two 30-mile swaths, one on either side of the airplane. The inflight recorder and display equipment permitted display of two ten-mile swaths, which could be selected as desired within the coverage limits. The all-up weight of the radar was 450 pounds (including antenna, recorder, transmitter and receiver).

The Goodyear employee foresaw the need for three principal changes to adapt the existing APS-73 radar for satellite use. The pulse repetition frequency (prf) and the average power would have to be increased, the transmitter-modulator (and perhaps other components), which used refrigeration cooling, would have to be repackaged to provide for conduction or radiation cooling, and the recorder would have to be modified to accommodate a large film supply and to provide for satellite-derived data inputs.

*** Lockheed was to perform system integration, engineering and fabrication of structural modification for three orbital vehicles; antenna design and fabrication; provide special batteries and other payload peculiar vehicle equipment; and do test planning, in-plans, and launch base checkout services. Goodyear was to be responsible for engineering, fabrication, qualification, and delivery of five flight-qualified satellite radars, one qualification test radar substantially identical to a flight article, one thermal equivalent test model, one mock-up, air-to-ground equipment for checkout at Goodyear and for system checks at Lockheed, and pad checkout equipment at Vandenberg AFB, including test beacons and apparatus for blockhouse checks of radar operation during countdown.

††† Attendees included Colonel Robert W. Yundt, who had succeeded W. G. King as Bradburn's immediate superior for Quill.

Existing development schedules called for initial bench testing of the first complete RF-110 radar in April 1963 and delivery of the first flight test item to Edwards Air Force Base in July. However, there was already some indication of slippage and a Goodyear employee cautioned that flight tests might not begin until September or October.

A representative from another organization described the operating principles of the optical correlator. The organization could achieve an azimuth compression ratio of 1000 to 1 with available production-type processors. (The azimuth resolution in the final picture would be 1000 times finer than the physical dimensions of beam width.) With laboratory-type demonstration equipment, the best obtainable azimuth compression ratio was about 5000 to 1. In the proposed satellite experiment, azimuth resolution would be limited primarily by ionospheric distortions. If all worked well, the overall system might produce azimuth resolution of 15 feet or better. At any rate, the optical processor would not be the limiting factor.

During the engineering discussions that afternoon, Bradburn specified that the payload configurations would be identical from flight to flight—there would be no growth changes. He emphasized the "minimum modification, as-short-a-time-span-as-possible" philosophy, which was to guide Quill. He also restated his determination to adhere closely to the primary goal of showing feasibility, not developing operational prototypes. One consequence was that the radar antenna would not be steerable. Concerned with acquiring a good picture at acceptable ground resolution and not with viewing specific targets, Bradburn foresaw no need to develop aiming capability; the swath would be wholly dependent on the orbital path of the vehicle.

Although recovery of the exposed film would be the primary data retrieval method, simultaneous readout of the radar data would provide a comparison in picture quality and reveal what data deterioration was caused by the transmission link. Readout would also provide a backup system in case the recovery system failed.

Lockheed agreed to provide within 24 hours an initial cost figure so funds could be added at once to an on-going Air Force contract. A work statement was to be ready by 21 November and a full cost proposal within the month. Contract negotiations, to begin in January 1963, were scheduled to lead to a definitive contract by 25 January 1963. Bradburn scheduled a meeting with Goodyear for the week of 18 November, in Phoenix, to discuss a draft work statement, proposed contract arrangements, and procurement schedules. Meetings with another organization were set for early December.[‡‡‡]

Bradburn emphasized the need for tight security. Each employee working on the project would have to be approved by the Air Force, sign a security agreement, and have a final secret clearance. Bradburn requested that he approve these names in advance, an arrangement he later changed to allow for after-the-fact notification to the limits of a quota for each company.

Bradburn also stressed the need to hold documentation to a minimum, both for security reasons and to lessen paperwork. Each company would deal directly with his office, so a multiplicity of reports would be a waste of time as well as a potential security risk. He emphasized that he intended to participate in most of the monthly engineering and technical review meetings and that he expected all program participants to use them as a primary means of informing all concerned parties of technical, cost, and scheduling details.[7]

To that point all had gone rather smoothly. But between Charyk and the Secretary of Defense there intervened one major review echelon, and on 15 November Bradburn learned that a potentially troublesome objection to Quill had surfaced during the final project review and approval process in the Pentagon. Dr. Eugene Fubini, then serving as senior technical advisor to Defense Secretary, Robert McNamara, had held up the release of program funds on the grounds that "we, [the NRO] intend to pay too much for the radar." Lieutenant Colonel E. J. Istvan, Bradburn's chief contact on the NRO staff, reported Fubini's protest that "APS-73 costs [only] a few hundred K." Fubini asked that the APS-73 project officer be solicited for a "more realistic" cost estimate.

From Fubini's viewpoint, concern seemed warranted. The program cost estimate that reached Fubini included a provision for funding to buy five radar sets, about five times as much as for APS-73 radar sets then on procurement schedules. But, as Bradburn pointed out, APS-73 was not being bought per se; although modifications were to be held to the minimum needed to qualify the equipment for space flight, they would nonetheless be comparatively expensive. The cost

‡‡‡ The principal contractors were in a state of financial near shock when Bradburn told them that Greer's organization had accepted their premises and promises and proposed to proceed with the program pretty much as they had briefed it—and at about the price they had proposed. As later became plain, and as everyone concerned privately acknowledged at the start, the financial estimates originally attached to the Lockheed-Goodyear proposal were sales figures, understated by about half. In the usual way of things, the contractors would have "recovered" their understated costs by charging for redesign and refinement needed to satisfy specifications and requirements that varied substantially from those assumed for the proposal. Bradburn's "acceptance" of the main elements of the original proposal meant that there was little occasion for such maneuvering, and that in a "less cost" direction, for the most part.

estimates Fubini had objected to, Bradburn observed mildly, had in fact been both prepared and validated by an APS-73 project officer, and although the funding was charged as "radar payload" costs, it actually included engineering, fabrication, checkout, and launch services associated with the payload. Until firm bids became available, probably in January 1963, no better estimate could be composed.[8]

The response satisfied Fubini's objections; no more was heard from that quarter, and funds were released on schedule.

That problem disposed of, Bradburn met with Goodyear people at Phoenix on 20 November. Although the company had no satellite experience, virtually all its contracts were with the USAF or the Navy's Air arm. Organizationally, the head of the Goodyear Arizona Division reported directly to T. A. Knowles, president of the Goodyear Aircraft Company (home based in Akron, Ohio), a subsidiary of Goodyear Tire and Rubber Company. The Navy was responsible for industrial security and quality assurance at Phoenix and the Air Force Procurement Office at Sky Harbor Airport in Phoenix handled auditing and accounting requirements.

Unlike Lockheed, Goodyear had very limited experience with the special security arrangements that characterized work on satellite reconnaissance. Bradburn noted at the onset of the Phoenix discussions that three aspects of the program were extremely sensitive: 1.) a version of the RF-4C radar was being packaged for satellite use, 2.) Goodyear and Lockheed were working together on a satellite radar project with Air Force funding, and 3.) Goodyear had an Air Force contract to build a satellite radar. Initially, only 50 people in Phoenix could be briefed. In hopes of keeping exposure minimal, Bradburn decided that the naval representative in Phoenix should not be informed of this new activity. (As events later dictated, his assistance became necessary and he had to be briefed.) Document control and visit requests would receive exceptional handling. Mail was to be sent to post office boxes and picked up by briefed individuals. Unless other business provided a sufficient cover, visits to Phoenix by the Air Force and Lockheed people would be arranged through direct contact with Goodyear's Administrative Engineer. Visible project activity was to be covered by the story that it involved proprietary work called KP II—Knowles Project Number Two. (Goodyear had somewhat earlier performed work under a sensitive contract covered by the proprietary description, "KP 1"). Such a cover would also ease procurement problems—radar components could be purchased "white" as commercial items—or so it was initially assumed, although there too problems were to develop subsequently.

Goodyear's draft work statement indicated a need for additional detailed technical specifications from the Air Force and Lockheed before manpower and cost estimates could be refined. For the moment, an estimate of expenditures for the first 60-day period was the best that could be provided.[9]

Security rules for Lockheed were defined the following day. Lockheed's white contract would not mention "radar" or "Goodyear;" the black version would be correlated by paragraph numbers to the white contract and would be specific.§§§ Inasmuch as Lockheed had been doing "black" work of one sort or another for a decade, few new problems were likely to appear.

Another radar associate contractor's work on another contract, due for routine contractual extension in March 1963, appeared easily exploitable to cover new activity. Funds could be readily transferred from the program office with no need for separate financial accountability. The contract would be white, though with a vague work statement, but to insure that priority would be given to the new paperwork, the contract's technical project officer and possibly the responsible procurement officer would have to be briefed.

The radar associate contractor's proposed work included the design of the synthetic-array radar experiment, considering in detail what radar parameters were required to obtain a successful demonstration, and preparing specifications for critical radar components. The other organization was to be responsible for determining what azimuth resolution actually was obtained on the radar maps generated by the system and for analyzing factors affecting resolution. The organization was also to develop and construct a breadboard optical processor capable of achieving "the largest attainable compression ratio." If the theoretically predicted azimuth compression ratio anticipated in the experiment were not attainable, the largest technically attainable (probably 2000 to 1) would be the key factor in the design.¶¶¶ The processor was also to be designed to process data, which might

§§§ The first security problem of Quill arose in the circumstance that Lockheed's original radar satellite notion had been "briefed" widely, before it "went black." In mid-November, the Strategic Air Command asked Lockheed to provide additional information regarding the Lockheed-Goodyear radar proposal. Bradburn vetoed the trip and got word to a witting SAC officer to "lay off."[10]

¶¶¶ According to a radar associate contractor employee, an early objective of the program was to place emphasis on obtaining fine azimuth resolution to the greatest possible extent—optimally ten feet—while aiming for a more readily predictable 50 feet in range resolution. As factors determining range resolution were generally well understood, it was desirable to the experiment and potential future projects to determine whether adequate compression of azimuth-phase histories of targets could be realized[11] be obtained under conditions that were departures from the planned experiment, as might occur during actual orbit. Primarily, those discrepancies were to include departures from the intended orbit of the vehicle and from the intended orientation of the physical beam.

In addition to processing the radar data, the radar associate contractor proposed to link the ground recording system to the optical display converters. The associate contractor also suggested developing and procuring microwave beacons to observe and record emission histories. Lastly, the organization proposed designing a test to determine the limitation on compression ratio imposed by the camera drives in the radar system.

The associate contractor's representative agreed to send to Bradburn by mid-December two work statement drafts to be approved for content and security. One would be complete; the second would be "sanitized," omitting any reference to actual satellite operations or satellite derived data, any reference to Goodyear, Lockheed, Special Projects Office, or the delivery of reports on "Design of Experiment." The problem of conducting covert work in the associate contractor's setting was not as easy as with Goodyear and Lockheed, but the basic procedures were much the same. As with Baird in Phoenix, the associate contractor's security officer was not to be briefed unless it became unavoidable at some later time.[****] Uncleared personnel were not to be aware of the existence of an orbital radar experiment,[††††] or that satellite derived data had been or would be processed by the organization, or that the organization had created a working relationship with Lockheed, Goodyear, Space Systems Division, or SAFSP.[13]

In mid-December, Bradburn learned that the organization on the existing contract would be able to revise its contract with the associate contractor to include Quill work before the contract expired in March. A few days later, Goodyear's draft work statement, specifications summary, and delivery schedule appeared. Not surprisingly, April 1964 rather than January 1964 had become the target for first flight. A formal Goodyear price proposal still was lacking, but Bradburn privately expected that it too would depart from the estimates earlier forwarded. When Quill had first been approved, four months earlier, Major Bradburn had very informally observed to Major John Pietz, with whom he then shared an office, that he expected the formal cost proposals to exceed preliminary estimates by a factor of two or more, and that his past experience with the several aspects of Samos led him to conclude that schedule revision would immediately follow the opening of negotiations for firm contracts. Shortly after being named project manager, Bradburn discussed those cost proposal expectations with General Greer. General Greer responded with an ironic smile and gave full support to the suggestion that Bradburn's cost estimate be used in requesting program approval from Charyk, rather than some modest variation on the proposal estimates first received from Lockheed and Goodyear. Lockheed's proposal of mid-1962 had postulated a cost of several million for a five-mission program; Bradburn calculated probable costs for three launches, but only if he could keep program objectives substantially unchanged from those approved by Charyk in November. There was no other way of preventing the cost growth that had characterized so many venturesome Air Force programs of the past decade. Concern for costs largely explained Bradburn's continued reiteration of primary program goals in discussions with contractors. He wanted all concerned to understand that in no circumstances would he consider incorporating either work additional to or technology newer than that originally contemplated.[‡‡‡‡]

In accepting the schedule revision, Bradburn pressed Goodyear to agree to build the transmitter modulator unit in Phoenix rather than Akron as originally planned. Aside from tightening security, that move would enhance engineering control over the significantly critical unit, which was going to require extensive redesign for radiation cooling. Although protesting that key personnel would have to be moved from Akron, Goodyear agreed.[14]

By early January 1963, the status of the Quill budget was becoming clearer. Cost proposals from contractors at this point in time were slightly under-running the tentative budget approved by the NRO comptroller the

**** It did. Indignant that he'd been left out of the loop, the associate contractor's security officer ignored strong hints to drop inquiries into security clearances at the organization for Quill work. He finally was briefed in April 1964. [12].

†††† Best laid plans had a way of being stepped on by idiots. The associate contractor's representative's secure phone system, essential to his operations, was installed virtually in the dead of night and in a manner that was designed to be wholly unremarkable. On the following day the local telephone people asked how they wanted to be billed for all the special work, thus enlightening several administrative people to the fact that the representative had a special phone and was a consultant to the Air Force for some spooky operation.

‡‡‡‡ In early 1963, General Greer's organization was battling a series of cost growth problems, virtually all of them having originated in faulty initial estimates by contractors and uncritical acceptance of optimistic projections by various program managers. Bradburn, who had by then spent nearly two years in Greer's plans and policy group, was fully aware of existing cost control problems and their origins. Colonel King, under whose guidance the Quill program had progressed from proposal to initial approval, was another whose skepticism about the validity of contractor proposals was pronounced and who shared with Bradburn the conviction that high-technical-risk programs entrusted to large management groups with complex reporting channels were sure to overrun. Quill and the P-35 (Project 417) weather satellite programs were the first SAFSP undertakings which conformed to the Greer-King philosophy, although Gambit was reconfigured to that model in 1963 after King became Gambit program manager. The archetype of small-staff, direct-management, risk minimization was Corona, as originally organized. The most successful commercial practitioner was C. L. Johnson, Lockheed's leading aircraft design manager, whose products included the original F-80, the U-2, and the A-l1.

previous November. Goodyear was estimating costs for fiscal 1963, 1964, and 1965 in black funds. White monies to Lockheed's 800-contract were estimated for 1963, 1964, and 1965. White funds transferred were expected to total the same in fiscal year 1963 and 1964, and less in fiscal year 1965. Proposed total costs for the Quill contracts for fiscal years 1963 and 1964 were less than the approved budget and reduced in 1965. Total costs for all three contracts were estimated to be less than November's approved budget. In November, working with his own figures, Bradburn had estimated total program costs to be less than the approved budget plus costs for boosters, launches, and orbital operations.

The three TAT/Agena D's with modifications, launch services, and three reentry capsules were additional costs to be funded, rather than as basic NRO costs. Additional costs included: Agena D plus launch, TAT plus launch, telemetry, tracking, and command (vehicle), and operations. Together, these doubled the price of the program.[15]

Meeting with those involved in the associate contractor's other contract in January, Bradburn approved the white and black versions of the contracts, but deleted some of the tasks the associate contractor had earlier proposed. He had decided that the raw radar film should be developed by the Satellite Photographic Processing Laboratory at Westover Air Force Base, Massachusetts, rather than by the associate contractor, although they would provide engineering liaison services. The ground-based photo recorders (for use with the readout mode of data retrieval) would be applied by Goodyear rather than the associate contractor. Lastly, Lockheed rather than the associate contractor would build the microwave beacons.

Under the circumstances, Bradburn decided that no formal black contract need be written for the associate contractor, since most of the very sensitive work had been assigned elsewhere. The white contract would therefore become the only binding agreement. Bradburn felt the motivation was so high at the associate contractor and his contacts with them so frequent that any black statement assigning deadlines for the reports that comprised most of the remaining black effort there would be extraneous.

It appeared that the associate contractor's effort would include costs for system design and analysis of parameters; data analysis and final report; design and build, and operate the optical correlator; collection and analysis of radar and beacon signals; design and operation of the camera drive evaluator. Of the total, about one-third would be spent in fiscal year 1963 and the remaining two thirds in fiscal year 1964.[16]

Basic arrangements having been made, Major Bradburn briefed Dr. Brockway McMillan in March and again in May 1963 (McMillan had replaced Charyk as Director, NRO early in March) describing the refined parameters for the Quill experiment as then designed and bringing him up to date on the status of Quill contracts, budget, and technology. It was Bradburn's first opportunity for describing fully the content of the program he had just created.

As defined in May 1963, the radar payload components of Quill consisted of (1) a transmitter-modulator, which was basically a high-power radar frequency (RF) pulse amplifier; (2) an RF-intermediate frequency (IF) unit, which generated a low-power RF pulse for the transmitter and received and compressed the reflected radar pulse; (3) a reference computer, which generated timing and control signals (and transmission pulses) and synchronously demodulated the received intermediate frequency to provide video data; (4) a power control unit, which controlled and switched power and generated regulated voltages necessary for the radar; and (5) a recorder, which recorded the received video from the reference computer on film by exposure from the face of a cathode ray tube.

Goodyear had estimated that in its operating mode the radar system would consume 2700 watts of power. (Radiated effective peak power was 450 kilowatts, actual peak transmitter power 30 kilowatts, and average transmitter power 250 watts.) The length of the transmitter pulse was 0.9 microseconds. By the use of pulse compression techniques, this was reduced to an effective pulse width of .06 microseconds. Pulse repetition frequency (PRF) had a l6-step variable range from 8216 to 8736 megacycles. The radar operated on a frequency of 9500 megacycles per second. Given such parameters, Bradburn estimated that slant-range resolution would be 50 feet and azimuth resolution 50 feet or better.

The Agena was to be injected into a near-circular orbit of 130 nautical miles (plus or minus 13 miles) at an inclination of 70 degrees. Precise attitude stabilization of the vehicle would orient the radar antenna so that the main lobe of the radar beam would be at a fixed depression of 55 degrees from the horizontal. In that attitude, the radar would map a slant-range interval of 5.95 nautical miles, or about ten miles along the ground.

Active radar operation was to be confined within the limits of the continental United States—and within the limits of control of the Vandenberg (California) and New Boston (New Hampshire) tracking stations.§§§§ The data obtained from the payload would be in the form of target echoes, which would be synchronously demodulated to preserve both phase and amplitude aspects of the signals. The resulting raw radar map data (a Doppler history of the illuminated terrain), would be recorded photographically on film in the recoverable capsule aboard the satellite. Simultaneously, the data signals would be transmitted over the wide-band data link to tracking stations, where they would be recorded both on photographic film and on wide-band magnetic tape recorders. After mission completion, the film record in the satellite would be recovered near Hawaii by air catch of the reentry capsule.

The radar antenna, being built by Lockheed, was a two dimensional slotted-waveguide array, 15 feet long and 1.8 feet in height, uniformly illuminated in both directions. The high-power output pulse of the radar was transmitted through the flat, phased-array antenna mounted on the side of the Agena, with the beam oriented perpendicular to the vehicle's longitudinal axis but depressed 55 degrees below horizontal. The beam was 36 degrees wide in the azimuth direction and 2.9 degrees wide in the vertical direction at the half-power points.[17]

Some of the early premises had to be altered early in the development program. The associate contractor's researchers learned, for instance, that bias errors generated by the Agena's attitude changes during flight were too large to be accommodated by the radar beam-width. To ensure that "zero Doppler" direction in azimuth would result, a clutterlock or electronic beam steerer had to be designed within the reference computer. Although the clutterlock oscillator output could conceivably degrade date returns, the associate contractor's group predicted that no serious degradation would occur except at initial lock-on.

McMillan was concerned about the assurance of obtaining qualitative data to support evaluation of radar performance. He therefore directed that ground resolution targets be provided so that a direct measure of radar resolution could be obtained from analysis of a finished radar map. He also suggested incorporation, of an altitude rate change recorder in the vehicle. (Changes in altitude rates would degrade the azimuth resolution; if accurate rate data were available during evaluation, degradation from that source could be more readily identified.)[18] Bradburn made the associate contractor responsible for resolution measurements and asked Lockheed to evaluate the feasibility of incorporating a rate recorder.

Bradburn also asked Lockheed to reverify reference computer specifications. Electronically, the most complicated component of Quill, the computer, was experiencing severe vibration problems, which, in the RF-4C program, were causing some structural redesign. Quill program specifications required testing at 7.5 Gs; the original computer, designed for aircraft use, had failed at 3 Gs.

Less threatening but equally troublesome problems appeared in the procurement area in April. Goodyear began experiencing difficulty in buying government-inspected parts under commercial auspices. A tentative solution had been initially worked out by having the local Air Force procurement specialist verbally approve as "Contracting Officer" Goodyear's requests for the delivery of high-reliability components. The rationale "we might sell it to the government" was used to justify the implied use of government-approved items in what was represented to be an "in-house" company-sponsored program. That tenuous network collapsed in early May when a government inspector, who had been "officially" asked to release parts from a bonded warehouse for which he was responsible, called Goodyear's security officer to confirm that the commercial purchase order he had received actually supported a government contract. Routinely attempting to confirm that the listed parts would be used in work for the government, the security fell into the local cover story—that they were needed to support a proprietary contract. Convinced that he had stumbled into something unsavory, the security officer immediately blocked the purchase. An alarmed Goodyear executive hurriedly notified the procurement specialist who called the security officer to verify that the work was indeed Air Force sponsored. The security officer, still sensing something highly irregular, said stiffly that he was obliged to notify his superiors in the Navy procurement chain. Seeing visions of a total collapse of security, the procurement specialist hurriedly alerted Bradburn, who instructed him to use some excuse—any excuse—to stall the security officer until program office personnel could get to Phoenix. The security officer grudgingly acceded to the procurement specialist's plea to postpone any action until the following Monday. (It was then Friday afternoon, and Bradburn appreciated that a delay until Pentagon closing time would represent two days of grace.)

§§§§ One of the principal doctrinal problems of conducting a radar-in-orbit experiment was uncertainty about the reaction of the Soviet Union. Although there were various justifications for using radar sensors for overflight reconnaissance—all-weather, all-season, all-sun position capability encompassing most of them—and no wholly rational reason for concluding that active radar in orbit would be more objectionable to a target state than photography, the sensitivities caused by the U-2 affair of May 1960 still were evident in 1963. (For entire text of footnote, please see end of chapter, p. 20.)

Colonel Ruebel and Major Bradburn flew to Phoenix on Sunday and enrolled the security officer who agreed to support the project. They agreed that all future requests for verification of government interest in commercial purchase orders would be referred to that security officer directly and he would confirm their validity. The security officer also agreed to assume the function of acting as cognizant security officer over the closed areas of the plant. No other Naval personnel were to be briefed or made cognizant of any special requirements.[19]

The potentially more troublesome problem of arranging, through the CIA, for General Electric to build and deliver three Corona-configured recovery capsules for use in the Quill experiment was resolved in the early Spring also. As with Lanyard and Gambit, CIA personnel were apprehensive about a security leak. Discussions between SAFSP and CIA security specialists in a series of meetings led to the agreement on 9 April 1963 that the procurement could proceed. The three capsules would be handled under Corona security procedures until their delivery to Sunnyvale and would thereafter be handled under Quill procedures.¶¶¶¶ Once that hurdle had been passed, the contracting and funding arrangements were quickly resolved.[20]

The first serious threat to scheduling expectations and Quill success occurred in early June 1963. Dr. McMillan had earlier expressed concern to Bradburn that arcing in high-voltage power supplies might become a problem. The original Goodyear specification, approved by Lockheed had established a level of .001 millimeters of mercury as the highest pressure in which the payload would operate. High-voltage arcing would not occur if that assessment were correct. Bradburn, nudged by McMillan, decided to insist on verification of Goodyear's estimate and asked the project manager for Lockheed to cover that item during the next monthly program review in late June. Although he did not fully share McMillan's concern, Bradburn asked for a complete review of design considerations, parts qualifications history, and qualification testing for Lockheed and Goodyear-furnished high-voltage supplies and any circuit points where high voltage existed.

Not until 17 July was the Lockheed team able to present its initial report, but the partial study was enough to indicate that a serious problem existed. Actual measurement revealed that pressures in and around the payload boxes could possibly be 10 to 100 times higher than anticipated. The greater molecular density thus suggested made it highly probable that high-voltage arcing would occur.

¶¶¶¶ The differences were entirely academic.

During the next several weeks Lockheed employees evaluated redesign alternatives, considered testing difficulties, and weight penalties, and estimated the effect of the unforeseen rework on launch schedules. There were, fundamentally, three feasible responses to the arcing problem: pressurization, to drive molecular densities above the critical level; venting, to help pressures remain sufficiently low; and insulation by the use of a potting compound. Goodyear strongly recommended that the transmitter be pressurized (as had been done in the RF-4C version) and maintained so that a pressure vessel could be designed and tested on the same time scale as a potting program, favored by Lockheed. Concerned by the conflict of opinions, Bradburn pressed the Lockheed investigators for more details and learned that Lockheed too would have recommended pressurization if the problem had been recognized at the outset of the program. He immediately ordered that preparations be made to pressurize the transmitter and any other modules that looked critical.

By the end of August it had been decided to pot and pressurize the transmitter, to use only potting compound in the recorder, and to provide for a back-up pressurization system that could be re-evaluated for need by mid-September. All concerned conceded that the transmitter-modulator and the recorder would present the most complex insulating problems; but that the high-voltage power supply being developed by Lear Siegler for Lockheed and the RF-IF unit might also be troublesome. Arcing problems in the control unit and the reference computer seemed to be controllable through the application of a void-free insulating conformal coating.[21]

But it appeared that redesign and rework would cause a program slippage. An associated difficulty appeared during the late summer of 1963. Colonel John Martin, head of the NRO Washington staff advised General Greer that fiscal 1964 funds might be insufficient to cover currently projected Quill costs. He directed that the third Quill flight be deleted from the launch schedule and consigned as a payload spare. Requesting program re-costing by 10 August, Martin advised that although Quill was authorized to spend at previously approved rates through the first quarter of the new fiscal year, the program office should be prepared for a possible ten percent cutback thereafter. Martin assured Greer that he was proceeding "through OSD channels" to overcome the deficiency, and that should those measures fail, he would be notified immediately.[22]

At the end of August it was clear that Goodyear was eight weeks behind its original schedule and that official launch dates should be slipped by two months.

Bradburn attributed one month of the slip to Goodyear's engineering and parts delivery problems and one month to the high-voltage redesign requirements. He estimated that the delay would cause costs at Goodyear to go up somewhat.[*****] On the whole, Bradburn informed Greer on 30 August, Goodyear appeared to be doing a good job and Lockheed, although somewhat sloppy in systems engineering, was improving.[23]

By late September, the launch slippage had been officially confirmed and a new date for first flight—5 August 1964—had been targeted. Negotiations for the deletion of the third Quill flight were completed that month: the third Agena D vehicle and the Thor were cancelled, as were all Lockheed efforts on the third payload beyond the installation of the radar components in the payload-supporting structure. The third Quill was now treated as a spare payload that could be readied for launch within five to six months after the first Quill flight. Bradburn recommended that any further action on number three be deferred until the results of the first Quill flight could be evaluated.[24]

Early October 1963 saw a new design problem. Goodyear, attempting to meet the stringent vibration requirements of the program, concluded that the rigid payload rack mountings originally called for could cause payload performance degradation and called on Lockheed to provide vibration-resistant shock mounts. The initial approach, a simple substitution of mountings proved inadequate. Payload racks in manufacture were stopped for redesign, a process that promised to take a month or more. A new interior distribution plan for the component equipment was called for, plus modification of the secondary barrel structure to provide the required structural stiffness. Lockheed's program manager anticipated the racks could be delivered by early December. Although that schedule would be tight, overall program scheduling should not be affected.

Goodyear and the special Lockheed high-voltage team were not enjoying similar success. Tests of the potting design in September and October had been disappointing. Poor surface preparation and improper cleaning and primer application techniques were blamed. But even after potting compound adhesion problems were disposed of, altitude testing disclosed the appearance of corona around potted components and cables. Lockheed recommended the use of lightweight closed-cell polyurethane foam as a countermeasure to corona generation in the RF-IF box. Extensively used to insulate and support high-frequency components, several such foam systems had been used by Lockheed on varactor multipliers similar to that Goodyear was building. The expedient worked, eliminating corona and breakdown in the unit.

Elsewhere, however, foam as a corona suppressant was not successful owing to the lack of a primer that would act as an adhesive between the foam and the silicone-insulated lead wires and high voltage components. External corona problems could also be eliminated by potting high-voltage components in metal cans, and eventually Goodyear decided to combine that expedient with the use of braid-shielded high-voltage cables and a conductive epoxy to interconnect the components.

For a time it appeared that the solution was working. Then one of the cylindrical cans containing the thyratron component burst at the seam because of potting expansion caused by the heat of component operation. Goodyear adopted a square can configuration to allow for bulging during thermal expansion and began to experiment with expandable-top cans. Such measures, when supplemented by the addition of an aluminum sling in the anode area (to reduce the bulk of the potting), proved successful. No further problems were experienced with thyratron potting, although repeated failures were to occur in later testing from other causes.

As a further precaution against high-voltage breakdown and corona, Lockheed resorted to venting of the payload boxes, one-inch diameter screened vent holes being cut on three sides on each box.[25]

By January 1964, Bradburn was able to assure Dr. McMillan that the high-voltage problem was under control. Arcing and corona phenomena in the transmitter-modulator had been eliminated. The backup pressurization vessel could be cancelled. The RF-IF unit, reference computer, control unit, and recorder had all been successfully potted. Tests on the antenna model had indicated it would not need pressurizing.

Payload qualification testing was scheduled to commence in Sunnyvale in January and Goodyear was to deliver the first flight payload for acceptance testing in February. Payload final assembly and checkout would continue through April; full-scale system tests would begin in April and continue through June. A 5 August launch date still seemed to be achievable.[26]

The uncertainties of funding that had appeared several months earlier continued to be irritating but did not yet represent serious problems. Lockheed's Quill work still was being funded under supplemental agreement to another contract and Bradburn anticipated no change in

***** It will be recalled that Bradburn's schedule and cost estimates were less optimistic than those proposed by the contractors and formally incorporated in contractor program plans.

that situation for the near term. As expected, Goodyear's need for additional money had to be acknowledged in February, and funds for the associate contractors were sufficient only to support work through September— if expenditures were continued at the rate originally contemplated. Bradburn advised the associate contractor representative that in all likelihood no more than limited additional funding could be made available through the end of the year, which meant that the associate contractor would have to stretch six months of contract dollars to cover nine months of work. No major technical problems were immediately apparent, although corona effects had again occurred in the high-voltage power supply and there were minor but troublesome difficulties with transmitter power and transmitter-modulator units in February and March. For the most part the response of program managers was to increase the tempo of testing. All of the radar units were scheduled to emerge from the manufacturing process in March and other principal elements of the payload were on schedule. A still-minor conflict of launch-pad scheduling caused Bradburn some concern in March, but he did not anticipate that it would become serious. (He planned to use a NASA gantry to mate payload and booster elements of Quill, and NASA had informally indicated a possible need for the equipment at about the time Quill was due to go into orbit.)[27]

From the time of program approval through March 1964, only five months short of the scheduled first flight date, Quill had been managed almost entirely by Bradburn, for the Air Force, and the three principal contractor project leaders at Lockheed, Goodyear, and another associate contractor. Although he had reported frequently to Greer, and periodically to McMillan,

Bradburn had for practical purposes exercised complete and near exclusive control of the program. In March, Greer decided, as he told Bradburn, to call in some non-participating experts for a detailed overview of the work and of the operational readiness of Quill. In advising his contractor associates of the prospect, Major Bradburn emphasized that the review was "not an inquisition" and did not indicate dissatisfaction with any aspect of the effort thus far. But he observed that they could expect a "thorough scrubbing."[28]

The review had some undercurrents of interest that escaped the notice of those who merely read the eventual review report. It had begun, as Bradburn recalled, with Greer's usual report to McMillan, "Brad's doing fine," followed by, "wait a minute. How do I know he's doing fine. He's the one who's telling me." The "Tiger Team" to review Quill was Greer's rejoinder to his self reminder.

That the review would be thorough was guaranteed by the composition of the review team. Headed by Colonel Paul Heran one of General Greer's most capable senior managers, it was composed largely of Aerospace Corporation specialists in reconnaissance radar. Unhappily for their state of temper, they had become "specialists" mostly through involvement in the "P-22" project— the "white" program conducted in part to provide a screen of cover for Quill. P-22 participants had generally believed, until being suddenly briefed on Quill, that what they were doing was an extremely important prelude to what might eventually become a radar-on-orbit system. At the time of the briefing they learned that the radar-on-orbit system was not an abstraction but was in being—actually only about five months short of scheduled launch. They were, in Bradburn's recollection, "somewhat upset to learn there was a real radar experiment going on." They developed what Bradburn described as "an intense interest in the quality of Quill."[29]

The specially appointed Aerospace team (which included several Air Force people) had instructions to look at payload and vehicle system designs; at qualification test history on new components; at power ground equipment design, availability, and placement; at preflight checkout philosophy and the adequacy of test planning; at operational effects of recovery system changes; at competence of tracking stations and Satellite Test Center (STC) personnel to support the mission; and at tracking station equipment readiness. Briefed first by Bradburn, the team studied project documentation generated by the contractors before beginning meetings with Lockheed, Goodyear, and another associate contractor's personnel in early April 1964. The briefings concluded on 7 May and the report was forwarded to Greer shortly after.

Overall the Aerospace group was optimistic that Quill would accomplish its main objective: obtain a high-resolution radar terrain map from an orbiting satellite within the designated short span of time. Nevertheless; they were less sure the experiment would contribute significantly to secondary objectives encouraging an operational future for an orbiting radar satellite. Secondary objectives had been stated as (1) evaluate the resolution potential and limitations of satellite-borne, ground-mapping radar; (2) evaluate the capability to retrieve the mapping information in real time by readout over a wide-band data link; (3) evaluate the feasibility of using satellite-borne radar for terrain reconnaissance; (4) obtain sufficient engineering information to determine the cause of a failure to achieve the primary mission, or portions thereof; and (5) improve future system design. Acknowledging that useful information would probably be obtained to support evaluation of the "resolution potential and limitations" of orbital radars, the team anticipated that the flights would not produce findings of greater significance. The tenor of the report was to recommend for the second and third flights a restructuring of mission objectives and emphasis. Inherent in these criticisms was distaste for the design philosophy that had guided Quill from its onset: use as many off-the-shelf components and as little modification as absolutely required. Perhaps no less could be expected of a group that until a few weeks earlier had considered itself to be leading the way to the first orbiting radar system.

The review group argued that "the use of a wide-band link for the retrieval of synthetic array radar data cannot be fully evaluated from the Quill experiment. Negative results will not be conclusive since the link was not engineered for this application. Positive results will not be conclusive since the quality of the Quill data is not representative of a high-quality radar." And elsewhere: "Since much better mapping performance than the Quill radar will provide is technically possible, this program will not fully evaluate the potential of orbital radar for high-quality terrain mapping." The group concluded rather tepidly, that at its least the experiment would determine the cause of "catastrophic failures."[30]

The first two recommendations of the report concerned work by the associate contractor supporting the project intended to define the sources of final image degradation. The reviewers urged that data be continually updated throughout the program with equal consideration for data retrieval from the capsule and via the wide-band data link, and to post-flight analysis of the final map product. Bradburn agreed that the researchers should devise both analysis and evaluation plans to satisfy the recommendations. But he did not accept uncritically a recommendation focused on the secondary objectives of the mission. The Aerospace team felt that consideration should be given to flying Quill in a lower orbit (which would nominally improve the signal-to-noise ratio) and in a synchronous orbit (which would permit Quill to overfly the same target on successive days). While the planned orbit seemed to satisfy the primary objective of the experiment the team felt it "marginal for the purposes of the secondary objectives."

Pointing out that a lower orbit would decrease the swath width and the payload operating times and thereby decrease the probability of seeing the resolution targets, Bradburn's people argued that "marginal enhancement" was not a sufficient justification for changing vehicle altitude. If the first flight were successful, lower flight altitude would be considered for follow-on flights. Synchronous orbits had been considered early in the program, but the necessary orbit adjust capability had been discarded because it ran counter to Quill's "minimum modifications" policy. Bradburn felt that gains from overflying selected targets on successive days were not worth the extra effort—and cost—of incorporating orbit adjust capability in the Agena.

The committee's report took note of several problem areas already well known to Bradburn and the contractors as a result of qualification and acceptance testing. They included, among others, "thumping" in the transmitter-modulator, continued cracking of the potting compound after repeated temperature cycling, and cathode ray tube spot sensitivity to vibration effects. The reviewers also expressed concern that antenna testing had not been sufficiently intensive, urging comprehensive tests to verify the characteristics of an antenna they characterized as an advance in the state-of-the-art (because of its size and its required precision). On the whole however, the acceptance and qualification testing program received approbation. The review team noted that system testers "appeared to be capable of giving the subsystems a thorough checkout; the schedule of retesting after major environmental tests was very good." But program reviewers also recommended that the associate contractor supporting the project prepare a system error budget to insure that tolerance margins did not become excessive, with a resulting degradation in payload performance.

In the end, the review team concluded that "no individual factor was uncovered which can be expected to prevent accomplishment of the primary objective of the Quill program." There were the usual injunctions urging continued diligent system engineering, analysis, and testing. The only significant remark in that category proposed "closer control of overall performance criteria to eliminate the possibility of either over-specifying or under-specifying subsystem requirements." The committee also felt that the three principal contractors insufficiently appreciated the problems of interfacing such subsystems as attitude control, data link, and the antenna.

But on the whole the review had to be considered approbatory of program conduct.[31] Comprising some 33 recommendations attended by lengthy comments, the report was submitted to General Greer, after which the program office and the main contractors spent much of May and June in responding by both comment and action.

In the meantime, Bradburn was more concerned with troublesome failures of the transmitter-modulator boxes in temperature-altitude simulation tests. During late

March and early April, the first such complete test had been interrupted by power supply failure—blamed on a faulty capacitor—and transmitter-modulator breakdown in altitude tests (charged to poor circuit design). After circuit redesign, a second altitude-temperature test of the complete payload, began on 6 May. Results were reversed. The transmitter passed altitude testing but during the sea-level run the klystron failed. After reviewing test status, Bradburn concluded late in May that 29 August 1964 was the earliest possible launch date and that the next series of environmental tests was likely to uncover more difficulties. He recommended that 29 August become the new launch date target, but that the program office be prepared to accept further delays.[32]

In June the potting problem drew new attention. Lockheed had reported to Bradburn in late May that Goodyear had no written procedures or quality control for potting procedures. Bradburn's response was to notify Goodyear that he wanted standards written and also to instruct the radar contractor to build eight of each potted item, to test all eight, dissect three, and if all three were good, to pass the remaining five. Although the remaining difficulties seemed relatively small, the schedule of manufacturing and acceptance testing had been irreparably affected; in July it was necessary to specify an additional two-week delay in the scheduled first launch. Goodyear's hardware delivery problems were the principal cause of the slippage.[33]

One of the important residual uncertainties of component interface compatibility was resolved by late July. In a series of tests at its Santa Cruz facility, Lockheed ran comparison tests of a parabolic antenna and the flight antenna, both aimed at a corner reflector four and a half miles distant. Test criteria was to compare pulse transmitted and received through the horn or parabola with the pulse through array in order to measure distortion of radar pulse caused by the flight antenna. The third objective was to measure system range resolution. Results demonstrated that the flight antenna was compatible with the basic radar generator, the antenna did not cause pulse distortion, and range resolution (with a corner reflector as a target) was better than 25 feet.

For all that reassuring news, the program incurred another schedule slip. Pulse-forming network redesign problems and klystron and plate choke potting failures in the transmitter-modulator forced a rescheduling of first launch to 24 October.[34] Then on 8 September, one of the klystrons in the transmitter-modulator failed during an altitude-temperature simulation checkout experiment. After replacement of the damaged elements, testing was resumed. Further component failures in the transmitter-modulator elements early in October forced Bradburn (now a Lieutenant Colonel) to postpone the scheduled first launch once again, this time to mid-November. In order to verify confidence in the reliability of the first flight-qualified payload, he insisted on exposing the complete unit to five hours of simulated operations at the temperatures and pressures that would be encountered during the mission. That represented about ten times as much operation as the equipment would be required to produce during its initial flight, but Bradburn was convinced that nothing less than a "thoroughly run-in but not worn-out" approach would satisfactorily demonstrate the reliability of the troublesome components.[35]

Goodyear was unable to promise delivery of a test-qualified transmitter-modulator unit before the last week of November, unexpected problems developed in final tests of the film drive unit of an orbital recording camera, and confidence in the design validity of the potted, shielded boxes earlier adopted to prevent high-voltage arcing was rapidly diminishing. (In November, Goodyear began the development of a backup design which discarded the shielding.) Although none of the problems were basic, all contributed to delay of delivery and testing schedules. A December first launch seemed achievable if technical readiness was the only criterion, but the classic problem of seasonal holidays introduced new scheduling complications. By mid-November, Bradburn was juggling holiday schedules, environmental test schedules, and launch pad (and satellite operations capability) availability in an effort to decide when a launch should be attempted. If Goodyear successfully completed altitude-temperature tests of the critical transmitter-modulator unit on 28 November as promised, launch could be attempted by 19 December—the last possible date for starting the mission without encountering holiday workload problems that might not succumb to a mere program manager's determination. After confirming his judgment in a meeting with Greer, Bradburn decided to push for a mid-December launch—which meant pressing Goodyear to complete the last of the environmental tests on or as close as possible to the critical 28 November deadline.[36] And he had another problem: although the essential validity of program funding remained intact, the recurrent delays in initial launch meant that both Goodyear and Lockheed were spending money that had originally been allocated to post-first-launch development and testing activities. (Lockheed calculated the amount expended in unprogrammed work in the period between the originally scheduled March 1964 launch date and the end of November 1964.)[37]

Late November and early December were thoroughly cluttered with technical and administrative problems that ranged from the absurd to the critical. Many months earlier, Bradburn had arranged matters so that no sudden influx of Goodyear people at Sunnyvale, Vandenberg, and the tracking stations would alert unwitting people to the imminence of an orbiting radar experiment, and in the event matters proceeded more or less as planned.††††† But there was late pressure to put Quill products in the Talent-Keyhole category, which meant making them available to a great many people who had been excluded from any knowledge of the NRO's plan to fly a radar satellite, and Bradburn had to divert his attention from technical to security matters, at least briefly, to prevent a breakdown of the original scheme.[38]

The transmitter-modulator tests finally were completed successfully on 2 December, resolving the chief remaining uncertainty of Quill qualification. Delayed delivery of Philco-produced data-link equipment to the Vandenberg tracking station briefly threatened postponement of launch pad system checkout, but by 5 December that too was settled happily. (Actually, several items of critical equipment were delayed in delivery, but Goodyear's transmitter-modulator was the pacing item through the last three months of pre-launch testing.) The last really troublesome issue revolved around the preposterous question of the high-temperature behavior of that common household item called Mystic tape—and for a time it threatened to delay the launch once again.

"The Mystic Tape Problem" had its origin in the temperature sensitivities of the main batteries in the Agena. In the wake of several battery failures and real failures in Agena flights earlier in 1964, Lockheed engineers had narrowed the allowable launch window for Agena-payload missions (thus changing the sun exposure characteristics of standard missions) and had redesigned the external paint pattern of the spacecraft. Black paint was applied to those portions of the vehicle where heat absorbance was desired, and reflective material elsewhere. The reflective material selected was adhesive-backed aluminum tape—Mystic tape. It covered 104 of the 255 square feet of the outer surface of the Agena's forward equipment compartment. Two weeks before the now-scheduled 21 December launch of Quill, a Vandenberg technician placed one of the Mystic-taped removable panels of the Agena under a heat lamp. It blistered. Although the manufacturer guaranteed that the tape would adhere to external areas where temperatures would not exceed 750 degrees (Fahrenheit), materials specialists at Vandenberg quickly determined that molecular outgassing in a low-pressure environment would cause blisters to form on the underside of a tape at temperatures of only 300 degrees. When blisters became large enough to extend to the edge of a piece of tape, the trapped gas escaped and the tape collapsed, reattaching itself to the surface—unless the blister reached the forward edge of the tape while there was a forceful airflow along that edge. In that case, it could conceivably fold back and tear away in the airstream. If enough tape broke away, battery overheating could result and mission success would be imperiled. It was a classic horseshoe nail phenomenon. Happily, the vulnerability came to light before launch rather than in a post mortem. Launch base personnel were instructed to tuck the tape over the leading edges of all removable panels and to cover with stainless steel strap all those edges where there were no removable panels. Extensive tests confirmed that the reflectance properties of the thermal control surfaces would remain within required tolerances if that precaution were taken.[39]

Simulated launch and flight tests and other compatibility tests at Vandenberg during the first half of December uncovered only a few minor glitches—a defective bearing in the film supply spool in the recorder, transients in one of the power supply units among them—but these were readily fixed and no significant malfunctions were detected in the integrated satellite system. The completion of the countdown, launch-minus-three-days checks, and the horizontal simulated flight operation completely revalidated flight vehicles and payload. The only exception to a complete functional check was radar transmission through the flight antenna, which had been validated in earlier testing. Every other payload function was exercised in the final flight configuration.

On 19 December the gantry was removed, and because rain was falling, a protective polyethylene cover was placed over the forward (payload) sections of the Agena. High winds during that night caused the cover to repeatedly slap against the newly-taped surfaces. When the gantry was repositioned the day before scheduled launch and the "protective covering" removed, launch personnel discovered that most of the normally shiny aluminum tape surface had been degraded to a dull, and in some areas, almost black finish. Additionally, finely divided aluminum had been transferred to adjacent painted surfaces. Happily, Lockheed's optical surface comparator was still in the gantry, so new measurements

††††† The arrangement was that Goodyear people visiting Sunnyvale would wear Lockheed identification badges and describe themselves as self-employed consultants to Lockheed if questioned about their status. At Vandenberg and the tracking stations they were given credentials identifying them as consultants to the Air Force, no corporate affiliation being specified. Because friends and families were not permitted to know that airborne radar specialists were involved with space programs, various cover plans had to be devised that would conceal the whereabouts of engineers who while actually visiting one of the space stations was nominally somewhere else. It would be interesting to learn how successful Goodyear people were in convincing spouses that their frequent out-of-touch trips were as innocent as represented to be.

could be taken at once. Less happily, the measurements indicated that the solar absorptivity of Mystic tape surfaces on the cylindrical sections of the vehicle had been increased by as much as 300 percent! Tape on the conical section had not been unacceptably degraded. But clearly large sections of tape would have to be replaced and painted surfaces cleaned.

Beginning with the surfaces most critical to battery temperatures, technicians replaced approximately 75 percent of the tape earlier installed on removable panels and cleaned the painted surfaces with distilled water and a mild abrasive soap. Ten hours before scheduled launch, the rework was completed and the gantry was removed. All but about 15 square feet of the degraded tape had been replaced, but as a further insurance measure the normal two-to-four-hour launch window was reduced to 48 minutes at midday, thus lessening the time during which the reflective sections were exposed to direct solar radiation.[40]

On 21 December 1964 at 11:09 Pacific time, Quill vehicle 2355 was launched from Vandenberg Air Force Base and injected into an orbit of 70.1 degrees inclination with an 89.4 minute period. All subsystems functioned properly. Tracking station personnel verified the operability of the data-link equipment during Quill's seventh orbit and on the next passes over New Hampshire and Vandenberg radar mapping was attempted. All were successful. Diagnostic telemetry returns indicated correct functioning of all payload components. Both stations recorded video information. Operator's displays showed the expected patterns. Ground recording equipment operated by project scientists showed the radar transmission to be radiating strong signals. The lead research scientist reported to Bradburn that a quick look at readout data from pass eight on a projector showed successful ground painting. A reconnaissance aircraft scheduled to photograph the "painted" ground swath was unable to fly because of poor weather in New England, but otherwise all went perfectly. Recovery was planned for 22 or 23 December, the final decision hinging on the higher priority of a Corona capsule also scheduled for recovery on one of those days.

Reports from the Quill command post at Sunnyvale on 22 December indicated continued mission success. The lead research scientist reported that data read out from pass eight, which at first seemed to be severely degraded, were susceptible of improvement if the correlator were refocused by hand. He also told Bradburn that the receivers had captured a successful wide-band recording of transmitted radar pulses confirming proper phase and amplitude characteristics and that a mobile narrow-band recorder positioned at the research facility had verified the correct functioning of the antenna.[41]

The payload continued to operate nominally through orbit 25, using 316 feet of film. Reporting to Greer on subsystem activities, Bradburn indicated that radar frequency power output and high voltage were well within predicted limits. Minor engine chamber pressure fluctuations during boost thus far represented the only-mission anomaly, although heavy cloud cover was causing some slightly out-of-specification roll excursions when the horizon sensors were turned on. (The horizon sensors, providing long-term pitch and roll stabilization for the vehicle, were not used during radar operation. Their response to cold clouds could conceivably cause instabilities which could lead to serious degradation of azimuth resolution.)

A second attempt to photograph terrain as it was being viewed by radar ended in another weather-induced flight abort of the assigned aircraft, but satellite operations continued to be flawless. When Corona flight controllers decided to continue their change in orbit until 23 December, Bradburn ordered Quill recovery to be conducted one day earlier.[42]

As with the balance of the mission, capsule recovery was routine. After retrieval and despooling, the film was dispatched to the special processing laboratory at Westover, arriving during the morning of 24 December 1964.

Quill's radar system was operated for a total of 14 passes over the continental United States between 22 December and 26 December. Thereafter electrical power and stabilization gas exhaustion prevented further experimentation and the Agena was deliberately destabilized for destructive reentry. It reentered over the South Atlantic on the morning of 11 January.[43]

As General Greer later wrote, "The flight of the satellite when it came in December 1964 was almost anti-climatic. So close was the system performance to that determined in tests, so nominal was the operation, so professional was the handling of the satellite by the Satellite Control Facility, (that) a participant had to remind himself that this was not just another rehearsal . . . The result was a 100 percent successful mission in quality and duration."[44] What remained was to evaluate the Quill take and to determine the immediate future of satellite-borne radar systems.

On 5 January 1965, Bradburn and the chief contractor project managers presented a P-40 "Quick Look" briefing in Washington.[‡‡‡‡‡] The primary objectives of the mission had been fully satisfied. Initial evaluation of final map quality, using recovered data film revealed azimuth resolution at 10 to 15 feet and ground range at 60 feet, far exceeded the project's resolution requirement of 100 feet or better. There had been no vehicle or payload system malfunctions of any significance.

Bradburn proposed postponing the launch of the second Quill vehicle until the several contractors could complete an intensive engineering evaluation, a process that would take almost six weeks. Decisions on whether or how to operate the second and third flight systems could be made on the strength of the initial analysis although a comprehensive engineering analysis would last for three months. McMillan promptly approved both proposals.

Final reports on the first Quill mission involved a quantity of material available for analysis in addition to the radar maps: telemetry records indicating vehicle attitude and radar performance, engineering specifications and preflight test results on equipment, computer best-fit orbit and attitude history, weather data, ground measurement of azimuth beam pattern, one-way pulse recordings, results from the corner reflector layout at the post-flight aerial photographs of target area, and radar maps of target areas taken with the airborne radar equipment. One of the most critical post-flight evaluation reports was that prepared by the associate contractor supporting the project, indicating the extent to which Quill's primary and secondary goals had been met. Responsible for preparing "the highest possible" final radar maps from both recovery and readout data, the organization's researchers measured range and azimuth resolutions and estimated system dynamic ranges. That analysis revealed the relationship of measured results to the radar design and performance parameters of Quill, propagation conditions, vehicle behavior, and data link performance.

The audience in the Pentagon on 5 January was able to view samples of the Quill output maps in the form of photographic prints and negative transparencies. Three different sets of maps were displayed. First, were maps made from the recovered data film, then maps reconstituted from tracking station photographs of the signals from a wide band data link, and finally maps made by playback of magnetic tapes of the data link signals. The recovered film provided the highest quality maps, and the magnetic tape playback data the poorest—because both data link and tape recorder signal losses were involved. But all were "good."[§§§§§] Bradburn was voluble in his praise of the rapidity and excellence of processing of recorded and recovered materials.

Although there was little explicit discussion of when, or if, another Quill mission would be flown, neither Greer nor Bradburn saw any need for one. Results had so thoroughly exceeded reasonable expectations that there seemed no justification for collecting additional data.[44]

Nevertheless, until a decision was announced the program office continued to study modifications that might improve the quality of returns from a later Quill mission. Quill contractors urged that a second experimental flight carrying modified equipment be attempted in September 1965. Bradburn thought the probable gain too slight to justify the cost—and so advised Greer. On 11 February, Greer told McMillan that the feasibility of radar reconnaissance had been "amply demonstrated" and that additional launches should not be scheduled until there was agreement on "desired operational use." He endorsed Bradburn's recommendation that Quill be closed out with the final reports due in April and that hardware be put in storage to include the vehicle equipment at Lockheed and all black radar hardware and ground equipment at Goodyear. Any decision to reactivate equipment for a second launch would require a minimum of nine months lead time, but Greer felt this break in the continuity of the project was justified in view of the "thorough evaluation" that would be given to the first Quill's returns in the meantime.

Greer carefully refrained from advocating the termination of satellite radar studies, but he argued that Quill data made it feasible to proceed using aircraft and ground tests, laboratory experiments, and other non-specialized satellites. "We have provided a good basis for further exploration of an operational system. This work should proceed when the conclusions of your evaluation committee are available," he told McMillan, who agreed.

Although Quill hardware was destined for storage, either permanently or temporarily, and plans for additional launches of the original Quill-configuration satellites had all but been cancelled, there still remained the original issue of whether radar satellite bomb-damage assessment or crisis management systems should be developed and deployed. And still to be formally assessed by intelligence specialists was what the Quill experiment had contributed to a better

‡‡‡‡‡ With Bradburn were representatives from Lockheed, Goodyear, and the associate contractor supporting the project.

§§§§§ All radar imagery was impressive, pictures of Phoenix, Chicago, and Richmond (Virginia) being particularly interesting for the detail they contained. Barges, ships, and railroad trains were readily identifiable through cloud cover, fog, and rainstorms. So were fine geographical details: hills, dams, streams, highways, islands . . .

understanding of both requirements and technology. Brigadier General James T. Stewart, who succeeded Brigadier General John L. Martin as chief of the NRO staff, had suggested in October 1964 that a formal evaluation team be immediately organized to determine means of "maximizing the knowledge gained from the Quill feasibility demonstration." At that point Bradburn and Greer were much more concerned with resolving equipment qualification problems than with planning for the evaluation of results that might or might not be returned by the first—or the second or third—Quill mission. Stewart wanted to schedule—and organize—a full-scale operational utility analysis. Greer, in the circumstances, urged that "we should avoid fanfare over this effort," that Quill as a system had absolutely no known operational utility or adaptability and should continue to be treated as an R&D project, and that the NRO should wait ". . . until after we have recovered and reconstituted something worth evaluating from an intelligence viewpoint . . ." before setting afoot any elaborate evaluation effort. It was all consistent with his position on Gambit and reflected the pragmatism of experience with the wholly unsuccessful Samos E-5 and Samos E-6 systems, only recently cancelled. Greer convinced Stewart, and the matter dropped from sight for several months.[47]

Owing in part to the increasing acrimony of CIA-NRO relationships in the early months of 1965,[¶¶¶¶¶] evaluation of Quill findings remained somewhat fragmented until April, being mostly confined to participating contractors and to informal review by various intelligence community personnel specified by the USIB's Committee on Overhead Reconnaissance. Bradburn, briefing senior CIA reconnaissance people early in March, explained the limited circulation of Quill's radar imagery (the National Photographic Interpretation Center had not yet been authorized to view the product) in terms of constraints imposed from USIB. He was advised by Dr. A. D. Wheelon, the CIA's Deputy Director for Science and Technology, that ". . . earlier CIA reservations were mainly procedural, and [that] there had been no intent to delay the evaluation," —following which an Ad Hoc Quill Intelligence Evaluation Team actually was formed. It met first in April, including representatives of the Defense Intelligence Agency and the several military services as well as CIA, NRO, and NPIC (which provided the chairman).[48]

Between April and June 1965 there was detailed consideration of a proposal for "... modifying the existing Quill system in storage to provide range resolution comparable to azimuth resolution . . . for a Quill mission over the USSR using the capsule recovery technique only," but like the several similar proposals of the early 1960s, it eventually fizzled into nothingness. Goodyear was convinced that Quill equipment could be modified to produce a slant-range resolution of about 25 feet but nobody in authority seemed to be much interested.[49] The SAC was the chief prospective customer and all the earlier reasons for avoiding the use of satellite radar over the Soviet Union weighed against SAC urgings. A special USIB committee that looked into requirements in 1967 emphasized again that quite apart from rather demanding technology, "... possibly an even more critical disadvantage of side-looking radar is that it actively transmits electronic pulses which will be detected and which might well become the basis for diplomatic protests of such serious nature that U.S. policy makers would deny permission to employ the system in peacetime." Given that the acquisition of basic radar data needed for the long-term support of post-strike, bomb-damage assessment operations "would require many missions and much activity . . ." there seemed little doubt that "protests would probably not be long in coming."[50]

The prospective costs of creating a radar satellite network for possible use in crisis management operations served as a deterrent to the approval of a formal operational requirement for such a system. It was impossible to evade the realization that a large complex of interlinked ground stations supporting a veritable fleet of satellites was necessary to perform the sort of daily coverage, near-real-time readout that crisis management required. Further, if crisis reconnaissance were to be an assignment of a radar satellite contingent, a comprehensive data base on "relevant installations" would have to be prepared and maintained "on a current basis," in the words of a COMOR (Committee on Overhead Reconnaissance) report assembled only months after Quill results first became available. That, of course, implied a requirement for peacetime overflight of denied areas by active radar satellites, and the fundamental policy objections to that sort of operation changed little during the 1960s.[51]

The basic attribute of side-looking radar that made it attractive was its synthetic aperture mode—but that also represented its principal shortcoming. Side-looking radar had a limited ground swath which could not be effectively broadened without compromising weight, power, and antenna-size factors. The system had limited fore and aft viewing capability and an inevitable blind spot directly below the carrier vehicle, the consequence of having to "look" at an oblique angle in order to obtain range resolution. In its 1967 study (published in 1968), USIB estimated that continuous coverage from an

¶¶¶¶¶ See Volume V pages 180 et seq in original.

altitude of 200 nautical miles would require "in excess of 32,000 vehicles . . . on orbit simultaneously"—which also suggested that rather a large number of readout installations might be needed to exploit the potential of 32,000 satellites. Raising operating altitudes reduced the numbers needed to about 6500 but imposed requirements from 10 to 1000 times the radiated power required for reconnaissance from 200 miles, power being dependent on the physical aperture of the antenna system. Because synthetic aperture radar relied wholly on antenna motion for its azimuth effectiveness, side-looking radar could not be adapted to operate from synchronous-orbit vehicles.[52] Quill had worked, and worked almost precisely as planned. But that radar could be effectively operated from orbit remained only one aspect of a complex problem that involved requirements, applications, technology, international politics, and needs for vast funds. It was particularly interesting that the feasibility demonstration finally cost roughly less than half what Bradburn had estimated when first confronted with the project, but that an operational system would surely have cost billions. (The difference would have been expended had two more missions been flown of course.) It was also interesting that the "Phase Alpha" research and development project conducted in concert with Quill tended, by 1965, to look more and more like a sophisticated Quill. When taxed with the NRO's apparent lack of interest in exploiting the capabilities of orbiting radar, Dr. A. H. Flax, McMillan's successor as Director of the National Reconnaissance Office, wanted first to cite the "Phase Alpha" work and its follow-on as evidence of a continuing NRO investment in radar satellite research and development, and then—if the issue were pressed—to point at Quill as evidence that the fundamental feasibility work had been very successfully conducted and to suggest that requirements, technology, funds, and politics were problems that should be effectively addressed before new experiments were undertaken.[53]

The Quill program had been designed to provide data that would permit evaluation of the technical feasibility of employing what Greer called "this valuable new military instrument for the furtherance of national policy." Although initial plans had assumed that the relevant data could be obtained by 1965, they had also assumed that three to five missions would be needed to provide the information. In the event, the first mission was delayed by seven months, but no additional missions were needed and the derived data were "of even better quality than had been expected from the most optimistic estimates." The best estimate of the cost of obtaining those data was estimated; the result was obtained for about two thirds of the estimate, and should further flights have proved advisable for any reason, fully flight qualified hardware was available. (Some of the findings were passed to NASA for use in lunar exploration programs and the hardware was as readily convertible to NASA applications as was the much heralded lunar survey camera system derived from the Samos E-l experience.)

In Bradburn's view, the spectacular success of the effort was in considerable part a result of the special circumstances under which it had been conducted—tight security being a principal element of those circumstances. Pressures for information, advice, and participation by the many agencies interested in radar satellites would have incredibly complicated what had been a very difficult development program. In a final meeting with several of the project participants, Bradburn also attributed program success to "individual efforts by individual people, each . . . a specialist in his area." And he skirted the treacherous path that stemmed from the all-too-common misapprehension that a successful development team and a successful development approach could be channeled fundamentally unchanged, into some new and different problem. Proposals for program continuance and for new experiments with modified Quill equipment still were current when Bradburn closed out the last of the Quill tasks, the final reports. Neither he nor Greer—nor Greer's successors—ever gave them serious consideration.[54]

Notwithstanding, the general reluctance of senior American officials to approve the development of operational radar satellites and the continuing premise that active radar surveillance might be politically unacceptable to the Soviet Union, that nation in 1968 began its own radar satellite development program and by 1971 had operational vehicles in orbit. They were generally similar to Quill in configuration employing synthetic-aperture radar and relying on readout for data retrieval. (They entered semi-equatorial rather than polar orbits, however.) But the Soviet satellites were—at least ostensibly—designed and used for ocean surveillance, for spotting and tracking ships and fleet movements. The radar seemed to be low resolution in character. Thus they did not violate the principles honored by American policy makers; operation over non-Soviet-bloc landmasses was not attempted. Nonetheless, the apparent capability of the Soviet ocean surveillance satellites to perform some level of bomb damage assessment, or even for low-grade crisis management assignments, could not be disguised. It was real enough.

...(footnote continued from p. 10) The arguments against active radar surveillance of the Soviet Union fell into two categories. One had to do with the premise that nobody could object to surveillance if there were no demonstrable evidence of it. Because photography was wholly passive, there was (in theory) no way of providing incontrovertible evidence that surveillance was in progress—unless, of course, the owner of the reconnaissance vehicle acknowledged what he was doing, or somehow physical evidence of the activity fell into unfriendly hands. Putting the entire reconnaissance satellite program behind dense security barriers late in 1960 effectively precluded the first of those circumstances; the United States neither denied nor confirmed that it was flying reconnaissance satellites over Russia, although that intention had been loudly proclaimed on several occasions between 1958 and 1960. The possibility that the Russians might somehow recover a camera-equipped U.S. satellite or enough of one to prove that it was a reconnaissance vehicle, had worried program managers since the first Corona launch in June 1959. Precautions against inadvertent descent of either capsules or camera sections within reach of Soviet recovery forces were extensive, and for several years they were believed to be effective. At least once in Corona experience, however, a largely intact capsule left a decay orbit and survived random reentry, and late in the 1960s sizeable shards of a Gambit mirror plus various bits and pieces of its electronic subsystems survived atmospheric reentry and were recovered in England. Enough capsules and orbital vehicles went astray in the 1960s to support reasonable speculation that some could have fallen into Russian hands—but nothing was ever said by the Soviets to suggest that had happened.

By its very nature, however, a radar satellite radiated recordable evidence of its purpose. That evidence might be sufficient to support a demand for a cessation of satellite overflight operations should the Soviet Union—or any other nation—make an issue of the matter: thus the reluctance to consider use of radar reconnaissance in satellite overflight of denied areas.

But there was another reason for such caution. Photographic satellites of the early 1960s were incapable of providing near-real-time information. They were superb instruments for doing targeting for technical intelligence, for force structure evaluation, and for various other tasks with military significance. But only a radar satellite could conceivably do wide-swath bomb damage assessment without concern for season, cloud cover, or time of day. As no radar satellite could provide the detail of photography, it followed, then, that one substantial justification for operating a radar satellite of 1963 vintage (limited in definition and resolution) could be to have something in position for immediate bomb damage assessment—which (according to the reasoning then current) could be interpreted to mean that a surprise nuclear strike was imminent. It was highly unlikely that any American president would order a preemptive nuclear attack solely on the strength of information that the Soviets were operating a radar satellite, but there was no such confidence in Soviet reactions were the United States to do as much.

There were other reasons for restricting on-orbit radar operations to the limits of the continental United States, the desire to keep the capability secret being one, but in the councils of Washington, uncertainty about Soviet reaction was the principal cause of caution.

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ACKNOWLEDGEMENT

Robert L. Perry (May 10, 1925- September 7, 1990) majored in journalism at Marshall University, graduating in 1947. He went on to a master's degree in history at The Ohio State University. From 1951 to 1964, Bob Perry worked for the Air Force—first at Wright-Patterson Air Force Base, Ohio, then as chief of the History Office at Air Force Systems Command, El Segundo. He was a retired USAF reserve officer who also taught or lectured at Ohio State, Wittenberg University, the University of Dayton, the Air Force Academy, the Air University, California Institute of Technology, and the Rand Graduate Institute. He also wrote extensively on Air Force system development programs, chiefly aircraft and missiles. In October 1964, Bob Perry joined the Economics Department of the Rand Corporation, where his list of publications includes more than 25 technological case histories, studies of Research and Development (R&D) policy, analyses of system cost trends, examinations of test program structures, and comparisons of U.S. and foreign technologies and R&D institutions. He also served on numerous outside panels and gave testimony to several congressional committees.

Quill: The First Imaging Radar Satellite

INTRODUCTION

In December 1964, the NRO launched a satellite called "Quill" that successfully demonstrated electonic imaging of the Earth using a synthetic aperture radar in outer space. How this test demonstration came about, its novel results, and what became of the work are ably described in the pages that follow. Dr. Robert Butterworth has incorporated the findings of extensive documentary research with interviews and oral histories. The result is a highly readable account of how SAR revolutionary technology first came to operate in space.

PREFACE

Quill was the world's first imaging radar satellite, launched by the National Reconnaissance Office (NRO) as an experiment in 1964. The NRO was young then—only three years old, in fact, when Quill's development got under way. But several dominant traits were already apparent: dedication to developing very advanced technology, aversion to bureaucratic management, and irresolution in the face of competing military and national intelligence needs.

I found pieces of this story while working for the NRO's former History Office and the IMINT directorate—a project that was aided by scores of people and dozens of organizations. Particularly important information about Quill came from interviews with its Air Force program manager, Maj. Gen. David D. Bradburn USAF (Ret), the program manager who built the radar system at Goodyear Aerospace Corporation, and an expert in Doppler data processing.

I could not have completed this work without superb research assistance and incomparable administrative support including the review of the manuscript in draft and the design and copyediting of several versions of the manuscript.

This work began under the direction of R. Cargill Hall, NRO Historian and contractor during 1998-2003. Hall proved a rare, steady helmsman in the temperament-tossed seas of research and writing. With this monograph he very nearly had a piece of NRO program history coming out of work commissioned and published on his watch. We were too slow for that, and must settle instead for being printed as part of his significant legacy.

Robert L. Butterworth
Chantilly, Virginia
December 2004

RADAR EYES

Military satellite work in the U.S. sputtered through the 1950s until the Soviet Union launched Sputnik in October 1957. Soon thereafter, articles in the trade press talked about an Air Force contract with Lockheed for "WS-117L," Earth reconnaissance satellites (some called "Pied Piper") that "would carry television, photographic cameras, [and] infra-red spotter or radar scanner systems."[1] A later article made further reference to payloads: "probably no single Pied Piper reconnaissance vehicle will incorporate more than one type of sensor for mapping—optical, infrared, or radar—because of payload restrictions and complexity of multiple scanning systems."[2] A 1958 advertisement *(Figure 1)* predicted that these satellites would "see" in various ways and that some would have "radar eyes."[3]

Those eyes would see using a focused synthetic aperture radar (SAR), which hit public attention on 20 April 1960, when the U.S. Army unveiled pictures of American cities taken at night and through clouds *(Figure 2)* with its new SAR system mounted in a small airplane.[4] This new technology made it feasible that radar could be used for reconnaissance from satellites, because unlike real-aperture side-looking airborne radar (SLAR), smaller antennas actually improved resolution, and distance from the target was effectively irrelevant.[5] At the same time, satellites appealed to SAR engineers as excellent platforms for their sensor.[6] Unlike aircraft—whose bumps, slides, and twists through the air had to be measured and subtracted from the Doppler returns—satellites offered almost perfect stability.

By the late 1950s, several research teams were studying the prospects for SAR imaging from very high or orbital altitudes. In 1959-60 the Air Force DynaSoar program funded two research teams to study how SAR might be used from a high-altitude stable platform; one team included employees from the Litchfield, Arizona facility of the Goodyear Aerospace Corporation, working together with engineers from the Glenn L. Martin company of Baltimore, Maryland.[7] The Air Force continued its long-

Figure 1. *Aviation Week* advertisement, 8 September 1958, pp. 100-101.

standing interest in radar technology with contracts in 1960 for the "Higasser" program, a classified effort to determine whether SAR images could be generated from very high orbits. Goodyear won a Higasser contract with one of their employees as project engineer; another research group did not win on Higasser, but a year later won a $1 million study in the "Logasser" program, which looked at SAR imaging at ranges of ten to 300 miles. This proposal, and the research, was led by the research group's employee. The research team included the Lockheed Missiles and Space Company of the Lockheed Aircraft Corporation, Sunnyvale, California, as the antenna subcontractor. Altogether they began to work on defining and resolving the technical issues in obtaining fine SAR resolution at the Earth's surface.

A summer exchange program in 1961 took the research group's employee to Sunnyvale to work with Lockheed on the early Samos satellite programs. While there, the employee gave some lectures on radar, was hired as a consultant to Lockheed, and became involved in exploring a business development idea for using Lockheed's launcher and satellite technology and the research group's radar imaging technology to build a SAR satellite. To build the radar itself, he recommended Goodyear as the best company. The employee had built an optical correlator used by one of Goodyear's earlier SAR products, the APS/AP-73,[8] and had come to know the Litchfield Park engineers, who were even then working on design parameters for a space-based SAR, such as the relationships among pulse repetition frequency, antenna length, power requirements, and coverage. A radar expert became Goodyear's project engineer for the effort, and in the summer of 1961 he and another engineer visited Sunnyvale, learned about the project, and began planning how to build the radar.

At that time Col. William G. King was deputy director of the new Special Projects (SP) staff in Los Angeles, which shortly would be constituted as Program A in the newly established National Reconnaissance Office (NRO). Program A worked closely with Lockheed on both satellites and launchers, and King headed a study group looking for new ways to use satellites for national

Figure 2. *The Washington Post* on 20 April 1960 displayed an early SAR image on its front page.

Figure 3. Left: Brig. Gen. William G. King, USAF.; right: Maj. Gen. David D. Bradburn, USAF.

reconnaissance. Sometime in the late fall of 1961, Goodyear's project engineer remembered, King's study group took up the possibility of launching a proof-of-concept SAR satellite.[9] One of the group's members was Major David D. Bradburn. A West Point graduate in electrical engineering, Bradburn had joined the Air Force and spent most of the 1950s serving in the Air Research and Development Command, where he became aware of the ongoing work on side-looking and SAR systems.[10] He entered the satellite world in 1957, when he transferred to Los Angeles to work on the WS-117L program, and in 1961 he was serving in Program A's SP-3 office, developing security plans and procedures.

To assess the merits of a SAR satellite demonstration, Bradburn looked into the potential utility of a fully operational SAR satellite. After talking with officers of the Strategic Air Command (SAC), he concluded that a radar with about a 10-foot resolution would be useful for post-strike bomb damage assessment, particularly because it could respond quickly and not have to wait for clear skies and sunshine. Meanwhile, in January 1962, Goodyear began preliminary SAR design work under a contract with Program A. After several months this project had matured enough for King to propose the experiment to NRO Director Joseph V. Charyk, who approved it in mid-November 1962.[11] Bradburn, chosen to direct the effort,[12] summoned Goodyear's project engineer, Lockheed's satellite bus expert and antenna expert, the research group's employee, and a few others to a meeting in Los Angeles before Thanksgiving, without telling them the subject. It turned out to be the official start for the SAR satellite demonstration, now known by the classified name "P-40." The satellite itself received the codeword name "Quill."

DESIGNING THE EXPERIMENT

Proposals from industry were solicited and received in short order, and contracts structuring a tripartite industrial team *(Figure 4)* were awarded in November 1962. Lockheed's group at the Agena facilities in Sunnyvale was responsible for overall systems engineering and technical direction, together with the upper stage/satellite body and associated subsystems.[13] The research group became an associate contractor responsible for design and evaluation of the experiment and for the optical correlator that would process radar data and produce images. Goodyear was responsible for the radar payload and for working with the associate contractor in the design, test, and operation of the experiment. The contract called for launching two identical vehicles, designated 2355 and 2356, the first to go in April 1964. The payload for a third vehicle was to be prepared as well, but a booster was not identified for it.

Bradburn designed Quill as an experiment tightly focused on the question of orbital functionality. As Lockheed emphasized, "the primary objective of the orbital flight was to *demonstrate that a fine-resolution radar strip map of a portion of the earth's surface can be generated through use of a satellite-borne synthetic aperture radar system*. For the purpose of this demonstration a resolution goal of 50 feet in azimuth and in slant range was established."[14] Secondary mission objectives included quantitative evaluations of the radar system performance (especially azimuth-direction behavior); determination of the limits imposed by payload design parameters, payload in-flight performance, vehicle attitude behavior, atmospheric conditions, and data link design and performance; and data collection on target field reflectivity, engineering parameters for aerospace radar system designs, and the capability of the ground recording equipment.

Quill would not seek to develop new technology or become the basis for an operational program.[15] In Bradburn's view, the orbital experiment intended to answer only two questions: whether the system could really integrate Doppler-shifted radar returns over a sufficiently long path in orbit to obtain the desired azimuthal resolution, and whether there was anything about the behavior of the atmosphere that might create noise in the system. He was determined to keep the experiment focused, so he sought to minimize technology development and to use proven equipment and procedures wherever possible.[16] Even so, significant errors could be introduced in several ways. There could be jitter in the transmitter's oscillator, for example, or erratic vehicle motion and errors in pitch, roll, or yaw as well as problems arising from incorrect beamwidth, atmospheric turbulence, receiver noise, and mechanical and chemical shortcomings in the data recording system.[17]

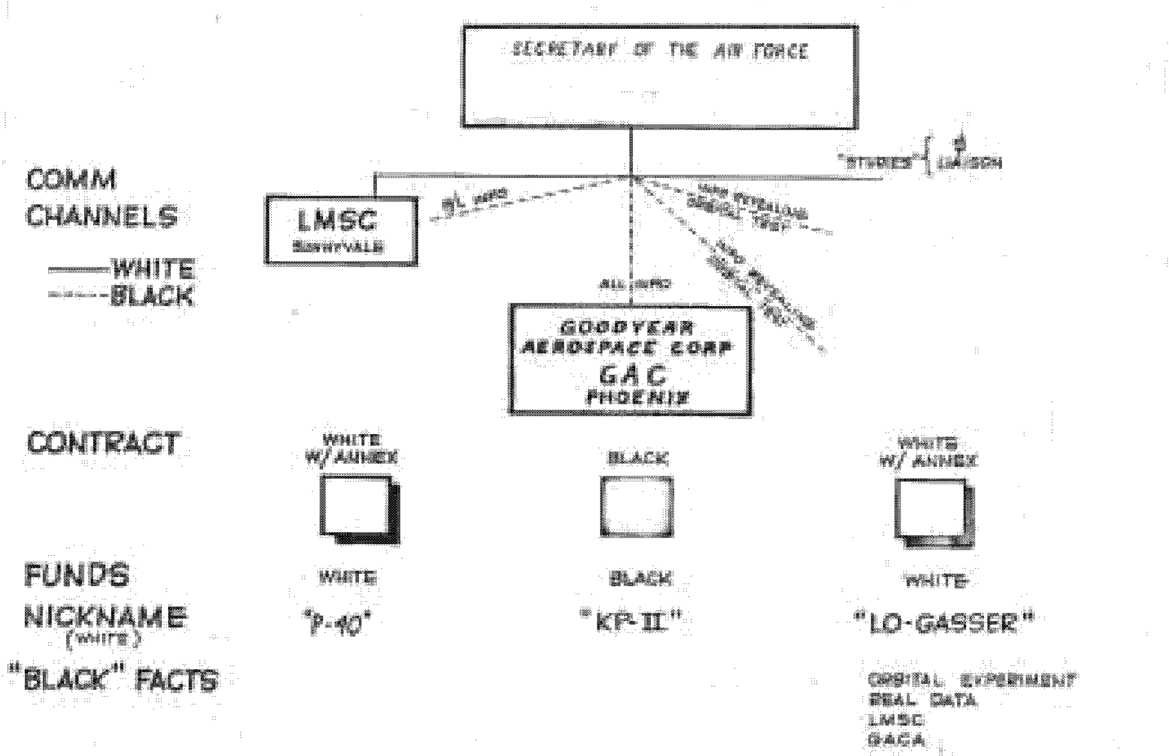

Figure 4. Quill project organization.
Source: Lockheed, *System Report 1*, p. 14

The radar itself, designated KP-II,* was an AN/UPQ-102 pulsed-Doppler system that Goodyear was then producing for RF-4C aircraft.[18] The contract with Program A called for producing five KP-II radars, enough to provide replacements in case of launch or test failures, because the ways in which the space environment might affect the SAR were still unknown. For example, what was the barometric pressure inside the Agena launch vehicle—10^{-3} millimeters of mercury, or 10^{-5}, or 10^{-1} because of out-gassing? The differences could be significant to the operation of power-generating devices.

The radar was stripped of unnecessary aerial subsystems (such as lateral motion compensation devices) and subjected to extensive reliability engineering, including testing and potting to control electrical discharge,† refinishing for environmental considerations, and x-ray examination of components. All the component boxes were instrumented with pressure sensors and mounted on special rubberized shock isolation mounts. Special wire was used with an insulating covering that promised little out-gassing, about which little was known in general. In keeping with the primary objective of the experiment—obtaining a terrain image from a SAR satellite—the overall system was simplified considerably and did not include capabilities that would be needed for operational systems. For example, there was no ability to select the terrain swath being imaged or to extend the length of the swath.[19]

As a Doppler system, the radar had to transmit pulses often enough to reduce azimuthal ambiguities while allowing a proper interval between pulses to record the returned signals. The timing of the pause depended on range to the target, and this distance could not be known precisely. The Goodyear engineers knew that the antenna was to look down at a 55-degree angle, but they could not know the exact altitude of the satellite. Their solution was a specially designed circuit that continually monitored the pulse repetition frequency and adjusted it slightly. Had it been important for the mission, other solutions to the range issue surely could have been applied; but Bradburn said he really did not care about range resolution for Quill because it could be readily changed by shortening the pulses or other tinkering. "With Quill we just wanted enough energy on the target, we didn't care how long the pulse was, range resolution was not a parameter we cared about, we just cared about being able to do the processing trick to produce synthetic aperture with [useful azimuthal resolution]."[20] Base frequencies for the system would be 9600 MHz for the transmitter carrier with a pulse repetition frequency of 8215 to 8735 Hz and an intermediate frequency of 70 MHz.

Another engineering challenge was thermal control, particularly for the klystron, the device that generated the high peak power needed to operate the radar.‡ Most of the klystrons that Goodyear used for aircraft radars were air-cooled; for Quill, the engineers designed a heat sink. It was an aluminum plate about ten inches long and five inches high and painted with a special thermally conductive white paint. Several copper fingers were braised to its back. The plate bolted to the anode of the klystron, and heat was conducted through the copper fingers to another metal heat sink, which was placed next to the satellite skin so the heat could then be radiated into space.

The mission was intended to last only 96 hours, with the radar operating no longer than five minutes per orbit, for no more than three orbits in succession, and for no more than 80 minutes altogether. Power was provided by three silver-zinc batteries, which determined the duration of the experiment; there was no provision for recharging them.

The KP-II would be installed in the same Agena upper stage used as a satellite body for Corona *(Figure 5).* The Agena would be launched with an augmented Thor missile, constituting a flight-proven package of booster and upper stage that offered tolerable launch environments (thermal, sinusoidal vibration, random vibration, shock, acceleration, and pressure). The Agena also was expected to provide sufficient stability for the SAR on orbit (±0.4 degrees of attitude uncertainty and ±.25 degrees limit cycle in pitch, yaw, and roll, with rates of change not greater than .002 degrees/second in pitch, .005 degrees/second in yaw, and .003 in roll).

The radar would transmit and receive through an antenna that was flush-mounted on the Agena body, thereby avoiding the risks associated with a design that would require unfolding or unfurling a structure on orbit. Based on calculations that determined dimensions for maximizing the portion of the slant range interval that could be mapped, consistent with the Agena vehicle dimensions, the antenna was made 15 feet long and two feet high *(Figure 6).* It was manufactured by Lockheed; the company's Antenna Laboratory had considerable experience with problems posed by constructing this type

* Goodyear designated its classified projects using the initial of the surname of its current president, who then was Tom Knowles. The orbital radar project thus became the "KP-II."

† Goodyear employees had to experiment with potting techniques as a way to keep the transmitter operating in the unknown space environment. Essentially, the electrical component was placed in a cocoon of elastic rubber inside a metal container. A vacuum was created in an effort to let the rubber set without air pockets. All leads were grounded and had wire shielding.

‡ "Klystrons are a family of microwave vacuum tubes that depend upon the conversion of a velocity-modulated beam into a varying current by the process of electron bunching." A. E. Harrison, Klystron Tubes (New York: McGraw-Hill, 1947), p. 1.

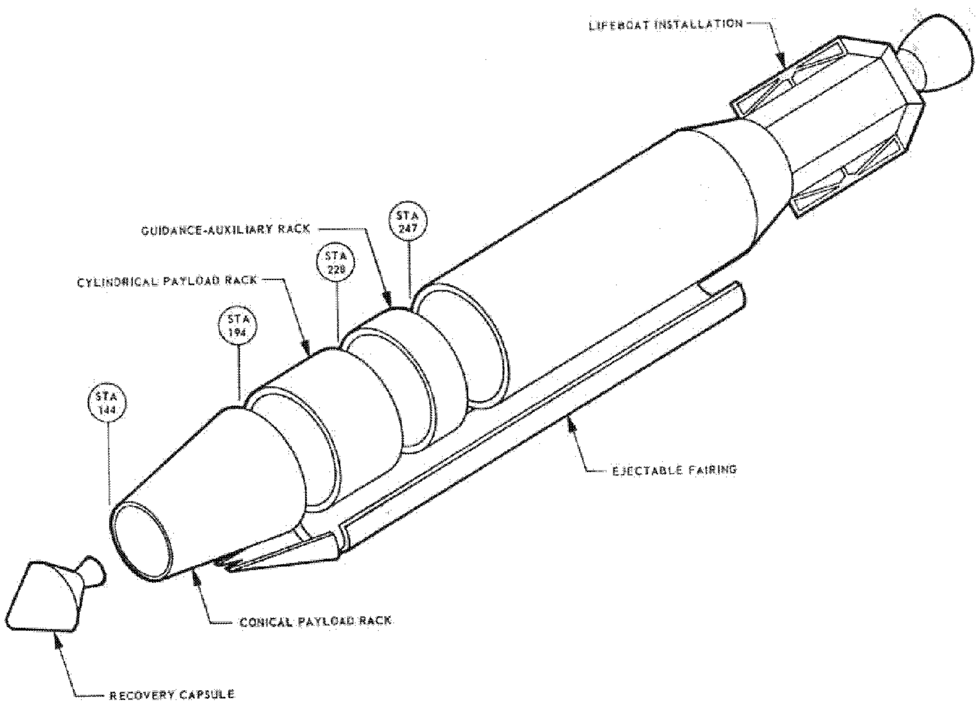

Figure 5. Agena D for Quill.
Source: Lockheed, *System Report 2*, p. 1-3.

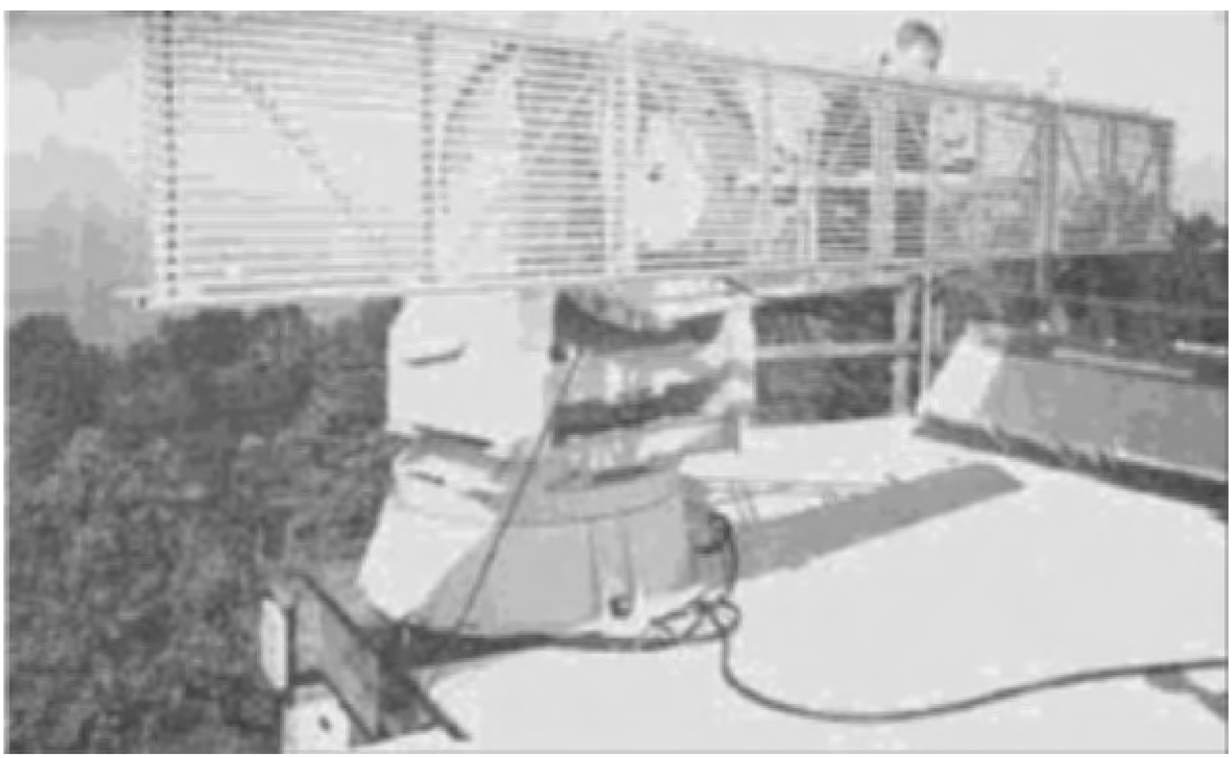

Figure 6. Quill Antenna.
Source: Lockheed, *System Report 2*, p. 1-143.

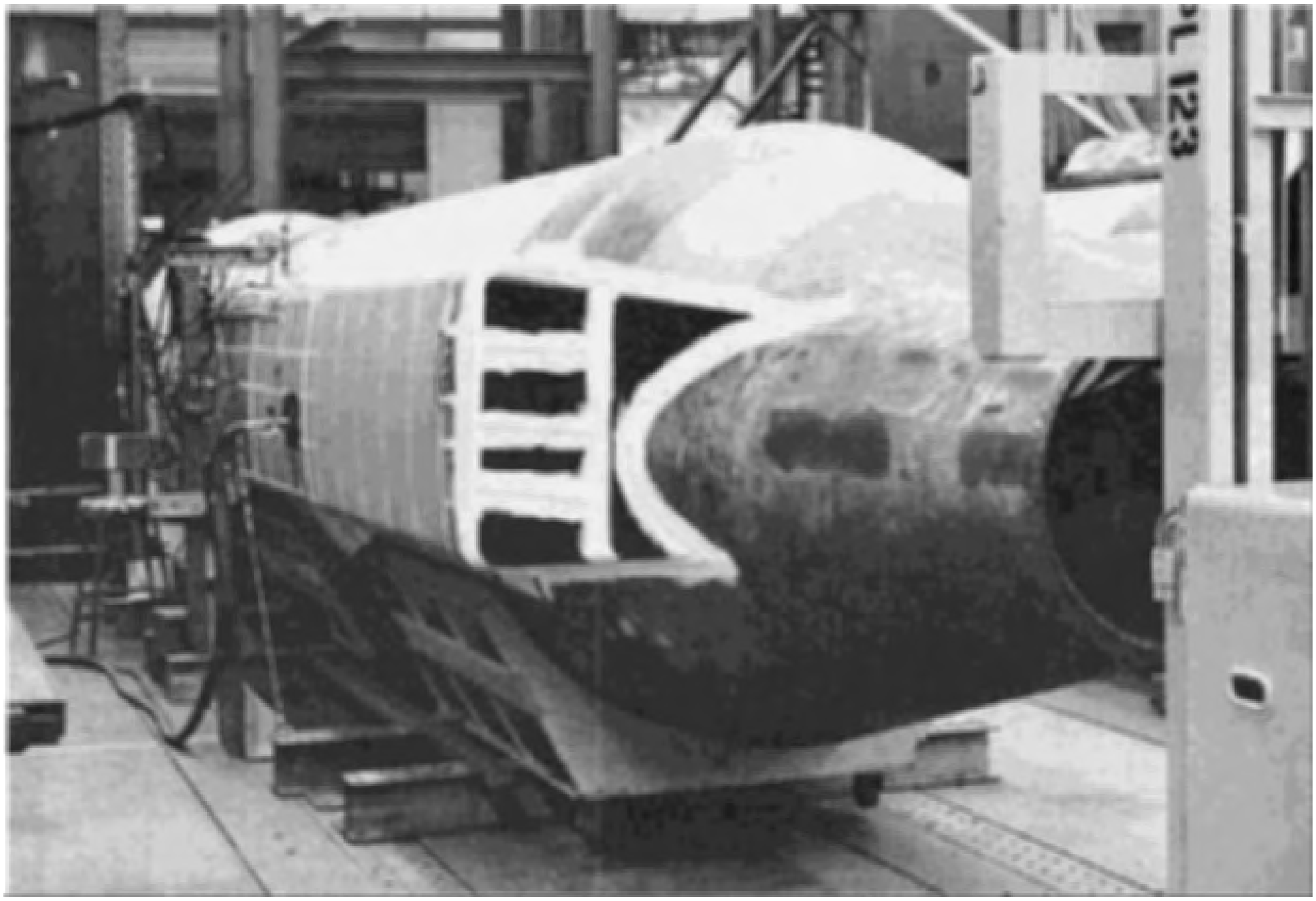

Figure 7. Antenna fairing.
Source: Lockheed, *System Report 2,* p. 1-44.

of antenna using the available stock, and its machining was done in the Agena D facility.[21] The antenna was mounted along the right side of the Agena body, occupying nearly its entire length and, when covered by protective fairing, protruding about two and a half inches from the surface *(Figure 7)*.

The fairing was designed to detach after the Thor booster engine cut off, thereby reducing the load to be lifted by the Agena motor *(Figure 8)*. To protect the antenna from deformations that might result from thermal loads on the orbiting Agena body, three of its four mountings allowed the antenna to slide along fixed points, while the fourth was fixed to the vehicle.[22]

After being injected into orbit, the Agena would rotate 180 degrees, so that it would fly tail first (facilitating film recovery and terrestrial coverage); the antenna would thus be located with the main lobe of the radar looking down at 55 degrees from the horizontal at a strip that would be 93 miles to the left of the satellite's ground track and 10 nautical miles wide *(Figure 9)*.[§]

Figure 9 also displays the two directions in which the fineness of the radar's measurements was assessed: along-track (in the direction of flight) and across-track (or azimuthal, normal to the direction of flight). The figure also displays the two surfaces on which resolution is commonly measured: the slant plane (the deeply shadowed side of the prism on the ground, 5.95 nm wide for Quill), and the ground plane, labeled "imaged swath (map plane)," 10.1 nm wide for Quill.

The reflections from each radar pulse traced a line on the display of a cathode ray tube that varied according to the intensity of the return. An image of the display was recorded on photographic film, which essentially meant that the varying intensity of the returns then corresponded to varying densities on the film *(Figure 10)*. The film moved across the display to record successive

§ These are Lockheed's numbers, which are slightly inconsistent with those in the associate contractor's depiction in Figure 9. Lockheed, System Report 1, p. 18.

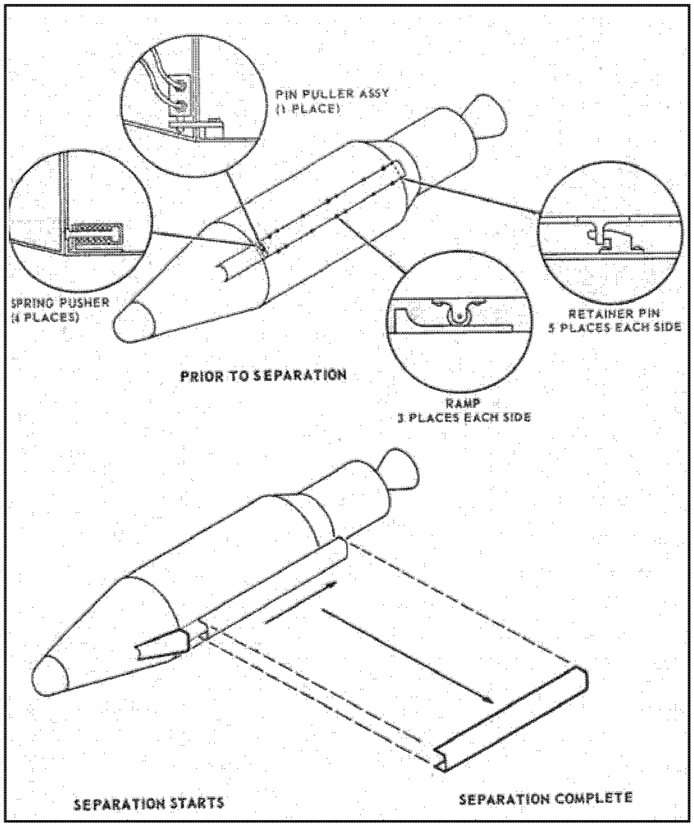

Figure 8. Fairing Separation.
Source: Lockheed, *System Report 2*, p. 1-14.

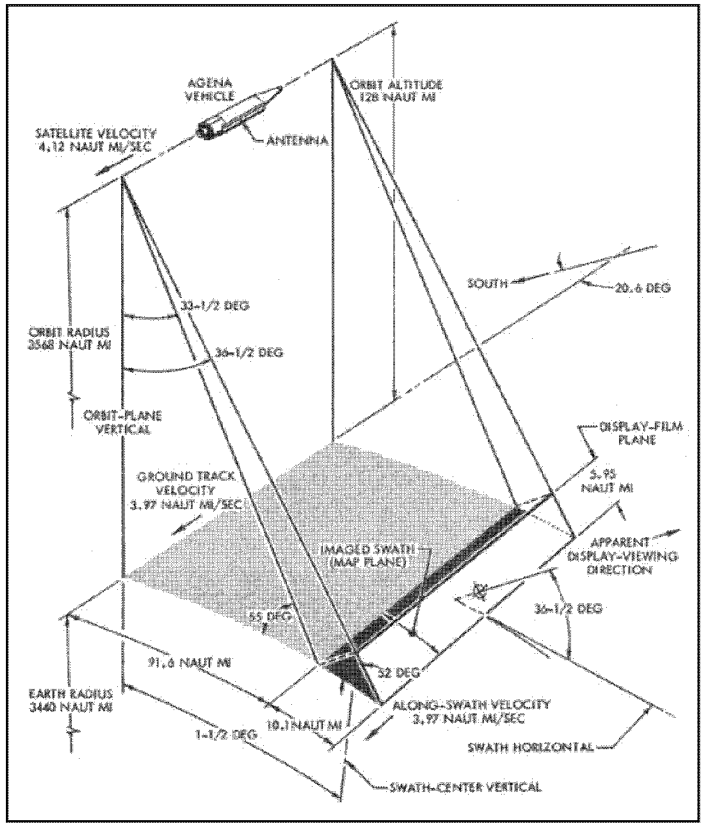

Figure 9. Imaging Geometry.
Source: Associate contractor, *Evaluation 1*, p. 18.

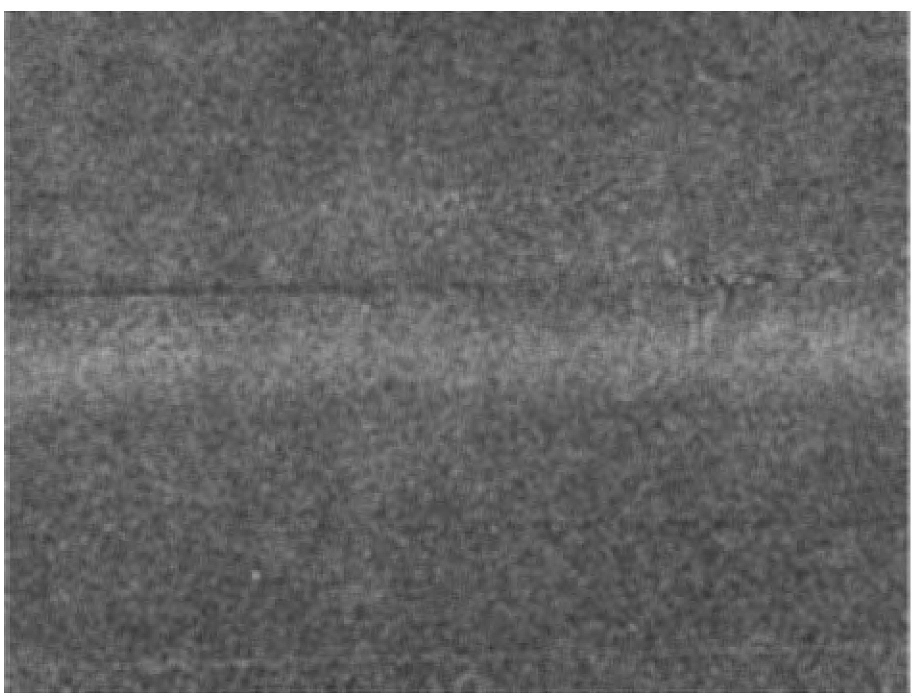

Figure 10. Signal film.
Source: Lockheed, *System Report 1*, p. 144.

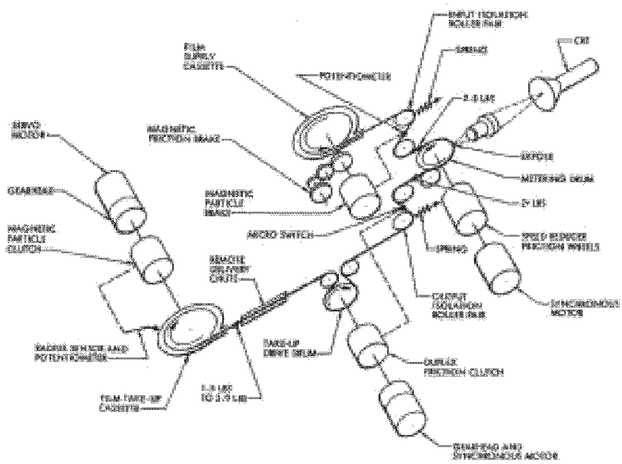

Figure 11. Film transport system.
Source: Goodyear, *Engineering Analysis*, p. 6-50.

intensity trace displays as adjacent positions on the film. Looking across the film from one edge to the other thus corresponded to the (slant) range dimension of the radar, and the ratio of the slant range imaged to the width of the film was called the range scale factor. Movement along the film reflected the azimuth direction and hence the along-track distance, with the ratio of the actual along-track distance to the length of film being called the azimuth scale factor. The ratio of these two factors, range scale to azimuth scale, was called the aspect ratio; with the KP-II setup, the aspect ratio was anticipated to be about 6.9.[23]

To make the recorder, Goodyear ordered from Westinghouse a special five-inch cathode ray tube with an electron gun that could withstand the anticipated shocks of launch. It had a single trace running across it, and the recorder imaged that trace down to about one inch on the data film. To keep the film drive uniform, free of variations in tension and slipping, Goodyear engineers coated the master metering drum with silicone rubber in a specific angle of wrap. The recorder was custom-made for Quill from a special mold, nickel-plated and radio-frequency protected.

Radar data would be conveyed to the ground in two ways. One method was film, which was handled in two assemblies totaling 99 pounds *(Figure 11)*. The recorder compartment housed the cathode ray tube and associated subsystems that allowed the film to record the images on the tube. The film itself was contained in a film-supply cassette. Exposed film went into an Itek take-up cassette in a General Electric re-entry vehicle *(Figure 12)* to be recovered by special C-130 teams *(Figure 13)*. This approach to data recovery, incidentally, had also been mentioned in the earlier 1958 article in *Aviation Week*.[24]

Data would also be transmitted to the ground using an UHF wideband data link, and recorded at the Vandenberg, California, and New Boston, New Hampshire, tracking stations. The preflight engineering analysis seemed to consider this task simple and straightforward: "it is only necessary to provide a KP-II Recorder and a means of triggering it so that the telemetered video can be recorded."[25] Each location thus had a recorder identical to the one on board, together with control systems for establishing synchronized reception from the satellite.

In either case the product would be a film transparency. This film—the "signal film"—essentially recorded Doppler-coded data about ground reflectivity. Once on the ground, this information was converted into visual imagery using the "Precision Optical Processor" developed by the associate contractor especially for Quill data. This processor derived from the original optical correlator developed in the early 1950s by the associate contractor to solve the huge data-processing chore required for the quintessential SAR task of integrating the Doppler returns. Those returns, after all, bore no relation whatsoever to visual images. Indeed, to the human eye even the earliest plan position indicator displays on cathode ray tubes more closely resembled a picture than what appeared on the SAR scope. Captured on film for subsequent processing, the returns on the scope at any particular instant resembled a collection of thousands, perhaps tens of thousands, of tiny shapes, mostly rectilinear, each a solid shade of gray—some lighter, some darker—some of them sharing perhaps some variation

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in coloring and thus forming striata across some areas, or band-like colorations somewhat reminiscent of alluvial deposits in the vertical face of a sandstone bank. Think not of the Gaussian snow filling an untuned television screen but of some densely intricate but visually uninterpretable mosaic.

The SAR processing challenge was to find ways to wring visual meaning from these returns. Another research group had tried to do the job electronically, but the computers of that day simply were not up to the task, requiring weeks of processing to render a few crude images. The genius of the associate contractor's approach was to recognize that optical lenses performed fast fourier transforms at, of course, the speed of light. The associate contractor's processor used a laser to generate a beam of coherent light that was diffracted by the signal film into three emerging waves, two of which produced images at focal lengths that varied with (slant) range. In essence, the coherent light produced

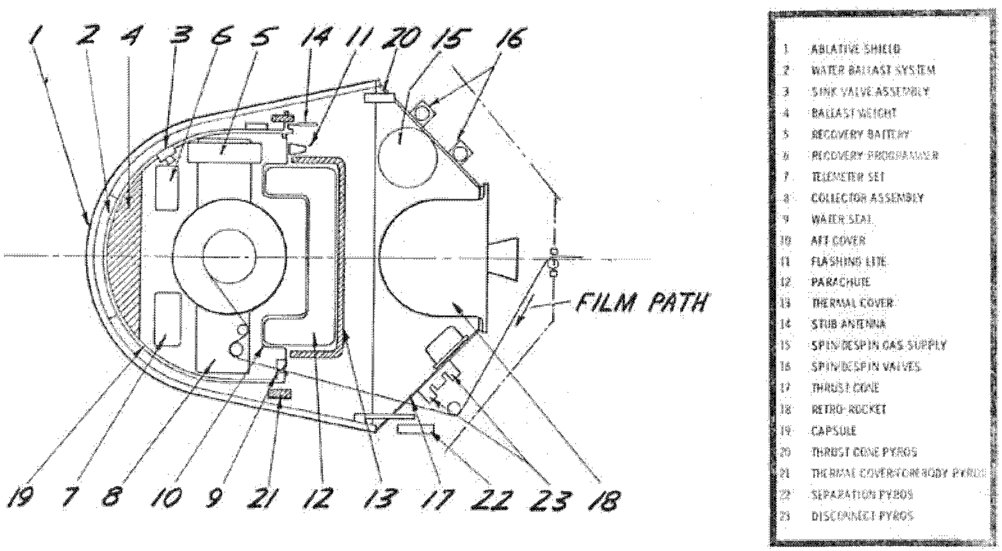

Figure 12. Film recovery system.
Source: Goodyear, *Engineering Analysis,* p. 6-50.

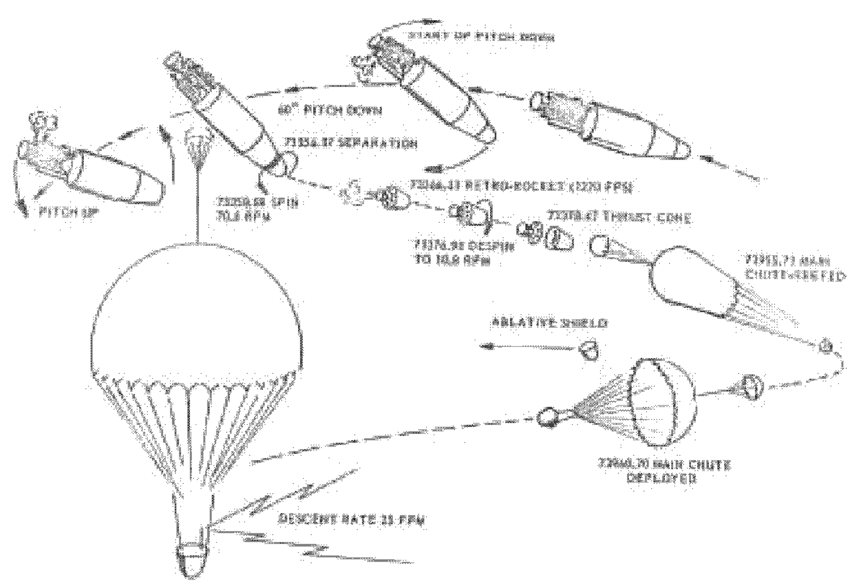

Figure 13. Capsule recovery process.
Source: Lockheed, *Project Report 2,* p. 3-50.

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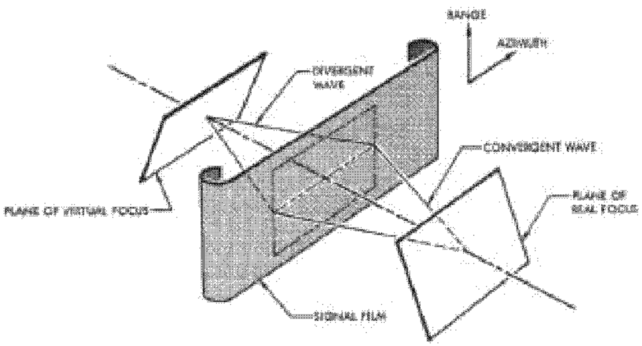


Figure 14. Focal plane relationships.
Source: Associate contractor, *Evalustion II*, p. 259.

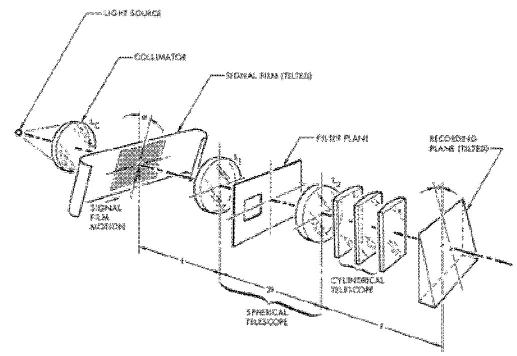


Figure 15. Anamorphic telescope processor.
Source: Associate contractor, *Evalustion II*, p. 261.

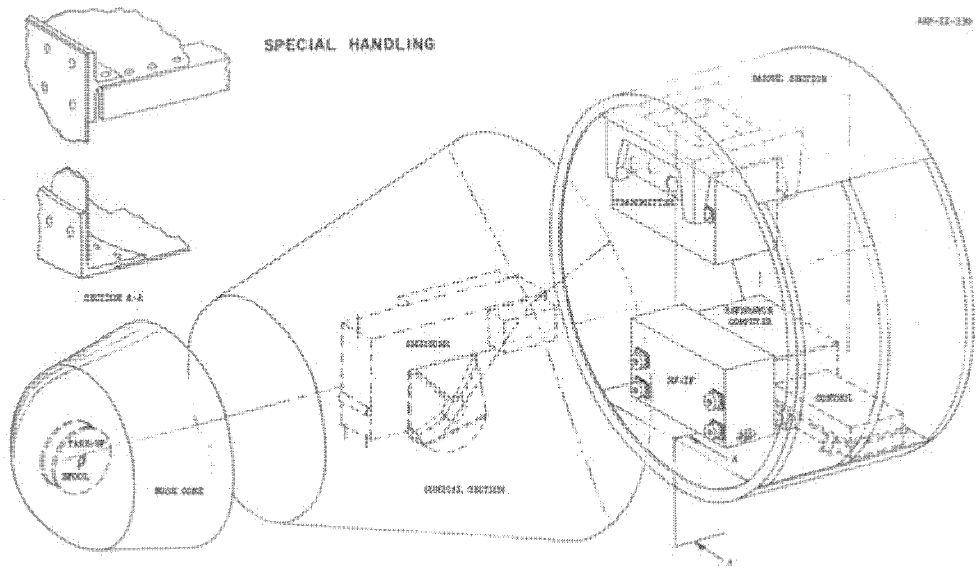


Figure 16. Agena nose assembly for Quill.
Source: Goodyear, *Engineering Analysis*, p. 4-4.

images on planes that were tipped relative to the signal film *(Figure 14)*, or in other words a plane of images that was focused in azimuthal direction and that was tilted with respect to the plane of images that were focused in range direction (which was the signal film itself).

The processor used an anamorphic telescope (meaning different magnifications in range and azimuth directions) to image both planes, apply the proper magnification, and produce an image sharply focused in both range and azimuth and with the correct aspect ratio. The fine-resolution image produced by the image processor system[26] *(Figure 15* is a schematic diagram) was recorded by a tracking camera, so radar data could be converted quickly and steadily to fully focused, fine-resolution optical imagery.

Figure 16 is a sketch of the Quill final layout. As indicated in that diagram, there are three sections to the Agena: barrel, conical, and nose. The KP-II radar system, weighing 370 pounds, was mounted in the barrel section, which was five feet across with structure rings 15 inches apart and a .06-inch skin. The recorder system, including the recorder and the film-supply cassette, weighed approximately 99 pounds and was mounted in the conical section, which tapered 15 degrees from a five-foot diameter at its base, where it joined the barrel section, to its height of 32.95 inches. The film containing the raw data was stored in the nose cone, which incorporated the reentry capsule for recovery.[27]

MANAGING THE DEVELOPMENT

Set up in this way, the Quill experiment could take advantage of the equipment and procedures for on-board photography and film recovery developed for the Corona program. In particular, Bradburn needed film cassettes, film recovery vehicles, and support for assembly, test, and checkout. In March 1963 these relationships came under the purview of Colonel Jack C. Ledford, an Air Force officer serving as assistant director of the CIA's Office of Special Activities (OSA).¶ Ledford recommended to his boss, CIA's deputy director for research, Herbert "Pete" Scoville, Jr., that the CIA provide contract support and security procedures for Quill. "Under the proposed plan, CIA would procure three (3) Corona Recovery Vehicles from General Electric, Corona Triple Prime Cassettes from Itek, and system assembly, test, and checkout by the LMSC [Lockheed Missiles and Space Company] A/P [Advanced Payload] facility [in Palo Alto, California]. The completed system would then be sent by covert means to LMSC, Sunnyvale, where it would be mated and checked out with the Goodyear Radar System."[28]

Scoville approved the recommendation, and OSA expended funds to acquire three film return vehicles from General Electric, take-up film cassettes from Itek, and services for checkout and assembly from Lockheed.[29] In addition to the procurement actions, the CIA had to develop procedures to keep information about Corona and Quill as separate ("compartmented") as possible. Not all the government or contractor personnel working on Quill needed to know about the Corona program, nor did most Corona people need to know about Quill. There were also different degrees of "knowing": Those who worked with particular pieces of classified hardware might not need to know anything about the overall system or its mission, while several who needed that information did not need to know about specific subsystem capabilities or technical specifications.

By the end of March 1963 Corona security officers had developed a plan for keeping each program's secrets.[30] The key difficulty was in finding a way to get hardware developed for Corona into the Quill program without directly associating the two. The plan called for establishing a payload laboratory for Quill, under compartmented security procedures, at the Lockheed facility where Corona space vehicles were processed. Integration of the Quill spacecraft components—including film cassettes, recovery systems, buckets, and waterseals—as well as any additional special tests that might be required for the Quill payload would take place in this facility. Normal weight and balance tests and pyrotechnics installation would be conducted in the same facility used for such tests on Corona satellites, and a third facility also would also be available for other integration and test procedures.

The Quill program would be directed to obtain its recovery system from a group at Lockheed that had already been identified as specialists. The Lockheed manager for this effort would assemble a group of engineers to work in the Quill laboratory area ostensibly to develop designs for cassettes and waterseals; after a suitable period of time, their "plans"—actually drawings of the existing Corona subsystems—would be presented and Bradburn would direct Itek to manufacture the desired items. The intended effect was to establish the cassettes and waterseals as hardware developed strictly and exclusively for Quill, and to disassociate Lockheed employees in the area from this sort of activity.[31]

The Quill contracts originally called for launching the first system in April 1964, but even Bradburn's tight focus and insistence on minimal technology development could not prevent delays. Bureaucracy was not the problem: Bradburn had few reporting requirements, good relations with Program B, and no awareness of any headquarters turmoil in Washington. The additional time was needed instead to resolve difficult technical and engineering issues. Like many program directors to follow him, Bradburn believed it was better to launch late with a successful satellite than on schedule with a failure, and so he determined that "emphasis will continue to be placed on thorough testing to insure a good probability of success on the first flight."[32]

At the end of May 1964 there was still considerable work left to be done. Environmental qualification testing had been completed for all radar components except the recorder. Several transmitter problems were identified during system-level Temperature-Altitude Simulation Chamber (TASC) tests, for which remedies had been designed but not verified. The flight vehicle was in an anechoic chamber for radiation and emissions testing. Film recorders and signal simulators were on site at the Vandenberg and New Boston ground stations (known as "Cook" and "Bos"), and this equipment had been installed in T-29 and T-39 aircraft for conducting fly-by tests. The optical correlator was nearly completed by the associate contractor and analysis of test films from the Goodyear

¶ OSA had been transferred to the Directorate for Research, and in March 1963 Scoville was head of that directorate. He was held responsible for CIA activities in support of the NRO, although he delegated the Program B job to a deputy and called himself the senior representative to the NRO. He left later in 1963, and his successor, Bud Wheelon, refused the Program B job entirely, leaving the title to the deputy DNRO, Gene Kiefer. Kiefer might certainly have called on Ledford's office for support.

recorders indicated that the design resolution was being achieved. A program review had been conducted by an ad hoc committee of Air Force and Aerospace Corporation people drawn largely from a concurrent Hughes radar program (P-22) being conducted outside the NRO. The review found the program to be generally on track and suggested some changes in the wiring harness, lowering the operating altitude, and altering the approach to setting the pulse repetition frequency. The launch date at this time had been 5 August 1964; it was changed to 29 August, subject to success in TASC and anechoic chamber tests.[33]

Steady progress was made over the summer of 1964. The anechoic chamber tests were completed, including all ascent and orbital sequences and full-power transmissions through the antenna, without signs of problems from electrical interference or interaction. Tests at the antenna range at Lockheed's Santa Cruz Test Base showed that the radar and the antenna were compatible, that the antenna did not distort the pulse, and that the slant range resolution of the system was better than 35 feet for the worst case (in-phase targets) and better than 25 feet for the best case (targets with 90 degrees of phase difference). Installation and testing of equipment at the tracking stations had been completed; the optical correlator was complete and had been used to verify proper adjustment of the recorders by using test films processed by the Air Force Satellite Photographic Processing Laboratory (SPPL) at Westover Air Force Base, Massachusetts. The associate contractor had also completed a performance evaluation plan for the mission.

The Agena D upper stage had passed acceptance testing and was at Vandenberg, awaiting the payload. But transmitter/modulator problems continued to surface in system-level tests at altitude, and the launch date was delayed once again, to 2 November.[34] That date also passed as the radar transmitter failed yet again. The troublesome component was redesigned and, at last, showed no problems during TASC testing of the entire planned orbital operating time. It was shipped to Vandenberg in keeping with Bradburn's security procedure *(Table 1)*, and by mid-December Quill was ready for launch *(Figure 17)*—eight months later than originally planned, but only 25 months after initial contract award.[35]

ORBITING THE SYSTEM

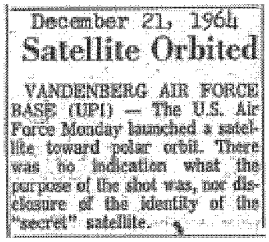
With Bradburn in command as launch control officer, on 21 December 1964 the world's first satellite-borne SAR was ready for launch from Vandenberg Air Force Base. Engineers had calculated a specific period during which

Table 1. Quill security procedures (payload equipment flow)

1.	Goodyear Aerospace Corp. fabricates and assembles radar payload, test equipment, and ground data handling equipment.
2.	Shipped to LMSC by military air as arranged by SAFSP; departs Litchfield Park NAS, Arizona, and arrives Moffett NAS, California, adjacent to LMSC; USAF or LMSC Quill-cleared courier accompanies shipment.
3.	Arrives Moffett NAS; transferred to Navy van and driven to Quill approved area. Courier accompanies equipment until it is secured.
4.	In covert area, equipment undergoes component, circuitry, and bench checks; performance tests, acceptance tests, and necessary modifications accomplished.
5.	Transferred in LMSC van to Complex C-12, Area 40 undergoes systems test with Agena vehicle, USAF acceptance procedures accomplished (DD250).
6.	Shipped separately from Agena vehicle to a Quill-approved area in Vandenberg AFB; transferred by LMSC van with Quill-cleared courier; mated with Agena vehicle and undergoes final systems run.
7.	Transferred to launch pad for R-Day checks, countdown, and launch.

Source: "Quill Supplement: Covert Program Security Plan," 2 March 1964.

Figure 17. Quill awaits launch in the rare USAF photo.



December 21, 1964

Satellite Orbited

VANDENBERG AIR FORCE BASE (UPI) — The U.S. Air Force Monday launched a satellite toward polar orbit. There was no indication what the purpose of the shot was, nor disclosure of the identity of the "secret" satellite.

Figure 18. Newspaper report. *Courtesy Goodyear project engineer.*

the satellite should be launched (the "launch window") in order to minimize the amount of heat it would encounter on orbit. As time approached to within 10 minutes of the launch window, all systems were brought to readiness so that launch could occur within 30 seconds of command. Only official personnel were permitted within a defined area of the base during launches, but a civilian railroad track cut through the restricted zone, and, with only a few minutes to go until the launch window opened, range safety officers reported that a train was approaching. If it entered the exclusion area, safety regulations would prohibit the launch from continuing until the train was gone. The delay might be so long that the launch window would close, forcing the launch team to "unready" the Thor/Agena (which might involve several complex processes, such as removing propellants, preserving environmental conditioning, and recharging batteries, depending on when the next window opened) and await the next opportunity. Bradburn thus found himself assailed by demands that he launch immediately, ahead of the planned schedule, before the train came closer. He refused, not wanting to execute a contingency plan that was being made up on the fly, and continued to wait for the appointed time. As it turned out, the train stopped while still outside the safety exclusion area, and the launch at 11:08 a.m. Pacific Standard Time proceeded according to plan.**

Knowing that the booster had worked, Bradburn headed north to the satellite control facility in Sunnyvale and soon learned that the Agena (international satellite

** Bradburn, interview, and SAFSP Director's Quarterly Report, 30 December 1964. NRO headquarters in Washington, DC, was kept informed of major developments by secure teletype, a relatively slow and limited form of communication. When Bradburn decided not to launch early, a short message was cabled to NRO headquarters from Vandenberg saying "holding for passenger train." Then the launch window opened, range safety reported that the train had stopped outside the closed area, Bradburn gave the command to launch, and the Thor/Agena lifted off. The next cable to the NRO reported that Quill was in orbit, giving rise to initial concern in Washington—and continuing folklore—that Bradburn had disregarded safety and launched over the train. Bradburn recounted this event, without revealing the purpose of the launch, in "The Evolution of Military Space Systems," in R. Cargill Hall and Jacob Neufeld, eds., The US Air Force in Space (Andrews Air Force Base, MD: Air Force Historical Foundation, 1995), pp. 61-65.

1.6 System Performance - The system performance was faultless throughout the orbital mission, until battery depletion on Orbit 72 - with the exception of minor unexplained voltage disturbances on Orbits 8 and 9. This section presents the significant payload operating information, radar imagery samples and discussions of the payload performance, preceded by a brief summary of system parameters and performance.

Launch

Date: 21 December 1964 Time: 1908:56Z

Location: Launch Complex 75-1-1, Vandenberg AFB

Vehicle: LV-2A #425 SS-01A #2355

Orbit	Predicted	Actual
Period (MIN)	89.44	89.66
Perigee (N.M.)	130	135.82
Apogee (N.M.)	154	157
Inclination (deg.)	70.0	70.11
Eccentricity	.003	.0036
Active Orbits	65	73
Recovery	65	33
Payload Operations	13	14

Area recorded as fine resolution radar imagery: approximately 70,000 square miles (nautical).

Figure 19. Summary mission data. *Source*: Lockheed, *System Report 1*, p. 23.

designation 1964 87A) had been placed in a useful orbit (*Figure 18*) and was responding properly to commands. Word about the mission itself—whether the radar worked—would take several hours longer. The ground station at Vandenberg that had been set up to receive wideband data from the payload included a video display (cathode ray tube, or CRT, monitor) that would show the characteristic shapes of radar pulses being received and decoded if the Quill system were operating and transmitting. This equipment was operated by Goodyear, which for security purposes was referred to as the "Program Associate Contractor" (PAC). Later that day, at Sunnyvale, Bradburn received the message "PAC Room reports Code One"—radar returns from Quill were showing up on the Vandenberg CRT.

The mission, summarized in *Figure 19*, lasted only four days, as planned, before the unrechargeable batteries ran out of power during orbits 72-73.[36] The radar operated 14 times in orbit,†† between 0644 Coordinated Universal Time (UTC) 22 December 1964 and 0618 UTC 26 December 1964, imaging the swaths of the northeastern and western United States indicated in *Figure 20 (also*

†† The original mission design had called for 16 radar passes; available documents do not address the reduction. Goodyear, Engineering Analysis, p. 1-4.

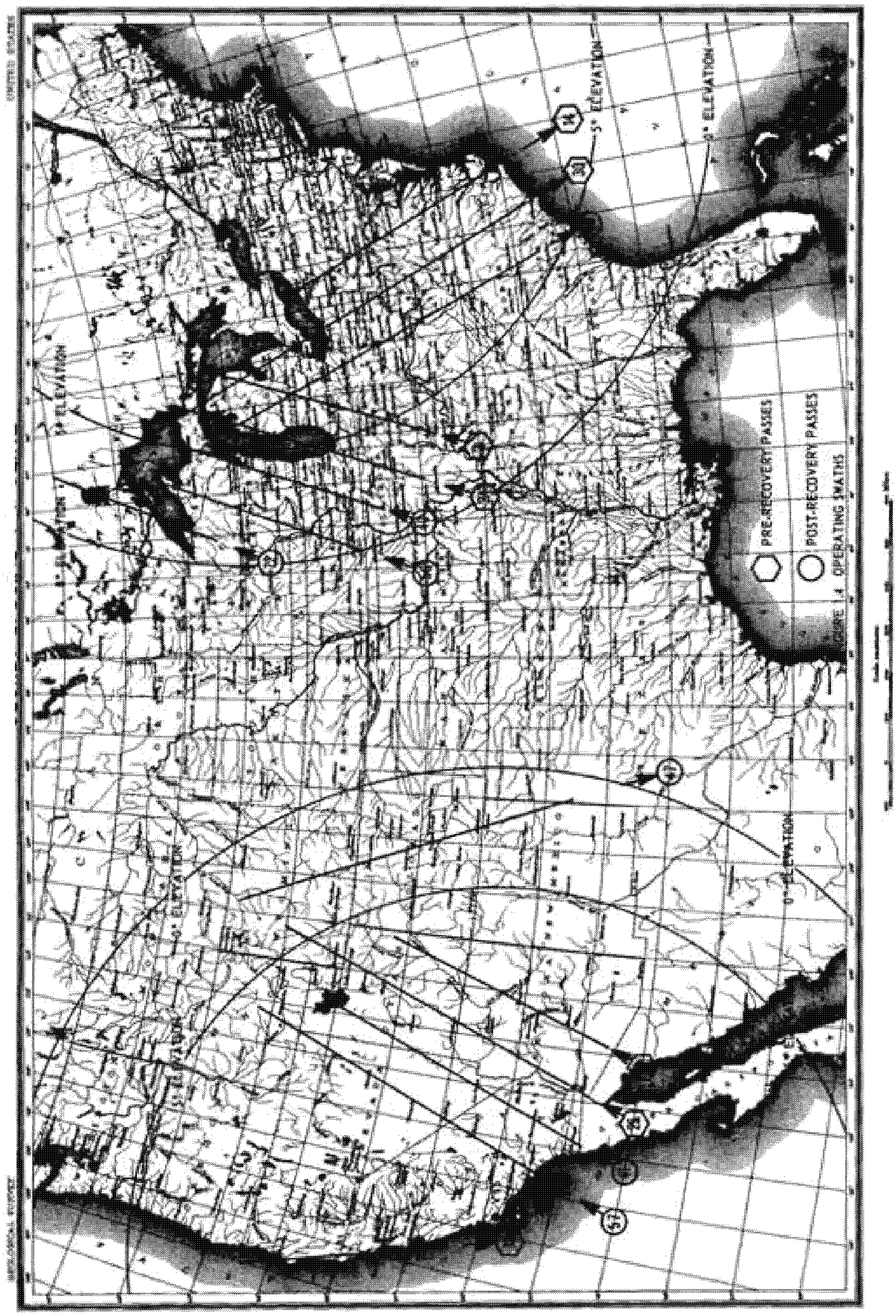


Figure 20. Ground traces for Quill imaging operations.
Source: Associate contractor, *Evaluation I*, p. 13.

see sidebar). Data collected from the 14 radar passes were transmitted over a wideband (UHF) data link as they were obtained ("real time") by the Vandenberg or New Boston ground station in view. In addition, during the first seven radar passes data was recorded on film on board the satellite, and on 23 December during the 33rd orbit the reentry capsule was jettisoned and recovered. The film was flown to Westover to be developed and the developed film then flown to another location where an associate contractor's employee ran it through the specially made "Precision Optical Processor" (known as POP-1) and developed the image films. They were dried, bundled, and given to another associate contractor employee to deliver to Los Angeles. The only delay in the process came when the employee's flight was cancelled, but the key question had already been answered. Associate contractor employees measured the azimuthal resolution to be 7.5 feet—the theoretical maximum from the 15-foot antenna—which immediately settled the question of whether there was a fundamental natural limit on SAR resolution from space.[37]

After less than two weeks of orbital decay the satellite re-entered the atmosphere at 1027 UTC 11 January 1965, on orbit 333. Several days earlier, Bradburn and his Program A superiors had already declared the mission a success. In his 30 December 1964 *Quarterly Report*, the Program A director said that "vehicle and payload performance were within acceptable limits on all parameters. . . . The radar maps . . . cover about 80,000 square miles. The resolution is better than 15 feet in azimuth and approximately 80 feet in ground range. . . . The volume of data is greater than had been anticipated. Technical evaluation has begun and will be completed in 90 to 120 days." In the meantime, "The second payload and Agena D booster are complete and are being held at [Lockheed]. The second flight has been removed from the launch schedule pending detailed analysis of the first mission. The third payload, which consists of forward structure, radar components, and recovery subsystem, is near completion at [Lockheed]. There is no booster for this payload. . . . Recommendations for disposition of the remaining Quill hardware will be made in 30 to 45 days."[38]

EVALUATING THE OUTCOME

The Quill team had wanted answers to several questions. Whether the satellite-based SAR would work was the main one, followed closely by others of practical engineering—how to make it work best. For example, it was helpful to experiment with the timing coordination among the functions of transmitting, receiving, and displaying the returns on the cathode ray tube:

> The sequence of events was as follows: the radar transmitted a pulse, the receiver and recorder waited 25 microseconds, and the CRT was then swept for 73 microseconds; the system then repeated the cycle after an additional wait of 16 to 24 microseconds (depending on the choice of prf). . . . On certain occasions, the sweep started a few microseconds before the return from the near-range arrived; the imagery corresponding to these occasions lacks contrast and [a good signal-to-noise ratio] at the near edge, but is better at the far-edge. Conversely, the opposite occurred when the sweep was late in starting. On still other occasions, the sweep was begun as the return from the far-edge was arriving, continued while the instantaneous return power level passed through its minimum, and was almost completed by the time return from the near-edge began to arrive; under these conditions, the CRT was inoperative for the major portion of the return. . . .[39]

Engineers also wanted to describe the SAR's performance quantitatively, particularly with respect to its azimuth-direction behavior, and to determine how it had been limited by design parameters and in-flight performance of the payload, attitude behavior of the satellite vehicle, atmospheric conditions, and design and performance of the wideband data link. They were interested in describing and diagnosing any anomalous system performance, in collecting data on the reflectivity characteristics of target fields, in demonstrating the capability of ground equipment to record useful data through the wideband data link, and in developing engineering data that would be useful in designing future aerospace radars. And they were most interested in seeing whether the analytic models derived from aircraft-borne SAR experiments, which had been used to prescribe and test satellite design, proved valid for operations in space.[40]

The associate contractor's engineers had designed ground-based tests to provide data for calibrating the

Could Our Adversaries Detect Radar?

Years later (see, e.g., Perry, pp. 35-37) a rumor began that Quill did not image territory outside the U.S. because the NRO feared international repercussions resulting from the radar emanations of its active imaging system. After the fact, DNRO McMillan said it was important: he wrote to the President's Foreign Intelligence Advisory Board (PFIAB) on 12 May 1965 that "radar operation during this mission was limited to Continental United States to insure availability of ground truth data, to obtain maximum quantity of all three types of products, and—since a radar sensor is an active device—to prevent possible complaints from foreign nations." There are, however, several inaccuracies in his presentation. (Notably, he stated that "the mission plan provided for simultaneous photography along the mission track by an RB-47," which would have required a truly remarkable aircraft.) Brockway McMillan, "Semi-Annual Report to the President's Foreign Intelligence Advisory Board on Activities of the National Reconnaissance Office," 12 May 1965 (TS/BYE), in ARC Job 200200001 Box 7 Folder 24.

Quill was an engineering proof of concept, and so it was operated where engineering test data could be obtained—where there were devices on the ground to check the far field antenna pattern, pulse repetition frequency, etc., and reflector arrays to check impulse response. In addition, there were only seven active passes during which data could be collected on film, and they were conducted where data could be simultaneously transmitted by wideband relay to ground stations at New Boston or Vandenberg. Bradburn told this story quite straightforwardly, and I [Butterworth] probed him on the question. Furthermore, how might have "international repercussions" been imagined to arise? Who would be able to detect the signal and classify it and reach the right conclusions about its source and the country responsible for it? The radar could be operated for no more than five minutes at any one time and for no more than three orbits consecutively without courting catastrophic failure. It operated at an average power level of 230 watts, from an altitude of 130 nautical miles and hence a slant range of about 160 nautical miles. It traveled at a velocity of 25,500 feet per second (about four nautical miles per second ground track velocity). It illuminated a swath about ten miles wide. True, sidelobes could be detected as well as mainbeam signals (though not backlobes), but even so the chance of detecting the signal and capturing enough of it to reach accurate conclusions is vanishingly small. The USSR would have had no ephemeris data on the satellite adequate to do ground measurements of any possible emanations.

SAR's performance. There were measurements at the earth's surface to check the operation of the antenna after launch,[‡‡] the transmitter pulse,[§§] and ground surface and weather conditions. Complexes of radar corner reflectors were laid out in near the associate contractor; their known cross sections and spacings could be used to calibrate estimates of the radar's range and azimuth resolution, sensitivity, and dynamic range. Because Quill's radar antenna was fixed, the associate contractor's engineers had to wait until they had obtained good ephemeris data and then scramble to move some of the corner reflectors to keep them in the satellite's field of view.[41]

‡‡ These were measurements of the azimuth beam pattern for the purpose of confirming that the antenna's far-field pattern remained correct after launch.

§§ "It was possible to detect and record the transmitter pulse, after it had propagated one-way from the satellite to the earth's surface, by detecting emissions via the sidelobes of the radar antenna pattern and recording these emissions on photographic film. This was done on several passes when the satellite was within line-of-sight of the airport near the associate contractor." Associate contractor, Evaluation I, p. 9.

These evaluations used visual images produced from the recorded data in the sequence outlined in *Figure 21*. First, the film of the video data was developed by the SPPL, using an approach aimed at maximizing the dynamic range of the recorder.[¶¶] The associate contractor team then used their precision optical processor to convert the data on the film into visual images. The highest resolution (and the best dynamic range) was obtained directly at the processor output, on photographic transparencies. The original output transparencies were then magnified 2.6 times and recorded as either paper prints or positive transparencies, neither of which was suitable for detailed analysis:

¶¶ "The flight system employed a [cathode ray tube] with a P-11 phosphor and a transfer lens which imaged the line trace of the tube at a 2:1 demagnification onto Kodak SO-266 blue-sensitive film. The film was developed in D-76 developer by SPPL. The dynamic range of the recording system in the flight vehicle was measured from test films generated prior to flight. . . . The value of the dynamic range of the flight recorder was about 19.5 db." Associate contractor, Evaluation II, p. 256. But cf. Lockheed, System Report 2, p. 4-11: "The video data recorded in the satellite and in the ground based recorders was recorded on 70 millimeter Eastman Kodak film, S. O. 119. The recorder CRT sweep covered a width of approximately 27.5 millimeters."

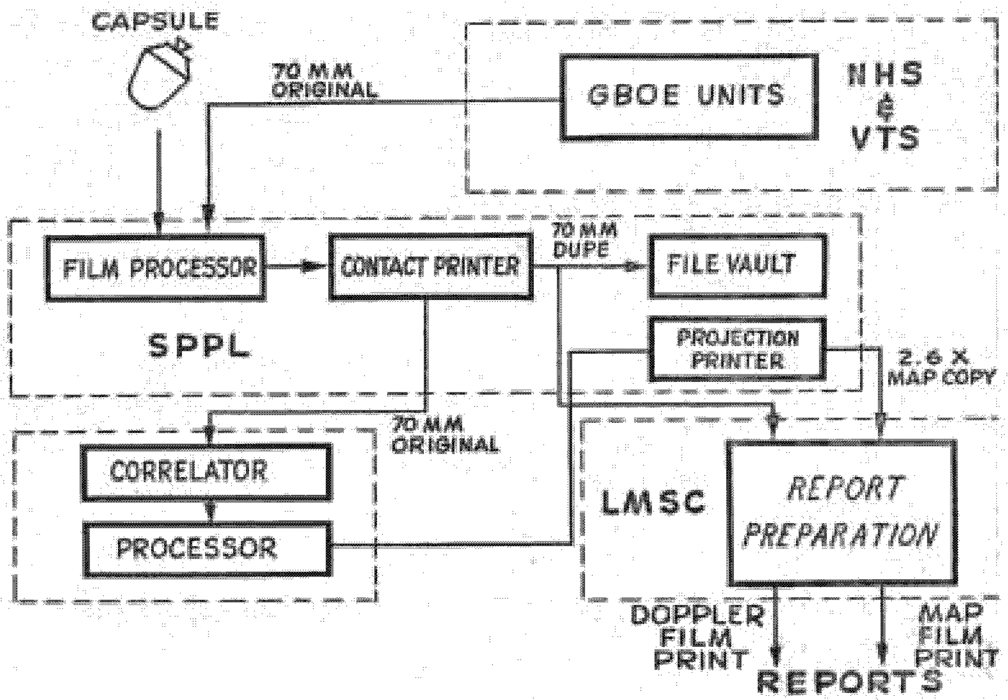


Figure 21. Image processing sequence.
Source: Lockheed, *System Report 2*, p. 4-2.

> The paper prints . . . have a resolution capability of perhaps 6 lines per mm; at the scale factors corresponding to the 2.6:1 enlargements, this poor resolution completely dominates the quality of the imagery. The resulting ground-range resolution is of the order of 90 to 100 feet. The degradations in the positive transparencies . . . are not as severe. In either case, imagery to the scale of the 2.6:1 enlargements is useful primarily for orientation and descriptive purposes only, and not for detailed study of the target complexes. Detailed examinations require the use of enlargements of greater magnification, the use of the original output transparencies, or in special instances the observation of the optical output of the processor prior to recording.[42]

The results showed the experiment to have been a great success. The radar worked and met the goal of 10-foot azimuthal[43] resolution.*** It had illuminated somewhat more than 100,000 square miles of terrain, almost 80 percent of which yielded usable images. Three-fifths of the images were of the best quality that the system could produce; the rest were degraded for testing or by slight errors in setting the pulse repetition frequency. Only four percent were lost unintentionally.[44]

As expected, the smooth trajectory of the satellite allowed it to provide relatively fine detail without the complex systems needed on aircraft to compensate for platform motion. In effect, "satellite borne systems are not subject to the resolution limitations normally imposed by platform instability in aircraft."[45] Slant-range resolution (which was not a design goal) was 45 feet, which at the Agena's depression angle provided a ground-range resolution of about 75 feet.††† The imagery showed several terrain and cultural features that held promise

*** Referring to the performance of a SAR in terms of "resolution" is a conventional solecism; usage today tends more often to the technically accurate "impulse response," or "IPR."

††† "Range resolution . . . was limited by the bandwidth of the electronics, which had been patterned after the AN/UPQ-102 radar system for reasons dictated by expediency; the most optimistic estimate of achievable slant-range resolution was of the order of 36 feet, which in turn implied a ground-range resolution of 60 feet at the design depression angle. Improvement of the range resolution to make it comparable with the expected azimuth resolution was not warranted, since it would not have affected the demonstration of the synthetic-aperture feasibility, and would have entailed considerable expense and delay." Lockheed, System Report 1, p. 33.

for strategic reconnaissance. Weather conditions did not seem to have affected the quality of the system's images except for a brief area of intense rainstorms, and even then the imagery revealed the underlying structure.

Quill answered dozens of technical and engineering questions. It showed that analytic models based on aircraft operations worked well for satellites. It showed that imagery processed from the transmitted data was only slightly degraded compared with pictures made using the recovered film. It showed that images obtained from orbit could fairly well match those from aircraft radars using similar technical parameters. It proved that ambiguous target indications could be minimized and that the slight inaccuracy and instability in the satellite platform could be compensated electronically. It also sampled the average radar reflectivities of several different types of terrain.

Altogether, in the words of the associate contractor's assessment, "the orbital flight satisfied the primary program objective by demonstrating that a satellite-borne SAR system could generate a fine-resolution image of a portion of the earth's surface; all secondary objectives also were met."[46] The Lockheed assessment added that the system proved its expected ability to produce radar imagery of a consistently high quality by day, by night, and through a variety of weather conditions; it also observed that the conditions that prevailed in most of the swath areas would have prevented successful photographic or infrared imaging *(Figures 22-26)*. Furthermore, the experiment did not produce any evidence of phenomena that would prevent future systems from realizing azimuth and ground-range resolutions on the order of 10 feet.[47]

The evaluation reports from the associate contractor, Lockheed, and Goodyear all exuded optimism and expectancy: Quill had been highly successful and the path to doing more—a further experiment, even an operational system—seemed clear. The associate contractor's report recommended that "designs of future systems be based on the type of analytic model used successfully for this design," that "proper use be made of radar equipment in manned aircraft for the purpose of collecting further data and testing configurations which are applicable to future satellite systems," and that various engineering adjustments be made to "future orbiting systems."[48] The Lockheed report agreed and recommended further that "future experimental orbiting systems incorporate power sources which are adequate for extended-duration missions, as required for operational applications."[49] Goodyear engineers undertook additional test work, demonstrating the value of improved potting techniques for the transmitter and modulator components of the radar as well as the ability to improve significantly the dynamic range of the recorded data by reducing film base density and reducing the recorder lens stop.[50]

A PAUSE

Yet Quill's seed fell on stony ground. Bradburn asked another officer, "What do you do when you come up to bat, and, the first time, you knock a ball out of the ballpark, what do you do then?" The reply was, "Well, Dave, I think you go down and sit on the bench."[51] On 5 January 1965 Bradburn gave NRO Director McMillan a "quick-look" briefing on the P-40 mission and got agreement that the second vehicle would be removed from the launch schedule, pending further recommendations to be made in February. On 11 February, several weeks before contractor evaluations of Quill's product and performance were completed, Major General Robert Greer, director of Program A, cabled McMillan that the Quill contractors recommended flying the second mission later that fall, but that he, Greer, did not agree. "In my opinion there is no need for more flights to show feasibility as such. We should have a definition of the desired operational use before we schedule any more launches. . . . The factors which need to be examined now do not require satellite flights." McMillan agreed, and the remaining hardware was placed in storage pending completion of the report of an evaluation committee commissioned by NRO headquarters.[52]

In his Program A *Quarterly Report* for June 1965—his last as director—Greer reported that further funding had been provided to the associate contractor to complete its studies, but that otherwise SP considered the Quill program completed.[53] At the end of the year Greer's successor, Brigadier General John L. Martin, reported that the DNRO had approved further funding for radar and associated tape recorder work. The RCA and Ampex tape recorder studies showed that the state of the art did not provide adequate bandwidth for existing radar applications; Goodyear completed a 100-hour life test of the Quill radar; Hughes produced and tested a space-qualified antenna, and also expanded the radar system design to a dual mode capability (high and low resolution); and Airborne Instrument Laboratory's research provided a feasible new radar system design as well as ongoing study of radar target signatures.[54]

Apparently none of this work went any further, and references to follow-on studies, operations, and plans disappear from the SP *Quarterly Reports* for several years after 1966. Three years later, in 1969, the NRO reported to its Executive Committee (ExCom) that "NPIC [National Photographic Interpretation Center] evaluated the [Quill] imagery, stated it was capable of providing

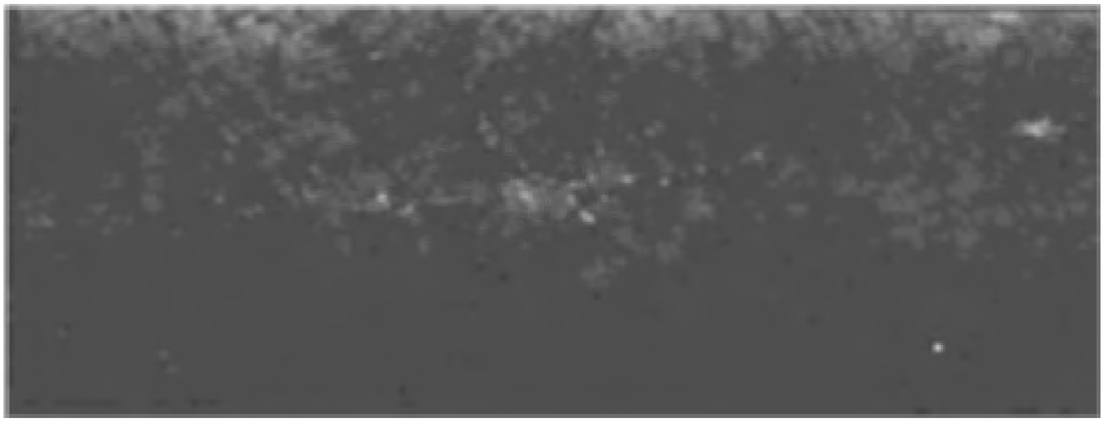


Figure 22. City/rural contrast.
(BIF-555-DP-12782-89) Courtesy associate contractor.

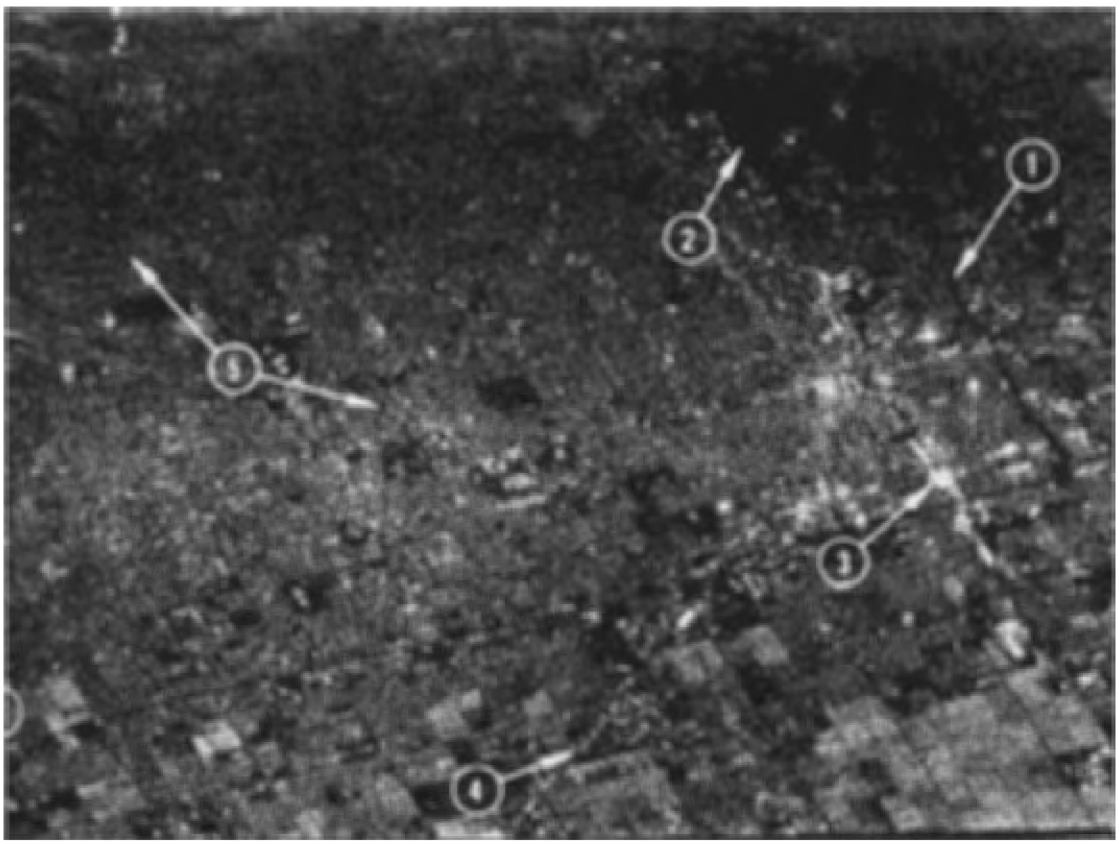


Figure 23. Phoenix, Arizona. Image taken on pass 9, northbound, at night (1:12 a.m. Mountain Standard Time, 22 December 1964). Weather: clear, temperature 48 degrees Fahrenheit, dew point 43 degrees, visibility 15 miles.

"The route of a major expressway (1) can be followed from the lower left around the most built-up portion of the city and up to the airport (2), the large return-free area at the upper right. Because the radar [pulse repetition frequency] was not matched to the beam illumination at the time, the airport edge of the swath fell in a poorly illuminated area near the edge of the beam. The railroad paralleling the left side of the airport does not stand out as do tracks across rural areas, but its course toward the lower right corner is marked by types of construction (3) that give strong returns. Similar returns accompany a diagonal branch line (4) ending at the lower center. The dark lines (5) that go irregularly up the center and along the base of the hills are canals." Associate contractor, *Evaluation I*, p. 30.

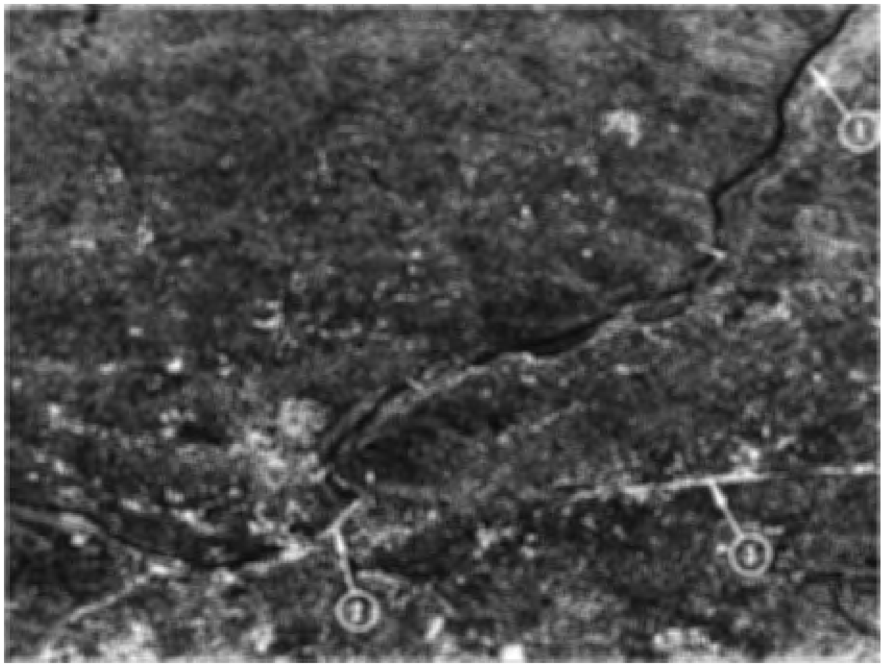


Figure 24. Richmond, Virginia. Image taken on pass 14, southbound, during daytime (11:08 a.m. Eastern Standard Time) on 22 December 1964. Weather was overcast with tops of clouds at 2,500 to 4,500 feet.

"Several road and railroad bridges cross the James River (1) and a mile-long elevated section of railroad (2) parallels the river near the center of the radial system. Again, the association of strong-return systems with railroad routes can be seen (especially (3)). Street, cultivation, and drainage patterns are recognizable." Associate contractor, *Evaluation I*, p. 33.

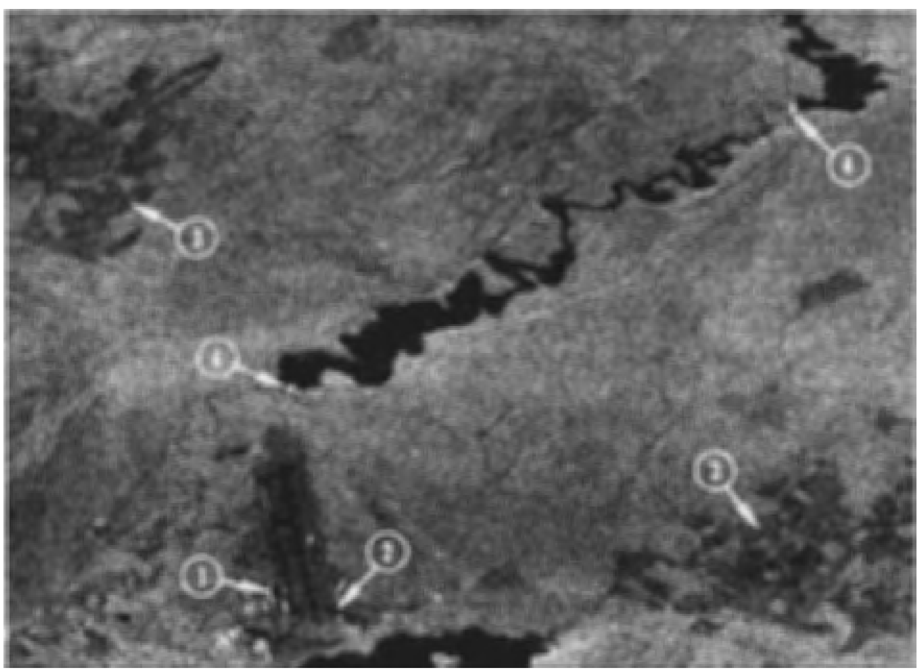


Figure 25. Wurtsmith Air Force Base, Michigan. Image taken on pass 30, southbound, during daytime (10:57 a.m. Eastern Standard Time) on 23 December 1964. Ground is covered by snow at least two inches deep; area is in fog, sky obscured, wind calm, one-mile visibility, cloud tops at 9,000-10,000 feet.

"This SAC facility stands out unmistakably from its wooded surroundings between Michigan's Van Etten Lake and the Au Sable River. Parked aircraft are likely to be responsible for the eight or more bright returns located on the rectangular paved area (1), but the rapid-egress parking spur (2) contains only one or two aircraft-like returns. Many roads, including some little-traveled ones, are seen as narrow gaps in the tree cover, although some such gaps are power-line clearings. Two large areas of cleared land (3) show where the forest has given way to farmland. . . . Two dams (4) and the reservoirs they form are readily detected and identified. No power lines are seen emanating from the hydroelectric plants here . . . ." Associate contractor, *Evaluation I*, p. 37

Figure 26. Point Reyes, California. Image taken on pass 15, southbound, during daytime (11:05 a.m. Pacific Standard Time) on 22 December 1964. Weather conditions: heavy rain, scattered clouds 700-1000 feet, heavy overcast 1400-2500 feet, clouds in layers to 35,000 feet.

"Intense rainfall was occurring locally in the area . . . . While the clouds themselves are generally not imaged, the occasional regions of dense rain (see arrow) scatter considerable signal back to the radar, causing cloud-like forms in the image. Inspection of the film shows that the ocean wave-structure patterns can be observed even in the densest parts of the rain-returns. Furthermore, although the raindrops both back-scatter and attenuate the radar waves, hence reducing the illumination at some greater slant range, no shadows of these rain cells have been noticed in the imagery. Of interest is the alteration of the wave pattern in the shallow water off the beach, and its diffraction around the point and into Drake's Bay." Associate contractor, *Evaluation I*, p. 77.

useful intelligence, and recommended further research and development."[55] And in 1972 an "NRO Position Paper on the NRO Satellite Program" stated that after Quill's flight, "it was concluded that no further satellite experiments as such should be conducted; instead efforts should be made to define precisely the system application desired, and then the development of the actual system should proceed. The system application studies, intended to be conducted in parallel with the engineering demonstration, were not decisively concluded. Thus by 1965 the NRO had completed an orbital demonstration, but no agreement had been reached that the proposed application, bomb damage assessment, or any other application, was sufficiently attractive to proceed."[56]

Bradburn helped where he could. Through his efforts, the associate contractor got new aircraft for further research and development, and in spring 1965 he took the associate contractor's employee to the NPIC to educate and help the photointerpreters make use of radar images. (The employee met with little success: the photo-interpreters generally picked up the radar images only to throw them away.[57]) In the summer of 1965, Bradburn left Program A to attend war college; he returned a year later at the request of Program A's director Bill King, but had little opportunity to work on radar.[58] The *Quarterly Report* for 30 June 1966 advised that in July project responsibility for Quill would be transferred from the sigint office to Lt. Col. Bradburn, working in the applied research and advanced technology office (SP-6) under Colonel Lew Allen.[59] The next *Quarterly Report* noted that SP-6 had a deficit of one officer: "Lt. Col. Bradburn transferred to sigint on 2 August. SP-6 not now manned to accomplish work in radar and elint technology."[60]

Reflecting on the question of Quill's singularity, Bradburn reiterated his objective: to show that satellite-based SAR imagery could help provide post-strike reconnaissance (bomb damage assessment) for SAC. That objective was accomplished and briefed to SAC. When SAC officials asked Program A's director, John Martin, "What's next?" Martin said: "Send money."[61]

Cancellation of further Quill flights gave SP a big boost in its annual "cost reduction" report—more than two-thirds of the total claimed for FY1965 and earlier. "We are pleased," stated SP Director Brig. Gen. Martin, "to report that these reductions have been made without adverse impact on mission performance."[62] The NRO had demonstrated the technical feasibility of an all-weather, day-night imaging system that could meet an important SAC need; if SAC wanted one, then SAC would have to create a program to develop it. Director Charyk had been emphatic in his cable of authorization: "The effort is to be strictly experimental in nature and is not to be considered in any sense as an operational prototype or the initial step of an operational system development. . . . The request for proposals should make clear the experimental, rather than the operational prototype or system nature of this effort."[63] The director of intelligence for SAC offered to help evaluate the Quill imagery and the NRO staff responded affirmatively, noting that an engineering evaluation was under way by contractors, that an intelligence evaluation was being established, and that "a separate analysis of the Quill product from the SAC operational viewpoint would be of great value to us in the overall evaluation of the system."[64]

Some of SAC's intelligence officers favored going ahead with a procurement,[65] and during 1965-66 they continued to visit Program A to stay up to date on the continuing analyses of Quill and imaging radar technology. The SP *Quarterly Report* for 30 June 1966 reported tersely that "on 26 May SAC briefed SAFSP (Office of the Secretary of the Air Force for Special Projects) on their desired radar system for post attack reconnaissance. No requirement for this system has yet been established."[66] Perhaps SAC delayed in the hope that some other budget would support the desired development; perhaps its officers did not get Martin's message as clearly as Bradburn did; perhaps they thought the mission was well ensured by the new SR-71 reconnaissance aircraft; or perhaps something entirely different accounts for the command's lack of initiative for further program development at that time.[67] Or perhaps the command had in fact pressed for an imaging radar satellite through different channels. Dr. Alexander Flax, who became director of the NRO on 1 October 1965, recalled seeing a statement of need to this effect coming through non-NRO channels when he was serving as Assistant Secretary of the Air Force for Research and Development. He passed it forward, without comment, to the Joint Chiefs, and did not hear about it again.[68]

Perhaps the NRO should have done more as well; it was responsible for developing intelligence collection satellites, and Quill had already demonstrated a resolution almost three times better than the early Corona cameras. Why was there no second, improved version of Quill? In part, even some officers in Program A thought there were good a priori reasons to discount the value of an imaging radar satellite, regardless of Quill's success. Pointing to its "small area coverage, narrow bandwidth, and low resolution," they argued that it could not serve either search or indicator monitoring purposes. "Only in the area of Post Strike Assessment can radar be expected to be satisfactory . . . whether a radar PSA system is practical as an operational system remains to be seen. There are practical difficulties and there exists doubts [sic] as to whether such a system is the best way to learn, quickly and surely and inexpensively where the bombs hit."[69] According to Bradburn, the NRO saw no point in conducting further demonstration missions. In Flax's view, the relationships among radar parameters and image interpretation needed to be explored and understood more systematically, and he insisted that Program A establish a program of experiments.[70] The NRO together with the Air Force and CIA continued to fund ground-based research at a low level, but none of those efforts involved orbital tests.

Reflecting on the effort later, Flax said that the real difficulty was opposition from the intelligence community.[71] There was strong support from defense leaders for proceeding with a radar satellite program: SAC was favorably impressed by Quill, and the new director of defense research and engineering, John S. Foster, Jr., urged Flax (and Flax's successor, John McLucas) to build another satellite.[72] Flax also thought it would be a good idea, but some in the CIA were resistant.‡‡‡ Quill had shown that satellite-borne SAR imagery was feasible, but the intelligence community thought and worked in terms of optical imagery, and in those terms a radar satellite would not be useful until it attained much finer resolution. A system that was worthwhile for tactical bomb damage assessment was not justifiable as a national intelligence asset. Officers in CIA's science and technology directorate declared that other technologies might be developed that could

‡‡‡ CIA's deputy director for science and technology, Albert D. "Bud" Wheelon, was not among them. He applauded the experiment and criticized Bradburn only for not going ahead to do more. (Interviews with both, May 2000, Los Angeles and Montecito CA.)

provide better images; yes, Flax replied, but SAR is a technology that we know how to do now.

Still, Flax did not believe he should press the matter in the absence of agreement, in the form of requirements, from the intelligence community. Mindful of the programmatic strife under his predecessor, Brockway McMillan, and working under a new NRO charter intended to repair that damage and prevent its recurrence,[73] Flax paid attention to bureaucratic diplomacy, taking care to base his decisions and recommendations on solid technological ground.[74] In doing so, Flax proved far more than a mere barometer of consensus; he successfully opposed the strong preferences of Program B, for example, in canceling the CIA's independent efforts to build a launch vehicle, in dividing program management responsibility for a new photo-reconnaissance system (Hexagon), and in choosing the molniya orbit recommended by Program A for a new program. The SAR satellite proposal, however, was not a question of how to do something but whether something was worth doing in terms of intelligence. And Flax believed that the NRO director should not under these circumstances unilaterally overrule the nation's premier intelligence agency. That action would have to be taken by the higher governing body that oversaw NRO programs, the executive committee (ExCom), and to that end Flax raised the issue with Deputy Secretary of Defense Cyrus Vance, the ExCom's chairman. Vance would also have heard from Foster, whose job as Deputy Director, Research and Engineering (DDR&E) included monitoring NRO programs and providing advice directly to the deputy secretary of defense. Flax thought Vance was impressed somewhat with the SAR technology but evidently did not feel strongly enough to press the issue with the new director of central intelligence (DCI), Richard Helms. Helms, in turn, came from a background in traditional intelligence, was not personally attuned to space technologies and satellite reconnaissance, and in this matter followed the recommendations of Program B.

Flax was left with pursuing a technology development program in an effort to persuade the intelligence community that there really was information valuable for intelligence purposes in radar data. The prospects, he thought, were not without hope. In practice, the standard to be met was radar imagery on a par with imagery obtained from optical systems—an order-of-magnitude improvement. A major advance was needed; evolutionary improvements in film emulsions, platform stability, signal timing, recorder dynamic range, and the like would not be enough to bring a 10:1 improvement in resolution. Bradburn predicted that such a gain would take considerable time, perhaps ten years.

CONCLUSION

No physical artifacts and few documents remain from the Quill experiment. The Thor/Agena launch vehicles were recycled into the Corona program, and the remaining radar equipment was broken up and destroyed. "It was heartbreaking," Goodyear's project engineer said. "One time," he went on, "someone came [to Litchfield Park] and had the right kind of credentials, and wanted to know if any hardware existed from the KP-II program. I said no, all had been destroyed. What did you want to do with it? He said they wanted to put it into the Smithsonian museum. Sorry, all gone. Unfortunate that the program has remained so highly classified. But that's the way it is. I'd like to be able to tell my son what I had accomplished and what I was a part of, but I can't and I won't."[77]

Gone, too, was a time of exploration and innovation that today seems as remote as John F. Kennedy's Camelot. Outside the Washington NRO headquarters, there was close and willing cooperation between Program A, the Air Force component of the NRO, and the CIA component, Program B. Government authority was vested in a project officer, Major Bradburn, who possessed both the relevant technical expertise and development experience. Only one management layer, Bill King, separated Bradburn from the director of the NRO, who became involved only to approve the project (and receive King's quarterly reports). Being himself knowledgeable in the technical field, Bradburn used informed peer review to select the contractor team, which worked intimately together and with him to ensure that vehicle, payload, and processing worked smoothly. Somehow, despite the absence of lengthy requirements studies, analyses of alternatives, voluminous proposals, large program offices, acquisition approvals, and extensive oversight, this risky experiment was completed in less than 30 months. It was in all respects a "sparkling success."[78] It generated a wealth of technical data, and it ended with money left over.

ENDNOTES

***Note on sources*: Documents and interviews cited in the references are filed in the Center for the Study of National Reconnaissance (CSNR) Reference Collection, unless identified as being held in the NRO Archive Records Center (ARC) or the Army Archive Records Center (AARC).**

1. "USAF Pushes Pied Piper Space Vehicle," *Aviation Week* (14 October 1957), p. 26.

2. "Test Firings for Pied Piper Due Soon," *Aviation Week* (16 June 1958), p. 19.

3. In *Aviation Week and Space Technology* 69:10 (8 September 1958), pp. 100-101.

4. Redacted.

5. Radar tantalized aerial navigators through World War II and into the Korean War with the hope of being able to see the ground despite darkness, cloud, or dust, but radar mappers and bombsights of the day never offered sufficient precision. The goal was pursued during the 1950s using two very different technologies. Greater emphasis was given to side-looking radar (SLAR), which concentrated on World War II real-aperture technology and could only find increased precision in larger antennas. Installed in wing pods, under the belly, or along the fuselage, the larger antennas looked to the side of the flight path and produced a range-delimited silhouette on the radar scope. The scope could be recorded by movie camera and played back to help navigators and pilots become familiar with what they might see on their radar screens during actual operations.

The needed precision finally came from a very different approach. During 1951-52 a handful of radar engineers in different organizations thought of using information contained in the phase of radar returns to construct images. Described in the early days as a kind of filtering or Doppler "beam-sharpening" before the term "synthetic aperture" was generally adopted, this approach was pursued most intensively by the associate contractor and at the Goodyear Aerospace Corporation

SAR systems point to the side of an aircraft's flight path but they are profoundly different from the real-aperture (SLAR) systems. "With the real array, the return from each range increment is received simultaneously by all array elements every time a pulse is transmitted; whereas, with the synthetic array, the return is collected by the individual elements serially over the period of time the radar takes to traverse the array." [George W. Stimson, *Introduction to Airborne Radar* (El Segundo, California: Hughes Aircraft Company, 1983), p. 528.] Pointing the antenna in a SLAR system, for example, changes the geometry of the scene obtained; in a SAR system it changes the signal-to-noise ratio.

6. Information about Goodyear's research into space-based SARs is drawn largely from an interview with the company's project engineer for the Quill radar, 10 May 2001, Litchfield Park, Arizona.

7. The Air Force funded several study teams in this effort. Goodyear and the Glenn L. Martin company were one study team, and Goodyear's project engineer and another employee spent time in Baltimore participating in the study program and writing a proposal to use SAR in the DynaSoar program.

8. Interview with the associate contractor's employee, 13 June 2001, Chantilly, Virginia.

9. Goodyear's project engineer thought that Lockheed and Goodyear developed the concept and that Lockheed got King's group interested in it during late fall 1961.

10. Maj. Gen. David D. Bradburn (USAF, ret.), interview, 2-3 May 2000, Los Angeles, California.

11. "Subject is satellite radar experiment," began a 21 November 1962 cable from NRO headquarters to Maj. Gen. Greer, head of the Air Force Special Projects activities on the West Coast. "SAFUS [Charyk] directs the establishment of a separate classified project under SAFSP management leading toward actual orbital tests and demonstration of the feasibility of radar sensors, including electronic data readout." Secret, ARC Job 199880073 Box 1 Folder 100. Charyk had been briefed on the potential advantages of radar imaging on 18 September 1962 by Captain Gorman, USN ("SAFSP Historical Chronology CY 62," Secret, ARC Job 199800072 Box 3 Folder 11). In December 1962 Charyk told DCI McCone briefly that "Project Quill is research toward an experimental radar payload for bomb damage assessment." Charyk to McCone, memorandum, 14 December 1962, "Memorandum for Mr. McCone," (TS/BYE), ARC Job 199700046 Box 4 Folder 14.

12. The Quill program Office had consisted of three people including Bradburn.

13. Information about the contractual arrangements for Quill is drawn from the Bradburn interview and from Lockheed Aircraft Corporation, *Vehicle 2355 System Report: Volume 1: Summary* (Sunnyvale, California:

Lockheed Missile and Space Co., 31 March 1965), pp. 8ff., S/BYE (BIF003/2-195008-80).

14. Lockheed, *Vehicle 2355 System Report 1*, p. 15. The description of mission objectives following in the text is from the same place.

15. Charyk wrote to DCI John McCone that "Project QUILL is research toward an experimental radar payload for bomb damage assessment" (Joseph V. Charyk, Director, National Reconnaissance Office, to Mr. McCone, memorandum, 14 December 1962, p. 4, TS/BYE, ARC Job 199700046 Box 4 Folder 14). Officers from Program A had been discussing the Strategic Air Command's need for reconnaissance data to assess bomb damage inflicted by nuclear strikes. A year later, the new director of the NRO, Brockway McMillan, told the United States Intelligence Board and the 5412 Group that "the Quill experiment is being conducted to demonstrate the feasibility of high resolution radar for terrain reconnaissance from a satellite," and that it was expected to achieve "about a 100-foot resolution over a swath width of 10 miles" ("Status of Satellite Reconnaissance Programs," 13 November 1963, p. 7, TS/BYE, ARC Job 199700046 Box 4 Folder 14). A Program A staff paper prepared during summer 1963 (but not released) reported that "20 ft. resolution is the very best we can expect from present know-how and resolutions of 40-50 feet are more likely. 20-50 feet resolution is considered adequate for the Post Strike Assessment mission where all we need to know is where the bomb hit, but whether a radar PSA system is practical as an operational system remains to be seen. . . . Further effort in this field should be held up until we are able to get some answers from the Q [Quill] tests. Only then can we assess the future capabilities of radar in satellite reconnaissance and only then can we know the feasibility of a practical operational PSA satellite" ("Satellite Reconnaissance," July 1963, p. 20, TS/BYE, ARC Job 199700046 Box 46 Folder 14).

16. Bradburn's approach to managing the project evidently embodied the precepts of the "King Doctrine," attributed to Bill King when he was head of a program. They admonished managers to keep the program office small, hand-pick their people, control contractors by direct personal contact, stress that program success is the raison d'etre for the program office, and "keep it simple." The latter meant using proven components whenever possible, trimming non-essential engineering, buying fewer spares, sticking to a single checkout, abbreviating documentation, and simplifying tests. Briefing attached to note from J. C. Fitzpatrick, annotated "given 28 Sept 1989 at LA," in file, "Jim Fitzpatrick 19 Jun 90," Bradburn papers on sigint history study, unaccessioned, NRO History Office files. In Perry's view, Bradburn "emphasized those qualities of incrementalism and low-risk technology espoused by King, [Col. C. Lee] Battle, [Col. Paul E.] Worthman, and Greer," and the project itself "seemed another proof of the validity of a policy of incremental acquisition." Robert L. Perry, "Recce Satellite R&D: Capabilities in Readout, Crisis Reconnaissance and Very High Resolution," final draft of Chapter XVII in his *NRO History,* pp. 10-11, S/BYE in ARC Job 199600096 Box 6 Folder 10.

17. Associate contractor, *Evaluation of a Satellite Radar Experiment I* (August 1965), pp. 115-117, SECRET-SPECIAL HANDLING.

18. Information about the payload is drawn from Goodyear Aerospace Corporation, *Engineering Analysis Report No. 1, KP-II Radar System* (Litchfield Park, Arizona: Goodyear Aerospace Corporation, 25 July 1964), SECRET-SPECIAL HANDLING.

19. Associate contractor, *Evaluation I*, p. 5.

20. Bradburn, interview.

21. Lockheed, *System Report 2*, p. 1-139.

22. Lockheed, *System Report 2*, pp. 1-133–1-154.

23. Associate contractor, *Evaluation II*, pp. 251ff.

24. "In its recent annual report, Lockheed referred to a statement by Maj. Gen. Bernard A. Schriever, commander of Air Research and Development Command's Ballistic Missile Division, that the reconnaissance satellite system will include a recoverable capsule." "Test Firings," *Aviation Week* (16 June 1958), p. 20.

25. Goodyear, *Engineering Analysis*, p. 9-1.

26. "A light source is collimated by lens L_c to illuminate the film with a coherent wave of light. The lenses L_1 and L_2 are set as a telescope and have the primary purpose of imaging the tilted recording plane. The three cylindrical optical elements are also telescopic and, in conjunction with the spherical telescope, image the tilted azimuth plane so that it is coincident with the imaged range plane at the recording surface. A three-element cylindrical telescope is used so that the azimuth magnification of the optical system can be continuously adjusted. This allows the processor to easily accommodate various azimuth scale factors. The filter plane aperture, between the two spherical lenses, serves the purpose of removing two of the three waves formed in the diffraction process, as only one of the waves (either the convergent or divergent) is

necessary to make the fine-resolution map." Associate contractor, *Evaluation II,* pp. 259-260.

27. Goodyear, *Engineering Analysis,* pp. 4-1–4-12.

28. Col. Jack Ledford, to Deputy Director (Research), memorandum, S/BYE (BYE-2453-63); AARC Job 80B00251A Box 1 Folder 3. Scoville did not long remain as deputy director for research; he had been frustrated for months in his attempts to create the research organization by acquiring elements of other CIA organizations, and in June 1963 he resigned. Director McCone chose Albert D. "Bud" Wheelon to replace him.

29. As of 24 July 1963 SAFSP funding (cable dated 1643Z 24 Jul 63, S/BYE, AARC Job 80B00251A Box 1 Folder 65). This cable also identified May 1964 as the intended launch date, and identified September 1964 as the date for having a second ready (payload only). The following month (August 1963) OSA estimated that its support to Quill would cost about the same; see memorandum dated 21 August 1963 concerning FY64 status of black funds, SECRET-SPECIAL HANDLING, AARC Job 80B00251A Box 1 Folder 65. Contractor requirements at that time were identified, leaving a balance in the CIA's Quill account.

30. Bradburn, "Security Plan—Action Items," memorandum, 19 December 1963, S-Special Handling, and enclosure 1, "Quill Supplement, Covert Programs Security Plan," 2 March 1964, S-Special Handling.

31. Cable dated 26 Mar 63 to OSA, SECRET, AARC Job 80B00251A Box 1 Folder 3.

32. SAFSP Director, *Quarterly Report,* 31 May 1964, TS/BYE.

33. SAFSP Director, *Quarterly Report,* 31 May 1964.

34. SAFSP Director, *Quarterly Report,* 30 September 1964, TS/BYE.

35. SAFSP Director, *Quarterly Report,* 30 December 1964, TS/BYE.

36. Cf. the *Quarterly Report* for 30 December 1964: "the batteries were depleted by Rev 79, which agrees with predicted battery life." Subsequent testing on the KP-II indicated that the mission would not have lasted much longer in any event. Small potting voids in two high-voltage modules grew in size with repeated temperature cycling and provided a high-voltage corona discharge path that eventually led to catastrophic failure. Once identified, the problem was readily addressed and the corrective action proven with an extended life test. See Goodyear Aerospace Corporation, *KP-II Final Report: Experimental Laboratory Investigations BKP-II-16* (Litchfield Park, Arizona: Goodyear Aerospace Corporation, 31 March 1966), pp. 5-6, SECRET-SPECIAL HANDLING.

37. Such a limit had been contended in some contemporary technical papers, including some from the Aerospace Corporation, according to the associate contractor's employee (interview).

38. SAFSP Director, *Quarterly Report,* 30 December 1964.

39. Lockheed, *System Report 1,* pp. 37-38.

40. Secondary objectives are described in Lockheed, *System Report 1,* pp. 15-17; and associate contractor, *Evaluation I,* pp. 3-4.

41. Associate contractor employee, interview.

42. Lockheed, *System Report 2,* pp. 4-14–4-15.

43. "Two independent measures of achieved resolution are available. The first of these is obtained from the imagery of Pass No. 8 itself—a test array of radar corner reflectors fell within the mapped swath. The image of this array showed that azimuth resolution of roughly 10 feet, and ground-range resolution of roughly 75 feet, were achieved. The second determination was made via a measurement of the two-dimensional response of the system to a strong isolated target which was imaged near the southern end of Pass 30. The system impulse response determined directly at the output of the optical processor, had a half-power width of 10 feet in azimuth and 72 feet in ground range." Lockheed, *System Report 1,* pp. 34-35.

44. "The usable imagery obtained represents 88,000 square miles or 79 percent of the illuminated terrain; of the total, 63 percent is substantially as good as the system was designed to produce, while 16 percent suffered only from uneven illumination caused by slightly incorrect pulse repetition frequency (prf) setting. Another 17 percent of the attempted coverage was sacrificed during various test sequences in which the prf and/or the attenuation level were intentionally mis-set. Of the 4 percent that was unintentionally lost, the major portion was the victim of occasional failures of the ground-recorder to resynchronize its sweep promptly when prf was switched, during those times when the system was dependent on the data-link output. An easily correctible fogging of the onboard film between active passes also accounts for some loss of imagery." Associate contractor, *Evaluation I,* p. 15.

45. Lockheed, *System Report 1,* p. 146.

46. Associate contractor, *Evaluation I,* p. 89.

47. Lockheed, *System Report 1,* p. 146.

48. Associate contractor, *Evaluation I,* pp. 91-92.

49. Lockheed, *System Report 1,* pp. 146-148.

50. Goodyear, *KP-II Final Report,* pp. 151-154.

51. Goodyear's project engineer, interview.

52. Greer's cable, 11 Feb 65, subject: Disposition of Quill Hardware (ARC Job 199800073 Box 1 Folder 106). In 15 Feb 65 NRO headquarters approved placing the remaining Quill hardware in storage pending receipt of the report of the evaluation committee in Washington.

53. SAFSP Director, *Quarterly Report,* 30 June 1965, TS/BYE.

54. SAFSP Director, *Quarterly Report,* 30 June 1966, TS/BYE.

55. Memorandum for the Record, "List of Topics for Discussion with ExCom," TS/BYE (BYE 12941/69), 13 June 1969, in ARC Job 199700046 Box 4 Folder 8.

56. "NRO Position Paper on the NRO Satellite Radar Program," attachment to John L. McLucas to Assistant Secretary of Defense (Intelligence) and Director, Defense Research and Engineering, memorandum, "Synthetic Aperture Radar Surveillance Satellite System," 10 October 1972, TS/BYE (BYE-13130-72), in ARC Job 199900005 Box 2 Folder 19.

57. Associate contractor employee, interview.

58. Bradburn had been promoted to Lieutenant Colonel by the time of the launch, and in the summer of 1965 left Los Angeles to attend the Air War College. He planned his next tour to be in Washington, D.C., but returned to Program A at the request of Brig. Gen. King. In June 1966 SP was planning to transfer the Quill project from the sigint office to the advanced technology office, headed by then-Colonel Lew Allen, Jr. Bradburn was promoted to Colonel during his year at the War College and returned to SP to head the sigint office. Bradburn, interview.

59. SAFSP Director, *Quarterly Report,* 30 June 1966.

60. SAFSP Director, *Quarterly Report,* 30 September 1966, TS/BYE.

61. Bradburn, interview.

62. Brig. Gen. John L. Martin, USAF, to Director, NRO (Dr. Flax), memorandum, "Survey and Audit of Cost Reduction Items," S/BYE (BYE-66289-66), in ARC Job 199800073 Box 1 Folder 125.

63. Charyk to Greer, 21 November 1962.

64. "We greatly appreciate your offer of SAC assistance in evaluating the Quill system; specifically, its application to the BDA [bomb damage assessment] problem." Brig. Gen. James T. Stewart, director, NRO staff, to Maj. Gen. Robert N. Smith, director, intelligence headquarters, SAC, memorandum, "Evaluation of Radar Imagery," 9 February 1965, TS/BYE (ARC Job 199800073 Box 1 Folder 106).

65. USAF Office, interview, January 2000, Waterton, Colorado.

66. SAFSP Director, *Quarterly Report,* 30 June 1966.

67. An imaging radar satellite, even with better resolution than Quill, might in fact have been irrelevant to SAC's operations. At the time, the declared nuclear strategy of the United States was an oxymoron, emphasizing both "damage limitation" and "assured destruction." Damage limitation called for building offensive forces that could destroy enemy offensive forces and so, together with antiballistic missiles and civil defense, make it more difficult for Soviet forces to damage the United States. Soviet leaders were presumed to see from these forces that they would not be able to achieve any reasonable war aims and so would be deterred from striking the United States first. Assured destruction, on the other hand, argued that deterrence was based more safely on the assured ability to punish a Soviet first strike by destroying Soviet cities and industries in significant amounts; Soviet leaders were presumed to see that by attacking the United States first they would lose far more than they could hope to gain and so would be deterred from doing so. The contradiction between these themes arose because efforts to improve a damage limitation capability undercut the assured destruction philosophy, as John Newhouse explained, "because it may degrade your adversary's ability to destroy your own cities in a second strike. His confidence undermined, he might then be tempted in a crisis to strike pre-emptively; in short, knowing you are effectively protected from his second-strike assault and fearing your intentions, he may choose to strike first." John Newhouse, *Cold Dawn: The Story of SALT* (New York: Holt, Rinehart, and Winston, 1973), pp. 9-10. Secretary of Defense Robert S. McNamara argued for the primacy of damage limitation in 1962 ("the principle [sic] military objective in the event of nuclear war should be the destruction of the enemy's forces [not

his population]),” and for assured destruction in 1967 (“I think we could all agree that if they struck first we are going to target our weapons against their society and destroy 120 million of them.” Newhouse, *Cold Dawn*, p. 11).

68. Dr. Alexander Flax, interview, 5 February 2003, Chantilly, Virginia.

69. Draft manuscript, “Satellite Reconnaissance,” marked “Colonel Study, Not Released,” July 1963, TS/BYE, pp. 20-21, ARC Job 199700046 Box 4 Folder 14.

70. Office of the Historian, National Reconnaissance Office, “Former NRO Directors Series: Interview with Dr. Alexander Flax,” 22 May 1997, LIB # 01881, S/BYE.

71. Dr. Alexander Flax, interview, 21 November 2002, Potomac, Maryland.

72. “Proposing the radar satellite just seemed so obvious. You could go to where they had the film [NPIC] and see lots and lots of clouds, week after week, nothing but clouds, and we needed timely information.” John S. Foster, Jr., interview, 4 December 2002, Washington, D.C. In his budget review in November 1966, Foster wrote that funding for “direct read-out” for imagery should be reduced and “emphasis placed on an all weather capability and in advanced development for overhead sigint.” Foster to Flax, memorandum, 22 November 1966, “Special Support Activities RDT&E FY 1968 Budget,” TS/BYE (BYE-5662-66; ARC Job 199800073 Box 1 Folder 118).

73. Perry, *Management,* pp. 106ff.

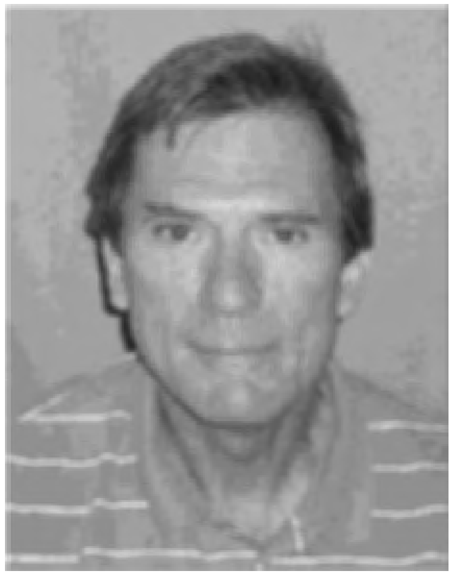
74. McMillan was less careful and cost himself technical credibility. He concluded fantastically that the NRO would accomplish the intercepts by building “a covert, and relatively inexpensive, element of a satellite openly developed for other purposes, purposes which in themselves come close to justifying the costs involved.” Such purposes, he went on to say, might be weather observation or communication relay. McMillan to deputy director, science and technology, CIA, memorandum, “Studies of Synchronous Satellites,” 5 November 1964, TS/BYE (BYE-23486-49), ARC Job 199800066 Box 3 Folder 2.

75. Paragraph redacted.

76. Paragraph redacted.

77. Goodyear project engineer, interview.

78. Perry, “Recce Satellite R&D,” p. 11.



ACKNOWLEDGEMENT

Robert L. Butterworth has written classified histories for the NRO. He is the author of several contributions to basic and applied research in national security affairs, is a former college professor, and has held staff positions in the Defense Department, the U.S. Senate, and the White House. His graduate degrees are from the University of California at Berkeley.

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COURIER CONTROLLED
MATERIAL
PROPERTY OF THE
UNITED STATES GOVERNMENT
IF FOUND, DO NOT OPEN
TRAILBLAZER 1964:
THE QUILL EXPERIMENTAL RADAR IMAGERY SATELLITE COMPENDIUM
SECTION II:
QUILL DOCUMENTATION OVERVIEW

QUILL DOCUMENTATION AT THE NATIONAL RECONNAISSANCE OFFICE

On 21 December 1964, the National Reconnaissance Office (NRO) launched its first radar imagery satellite, known as Quill. The Quill program was purely experimental, designed to test the proof of concept of whether or not imagery derived from radar could be captured from space. The experiment proved highly successful and was an important first step on the long path that led to regular radar imagery from space. In the summer of 2012, the NRO announced the declassification of all documents found in the NRO records holdings related to Quill. NRO declassification officials located only 28 documents related to Quill and they are contained in either printed or electronic formats in this compendium.

The documents can be divided into four groups. The first group of documents contains details of the efforts to develop and launch the Quill experimental satellite. These documents identify the purpose of the Quill experiment, the security necessary for the experiment, the program management, and the coordination between government agencies necessary to build a successful program. The second group consists of flight vehicle assessments of the Quill program. This group includes a three volume assessment from the prime contractor, Lockheed Missiles and Space Company as well as a two volume assessment from Goodyear Aircraft, the primary developer of the radar imagery sensor. The third group of documents consists of evaluations of the Quill radar products including reports from the NRO and the National Photographic Interpretation Center of the Central Intelligence Agency. The final group includes three documents on the final security closeout of the Quill program, which essentially brought the experiment to an end, slightly more than five years after its single highly successful launch in 1964.

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As might be expected, a number of organizational challenges arise in trying to successfully carry out a new technology development. Such is the case with the Quill program. The documents in this section provide glimpses into the development of the program. Clearly the program was developed mostly to test radar imagery from space as a means to assess post-attack bombing damage. Only later would the Intelligence Community evaluate radar imagery from space for broader intelligence applications. These documents also reveal details about the program management of the Quill experiment with particular emphasis on the experimental nature of the program. Perhaps the largest organizational issue associated with the program was security. Because Quill was incorporating hardware components developed for other programs, it crossed security boundaries established to protect those programs, especially Corona. These documents illustrate the pragmatic approach and cooperation extended to facilitate Quill's acquisition of necessary components while still preserving the security of other programs.

Document 1 — Memorandum from Director of the National Reconnaissance Office to The Director of Central Intelligence concerning status of current national reconnaissance satellite programs, 14 December 1962: The Air Force program at the National Reconnaissance Office (NRO) proposed Quill as an experimental study of the effectiveness of imagery derived from radar returns for assessing bomb damage after military attacks. The first document is a memorandum from Dr. Joseph Charyk to the Director of Central Intelligence (DCI) Mr. John McCone. At the date of this memorandum, 14 December 1962, the Director of the NRO (DNRO) answered to both the Secretary of Defense and the DCI. DNRO Charyk prepared the memorandum in response to a request conveyed from CIA's Deputy Director for Research, Dr. Herbert Scoville, for a summary of the NRO's national reconnaissance programs under development. Charyk makes a passing reference to Quill in the concluding paragraph of the memorandum, describing Quill as an experimental program for assessing bomb damage by using imagery derived from space based radar.

Document 2 — Secure Cable concerning open and covert procurement for the Quill program, 06 March 1963: Like all national reconnaissance programs, Quill program managers had to determine how to develop and launch a satellite in an open society without revealing the true purpose of the satellite. In a 6 March 1963 secure cable, program managers outline which elements of the Quill program will be described in the context of "white" or overt programs, and which elements of the program will be managed in "black" or covert procurements. Also, like most early national reconnaissance satellite programs, Quill incorporated components from the Corona program. The challenge was always to protect the Corona program's security. The cable demonstrates how the program managers did that by limiting insight into Corona by Quill program participants. Finally, funding is the lifeblood of any project. Although the actual dollar figures are redacted in this document, the document does provide insight into how funding was managed in both a covert program and in a program that relied on another covert program for essential hardware components.

Document 3 — Security Memorandum concerning request for support from the Corona program, 1 April 1963: The Quill experiment's success depended on obtaining components used in the CIA's Corona satellite program. On 22 March 1963, Major David Bradburn, Quill's Program Manager, convened a meeting of Air Force and CIA representatives to resolve CIA security concerns about using components from the then highly classified Corona program. In a 1 April 1963 memorandum summarizing that meeting, a security officer described accommodations that Bradburn agreed to in order to receive Corona components. At the meeting, CIA and Air Force representatives agreed that few people would need to be cleared into the Corona program. They also agreed to use an Air Force security officer, who had previously worked on the Corona program, to address security concerns. The security officer describes the Quill program in detail including technical requirements, program objectives, and post-flight processing of data to be obtained from space.

Document 4 — Security Memorandum in preparation for meeting with the Quill program manager, 21 March 1963: In late March 1963, Quill Program Manager, Major David Bradburn planned to travel to Washington, DC and brief the DNRO on the Quill program. In a 20 March 1963 meeting, security officers assigned to the NRO met to discuss security concerns with the Quill program. They discussed concerns about possible exposure of the highly classified Corona program because of the use of Corona components. Bradburn was procuring Quill under another satellite program that was being procured overtly, but carrying a classified payload. The meeting attendees also discussed the possibility that Soviet trawlers navigating the coastal waters of the United States might obtain radar returns, and identify Quill as radar satellite when it reached orbit and operational status. The meeting attendees agreed to discuss these security concerns with Major Bradburn during his meetings the following week.

Document 5 — Security Memorandum summarizing security officer meeting with the Quill program manager, 29 March 1963: On 28 March 1963, Quill Program Manager, Major David Bradburn met with security officers supporting NRO satellite programs. The memorandum summarizing the meeting includes Bradburn's description of the mission, objectives, and technical approach for the Quill program. The memorandum also includes Bradburn's management structure for the program including how Lockheed Missiles and Space Company (LMSC), Goodyear Aerospace, and an associate contractor would participate in the program. The memorandum includes a hand-drawn summary of organizational management structure as well as security approaches developed within the structure.

Document 6 — Security Cable providing guidance on Quill security, 9 April 1963: In a 9 April 1963 security cable, a NRO assigned security officer identifies the cover story and overall approach for maintaining the secrecy of the highly classified Corona photoreconnaissance satellite while using components from that program for Quill. At a key meeting, Quill Program Manager, Major David Bradburn and representatives of the CIA, Air Force, and LMSC (including future DNRO James Plummer), agree to incorporate Quill's film cutter and cassette into the Corona-based recovery vehicle before shipment to Program A for use in the Quill program. The cable also indicates that few if any additional personnel will need Corona clearances because the Quill program will use individuals who were already cleared into the Corona program.

Document 7 — NRO Programs' Status Paper supporting the Director of the National Reconnaissance Office's Briefing to the United States Intelligence Board, 13 November 1963: On 14 November 1963, the then DNRO Dr. Brockway McMillan provided the United States Intelligence Board and the National Security Council's special committee on covert operations updates on the NRO's satellite programs. The NRO staff provided a 13 November 1963 status paper to support Dr. McMillan's briefing. Regarding Quill, Dr. McMillan was prepared to report that the program was expected to launch two experimental radar imagery satellites, each with 100 foot resolution covering a ground swath 10 miles wide. Dr. McMillan also reported the satellite would have both film readout and film recovery capabilities. The first flight was then scheduled for April 1964.

Document 8 — Memorandum from the Director of Central Intelligence to the Director of the National Reconnaissance Office identifying questions and concerns about the National Reconnaissance Program Budget, 23 July 1964: In a 23 July 1964 memorandum, DCI Mr. John McCone responds to material that Dr. Brockway McMillan had provided concerning the NRO budget. McMillan provided the information in advance of a meeting on NRO resources. In his memorandum, McCone comments extensively on many of the NRO programs. With respect to Quill, McCone declares a lack of familiarity with the program and asks for additional details. McCone and McMillan would have a very contentious relationship over differing viewpoints on national reconnaissance satellite programs and management responsibility for the programs.

Document 9 — Memorandum from the Director of the National Reconnaissance Office to the Deputy Secretary of Defense addressing the Director of Central Intelligence's concerns about the National Reconnaissance Program Budget, 29 July 1964: On 23 July 1964, DCI Mr. John McCone sent a memorandum to the DNRO Dr. Brockway McMillan in response to the proposed Fiscal Year (FY) 1965 budget for the National Reconnaissance Program. In that memorandum, McCone raised concerns, asked questions, and made requests for more information concerning the budget proposal. McMillan prepared a 29 July 1964 memorandum to Deputy Defense Secretary, Cyrus Vance, commenting on McCone's questions and concerns. In that memorandum, McMillan agreed to brief McCone on Quill, but noted Quill had little effect on the FY 1995 budget since most of the required Quill funding was included in the FY 1964 budget.

Document 10 — Security Memorandum concerning handling of future imagery from the Quill program, 22 October 1964: In a 22 October 1964 memorandum, a security officer addresses the question of how to handle future imagery from the Quill experimental satellite. This request came from the Program A staff. Quill was developed to assess whether or not radar imagery could be used for bomb damage assessment, and therefore viewed as military rather than intelligence imagery asset. The use of Quill imagery for intelligence purposes remained unclear. The security officer indicates that Quill products should remain under security controls established for national reconnaissance satellites until the potential uses of Quill imagery were better defined.

Document 11 — Security Memorandum on security protection of Quill imagery, 22 October 1964: The viewpoints of the NRO Staff's Chief Security Officer, Louis Mazza, on security protection of Quill imagery products are recorded in a 22 October 1964 Security Memorandum. Mr. Mazza indicated that he thought it was premature to establish special controls for the Quill product until the uses of the product were fully evaluated. He recommended keeping the Quill product under existing security controls until evaluation occurred and further justified unique security controls.

Document 12 — Security Memorandum on need for special security controls for the Quill program, 23 October 1964: In a 23 October 1964 memorandum, a security officer summarizes the views of several officials and security officers on the question of whether or not to develop special security controls for Quill. The officer recommends the consensus view, that Quill remain under the main security control system, the Byeman control system, established for national reconnaissance satellites.

Document 13 — Security Memorandum on use of Byeman security controls for the Quill program, 7 December 1964: The NRO Staff's Chief Security Officer prepared a memorandum on 7 December 1964 as a cover for conveying two documents concerning security controls for the Quill program. The first attachment is a 1964 memorandum from the CIA's Director of Security that affirms the decision to keep Quill products within the Byeman control system, established as the main control system for national reconnaissance satellites. The second attachment is a memorandum with the Quill security plan prepared by the U.S. Air Force. The security plan addresses secure processing of Quill products as well as how Quill products will be securely couriered. The plan also summarizes planned efforts to secure data at the two tracking stations used for the Quill experimental program.

LIST OF QUILL PROGRAM DEVELOPMENT, MANAGEMENT, AND SECURITY DOCUMENTS

EXCLUDED FROM AUTOMATIC REGRA IG; DOD DIR. 5200.10 DOES NOT APPLY

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(7)

14 December 1962

MEMORANDUM FOR MR. McCONE

In accordance with your request through Mr. Scoville this memorandum is a summary of the Satellite Reconnaissance Program and its current status. A current schedule is attached.

The CORONA-MURAL 24" focal length stereo search system is operational. Thirteen of sixteen flights have returned material for exploitation with average resolution of ten to thirteen feet. A small percentage of the material has measured resolution down to seven feet and a portion of the material has resolution ranging up to twenty feet. The system also includes a 1.5 inch focal length framing camera and 85 mm stellar camera unit to enhance the use of the panoramic reconnaissance photography.

In May of 1963 the CORONA-J configuration should be available for test. The CORONA-J is identical with the CORONA-M system except that the vehicle is modified to have two complete recovery systems. The operational plan for this system is to operate for four days and then recover the first capsule. The vehicle may then be placed in an inactive mode and reactivated at any time up to about 20 days (depending on orbital decay parameters). After reactivation a three-day mission and subsequent recovery of the second capsule will complete the active life of the vehicle.

The CORONA-J is dependent on the thrust-assisted Thor-Agena configuration. However, in the event this booster is not immediately successful, a standard CORONA-M system can be flown in the same configuration as currently exists.

As of 11 December 1962, I issued termination instructions for the 722 system. This system was designed to obtain area coverage at eight to ten feet resolution with a 36" focal length panoramic stereo system. This action was predicated on recovery vehicle problems, and I am now considering the possibility of an experiment using a Thor-Agena vehicle and the proven recovery capsule system to obtain data on the performance of the payload and the increase in intelligence content inherent in the better resolution system.

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The LANYARD system is a 66" focal length panoramic system with optional stereo capability designed for reconnaissance of specific targets. This system is scheduled for first flight in February 1963. It is completely dependent on success of the thrust-assisted Thor-Agena vehicle. Recent dynamic resolution tests have obtained 80 to 85 lines/mm at low contrast which is equivalent to about five feet resolution which is the design goal.

The GAMBIT system is the only Atlas-Agena boosted system in the current program. The objective of this 77" focal length strip camera, which also has optional stereo coverage, is to obtain specific target coverage at 2-3 feet resolution. It is scheduled for first flight in June 1963. Dynamic resolution tests of the engineering model of the camera have shown 118 lines/mm which is above the specification requirement. The major development problems are associated with the control and stabilization of the vehicle. The desired resolution can be obtained only if vehicle motions are held to maximum values less than those currently obtained in other programs. A major portion of the solution to this problem is dependent on the establishment of an accurate vertical reference by means of horizon sensors and an inertial reference system. There are parallel competitive developments of the horizon sensor, which is the most critical element, and both sensors are now proceeding satisfactorily. The other problem is the accuracy required for pointing the camera at the target. The swath width at nadir is only 10.6 nautical miles and exact knowledge of target and vehicle location and precise controllability are necessary. I am considering a proposal to leave the satellite vehicle attached to the Agena during portions of early flights in order to check out critical elements of the system without complete dependence on proper operation of the new control system.

The ARGON geodetic and mapping system has had two successful tests. Further flights of this system are deferred until next year. I am now considering a proposal for a new geodetic and mapping system with greater capabilities.

Project 417 is a small weather satellite in support of the satellite photographic reconnaissance program. The first successful launch was accomplished 23 August 1962. As of 5 December, 5500 pictures had been received of which 70% were usable. This satellite will probably continue to provide useful information through mid-January 1963. The next vehicle is ready for launch when the payload now in orbit ceases to function.

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[redacted]

[redacted] The POPPY type payloads are real time signal repeaters in 20" diameter solar-powered spheres having a long life on orbit. Two POPPY payloads were orbited on 12 December but will not be exercised for several days.

[redacted]

There has been a major effort made to provide the maximum flexibility within the physical constraints of the overall system, and an important aspect of this effort has been to require an interchangeability of payloads that could be used on the Thor boosted systems. Currently there exists the possibility at R-35 days to interchange the CORONA, ARGON, LANYARD and CORONA-J payload subsystems. It is planned that there will be "on the shelf" payloads available so that the launch rate can be increased over the planned schedule in any particular month. It is also possible to replace the entire Agena and [redacted]

In August of 1963 and every other month thereafter we have programmed a CORONA-J vehicle to be available which will not necessarily be flown in these months. The purpose is to provide a relatively quick-reaction capability which will allow reconnaissance flights to be executed rapidly in future emergency situations. Our launch pads will, however, restrain us from maintaining a sustained rate of more than three Thor-Agenas per month.

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We are conducting several research efforts looking toward extension of our capabilities in the future. Under the code word VALLEY we have recently initiated a program for design and test of the critical components of a camera system which would provide GAMBIT or better resolution in a panoramic camera, thus reducing the severity of the pointing problem inherent with long focal length strip type cameras. Project QUILL is research toward an experimental radar payload for bomb damage assessment. In addition to these two payload efforts we have a research study effort with the Martin-Marietta Company to develop basic design information for a manoeuverable lifting re-entry vehicle to permit accurate land recovery of large payloads. I am also evaluating a proposal for a 150" focal length non-stereo strip type system, launched by a thrust-assisted Thor-Agena, which could provide an alternate approach to the resolution we are seeking in the GAMBIT project.

Signed

Atch
schedule

Joseph V. Charyk
Director
National Reconnaissance Office

cc: Mr. McNamara
Mr. Gilpatric

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LAUNCH SCHEDULE

AS OF 12 Dec 62

PHOTOGRAPHIC

			1963												1964												1965						
		D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J
CORONA "M"	10-15' resolution general search	1	1	1	1	1																											
"J"	10-15' resolution general search						1	1	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2									
"L"	5' resolution specific coverage			1	1	1	1	1	1		1	1																					
ARGON	Geodetic coverage 350' resolution					1		1																									
206 GAMBIT	High resolution 2-3' specific coverage							1		1	1	1	1	1		1	1		1	1	1	1	1	1									

ELECTRONIC

		D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J
[redacted]																																	
POPPY	Long-life real time signal repeaters	1				1				1																							

WEATHER

		D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J
417 (P-35)	Weather coverage of area of interest		1			1			1			1			1			1															

[redacted]

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CLASSIFIED MESSAGE

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ROUTING: 1 C/DD 4 DDR

DATE 2353Z 06 MAR 63

TO : DIRECTOR

FROM : [redacted]

ACTION: OSA (1-2-3-4-5-6-7-8-9-10)

INFO : S/C (11)

SJ-1939 T-6

PRIORITY

TOR: 0140Z 07 MAR 63

IN 68210

TO PRITY [redacted] INFO PRITY [redacted] CITE [redacted]

REFS: A. [redacted] 15 JAN 63
B. 21 FEB 63
C. 5 MAR 63

1. THIS IS THE DETAILED PLAN REQUESTED IN YOUR [redacted]

PART I - QUILL (BYEMAN) SECURITY POLICY: THE QUILL PROGRAM CONSISTS OF 3 TAT/AGENA LAUNCHES IN MAY, SEPT, AND NOV 1964. THESE LAUNCHES ARE ADMINISTRATIVELY PART OF [redacted]. THE RELATIONSHIPS BETWEEN QUILL [redacted] ARE ANALOGOUS TO THE RELATIONSHIP BETWEEN [redacted] EXCEPT THAT QUILL IS A RADAR PAYLOAD WHEREAS [redacted]. ONLY QUILL BRIEFED PERSONS ARE AWARE OF THE WORD "QUILL" OR OF THE FACT THAT THE PAYLOAD IS A RADAR. OTHER PERSONS ARE GIVEN THE COVER STORY [redacted].

IN KEEPING WITH THIS SECURITY FRAMEWORK ONLY THE RADAR PAYLOAD IS "BLACK". MOST OF THE PROJECT IS "WHITE, HIGHLY CLASSIFIED" THE WHITE FACTS INCLUDE TAT/AGENA D, SATELLITE, WIDE-BAND DATA

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GROUP 1 Excluded from automatic downgrading and declassification

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[redacted] (IN 68210) PAGE TWO

LINK, REPEAT TAT/AGENA D, SATELLITE, WIDE-BAND DATA LINK, AND RECOVERY REPEAT RECOVERY.

QUILL BRIEFED PERSONS DO NOT, IN GENERAL, REQUIRE ACCESS TO CORONA AND VICE VERSA. THE RECOVERY SUBSYSTEM IS DEFINED AS [redacted] THE RECOVERY SUBSYSTEM WILL REMAIN UNDER CORONA SECURITY.

PART II - QUILL PROJECT SECURITY PROCEDURES: THE QUILL PROGRAM OPERATES [redacted] PERSONS WHO MUST KNOW THAT THE PAYLOAD IS A RADAR ARE CLEARED AND BRIEFED IN ACCORDANCE WITH BYEMAN CRITERIA. CORRESPONDENCE CONTAINING ANY REFERENCE TO RADAR OR ANY SENSITIVE ASPECT OF THE QUILL PROGRAM (NAME OF RADAR CONTRACTOR, PAYLOAD DETAILS) IS HANDLED VIA BYEMAN CONTROLS WITHIN THE GOVERNMENT. PROCEDURES EQUIVALENT TO BYEMAN ARE USED FOR COMMUNICATION AND SECURITY CONROL BY CONTRACTORS. QUILL SECURITY OFFICERS AT CONTRACTOR FACILITIES ARE CONTRACTOR EMPLOYEES.

PART III - FUNDING PROCEDURES AND RESPONSIBILITIES: THE WHITE FUNDS FOR QUILL ARE PROGRAMMED BY THE AIR FORCE AS PART OF [redacted] THESE FUNDS COVER EVERYTHING EXCEPT THE RADAR PAYLOAD AND THE RECOVERY SUBSYSTEM, WHICH ARE PAID FOR IN THE BLACK [redacted] ALL WHITE PROCUREMENTS AND THE BLACK RADAR PROCUREMENT ARE MADE BY THE AIR FORCE. THE BLACK RECOVERY SUBSYSTEM PROCUREMENT IS MADE BY THE CIA WITH [redacted]

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[redacted] (IN 68210) PAGE THREE

PART IV - CONTRACTORS' RELATIONSHIPS:

A. FOR BASIC QUILL PROGRAM (NOT INCLUDING RECOVERY SUB-SYSTEM) THE TRANSLATION IS AS FOLLOWS:

LMSC REPEAT LMSC: (WHITE CONTRACT WUTH SAFSP); SE/TD, AGENA VEHICLE, SPECIAL ANTENNA, LAUNCH AND TRACKING SERVICES.

[redacted]: CONSULTANT FOR RADAR, ALS O OPTICAL PROCESSING OF RAW RADAR DATA TO PRODUCE FINAL RADAR MAP.

DAC REPEAT DAC: (WHITE CONTRACT); TAT BOOSTER, LAUNCH SERVICES.

GOODYEAR AIRCRAFT COMPANY REPEAT GOODYEAR AIRCRAFT COMPANY: (BLACK SAFSP CONTRACT); RADAR PAYLOAD.

B. FOR THE 3 REQUIRED, COMPLETE RECOVERY SUBSYSTEMS, THE CORONA CONTRACTUAL ARRANGEMENT WILL BE USED WITHOUT ANY CHANGE. SPECIFICALLY, THE FOLLOWING PROCUREMENTS WILL BE MADE:

(1) LMSC (HILLER) WILL PROVIDE HARDWARE AS FOLLOWS: AFT CAPSULE COVER, MODIFIED WATER SEAL, BLOSSOM TELEMETRY, BALLAST SYSTEM, DRAIN AND SINK PLUGS, AND PARACHUTE. LMSC (HILLER) WILL MODIFY AND INSTALL LMSC HARDWARE AND WILL ACCOMPLISH TEST AND CHECKOUT OF COMPONENTS AND COMPLETED ASSEMBLIES. DELIVERY DATES: 1 NOV 63, 15 JAN 64, AND 15 APR 64.

(2) GE WILL PROVIDE THREE MARK VA SPACE VEHICLES, GE PART NUMBER 196R300G12, MODIFIED SO THAT THE CASSETTE MOUNTING RAILS WILL ACCOMMODATE THE IDENTICAL 70MM CASSETTE USED IN THE MARK IV CONFIGURATION. DELIVERY DATES TO LMSC: FIRST SYSTEM TO

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[redacted] (IN 68210) PAGE FOUR

LMSC 1 SEPT 63, SECOND AND THIRD AT ONE-MONTH INTERVALS DESIRED; TWO-MONTH INTERVALS ACCEPTABLE.

(3) ITEK WILL PROVIDE THREE TAKE-UP CASSETTES, ITEK PART NUMBER 39178. REQUIRED DATE AT LMSC SAME AS FOR MARK VA SYSTEMS ABOVE. (CASSETTES MAY BE AVAILABLE AS RESIDUE TO PRIOR WORK.)

(4) ENGINEERING COORDINATION WILL BE ACCOMPLISHED THROUGH LMSC SE/TD.

(5) BUDGET ESTIMATES:

	FY63	FY64	TOTAL
LMSC	[redacted]		
GE			
ITEK			
TOTAL			

PART V - HARDWARE HANDLING AND CHECKOUT PROCEDURES: THE QUILL RADAR PAYLOAD WILL BE FABRICATED IN PHOENIX, SHIPPED TO SUNNYVALE FOR INSTALLATION AND CHECKOUT IN THE AGENA, AND THEN SHIPPED IN THE AGENA TO VAFB FOR LAUNCH. WHENEVER THERE WILL BE EVIDENCE THAT THE PAYLOAD IS A RADAR, QUILL SECURITY WILL BE ENFORCED.

THE RECOVERY SUBSYSTEM WILL BE ASSEMBLED AND CHECKED OUT BY LMSC (HILLER) UNDER CORONA SECURITY. FUNCTIONAL TESTING WITH THE RADAR PAYLOAD WILL BE ACCOMPLISHED IN [redacted], LMSC, AN [redacted]-CLEARED AREA. THEN THE PAYLOAD AND RECOVERY SUBSYSTEMS MOVE TO [redacted], LMSC, FOR SYSTEMS TESTS AND ENVIRONMENTAL CHAMBER TESTS. RECOVERY SUBSYSTEM THEN SHIPS TO VAFB FOR FINAL

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[redacted] (IN 68210) PAGE FIVE

PREPARATION IN "L" BLDG. RECOVERY SUBSYSTEM MATES WITH AGENA AND PAYLOAD IN [redacted] AT VAFB PRIOR TO LAUNCH. CIA IS RESPONSIBLE FOR ALL RECOVERY SUBSYSTEM HANDLING AND SECURITY. IN THIS WAY INTERACTION BETWEEN CORONA AND QUILL WILL BE MINI-. MIZED.

PART VI - LAUNCH AND RECOVERY RESPONSIBILITIES: THE LAUNCH WILL BE CONDUCTED AS [redacted] OPERATION. THE RECOVERY WILL BE FUNCTIONALLY REPEAT FUNCTIONALLY SIMILAR TO PRESENT 162 OPERATIONS, BUT WILL BE IDENTIFIED WITHIN THE RECOVERY FORCE AS [redacted] THE PRIMARY (FILM) RECORD WILL BE TRANSMITTED TO HILLER FOR DE-SPOOLING, TO SPPL FOR PROCESSING, AND THEN TO [redacted] FOR OPTICAL TRANSLATION TO FINAL FORMAT. AS IN THE CASE OF PRE-LAUNCH ACTIVITIES, CORONA SECURITY WILL DICTATE THE RECOVERY SECURITY CONTROLS.

2. CONSISTENT WITH THE ABOVE PLAN WE WILL COORDINATE THE PROCUREMENT AND SECURITY MATTERS PERTAINING TO THE RECOVERY SUBSYSTEM ON A CONTINUING BASIS THROUGH LOCAL REPRESENTATIVES, MESSRS [redacted]

3. FOR COL MARTIN: WE CONSIDER THE FOLLOWING TO BE MOST IMPORTANT ACTION ITEMS:

A. TRANSFER OF FUNDS TO CIA (REF PARA 1, PART IV, B).

B. AUTHORIZATION FOR LT COL MURPHY AND MESSRS [redacted] AND [redacted] TO PARTICIPATE ASSSET FORTH ABOVE.

END OF MESSAGE

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Approved for Release: 2022/08/18 C05139542

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1 April 1963

MEMORANDUM FOR: Chief, SB/OSA/DDR

SUBJECT : Status of Air Force QUILL Program

1. On 22 March 1963, the writer was given a two hour briefing on the QUILL program at SAFSP, Los Angeles, by Major David Bradburn, Project Director. Present were, Col. Joseph Ruebel, Lt. Col. Ralph Ford, Lt. Col. John Pietz, Mr. [redacted] and the writer. Prior to the briefing it was indicated by Col. Ruebel to the writer that the program is currently in a state of suspension as a result of OSA/DDR Security disapproval of Major Bradburn's security plan as presented in [redacted] (in 68212) dated 7 March 1963. Major Bradburn and Mr. [redacted] have stated that they had conferred by phone with Mr. James McDonald, OSA/DDR Contracting Officer and that McDonald allegedly stated that he could not give contractual approval until Security had approved of the security aspects of the program. The writer advised that he was taken by surprise by this assertion and added that it was his understanding that McDonald was not in a position to award any contracts for QUILL as he had not been given Agency approval by DDR and had received no funding from NRO Comptroller.

2. The QUILL program is a bomb damage assessment design using high frequency radar as the sensor. It is both a readout and recovery system. It will use a TAT booster, Agena D second stage and guidance system, RF-4c radar and a Discoverer recovery system. Five complete systems will be procured but it is intended that only three will be flown. Operationally, the system will be launched from Vandenburg Air Force Base and recovered in Hawaii. The radar system will transmit its return in real time to the tracking stations at Vandenburg and New Boston, New Hampshire, but will also store the return on 70 mm film, which will be recovered. The film format will cover an area of 1500 miles long and 10 miles wide as it operates during each five minute pass over the indicated tracking stations. It is anticipated that there will be 16 such passes during the four day mission utilizing approximately 2000 feet of film. The details regarding the recovery procedures at Hawaii apparently have not yet been well thought out but it was indicated that it was their desire that the OSA/DDR Security function on QUILL in the same manner as on CORONA. One plan presented was to fly the take to Moffitt Naval Air Station, California, in a C-130, have Mr. [redacted] perform the same functions as he does on CORONA, de-spool the take at the AP facility and have a CIA

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courier escort the take to SPPL, Westover Air Force Base, Mass. An alternate plan presented by Lt. Col. John Piets was that the take would be flown from Hawaii directly to an Air Force Base in the vicinity of Westover Air Force Base, but not Westover Air Force Base, in a KC-135. [redacted] advised that approval for use of the KC-135 has been obtained from the Under Secretary of the Air Force and has been coordinated with Lt. Gen. Emmett O'Donnell.

3. The QUILL program is managed by SAFSP with Major Bradburn as the program officer. Lockheed Missile and Space Company has the contract for SE/TD, systems intergration and manufacture of the radar antenna. Goodyear Aircraft Company will produce the radar pay load, the AGE and field support for the pay load system. The [redacted] will do the data reduction and translation of the radar return upon receipt of the processed film from SPPO.

4. The pay load system is composed of four sections. The faring just fore of the Agena interface will house the radar system. Riding in front of that will be a barrel section carrying the recorder. The fifteen foot antenna will be attached to both the sections housing the radar and the Agena. The recovery systems will be located fore of the recorder section.

5. The radar recorder and antenna will be shipped from Phoenix, Arizona, to [redacted], LMSC, Sunnyvale, California. The recovery system will be shipped from General Electric, Phila. to the AP facility, Palo Alto. At this briefing, Major Bradburn indicated that the complete recovery bucket including the film cutter would be sent from the AP facility to [redacted] in Sunnyvale for HATS tests and ANECHOIC tests. He advised that during these tests AP facility personnel would have to be present in order to provide necessary technical competence. He advised that the recovery system would be returned to the AP facility for final check out and shipment to Vandenburg. He advised that at Vandenburg, it will go to the L Building for weight and balance and then mated with the rest of the pay load system in the MAB for pad compatability checks, pre-launch check-out and flight.

6. The writer pointed out to Major Bradburn and Col. Reabel that the system as stated exposed the CORONA program.. Both officers agreed that there were points of exposure, but that they felt these could be covered by a good deception plan. The writer pointed out that it was not the intention of OSA/DDR to inhibit the program and that

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we would do everything possible to get it moving. However, the security holes would have to be plugged in order to protect the CORONA program, which is an ultra-sensitive intelligence gathering mission currently productive. Both agreed and indicated they were amenable to any suggestions or plan that OSA/DDR proposed.

7. The writer suggested that he did not feel it was good security procedure to depend on a contractor security representative to implement the security for a sensitive program at the contractor site and requested that Col. Rumbel assign an Air Force officer to the program at Lockheed to assume the security responsibilities. Col. Rumbel proposed the name of Major [redacted] who is currently assigned to the Air Force Plant Representative's Office at LMSC, Sunnyvale. The writer readily agreed to this proposal, as he is acquainted with the competence of this officer through Major [redacted] previous assignment in Space Systems Office of the Under Secretary of the Air Force in the Pentagon where he held a CORONA Cat-I clearance. The writer also suggested that, regardless of the indication in [redacted] that few if any CORONA clearances will be required, there will be a requirement for additional CORONA clearances at LMSC and Goodyear. Both agreed that they felt the number would be very small.

8. On 27 March 1963, Mr. [redacted] telephoned the writer and stated that Major Bradburn had been at the AP facility the previous day and had met with [redacted], Col. Charles Murphy, James Plummer, LMSC, and Mr. [redacted], QUILL program manager for LMSC. This had been the second time Major Bradburn had discussed QUILL procedures with Col. Murphy and Mr. [redacted] at the AP facility. The results of the 26 March meeting were reported by Mr. [redacted] in [redacted] (In 70306). During the telephone conversation, Mr. [redacted] indicated that Major Bradburn had agreed with the procedures proposed. On the afternoon of 27 March 1963 Major Bradburn phoned the writer and stated that he had met with Col. Murphy, Mr. [redacted], etc. on the previous day at the AP facility and stated that they had established a working arrangement for processing the QUILL hardware at LMSC which he felt was satisfactory to all and would not jeopardize CORONA security.

9. On 28 March 1963, Major Bradburn presented a briefing on the entire QUILL program to Mr. [redacted], Mr. [redacted], Mr. James McDonald, Mr. [redacted], Mr. Lou Mazza, Mr. [redacted], and the writer. Major Bradburn explained that the system was not

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an intelligence gathering device in that it would be operative only over the United States. Mr. [redacted] questioned the probability of Russian trawlers positioned off the North East Atlantic Coast Line picking up the radar signals emitted from the QUILL bird. Major Bradburn explained that it was possible but that the probability was small in that the trawlers would have to be positioned exactly in the tight cone of the radar transmission and be tracking the bird during the short time it was operative.

10. Mr. [redacted] then read to the group Mr. [redacted] TWX of 27 March ([redacted] In 70306) which purportedly was the agreement reached with Major Bradburn on the 26th of March regarding QUILL procedures at ITEK. At the conclusion, Major Bradburn stated that he agreed with the summary and conclusion indicated in paragraph 5 of [redacted] but that he had reservations regarding the specific procedures. Major Bradburn stated that it was his desire, as Program Officer, to have the recovery system shipped to the AP facility, assembled and checked out by AP personnel and delivered to the QUILL area at [redacted], Sunnyvale, as a complete unit. Major Bradburn stated that this was his desire because he felt it mandatory to have as much reliability in the system as possible and he felt this could be accomplished only by taking advantage of the experience and expertise of the AP facility personnel. This was a departure from the proposal presented in [redacted] Mosham suggested that the 70 mm cassettes would be furnished the QUILL program directly by ITEK. [redacted] proposal was that the film cutter, which is manufactured black at the AP facility, would be sent to ITEK and furnished directly to the QUILL program as an ITEK component. It was Major Bradburn's contention that to provide a recovery system, cassettes and film cutter separately would require another installation and check out at [redacted] by personnel not experienced with the hardware. Major Bradburn stated that in the meeting of 26 March Mr. Plummer guaranteed system reliability if it were done piecemeal but it was Bradburn's observation that this was an attempt by Plummer to generate another check-out laboratory and capability at Sunnyvale at the expense of the QUILL program. The writer suggested to Major Bradburn that it was his understanding that Plummer indicated such a facility was possible under the present scope of the QUILL contract. Bradburn replied that Plummer's statement was true in so far as there was no definition of scope at the present time or any commitment of dollars.

11. Major Bradburn stated that it was his understanding that processing the recovery system would require the services of several

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experienced AP facility people on a consultant basis but that this could be provided without endangering CORONA security as they were already identified as the 162 program recovery people. Major Bradburn advised that several of the people already employed on QUILL at Sunnyvale hold CORONA clearances and that any interface with the AP facility can be conducted by them. Major Bradburn stated that he agreed with the [redacted] proposal to establish a pseudo design effort within the QUILL program at Sunnyvale to account for the black components of the recovery system. During the ensuing conversation, however, it was Major Bradburn's opinion there would only be a small number of the 100 plus people employed on QUILL at Sunnyvale who might become suspicious of the 162 program as a result of the QUILL activity. Major Bradburn felt that the majority of the people would be satisfied that the pseudo design effort was the explanation for the existence of the film cutter, cassettes, take spool, etc.

12. Major Bradburn advised that regardless of the configuration of the complete recovery system on its arrival at Sunnyvale, it would be checked out with the remainder of the pay load system at [redacted] then the complete system transported to [redacted] for the environmental testing ([illegible]). It would then be returned to [redacted] for approximately 30 days testing in the ANECHOIC area. Major Bradburn, though not sure, felt that the complete pay load would be disassembled and shipped to the base separately. The recovery system would go to the AP facility for shipment to the L Building at Vandenburg AFB. The other components of the pay load will be shipped directly to the Missile Assembly Building at VAFB. The recovery system would be weighed and balanced and spooled with film leader. It would then be shipped across the road to the MAB for mating with the rest of the pay load and pre-launch check out. Presumably, though again uncertain, the CORONA people at Vandenburg would have nothing to do with the pay load after it was turned over to the people at MAB. Major Bradburn was queried regarding the recovery procedures to be employed at Hawaii and the West Coast but advised that not much thought had been given to that area as the first launch for the QUILL program is not scheduled until September 1964.

13. On 28 March 1963, the writer telephoned Mr. [redacted] at Palo Alto and explained to Mr. [redacted] the substance of the day's meeting with Major Bradburn. Mr. [redacted] was surprised that Major Bradburn had retreated from his previous position and advised that he felt the best possible way to go was that outlined in [redacted]. Mr. [redacted] stated that he and Col. Murphy and appropriate LMSC personnel had given due concern to every aspect of the procedures and felt that their proposal

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would best safeguard CORONA security. Mr. [redacted] felt to produce the recovery system complete with film cutter, etc. to QUILL would open the door to speculation among QUILL people at Sunnyvale. Mr. [redacted] felt that Major Bradburn was being some what unreasonable in that he was unwilling to concede to anything and expected CORONA security to bend in favor of expediency and economy. Mr. [redacted] advised that the additional check-out equipment required if the recovery system was delivered to Sunnyvale in pieces would not be extensive and that in all probability this equipment would have to be purchased any way in order to handle the additional systems at the AP facility. Mr. [redacted] felt that there would be quite a number of QUILL people who would require CORONA clearances and that once the QUILL hardware was fabricated, they would have nothing further to contribute to CORONA and would have to be debriefed. Mr. [redacted] advised that Col. Murphy had concurred in his plan and thought it was the best way to go. The writer advised Mr. [redacted] not to take any further action on this proposal at this time and that the writer would discuss it with Chief, SR/OSA and advise Mr. [redacted] of what action we wished him to take.

14. Summary - the problem reduces itself to how best to insure reliability of the complete recoverable system without compromising CORONA security. Major Bradburn now feels that this can be obtained only by utilizing the experience of the AP personnel for assembly and check-out of the complete system and delivering it to the QUILL area at Sunnyvale in one piece. This is a change from his agreement on 26 March to accept the recovery bucket without the film cutter, cassette and take-up spool. He was assured by Mr. Plummer on 26 March that reliability would be guaranteed even if the recovery system was delivered to QUILL in separate pieces. Major Bradburn, after some self deliberation and no doubt consultation with more experienced people at SSD, feels Plummer is attempting to develop a laboratory and check-out capability at Sunnyvale so that he will be prepared to accomodate any similiar programs utilizing the 162 recovery system with an all-LMSC facility. The present facility is owned by Hiller Aircraft and, though all of the engineers are LMSC, the technicians are Hiller employees. There is some vagueness about several points of the QUILL hardware flow, but apparently the real problem area is should the bucket be delivered to QUILL in pieces or completely assembled. It should be done in the manner insuring the most reliability. If mal-function in flight were traced to failure to take advantage of available asset proven reliable for security reasons, OSA/[redacted] and SAFSP would subject to severe critisism by higher authorities.

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15. Recommendations:

A. It is recommended that the recovery system be furnished to the QUILL program completely assembled and qualified by the CORONA experienced people at the AP facility. Col. Murphy and Mr. [redacted] are correct in stating that this procedure will expose the film carrying capability of the 162 recovery system. But it is the writer's opinion that this is the best procedure for insuring the reliability of the system. If parts are removed after check-out and shipped round-trip cross country they may well be damaged upon arrival at the QUILL area. Regardless of whether they were damaged, they would again have to be qualified, perhaps by people with less experience than those at the AP facility. It is realized that delivery of the complete system to QUILL will expose CORONA to uncleared people. But it must be remembered that these people supposedly have met BYEMAN clearance standards and are QUILL briefed. It is not known how many people will be thus exposed. It is felt that many of these people will be adequately deceived by a pseudo design effort and an indication that the sensitive parts were delivered by outside vendors directly to the 162 program.

B. Many of the engineers and desingers on QUILL will not be deceived by this pretense. It is recommended that Major Bradburn be authorized to decide which of his people may require a CORONA clearance because of an interface requirement or security precautionary measure and submit requests for CORONA clearances. Major Bradburn feels that the number requiring CORONA clearances will be less than twenty.

C. It is recommended that, where feasible, these people not be given a full CORONA briefing. They should not be told the history of the CORONA program and should be given no indication that satellite photography is being successfully recovered.

D. It is recommended that as few QUILL people as reasonably possible be permitted access to the AP facility, even though they are CORONA briefed. Existance of the AP facility should be made known to the few QUILL people who may be required to solve interface problems.

E. It is recommended that Major [redacted], or another acceptable Air Force officer, be given the responsibility for daily supervision of QUILL/CORONA security at LMSC. This will give Mr. [redacted] an avenue in-putting his security requirements to the QUILL program, particularly the manner in which QUILL people are to be briefed.

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F. It is recommended that no AP facility personnel be required to "crew chief" the recovery buckets at Sunnyvale or VAFB, unless it is specifically understood they disclaim any expertise regarding the film cutter, etc.

G. It is recommended that the recovery system not be returned to the AP facility after it is delivered to the QUILL program at Sunnyvale. It should be shipped from Sunnyvale directly to VAFB after HATS and ANECHOIC testing.

H. It is recommended that the recovery system go to the "L" Building at VAFB only for the routine weight and balance testing, then returned immediately to the MAB. This will eliminate the need for CORONA cleared people at the "L" Building to be directly involved with the QUILL program.

I. It is recommended that a meeting be held at the AP facility during the week of 8 April 1963 to finalize the security plan for QUILL and that representatives of SR/OSA/DDR, Major Bradburn, Mr. [redacted], Col. Murphy, Mr. [redacted] and Mr. Plummer attend. Since final approval of the plan rests with Chief, SR/OSA/DDR, it is suggested that consideration will have to be given by any alternate proposals submitted by participants. As has been suggested by Mr. Plummer, LMSC may be able to demonstrate and guarantee quality assurance of the complete system if the sensitive parts are delivered separately. I suggest, however, that even going this route we will have to CORONA clear technicians to do the job. Regardless of the difference of opinion at the current time, it is felt that a days discussion among the indicated people will resolve the security problems and remove the obstacle allegedly barring the advance of the QUILL program.

[redacted]
Security Officer
OSA

MJTG:rfm

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21 March 1963

MEMORANDUM FOR THE RECORD

SUBJECT: Discussion regarding Project Quill

1. A meeting was chaired by Mr. [redacted] on 20 March 1963 in his Office, regarding the security aspects of Project Quill. Those in attendance were Mr. [redacted] Mr. Mazza, Mr. [redacted] Mr. [redacted] and Mr. [redacted]

2. The gist of the matter discussed at the meeting is as follows:

Mr. Mazza: The NRO has received a message from the West Coast regarding "Q" which indicates that Major Bradburn will be coming to Headquarters some time next week to discuss the status of "Q" with the DNRO. I have suggested to the NRO Staff that preliminary meetings involving the NRO Staff and the SSC be held before DNRO makes a decision regarding the future of Project "Q".

Mr. [redacted] Program "B" has very little to offer in this respect since Project "Q" definitely is under the authority of Program A. How close is "Q" to becoming operational?

Mr. Mazza: I do not have the exact date. It is currently regarded as in the research and developmental stages.

Mr. [redacted]: The first firing of "Q" is scheduled to take place in the middle of 1963.

Mr. Mazza: The unique aspect of "Q" is that it uses radar. The radar messages are "spit out" at the appropriate signal from the ground control station. If this radar capability was used over a denied area it could trigger an international crisis.

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Mr. Mazza: The current plans are for the radar to be used over the United States only. The question at this time concerns the best cover for "Q". At the current time [redacted] is expected to be the cover mechanism.

Mr. [redacted] What do you think is the best cover arrangement?

Mr. Mazza: As it stands at this time CORONA cleared people know of "Q". "Q" cleared people know that QUILL is a research developmental project which uses radar. (The radar aspects are regarded as Covert) The [redacted] cleared people think that QUILL is just another [redacted] with a recoverable package. The [redacted] people will not see the film. I believe that the proper cover for "Q" is not essentially a security problem but more of a management problem. I don't believe the DNRO has completely thought through the working aspects as to the risks involved with "Q". Since there are risks we must realize that there will be security problems.

Mr. [redacted] I think the concept of "Q" is splendid. We would support it completely. I have been advised that General Greer expects to watch the first LANYARD shot. This concerns me inasmuch as his presence in the area might blow our "skunk works" and focus attention on our CORONA and DISCOVERER people there. (150 people) [redacted] suggests it might be better if "Q" were handled on a black basis and not in the [redacted].

Mr. [redacted] Why not leave "Q" as part of the DISCOVERER program since it involves the Thor-Agena combination?

Mr. Mazza: The Soviets who track our satellites will know that this one has radar on it. The Soviet trawlers that patrol our coast should be able to monitor the radar impulses without any difficulty. We must keep in mind that radar in this nature is a war indicator.

Mr. Mazza: [redacted] was under the impression that "Q" could best remain in the DISCOVERER Program.

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Mr. [redacted]. Both Colonel Ruebel and Colonel Ford seem to be horrified at this suggestion of Rod's. I understand that the recovery package designed by Lockheed should be used for QUILL.

Mr. [redacted] How well known is [redacted]? [redacted] I have been reading about in the press?

Mr. [redacted].

Mr. Mazza: The lid has been put on [redacted] regarding any release of payload data. Security in this respect has been very effective.

Mr. [redacted]. If QUILL is not to be under [redacted] but should be under DISCOVERER what will the problems be?

Mr. [redacted] QUILL is a black program at this time. [redacted] is a Department of Defense SECRET Project. "Q" contains radar and this will be generally known as soon as it goes into operation. For this reason it has been suggested that an Overt Program such as [redacted] would provide the better cover then the black program.

(At this point in the discussion Mr. [redacted] entered the room)

Mr. [redacted] Mr. [redacted], Would you give us some general background information regarding [redacted] as the result of your inspection of this Project last month.

Mr. [redacted] is classified SECRET and is being developed under a Department of Defense White Contract. Since the hold down is only a SECRET classification it is known by an extremely large number of people on the West Coast as a [redacted]. The basic difference between [redacted] and our other programs is that with respect to CORONA approximately [redacted] persons have access to information because of their proximity to the launching pad. There are also approximately [redacted] persons with access to [redacted] on the launching pad but the difference is that anyone with a SECRET clearance can be told of [redacted]. CORONA is held down much more severely. The mating of the [redacted] is done at [redacted] in Sunnyvale, California.

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Mr. [redacted] I have asked [redacted] for a paper on the CORONA Program, with respect to the early conditions under which it operated versus the current conditions. What is especially important to us is a determination as to what is the secret that is being protected. It appears to me that if QUILL to3w under [redacted] cover it will be one more thing that could "water down" the security we have built around CORONA.

Mr. [redacted]: In what specific areas will QUILL be associated with [redacted]? Which [redacted] people will be aware of QUILL?

Mr. Mazza: The QUILL Project is using [redacted] cover to order boost for their program.

Mr. [redacted] With respect to the recoverable package of QUILL the Intelligence Community must protect this. Security should consider a modified security plan so that [redacted] could be utilized for the boost for QUILL under a White Contract but that the "skunk works" and the launching pad facilities could be utilized under a black contract basis to afford better protection to the recoverable package.

Mr. Mazza: If the arguement regarding the proper cover for QUILL goes to the DNRO for the final solution the DNRO should be aware of all the risk factors.

Mr. [redacted] Should QUILL be a separate clearance or a part of CORONA. I know this is a political question.

Mr. [redacted] QUILL is not a passive Program. It is an offensive system.

Mr. [redacted] Mr. [redacted] indicates that our concern with QUILL must not result in a compromise in CORONA.

Mr. Mazza: Colonel Martin has indicated he would like the technicians affiliated with QUILL to meet with security representatives to discuss the matter in depth.

Mr. [redacted] Mr. [redacted] should be back from his trip by Monday. I think it necessary that additional discussions be held prior to any position statements made by the Agency to the NRO with respect to "Q".

Mr. [redacted] From a policy point of view I have been giving some consideration to a plan wherein all satellite programs would be under General Greer. This would mean that CIA would pull all of its security people out of the "skunk works" in similar installations if CIA accepts total security responsibility for projects regarding which we lack complete information. There is an excellent opportunity that security affiliations might occur because of changes with which we are not in agreement.

(At this point Mr. [redacted] left the meeting)

Mr. [redacted] There are definite political ramifications regarding QUILL. If the USSR would say they have proof that the U. S. is painting the USSR with radar, would we have a definitive position to counteract this charge? The major question for our office is whether the radar capability of QUILL can be utilized without the USSR knowing they are doing it. If the [redacted] area should be used to "read out" this radar there is no doubt but that the USSR will be aware of the radar capability of this satellite. The question then is whether Security has an obligation to advise the Special Group of the security risks in QUILL because of this political question.

Mr. [redacted] Who has made the determination that radar pictures are war-like actions?

Mr. Mazza: The Pentagon thinks so. They regard radar utilized in this manner as a military weapon and as a war time capability.

Mr. [redacted] This country may be asked by the USSR why the satellite is utilizing another south orbit if it is not intended to paint the USSR with radar. I believe that the Special Group should be advised of the QUILL Project.

Mr. Mazza: I do not think that there is the serious political issue involved here as you have indicated.

Mr. [redacted] Could the radar capability of QUILL be "read out" elsewhere than on the East Coast? If this is not the case it would appear that the NRO Staff should be advised of our security concern regarding the political ramifications inherent on the QUILL radar being read out by Soviet trawlers. Lou, Do you believe it advisable to

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advise the NRO of this concern on a verbal basis.

Mr. Mazza: No, I think it would be most appropriate if a formal memorandum was forwarded to NRO.

Mr. [redacted] It is my opinion that the use of QUILL definitely involves a security problem inasmuch as there may be a serious political issue arising from the results of the program.

Mr. Mazza: I would recommend that your position in this matter be discussed with Major Bradburn prior to a formal position statement being forwarded to the NRO.

The meeting was terminated with Mr. [redacted] requesting Mr. [redacted] to follow developments regarding the discussions of the representatives from Program A with the NRO Staff.

[redacted]

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29 March 1963

MEMORANDUM FOR THE RECORD

SUBJECT: Discussion Regarding Project QUILL

1. A meeting was held in the office of Mr. [redacted] on 28 March regarding the security aspects of Project QUILL. Those in attendance were Mr. [redacted], Lt. Col. David Bradburn, Mr. [redacted], Mr. Massa, Mr. [redacted] and Mr. [redacted].

2. Lt. Col. Bradburn indicated that he would be briefing the NRO Staff regarding QUILL the following day and would be happy to present the gist of his proposed briefing to the group.

3. He then indicated what General Greer considered to be the mission of P-40 (Project QUILL).

MISSION: a. Ionosphere effect on resolution.
b. Radar technolpgy in satellite environment.

OBJECTIVES: a. 100 feet resolution.
b. Read out and recovery
c. Minimum modification to existing radar.
d. As soon as possible.

APPROACH: a. With TAT (thrust augmented Thor) AGENA D, RF4C radar on [redacted] optical corollator.
b. With existing facilities (launch, track, recovery).
c. Bly five payloads, fly three.

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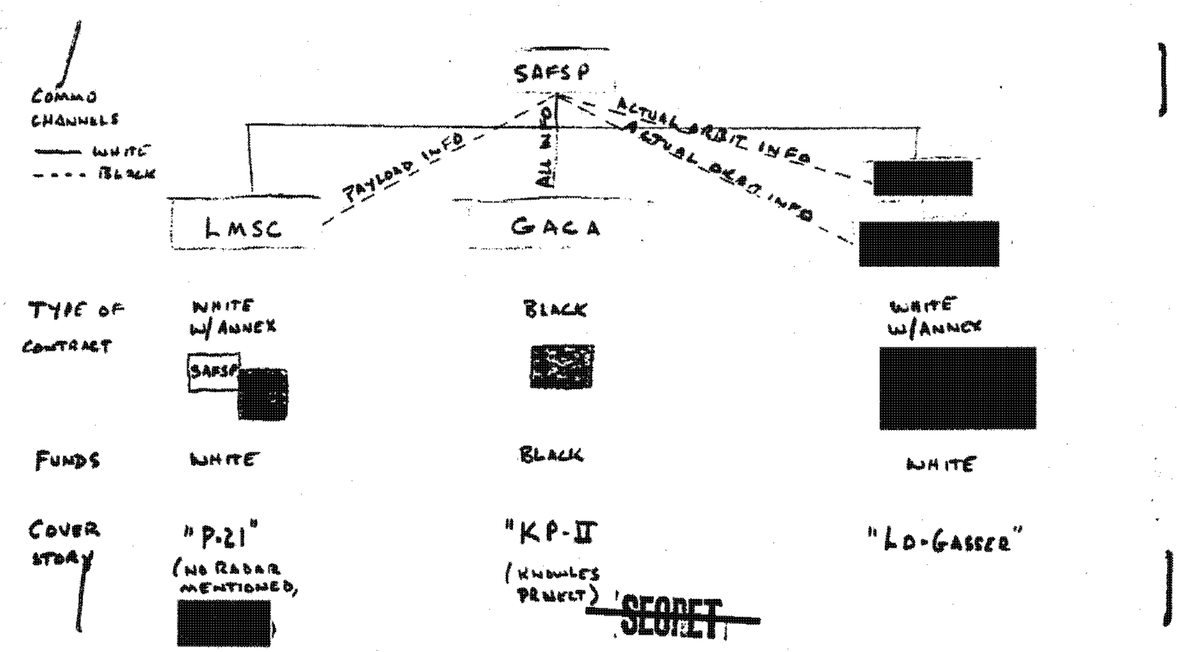
4. Bradburn indicated that this would primarily be handled on a secret--special handling basis with respect to communications. He added that QUILL would not be used to look at Russia at this time. He also indicated that one of the bad features of QUILL was that it would radiate and that Soviet monitoring equipment might be able to determine the nature and extent of our use of radar from a satellite.

5. Bradburn also indicated that the radar equipment should be able to photograph a track of land approximately 10 miles wide and up to 1500 miles in length. He indicated that the satellite would be orbiting at about 125 miles above the earth. He said that receiving stations would be reading out the radar at [redacted] Vandenburg Air Force Base. He said that QUILL would probably be programmed for a 4-day orbit with the recovery of the data film.

6. Bradburn indicated that the management structure for QUILL would be as follows:

A. SE/TD, system integration and antenna-LMSC.
B. Radar payloads, AGE, field support--Goodyear Aircraft, Phoenix.
C. Radar consulting services, optical corollation--
[redacted].

7. Bradburn briefed the group from a chart with respect to the type of contract funding, and cover stories which were under consideration. An approximation of his chart is as follows:



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CORONA QUILL CONTRACTS SECUR

REF A. [redacted]

B.

C.

D. PART IV, PARA B

1. MEETING REF A ATTENDED BY COL MURPHY MAJOR BRADBURN, MSSRS [redacted] PLUMMER, [redacted]. FOLLOWING IS COVER STORY AND FLOW PLAN AGREED TO BY ALL PARTICIPANTS.

2. MARK V-A RECOVERY SYSTEMS, FILM CUTTERS AND CASSETTES WILL BE PROCURED BY [redacted] CONTRACTS UNDER EXISTING CONTRACTUAL ARRANGEMENT AND DELIVERED TO A/P FACILITY FOR ASSEMBLY AND CHECK-OUT BY CORONA/162 PEOPLE. THE SYSTEM, WITH CUTTER AND CASSETTE INSTALLED, WILL BE DELIVERED TO QUILL AT SUNNYVALE AS A COMPLETE UNIT IN, APPROXIMATELY, NOVEMBER 1963.

3. TO ACCOUNT FOR THE EXISTANCE OF THE FILM CARRYING CAPABILITY OF THE 162 BUCKET MR [redacted], LMSC QUILL PROGRAM MGR, WILL PREPARE A PRELIMINARY DESIGN OF THE CUTTER AND CASSETTE FOR PRESENTATION AT A

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[redacted] IN 71774 PAGE TWO

QUILL SE MEETING IN MAY 1963. MAJOR BRADBURN WILL APPROVE THE PD. [redacted] WILL GENERATE A LETTER TO MR [redacted], LMSC 162 PROGRAM DIRECTOR, REQUESTING [redacted] PROCURE THREE 162 RECOVERY SYSTEMS WITH A CUTTER AND CASSETTE OSTENSIBLY DESIGNED BY QUILL PEOPLE. THE DESIGN, LETTER, DRAWINGS, ETC, WILL BE HANDLED QUILL BLACK. THE PSEUDO-DESIGN WILL BE GAMED BY CORONA CLEARED PEOPLE NOW WORKING ON QUILL. THE COMPLETED TOP DRAWINGS, NOW ON FILE AT A/P, WILL BE DELIVERED TO QUILL AND SURFACED AFTER A REASONABLE TIME, APPROXIMATELY 1 JULY 1963. DRAWINGS FOR CUTTER WILL APPEAR ON ITEK TITLED PAPER. PLUMMER APPROVED. THESE DRAWINGS WILL ALSO BE HANDLED QUILL BLACK.

4. COL MURPHY WILL APPRISE MR WALT LEVISON, ITEK, THAT THE ADDITIONAL HARDWARE IS GOING TO BE USED IN [redacted] NO QUILL BRIEFINGS AT ITEK ARE ANTICIPATED.

5. THE COVER WILL GIVE A/P PERSONNEL LOGICAL REASON FOR ASSOCIATION WITH THE RECOVERY BUCKET AT SUNNYVALE IF NEED ARISES. HOWEVER, NO BREAKDOWNS ARE ANTICIPATED AT SV AS THE RECOVERY SYSTEM WILL NOT BE EXERCISED THERE. THERE WILL BE NO REQUIREMENT FOR TRAINING OF QUILL TECHNICIANS ON CORONA HARDWARE AT A/P FACILITY. IT IS EXPECTED THAT THERE WILL BE NEED FOR VERY FEW ADDITIONAL CORONA CLEARANCES DUE TO ENGINEERING INTERFACE.

6. HARDWARE FLOW WILL BE AS FOLLOWS: COMPLETE RECOVERY SYSTEM WITH CASSETTE AND FILM CUTTER INSTALLED WILL BE DELIVERED TO [redacted] FROM A/P. AFTER PAYLOAD COMPATIBILITY CHECKS IN [redacted] AND SYSTEMS TESTS AND OTHER SPECIAL TESTS IN [redacted], THE ENTIRE VEHICLE INCLUDING RECOVERY SYSTEM WILL BE SHIPPED TO MAB, VANDENBERG. RECOVERY SYSTEM WILL LEAVE THE MAB ONLY TO GO THROUGH NORMAL

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[redacted] IN 71774 PAGE THREE

WEIGHT AND BALANCE CHECKS AND RECOVERY SYSTEM FINAL INSPECTION IN "L" BUILDING. THIS IS THE ONLY FUNCTION PERFORMED BY "L" BLDG PERSONNEL AT VAFB. FILM LEADER WILL BE INSTALLED BY QUILL PERSONNEL IN HAB. A FEW CORONA PEOPLE AT VAFB WILL REQUIRE QUILL CLEARANCE, BUT IT IS ANTICIPATED THAT NO QUILL PERSONNEL WILL REQUIRE CORONA CLEARANCE.

7. THE T/M READOUT OF CASSETTE FUNCTIONS WILL NOT COMPROMISE THE CORONA MISSION.

8. THIS PLAN SATISFIES THE OBJECTIONS INDICATED REF C. IT IS REQUESTED THAT CONTRACTS PROCEED IMMEDIATELY WITH PROCUREMENTS REF D.

END OF MESSAGE

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(CLASSIFICATION)

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BYEMAN

Memo for Record:
This paper was the basis of a status report given verbally to the USIB and the 5412 Group by Dr. McMillan on 14 November 1963. [redacted]

WARNING

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

This document contains information referring to Projects:

CORONA GAMBIT LANYARD ARGON [redacted] POPPY QUILL

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(CLASSIFICATION)

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13 November 1963

STATUS OF SATELLITE RECONNAISSANCE PROGRAMS

CORONA

The CORONA Program at present has two payload configurations--the basic single-recovery Mural configuration flown in 1962, spring and summer of 1963, and presently available as backup, and the dual recovery J configuration.

The most recent Mural mission (M-24) was launched on 9 November 1963 but failed to orbit when an in-flight malfunction in the THOR control system caused the vehicle to become unstable and to destroy itself. The malfunction has been isolated to the "engine follow-up" circuit but the specific cause of failure has not yet been determined.

This was the 79th THOR-AGENA launching (includes 10 Improved THORS) - 78 AF and one NASA. Of this number, previous mission failures due to THOR were two in February 1960 and one in July 1961. None of these failures was similar to the 9 November problem. (In addition, the first attempted launch of the Improved THOR failed in February 1963 due to improper connection of a plug to one of the three solid motors.)

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Total THORs launched to date (missiles and satellites)--210. On four THORs there were problems which may be related to the one experienced on 9 November (although none of these was THOR/AGENAs).

The next launch, scheduled for 27 November, will be Mural 25 on a basic THOR-AGENA. Mural 26 on a TAT AGENA [redacted] is available for launch on 14 December if required. Mural 27 as a reserve vehicle (R-7) will be available in January and Mural 28, another reserve, in February.

CORONA J's will be utilized to provide future reserve as necessary after the Mural missions available in January and February are actually launched.

Two CORONA J missions have been launched. On each of these, the first half mission and recovery (equivalent to a full Mural mission) was successful, while the second half was unsuccessful. On the first, an inverter failure prevented main camera operation after reactivation and a battery failure prevented recovery chute deployment. On the second, secure command system problems prevented reactivation of the satellite after its deactivated period.

As subsequent J payloads experienced difficulties in the ground test cycle, decision was made to use the back-up Mural payloads in this time period while completing the R&D on the J configuration. The primary J payload problem is on of adjusting for proper tension in the

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Control System

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film transport system. Tests now underway at Sunnyvale are providing data on these adjustments. These tests are scheduled for completion on 16 November. After these tests are completed, a J payload will be prepared for flight and, if it successfully passes ground tests, will be available for launch about 20 December. In the meantime, other known problems in the J system (inverter and command system) have been fixed by providing redundant equipment.

GAMBIT

The third GAMBIT mission was launched on 25 October 1963 and was successfully operated in the hitch-up mode (i.e., Orbital Control Vehicle tied to the AGENA, without roll capability) and recovered on 27 October. During ascent, an error occurred in the injection angle, thought to be due to the influence of a cold cloud on the infra-red horizon sensors which provide the reference for orbit injection. This error resulted in an orbit which differed from that planned as follows:

	Planned	Actual
Apogee	180 (n. m.)	182
Perigee	95.48	78.18
Period	89.27 (min.)	88.97
Inclination	98.96 (deg.)	99.11

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Although the difference in orbits had considerable effect on the number of targets that could be covered by this particular mission, limited to vertical photography, it should be noted that it would have little effect on an operational mission since it could be corrected by the orbit adjust system, and full roll capability will also be available. After the recovery, the OCV was separated from the AGENA and exercised "solo" for two days. These exercises, all of which were extremely successful, provided a full test of the roll capability, the orbital adjust capability, and the deboost capability, the latter being used to de-orbit the OCV over the South Pacific.

In the photography from this mission, the ribbing structure of radomes, types of railroad cars and motor vehicles, and players on a football field could be distinguished.

The next GAMBIT mission is scheduled for launch on 13 December. This mission is planned for two days with full solo OCV operation with roll and orbit adjust capability, recovery of the film, and then additional OCV exercising. "Lifeboat" emergency recovery system is available on the OCV if needed.

On the basis of progress made to date in the R&D missions, it is estimated that the GAMBIT project may be fully operational by the fifth or sixth flight, with substantial intelligence take being obtained

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as an important bonus during the R&D period. It is also evident that the performance will exceed the design specifications in regard to photographic quality.

LANYARD

LANYARD was initiated solely as a back-up to GAMBIT, with the expectation of providing coverage of quality better than CORONA but not as good as GAMBIT. It is now evident that LANYARD is not required for this purpose. The LANYARD launch for November was cancelled and the TAT/AGENA converted to other uses. Five payloads are being completed and will be stored.

ARGON

The ARGON launch in October operated for five full days on orbit and was successfully recovered. Four additional ARGON payloads are on procurement for use in CY 1964, if required.

SIGINT

The two general search POPPY payloads launched last December continue to operate satisfactorily. They have now operated almost double their design lifetime of six months. [redacted]

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[redacted] Additional coverage will be obtained from another [redacted] available for next month. [redacted] launched this month and next. These payloads are designed to meet portions of the proposed COMOR coverage requirements directed against [redacted].

A three-ball POPPY launch is scheduled for 10 December 1963, and the first Project 315 [redacted] is scheduled for 25 January 1964. These launches are designed to meet general search and other directed coverage requirements. The next Project 315 [redacted] is scheduled for March 1964 for electronic-order-of-battle updating. Development work has started on combining the Project 315 [redacted] along with the inclusion of more reliable componentry and response flexibility.

417

The last two 417 missions attempted have failed because of Scout booster malfunctions. Because of this poor experience (3 failures out of 5 launches) and the continuing difficulties encountered with the rocket motors, decision has been made to utilize the THOR-AGENA booster for 417 launches. Two 417 satellites will be launched at once

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by this booster combination in order to increase the probability of success and maximize the expected useful operating time per launch. The first of these double payloads will be launched in January 1964. Both satellites will be placed on the same orbit. On later missions, the individual 417 satellites will be placed on different orbits by the use of solid rockets so as to optimize weather coverage. Development of an improved 417 payload is underway to increase reliability and operating life and improve performance. The first of these modified vehicles is scheduled for October 1964.

QUILL

The QUILL experiment is being conducted to demonstrate the feasibility of high resolution radar for terrain reconnaissance from a satellite.

The experiment will use an Improved THOR for the booster and the AGENA for the second stage and satellite vehicle. It will utilize the Goodyear RF-4C side-looking radar which is predicted to give about a 100-foot resolution over a swath width of 10 miles.

Data will be transmitted to the ground by direct (real time) electronic readout while the satellite is over the U. S. and by physical recovery of film at the end of a four-day flight. This will increase the

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probability of usable data return and permit a good evaluation of the degradation of data due to electronic readout.

Two flights are scheduled with the first to be in April 1964.

<u>THOR-Based Photo Payload Inventory (as of 13 Nov 63)</u>

Payload	Programmed	Expended	Balance
M	6	2	4
J	20	2	18
L	5 + 3 + 5	3 (+ 5 cancelled)	5
A	2 + 4	2	4

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SYSTEM ONLY

THE DIRECTOR OF CENTRAL INTELLIGENCE

WASHINGTON 25, D.C.

COPY 1
BYE 4588-64
23 July 1964

MEMORANDUM FOR: Director, National Reconnaissance Office

SUBJECT : Review of FY 1965 (TS) NRP

1. I have reviewed the material you sent me for use in our discussion on Monday on the FY 1965 program. In order that you may have the benefit of my preliminary review, I make the following comments. Unfortunately the information available to me is limited and any constructive suggestions on my part will require more detailed information which, I assume, you will make available. Nevertheless, my comments are intended to be helpful to you in further discussions of this FY '65 National Reconnaissance Plan and will indicate specific areas in which I need considerably more clarification and details.

GENERAL

One thing that strikes me as most interesting is the fact that the Program A and Program D funding under the President's budget was fully authorized in the NRO tentative program, and in fact Program A was increased [redacted]. Contrasted with this, Program B funding indicates [redacted] remaining to be justified. This gives me cause for concern since Program B is an operational responsibility of elements of the Central Intelligence Agency over which I have direct control.

My views on GAMBIT-3 and the FULCRUM program are covered in my letter of July 23rd to Secretary Vance, a copy of which I attach for your information and reference. Furthermore, I expect that the COMOR study which will be presented to USIB on July 29th will throw further light on the desirability of new photographic reconnaissance systems to improve our reconnaissance inventory and I presume that USIB's desires will serve as guidance to NRO for its program in Fiscal Year '65 and subsequent years.

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2. My subsequent specific comments are designed to point out areas in which I think we must take a very close look to determine whether or not the Programs are in fact necessary and whether or not the funds presently designated for them should not, perhaps, be reassigned to higher priority programs designed to meet the more critical needs of the intelligence community.

SPECIFIC

Program A.

CORONA J -- While this amount appears reasonable, our discussion yesterday indicated that beyond those funds presently contracted for by Program B, no procurement of payloads by Program B is contemplated for the latter part of FY '65. This appears to prejudge a decision that the CORONA Program will be transferred in toto to Program A. I anticipate further discussions with reference to contracting responsibilities for Program B. You are familiar with my views which were expressed in a memorandum to Secretary McNamara commenting upon the PFIAB report which memorandum, I am sure, you have seen. With respect to introduction of Aerospace in the CORONA Program, I have given this serious thought and have concluded that such a move would be most undesirable and would risk serious damage to the Program and hence I request through this memorandum that the present arrangement, which was continued by letter contract through July, 1964, be put on a permanent basis. Any other action would be confusing and would seriously risk this important intelligence collecting asset.

ARGON -- This figure appears reasonable and I have no comment.

CORONA OCV -- I understand the original purpose of proposing the use of the expensive GAMBIT Orbital Control Vehicle (OCV) as a carrier for the CORONA cameras was to provide some degree of competition and therefore incentive to Lockheed for better performance. It seems to me that this move will introduce a whole new set of reliability problems and will increase the launch costs from [redacted] per launch as we go from Thor Agenas to Atlas Agenas. This would be in addition to the [redacted] tentatively budgeted. I am not convinced that this is either a necessary or desirable move. In view of General Greer's statements, I invite further discussion concerning the advantages of using the Atlas Agena for the CORONA.

GAMBIT -- This schedule looks about right and the tentative financing appears adequate. As indicated in my letter, it appears that developmental activities necessary to bring the GAMBIT resolution down to 2' as indicated by Eastman Kodak representatives on Monday would be desirable. I would recommend that these activities be funded promptly.

GAMBIT-3 -- Note recommendations in my letter to Secretary Vance.

QUILL -- Although we have never been briefed in any detail on this program, I understand it is a satellite-bearing, side-looking radar and is primarily a research and development item concerning the feasibility/utility of such an all-weather approach. I would like further information on this Program.

417 -- These weather satellites contribute to weather planning for NRO missions and I therefore am in support of them. In the future, if we have problems as to the size of the NRO budget, we might consider transferring the satellites out of that budget and possibly to the Air Force Systems Command. This is not an item of importance at the moment, however, and the amount funded seems adequate.

SIGINT -- I have never been fully briefed on the intelligence requirements for this Program, or whether or not it is providing information of real value meriting this sizable expenditure. I would like a comprehensive analysis and briefing prior to making commitments of this magnitude.

NEW GENERAL SEARCH -- I do not have any information as to what is contemplated under this line item and will need full justification for it.

SATELLITE CONTROL FACILITIES -- I do not have any information as to what is contemplated under this line item and will need full justification for it.

APPLIED RESEARCH/ADVANCED TECHNOLOGY -- I do not have any information as to what is contemplated under this line item and will need full justification for it.

AFSSPL -- I have no way to judge the adequacy of the funds provided for the Air Force film processing at Westover. However I would like to discuss with you the use and the relative contributions of the government-financed film processing facilities at Eastman Kodak which were established some time ago by CIA and those of the Air Force facilities at Westover. Opinions have been expressed to me that the former facilities are not being used productively with the result a very considerable amount of Eastman's knowledge in the field of film processing is being sacrificed. I would appreciate an opportunity to discuss this matter with you at your early convenience. This is the first time that I have noticed the budget for Air

Force film processing at Westover as a line item in the NRO budget. I am interested in knowing whether this has previously been included in the NRO budget. It appears to me that now is the time to establish just what the separate or supplementary roles of our facilities at Eastman Kodak and the facility at Westover should be. I would like a briefing as to what your plans are in this regard.

[redacted] -- I am most concerned over the level of effort in the area of [redacted] As you know this responsibility was assigned to the Air Force through NRO by the Special Group. CIA feels that there is a very considerable possibility that the Soviets will come up with an [redacted] Thus I believe that this area of study and research must be given a very high priority, adequately financed, and pursued with competence.

MISCELLANEOUS -- I do not have any information as to what is contemplated under this line item and will need full justification for it.

Program B.

The Program B submissions for FY 1965 budget total [redacted]. These submissions were made on 20 September 1963. On 20 December 1963 the D/NRO furnished an approved OSD FY '65 budget estimate of [redacted] including [redacted] for KEDLOCK. Subsequent advices from D/NRO and instructions as to budget submissions have resulted in the directed figure of [redacted] of which [redacted] of this figure appears to be withheld for further justification or consideration as an addendum item. The reasoning behind all of these adjustments and the very tentative nature of the commitments requires further explanation.

OXCART -- The tentative program is significantly lower than the President's budget or the recommendations of Director, Program B, and I would predict a year-end deficit situation, particularly if operational missions are called for this year. It would appear that funds from KEDLOCK and TAGBOARD (in Program D) should probably be recaptured in magnitude sufficient to restore the Director-recommended OXCART funding.

IDEALIST -- The matter of additional U-2's for the U. S. inventory should be decided now. As discussed on Monday, two courses of action are open. The first is to build up the CIA inventory by modifying SAC U-2's on the assumption that such planes are available without impairing SAC's capabilities to fulfill its assigned missions. I have been told this situation might result if B-57F's are substituted for U-2's for certain atomic energy missions. The alternative is the building of new U-2L's. These would be better planes than the converted U-2's; however they would be more costly and furthermore to make it worthwhile to open up the production line, an order for 25 aircraft is indicated. I think we should confer and reach a decision on this matter at an early date.

COUNTERMEASURES -- In view of the OXCART supermarket program, it appears that all of the [redacted] recommendation should be furnished to Director, Program B, particularly since this Program was not in sight when the Presidential budget was set at [redacted].

[redacted] -- These funds appear adequate to do the job.

PHOTOGRAPHIC -- These funds appear adequate to do the job.

ADVANCED SYSTEMS STUDIES -- This funding is adequate to determine FULCRUM feasibility and program definition during the first six months of the fiscal year but is not adequate to carry on into the second phase. The funding is adequate to determine [redacted] feasibility as well as initial funding for financing [redacted] during the second half of FY '65 if the first half looks good. Money should also be made available to continue preliminary design studies of the advanced aircraft and [redacted] which is now funded out of FY '64 funds.

FULCRUM -- My views are set forth in my letter to Secretary Vance.

[redacted] -- The first [redacted] has been approved and if the Program is successfully demonstrated in detail, the additional money required is available in the Advanced Systems Studies fund of [redacted] proposed.

AKINDLE -- Subject to Special Group encouragement, which I understand you will elicit at the Special Group meeting on July 23rd, no further action appears necessary at this time.

Program D

R-12 EARNING -- The amount tentatively programmed is [redacted] less than Director, Program D recommendation and does not appear adequate to prevent slippage. It appears to me that such a reduction would cause slippage or possible supplemental request. This, however, seems to be an Air Force problem. In fact, I wonder if the time is not approaching for the R-12 to be taken from the NRO budget and transferred to the Air Force.

KEDLOCK -- I notice no reduction in the KEDLOCK programming although most of the OXCART items have been seriously reduced. The question here is which comes first.

TAGBOARD -- I think it is now time for us to take a real hard look at TAGBOARD. My tentative conclusion is that this is a marginal program of unlikely utilization as an NRO operation and we might better divert the funds to other programs of greater promise over the long run.

DRAGON LADY -- Funds appear adequate.

[redacted] -- Funds appear adequate but, in any event, could be easily compensated at that order of magnitude.

SUMMARY

To summarize, I need much more information in considerably greater depth on those questions I have raised above and suggest that we continue these budget discussions at your earliest opportunity. In the meantime, major commitments of FY '65 funds in those controversial areas noted above should be held in abeyance until Secretary Vance and I can agree on a FY '65 NRP.

JOHN A. McCONE
Director

Attachment:

cc: Secretary Vance

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GAMBIT DORIAN CORONA ARGON QUILL LANYARD FULCRUM

OXCART IDEALIST [redacted] AKINDLE [redacted]

July 29, 1964

MEMORANDUM FOR THE DEPUTY SECRETARY OF DEFENSE

SUBJECT: Comments on the 23 July 1964 Memorandum to ~~(S)~~ DNRO from DCI, BYE 4588-64

The same headings are used as in the referenced memorandum.

Paragraph 1. No comment.

GENERAL

The budget for Program A for 1965 was developed against a detailed launch schedule and statement of R&D objectives which was transmitted by ~~(S)~~ DNRO to Director, Program A, for his guidance. His budget was submitted by the deadline set, was responsive to the guidance given, and was supported by very detailed back-up information. Consequently, it has been possible to review the budget expeditiously and arrive promptly at many decisions.

In response to guidance given, the Director, Program A, submitted alternate budgets. His lowest alternate figure was [redacted]. This was reduced by ~~(S)~~ DNRO action to [redacted]. Some of the reductions were made by explicit elimination of activities proposed by the Director, Program A; others were essentially arbitrary, as will be noted later. In the cases of these arbitrary reductions, it yet remains for the ~~(S)~~ DNRO and the Director, Program A, to develop the details of the program to be accomplished under the reduced ceilings.

The tentative budget of Program A as submitted to you and the DCI on July 16th appears as [redacted]. This is a formal figure, based on the assumption that [redacted],

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GAMBIT DORIAN CORONA ARGON QUILL LANYARD FULCRUM

OXCART IDEALIST [redacted] AKINDLE [redacted]

reprogrammed late in FY 64, will be applied to the development of G3. In practical fact, the money proposed for Program A in FY 1965 is [redacted]. This is [redacted] more than the President's budget. The [redacted] increase has already been mentioned; the other [redacted] will cover "black" studies to be done in connection with the manned orbital laboratory and will be offset in the total Air Force financial plan by a transfer of [redacted] from Air Force sources.

The submission of the Director, Program B, was developed against only general guidelines from ~~(S)~~ DNRO, relating mostly to format and timing. The Director, Program B, established the detailed program and schedules against which his budget was figured. His initial recommendations reached me on 8 June, three weeks later than the deadline set in the original instructions. Since the original submission of the Director, Program B, there has been an addendum submission received about July 9th and two briefings, not fully consistent with each other.

During the period since receipt of the Program B recommendations, the ~~(S)~~ NRO Comptroller has been in regular consultation with the Program B staff to establish detailed background for and justification of the Director's recommendations. The material used for discussion on 20 July reflected my recommendations based on the then current state of my understanding of the Program B resolutions. There have since been approved increases to the photographic and countermeasures accounts.

Paragraph 2. No comment

Numbered Paragraph 2. No comment

<u>SPECIFIC</u>

CORONA J. The funds recommended for CORONA J include all of those that are required for the conduct of the program, whether contracting is done through CIA or Air Force channels. This is the budgeting procedure that was followed in Fiscal 1964.

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GAMBIT DORIAN CORONA ARGON QUILL LANYARD FULCRUM

OXCART IDEALIST [redacted] AKINDLE [redacted]

At the present time, funds have been released to CIA to cover current needs of all contracts presently in force; no funds have been authorized for subsequent contracts that will be required to complete the program in Fiscal 1965. The DCI comments that he has given serious thought to the introduction of Aerospace Corporation into the CORONA program and has concluded that such a move would be "most undesirable". This is not quite consistent with his statement to me on 28 May 1964 as recorded in my Memorandum of Record of that date. In any case, the inclusion of Aerospace Corporation as systems engineer and source of technical direction on the CORONA program is an integral part of the whole issue of centralized management of the CORONA program. I do not intend to accede to the Director's request to continue permanently the present arrangement without explicit direction from you or the Secretary of Defense to do so.

ARGON. No comment.

CORONA OCV. The [redacted] appearing in the budget against this item is to fund the engineering and fabrication of four conversion kits to adapt the GAMBIT Orbital Control Vehicle to carry the CORONA camera. With these kits on hand, a launch of the CORONA camera in a GAMBIT vehicle can take place seventeen weeks after boosters and cameras are committed. Four kits suffice to cover monthly launches in this configuration during the period required to fabricate further conversion kits. I consider that this capability, rather inexpensively acquired, has several values. First, as originally proposed, it provides some degree of competition to Lockheed. Second, and probably in the long run more important, it gives the CORONA program an opportunity to fly in a considerably more versatile and flexible vehicle. In particular, by far the best protection we have today against attack upon our satellite vehicles is to alter the orbit from pass to pass to prevent targeting by a Soviet attack system. Under our vulnerability program, we have engineered a limited capability for orbit adjustment into the present CORONA system. The capability is limited by the

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GAMBIT DORIAN CORONA ARGON QUILL LANYARD FULCRUM

OXCART IDEALIST [redacted] AKEDDLE [redacted]

weight carrying capacity of the booster; in turn, the presence of this capability limits the orbits available to the CORONA system. Neither of these limitations would apply if the CORONA cameras were flown in an OCV; in particular, the amount of orbital adjustment available for dodging an enemy attack would be vastly greater than that allowed under our present development.

GAMBIT. The developmental activities necessary to bring the GAMBIT resolution down to about 2 feet are almost completed; any additional funding that is required is included in the present GAMBIT budget. Most of these developments will have their effect during Fiscal Year 1965.

GAMBIT-3. No comment.

QUILL. A briefing on QUILL can easily be supplied. However, present planning would terminate the QUILL program with two launches in FY 1965, and the bulk of the costs have been paid in FY 1964.

417. I have several times given thought to the possibility of transferring 417 into the Air Force Systems Command. I am convinced that the phenomenal performance of the small project office that has run this program up to this time would be completely destroyed if it were submerged in the Systems Command. It is in the interests of (1) efficiency, (2) morale of the highly competent people involved, and (3) maintaining an effective DoD position in the Weather Satellite business that I recommend 417 be continued under ~~(S)~~ NRO management.

SIGINT. In truth I share some of the DCI's concern whether this program is really producing. On the other hand, this is an area which has had altogether too many comprehensive analyses. There is no more complete and detailed statement of requirements anywhere in the military literature than that which applies to the SIGINT program. I am sure that the DCI could be briefed on this matter. I am equally sure, however, that he would get little information useful to him from such

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GAMBIT DORIAN CORONA ARGON QUILL LANYARD FULCRUM

OXCART IDEALIST [redacted] AKEDLE [redacted]

a briefing and I recommend that we do not consider this budget item as contingent upon his being informed.

NEW GENERAL SEARCH. In developing a preliminary financial plan for FY 64, approximately a year ago, I included parallel developments of two new general search camera systems, scheduling a decision point for selection between the two or possible cancellation of both. The program included adequate boosters and payloads to allow for R&D launches on the new development and to allow for operating under any of the three conditions that might result, i.e., adoption of one or the other of the new systems or adoption of neither. During June of 1963 a Panel, convened by the DCI to review the ~~(TS)~~ National Reconnaissance Program, stated that in their view it was premature to consider major efforts toward developing an improved General Search System. This Panel recommended instead that every effort be devoted to improving as much as possible the performance of the CORONA system. A report of this Panel dated 3 July 1963 was transmitted to me by the DCI. This was then, has been until today, 29 July 1964, the only written statement bearing on the requirement for a development of a new General Search System that I have officially received, other than the original USIB statements of 5 July 1960. On the strength of this Panel report, I took a convenient way out of severe financial difficulties in FY 64 and scratched all consideration of a new General Search development in the FY 64 Financial Plan. The ~~(S)~~ NRO budget for FY 65 and following, submitted in the fall of 1964, provided for initiating development of a new system, characteristics unspecified, in FY 65, and initiation of a second new system, characteristics also unspecified, in FY 66. During the past winter and spring it became evident that a new pointing system, now called G3, was completely feasible and desirable. It has been my plan, as indicated in the present financial plan, to utilize the money budgeted in FY 65 for a new system, plus other money made available by savings and reprogramming, for the development of G3.

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GAMBIT DORIAN CORONA ARGON QUILL LANYARD FULCRUM

OXCART IDEALIST [redacted] AKEDLE [redacted]

During the fall of 1963, after cancellation of LANYARD, studies of new systems were undertaken with ITEK. These studies were directed exclusively toward general search systems at the time that it became evident that G3 was overwhelmingly the most desirable approach to a new pointing system. Guidance that went out to the Director, Program A, for preparation of his Fiscal 1965 budget plan directed him to plan on the initiation of a new general search system at such a time during Fiscal 1965 as information from the ITEK studies and others would make a rational selection possible. The Director of Program A submitted alternative budgets assuming a decision point during December 1964. His lowest estimate for initiating development in FY 65 of a new general search system was [redacted]. The item of [redacted], carried in the financial plan at the present time, represents an arbitrary reduction made to close the budget at the figure established in the President's budget, as increased by [redacted] to be transferred from the Manned Orbital Laboratory. This New General Search item represents one of several sources of funds which can be used should the development of a new general search system be decided upon during Fiscal 1965.

SATELLITE CONTROL FACILITIES. The DCI requests "full justification" for this item. This item represents the bulk of the funds used to support the tracking, telemetry and on-orbit control functions required in our satellite operations. It is not a new item, but has been separated from system costs for the first time in FY 1965 for several reasons. It is a strictly DoD support function and I see no reason why the DCI should be interested in any details. We can however overwhelm him with details if this is desirable.

APPLIED RESEARCH/ADVANCED TECHNOLOGY. This item is being carried at an arbitrary figure of [redacted], representing a reduction of [redacted] from the submission of the Director, Program A. At the present time, details on this item are not complete. I will be glad to brief the DCI on these details

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GAMBIT CORONA DORIAN ARGON QUILL LANYARD FULCRUM

OXCART IDEALIST [redacted] AKINDLE [redacted]

when they are available. The Director again asks for "full justification". I am pleased to give him information, but I think we should be the judge as to whether the information constitutes justification or not.

AFSSPL. The Director quotes an opinion that the Eastman Kodak facility for development of film is not being used productively with the result that a "very considerable amount of Eastman's knowledge in the field of film processing is being sacrificed." In my judgment, there is no element of Eastman's knowledge of film processing that is in any way being ignored or sacrificed. One can raise the question whether personnel, equipment and facilities, either at Eastman Kodak or at the AFSSPL at Westover AFB are being efficiently used. Annual examinations of this question have been made and so far their results have appeared inconclusive. I have some hopes that a current investigation of the matter will lead to conclusions. The budget figure that is established for AFSSPL in our budget for Program A, and the budget figure in Program B, established for Eastman Kodak's film processing activities, reflect conclusions already drawn from the analysis now going on. I will be glad to present the results of these analyses both to you and the DCI when they are available. The essential problem is a simple one. A highly trained organization exists at Eastman Kodak, beautifully equipped for the very finest processing of film that one knows how to do. This facility is alternately taxed to the utmost and virtually idle as the "take" from various reconnaissance missions comes in for processing. The demands of the intelligence community for very rapid processing of the take once it is available, and for wide dissemination of high quality duplicate copies, make it very difficult to maintain an even flow of work or maintain the appearance of efficient use of this prime asset. A somewhat similar capability manned by military personnel exists at Westover AFB. Without claiming for this facility either the skill or the capability that we know exists at Eastman Kodak, I can state that it is available and is used to some degree for processing of intelligence take. It is not used to capacity

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GAMBIT CORONA DORIAN ARGON QUILL LANYARD FULCRUM

OXCART IDEALIST [redacted] AKINDLE [redacted]

and its capability could be drawn upon to improve the efficiency of operation at Eastman by smoothing out the peaks of processing load. However, to do this efficiently requires either that some pressure for rapid processing of film be withdrawn or that the intelligence community be willing to entrust to AFSSPL some of the highest quality processing load. I am not yet prepared to make a firm recommendation as to how this dilemma should be resolved. I do not think that its resolution will influence the budget of the AFSSPL because there are no salaries or overtime figures in this budget. The resolution may influence the budget for the Eastman Kodak processing activity which is carried under Program B.

[redacted]. This program is regularly criticized by the DCI and by Dr. Wheelon on every occasion they can find to mention it. I think that some of the criticism is deserved, but I take it fully upon myself because I believe the greatest weakness of the program is that it is not cohesive nor firmly directed toward clearly stated objectives and priorities. The budget figure of [redacted] proposed for Fiscal 1968 is 30% lower than that spent in Fiscal 1964 and less than one-half of that proposed in the President's Budget and recommended by the Director, Program A. This reduction is an arbitrary one and implies only that I feel that the program needs better direction and orientation. I am not prepared at the moment to report in detail on what program will be accomplished for the [redacted]. I have in mind, as stated earlier, that perhaps the most important thing we can do for the more immediate protection of our CORONA system is to provide the great orbital maneuver capability that would result from putting the CORONA camera into the OCV. Purchase of kits as proposed earlier would permit this kind of reaction against Soviet attack in a reasonable time, something short of instantaneous, after an attack was experienced. We could delete the [redacted] item labeled CORONA OCV and increase the [redacted] program to [redacted] if this is what is required to get approval for engineering the CORONA cameras into the OCV.

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GAMBIT CORONA DORIAN ARGON QUILL LANYARD FULCRUM
OXCART IDEALIST [redacted] AKDUDLE [redacted]

MISCELLANEOUS. Again the Director asks for "full justification". These are items such as the MOL effort, first destination transportation, and a [redacted] study.

Program B

First paragraph. While the Program B FY 1965 budget submission totaled [redacted], there were a number of entries which could not be substantiated by specific proposals, and were deleted for the President's budget. For example, [redacted] was recommended by Director B for an unknown covert satellite and [redacted] for an unknown advanced aircraft. In the April 1964 instructions for the FY 1965 recommended program, Director B was given the opportunity to recommend in an addendum budget any requirement which he considered to be necessary above the basic budget, stated to be [redacted]. His June 1964 submission reflected a [redacted] basic and addendum request, compared with a September 1963 submission of [redacted] for the same accounts, involving a reduction of [redacted]. The [redacted] was later supplemented by additional FY 1965 requests for FULCRUM, etc. The [redacted] now identified with Director B is compatible with the [redacted] program, with the difference being solely related to KEDLOCK under Director D.

OXCART. Reductions to date in this program have been accepted by Director B. The only remaining area for resolution is Airborne Electronic Equipment, which is expected to increase above the tentative program. With respect to a possible year-end deficit, experience in FY 1964 would indicate that this is unlikely. The initial Director B FY 1964 recommendation for OXCART was [redacted]. This was reduced in detailed reviews to [redacted], with the understanding that certain accounts would be on an expenditure basis. On 22 November 1963, we received a memorandum that indicated a significant expected deficiency. In contrast, the final FY 1964 data indicate that not only was the funding adequate, but that over [redacted] of obligations above the expenditures could be covered on the service contracts alone, allowing this account to start FY 1965 on an obligation

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GAMBIT CORONA DORIAN ARGON QUILL LANYARD FULCRUM

OXCART IDEALIST [redacted] AKBDLE [redacted]

basis. Accordingly, there would seem to be no need to recapture KEDLOCK and TAGBOARD funds to restore the OXCART funding originally recommended by the Director, Program B.

IDEALIST. There is no question in my mind that Agency needs for U-2 aircraft can be met for the next several years by conversion of existing U-2 airplanes to a configuration desired by the CIA. Such a converted airplane does not have all the features that one would get in a redesigned U-2L. The cost of going to a U-2L under the presently forecast need would be considerably greater than that involved in converting existing assets. There is no question that the most economical way to provide the aircraft is to modify individual aircraft as they go through the IRAN cycle. I see no need to discuss further or to "reach a decision". I believe we should simply state that aircraft will be made available as justified requirements demand. The FY 1965 budget for Program B includes enough money for modification of three aircraft during the year; arrangements are already being made to have these aircraft modified.

COUNTERMEASURES. All of the OXCART so-called "super-market" program is included in the funds already authorized to the Agency under the Countermeasures line. The remaining justification has not been fully received and the amount not authorized.

[redacted]. No comment.

PHOTOGRAPHIC. This is a DCI mis-statement. Our tentative program allowed [redacted] against Director B's recommendation of [redacted], and we have since agreed to a [redacted] amount.

ADVANCED SYSTEMS STUDIES. In the budget discussion of 20 July, Dr. Wheelon stated that all of his requirements for Advanced Systems Studies had been submitted to us. This then implies that his requirements are for studies of [redacted], FULCRUM, and [redacted]. Indeed, his stated requirements go beyond "studies" and into design and development. Since I do not now intend to authorize to CIA anything like the amounts

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GAMBIT CORONA DORIAN ARGON QUILL LANYARD FULCRUM

OXCART IDEALIST [redacted] AKINDLE [redacted]

asked for on [redacted] or FULCRUM, inasmuch as I do not believe that development is justified, it seems to me that this item - advanced systems studies - offers money that can be used elsewhere. At the present time I am developing a draft financial plan that includes transfer of the excess in this line to Program A against the new General Search development item.

FULCRUM. No comment.

[redacted]. See comments above.

AKINDLE. The DCI apparently agrees that this project is contingent upon a clear endorsement by the Special Group. I hear by the grapevine that his people may have already committed funds to it without authorization, but that is their problem.

Program D

R-12 EARNING. The DCI notes a difference of [redacted] between the Director of Program D submission and our tentative authorization. Since the time of that tentative authorization, I have learned that Mr. McNamara is willing to authorize an increase of [redacted] against this item and we believe this will be adequate to meet the major needs of the program in Fiscal 1965. The Director notes the possibility of transferring this program to the regular Air Force budget. This, of course, has been contemplated by Mr. McNamara for some time.

KEDLOCK. Most of the money in KEDLOCK is for flight test and development of a fire control system. The program has not been subject to the same kinds of overrun that were involved in the R-12 program.

TAGBOARD. I believe that the Director will be asked by the Foreign Intelligence Advisory Board at its meeting next week what his views on the TAGBOARD program are.

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GAMBIT CORONA DORIAN ARGON QUILL LANYARD FULCRUM

OXCART IDEALIST [redacted] AKIDDLE [redacted]

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BYE 23128-64

DRAGON LADY. No comment.

[redacted] No comment

SUMMARY

It is appropriate to comment on this paragraph that this whole memorandum to me takes a much more imperative tone than any previous correspondence from the DCI save perhaps brief notes or brief paragraphs concerning very specific items, e.g., a change of contract or reassignment of program responsibility. Coming from the DCI, the document as a whole represents in my judgement a complete rejection of the word and spirit of the ~~(S)~~ NRO Agreement of March 13, 1960. Inasmuch as the ~~(S)~~ DNRO is responsible directly to the Secretary of Defense as Executive Agent for the ~~(NR)~~ NRP, the DCI should not assume the authority to direct specific actions or require separate program justifications in a manner that implies exclusion of your office. The series of discussions with the DCI that began on 20 July and which should be completed as soon as possible will fulfill the requirements imposed upon the ~~(S)~~ DNRO by Paragraph III A and K of the 13 March Agreement; namely

"Development on a continuing basis for the approval of the Secretary of Defense and the Director of Central Intelligence of a single National Reconnaissance Program of all projects...."

and

"Preparation of budget requests for all NRO programs, and presentation and substantiation of such budget requests to the Secretary of Defense and the Director of Central Intelligence...."

Until such time as the PFIAB report and recommendations may be acted upon by the President, I very much appreciate your continued support in pursuing a positive and unified approach in our relations with the CIA in the conduct and management of the ~~(NR)~~ NRP.

signed
Brockway McMillan
Director
~~(S)~~ National Reconnaissance Office

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22 October 1964

MEMORANDUM FOR: Chief, Special Security Center

SUBJECT : Status of QUILL Project

1. As the Special Security Center had been requested to furnish an opinion concerning the protection of the QUILL product, Lt. Col. John Pietz of General Greer's Staff was questioned about the QUILL status on 20 October 1964 during his visit to the Headquarters Building.

2. According to Colonel Pietz the QUILL Program was generated by a DNRO request of General Greer to orbit a radar satellite quickly in order to test the validity of certain claims. The plan was not for an operational intelligence system, and the end product was not to associate itself with any intelligence function. The orbiting satellite was to look only at a narrow 10 mile beam over the U. S. Although not clandestine in nature Pietz believed that its operation would not be obvious to those on the ground.

3. If the first flight is not successful then a second QUILL shot will be made. However if the first flight is deemed to accomplish the task set out then a DNRO decision must be made on the future of the program.

4. Pietz also advised that approximately three weeks ago General Stewart of the NRO TWX'd General Greer and suggested that an intelligence evaluation team examine the QUILL product. However, General Greer did not look favorably upon the idea and so advised General Stewart that it was too early to bring the intelligence personnel into the picture. The first group of QUILL end-products will not contain intelligence, and he reasoned that if a decision was later reached to conduct an intelligence mission there would be time enough to form an evaluation team.

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5. Pietz stated that QUILL is a side looking radar satellite that will take radar pictures of the U. S. The film in the satellite will result in the synthetic putting together of signal intensities. In the meantime these signals will also be relayed to tracking stations at VAFB or New Boston. The film will be recovered similarly to the CORONA System. Hopefully both films, the one returned to earth and the one received at the tracking station, will be duplicates. After the film is processed (probably at EK) it will be sent to the [redacted] where it will be put through an optical correlator. The product of this operation will then be used to make a radar map. The radar map will then be sent to SAFSP and then to the DNRO where the decision will be made as to the future of the QUILL Program.

6. If the DNRO's decision is to continue the QUILL Program as a post attack radar system, he probably will turn over the operation of the program to SAC. The question then arises as to whether the program will be "black" or DOD Secret. If intelligence is involved the "black" operation will probably prevail. However, if bomb damage assessment is the primary mission, the R&D may be black, but that since it will be SAC's decision as to when the operation will be launched, it will then be turned over to the white community. According to Pietz they (Program A) have not given these possibilities much thought. If it is decided that the QUILL has any potentiality as to either intelligence or post attack surveillance then a new set of circumstances will be present at that time and a decision rendered as to the control of the product.

7. Pietz also stated that [redacted] has a contract with the [redacted]. Program A is funding the QUILL product through [redacted]. There are approximately 12 to 15 QUILL cleared personnel at the [redacted] and 2 or 3 cleared at [redacted]. Pietz wishes to keep the product in the BYEMAN System at this time. The Chief, SSC agreed that this protection should be utilized until the time comes that the product begins to furnish the community with an intelligence take.

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COMMENTS OF LOUIS MAZZA AT 22 OCTOBER 1964 QUILL MEETING IN THE SPECIAL SECURITY CENTER

I have explored with appropriate personnel of the (S) NRO, the matter of security classification and control to be applicable to the products of Project QUILL. I find the following facts to be germaine to consideration of this matter:

(1) Project QUILL is essentially a feasibility demonstration relating to the use of radar as a satellite intelligence collection system.

(2) The program is of a highly experimental nature and the three presently available payloads are not adaptable to operational employment. There is no plan to scan other than U. S. territory.

(3) Whereas it is envisioned that representatives of the exploitation community will subsequently be asked to assist in the evaluation of the results of this demonstration, maximum effort is being focused at this time on the task of recovering and reconstituting a satellite radar product and evaluating from an engineering standpoint. Following this, intelligence utilization evaluation will be considered.

(4) The acceptable limitation of operation from the national policy standpoint has not as yet been defined (radar after all is a non-passive collection system) and these parameters when developed could have a direct bearing upon the matter under consideration.

For these reasons I feel it is premature to consider the matter of security classification and controls at this time, and I have concurred with recommendation of the (S) NRO Program Directorate A to retain the results of this demonstration under Project QUILL controls until such time as circumstances indicate that other action is appropriate.

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Approved for Release: 2022/08/18 C05139542

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23 October 1964

MEMORANDUM FOR: Chief, Special Security Center

SUBJECT : QUILL End Product

1. Attached is a resume of our discussion with Lt. Colonel John Pietz setting out background information regarding QUILL. This resume also reports Pietz's feeling that the end product of QUILL should be protected in the BYEMAN System. It is assumed that Pietz is only repeating the feelings of General Greer.

2. Also attached are the recommendations of Mr. Louis Mazza that the QUILL end product remain in the BYEMAN System.

3. In addition an attached TWX from General Stewart to General Greer [redacted] sets out a recommendation that an intelligence evaluation team be formed to review the QUILL end product and help determine future actions.

4. General Greer's reply [redacted], which was concurred in by General Stewart [redacted], disagreed with premature action to establish an evaluation team. In General Greer's reasoning he set out the highly experimental nature of the QUILL Project and the total lack of adaptability of the present QUILL payloads to any operational effort. He recommended that no evaluation team be established until the product has been recovered and reconstituted.

5. As Mr. Reber has asked for your opinion concerning the protection of the QUILL end product, it is recommended that you advise him that it will at this time be protected under the BYEMAN System. This recommendation is based on the following facts:

(a) QUILL is a feasibility experimentation.

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(b) Present hardware cannot be utilized operationally.

(c) The end product will, if successful, be of no intelligence value since it will scan only U. S. territory.

(d) After a successful experimentation, a decision must still be reached concerning any future intelligence use.

(e) Director Program "A", the DNRO and you wish to maintain the end product in the BYEMAN System at this time.

[redacted]
Survey Officer, Survey Branch

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SAFSS

RAj Mr. Mazza/nao/7 Dec 64
QUILL

1964 DEC 8 08 16

7 December 1964

MEMORANDUM FOR [illegible]/DIA
ATTN: Major [redacted]

SUBJECT: Project QUILL, Product Security Control and Classification

REFERENCE: BYE-[illegible]-64
BYE-[illegible]-64

Reference is made to our recent conversation with respect to security controls and handling which will be afforded the products of Project QUILL.

I am forwarding referenced correspondence for your information.

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2. BYE-[illegible]-64

LOUIS F. MAZZA
Chief Security Officer
(O) NRO Staff

DISTRIBUTION:
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4 to RF #1
5 to RF #2

QUILL

~~SECRET~~ QUILL

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MEMORANDUM FOR: Director, National Reconnaissance Office

SUBJECT : End-Product of Project QUILL

1. Consideration has been given to the controls which should be placed upon the end-product from the currently planned tests of Project QUILL over territory within the United States.

2. After consultation with representatives of your Office and of Program Director "A", a decision was reached that for the present time the end-product of Project QUILL should be protected under the BYEMAN Security Control System. This was based upon the following:

a. Project QUILL is presently only a feasibility experimentation;

b. Present plans call for the experimental scanning to be of U. S. territory only and with no intelligence resulting;

c. If at a later date it is decided to use QUILL operationally for intelligence collection, further consideration will be given to the control of the end-product.

3. It is requested that you advise Program Director "A" of this decision.

FOR THE DIRECTOR OF CENTRAL INTELLIGENCE

Howard J. Osborn
Director of Security

~~SECRET~~ QUILL

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DEPARTMENT OF THE AIR FORCE
WASHINGTON

QUILL
~~SAFSS~~

OFFICE OF THE UNDER SECRETARY

1964 NOV 16 13 34
16 November 1964

MEMORANDUM FOR CHIEF, SSC/CIA

SUBJECT: Project QUILL Security Plan

The provisions outlined in the attached plan will be incorporated into an overall Project QUILL Plan which is being prepared by the QUILL Project Officer, SAFSP. You will be furnished a copy when completed.

1 Atch
QUILL Security Plan

FRANCIS L. LISCIOTTI
Major, USAF
Assistant Security Officer
~~(S)~~ NRO Staff

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Page 1 of 1
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QUILL

PROJECT QUILL SECURITY PLAN

I. PURPOSE.

On 6 November 1964, a meeting was convened at the QUILL Processing Facility (AFSPPL), Westover AFB. This memorandum outlines results of discussions pertaining to security procedures, processing and handling of the QUILL product. Participating in these discussions were the following personnel:

Lt Col David D. Bradburn, SAFSP QUILL Project Officer
Colonel [redacted], AFSPPL
Major [redacted], AFSPPL
Major Francis L. Lisciotti ~~(S)~~ NRO
[redacted], Goodyear-Aerospace Company

II. GENERAL.

QUILL is a feasibility demonstration of the satellite borne radar for ground mapping. In this experiment, radar data signals acquired over the U.S. will be recorded on photographic film. The initial image on the film will consist of doppler histories of radar returns from ground targets. Hereafter, this film will be identified as "data film". Another data film with the same returns recorded thereon will be physically recovered from the satellite recovery vehicle (SRV) at the end of the 4-day mission. Each data film is used as the input to an optical correlator located at the [redacted]. The output of the correlator is another film to be called a "radar map". The radar map will show imagery (identifiable objects on the ground). During the QUILL mission, data films will be generated from 3 sources: (1) New Hampshire Tracking Station (NHS); (2) Vandenberg Tracking Station (VTS); (3) recovered satellite film.

III. PROCESSING.

All the data films will be processed by the AFSPPL and forwarded to the [redacted]. The product resulting from the correlator at the [redacted] will be exposed but undeveloped film radar maps. The undeveloped film radar maps will be sent to the AFSPPL for processing, duplicating, and distribution. An exception to this will be Pass #8 and/or #8. Pass #8 data film will be picked up at the NHS by an AFSPPL courier, processed at AFSPPL, and couriered to the [redacted]. After correlating this data film to produce the radar

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Attachment

QUILL

map, the [redacted], which has limited in-house film processing capability, will process this radar map for immediate engineering analysis. The purpose of this is to evaluate for equipment adjustment, if needed, in the satellite, at the tracking stations or in the optical correlator. If Pass #8 does not satisfy this requirement, they will repeat this process with Pass #9, which will be couriered from the VTS.

Processing at the AFSPPL will be done by TKH cleared individuals. The optical correlation and limited processing performed at the [redacted] will be by QUILL indoctrinated personnel. The AFSPPL will affix the classification "Secret" on the head and tail of the roll of film. A control number, prefixed by "BCS", will appear on the head end of the film, the spool, and the film can. Although a code punched at the beginning of the film roll will identify it as related to project QUILL, the actual word QUILL will not appear thereon. This will provide for greater flexibility in the event it is subsequently decided that the assistance of TKH only cleared elements are required to the performance evaluation.

IV. COURIERS.

Couriers from the New Hampshire Tracking Station to the AFSPPL to the [redacted] will be supplied by the AFSPPL. Couriers from the VTS to the AFSPPL will be furnished by Goodyear-Aerospace Company. Couriers from the [redacted] to Washington, DC (Pass #8 or #9) will be furnished by the [redacted]. Couriers from Hickam Field to Moffett Field to AFSPPL will be supplied by the 6594th Aerospace Test Wing. This will be via commercial airline. A Command Post will be established at the Satellite Test Center, Sunnyvale, for purpose of monitoring all courier activities from Hickam to Moffett and the VTS to the AFSPPL. The couriers will be either BYEMAN or TKH cleared individuals. Civilian couriers will be QUILL indoctrinated.

V. GENERAL SECURITY.

At the Vandenberg and New Hampshire tracking stations, the recorders will be located within the secure [redacted] area and will be monitored by QUILL cleared personnel who have met clearance standards through a completed BI. The film at the [redacted] will be handled exclusively and in an approved QUILL secure area by QUILL cleared personnel.

All classified QUILL administrative matters conducted with the [redacted] by the AFSPPL, SAFSP, and Goodyear-Aerospace Company is via registered mail.

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Attachment

QUILL

The original copy of the data film will go to the [redacted], with one copy to be retained at the AFSPPL.

At the time of this meeting, there had been no provisions made for distribution of the film radar maps other than the copies for the [redacted] and a copy for the ~~(S)~~ NRO. It was discussed and agreed to, that any further distribution of the film radar map by the AFSPPL would have to be approved and coordinated with the ~~(S)~~ NRO.

QUILL

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COPY 4 OF 6
PAGE 3 OF 3
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Attachment

Approved for Release: 2022/08/18 C05139542

By every measure, Quill was a highly successful satellite experiment. Five volumes of evaluation and assessment reports were issued concerning the program. Together the volumes describe the extensive testing that occurred in advance of the Quill program to assure program success. The volumes also describe the operation of the experimental satellite once it was launched, and the care taken to assure program success. Finally the assessment volumes suggest a future for radar imagery from space including recommendations for additional steps following the Quill experiment.

Document 14 — Quill Vehicle System Report, Volume I, 31 March 1965: Approximately three months after the highly successful single flight of the Quill experimental radar imagery satellite, Lockheed Missiles and Space Company (LMSC) delivered a three volume assessment of the experiment. Volume I is the overall summary of the program. LMSC first identifies the organization instituted to develop the Quill program. The program was established at the request of NRO's Program A—the Air Force element at the National Reconnaissance Office (NRO). LMSC served as the primary contractor providing systems engineering and technical direction. Goodyear Aerospace Corporation was an associate contractor responsible for the development of the radar subsystem. Another associate contractor provided guidance on processing and interpretation of the radar imagery. LMCS's volume I also includes a description of the mission, which was to obtain high resolution terrain mapping imagery using a side-looking radar sensor. The system was to operate in both near-real-time and provide film return images for a comparative basis. This volume also includes a brief evaluation of the imagery obtained from the system and summary of the system performance.

Document 15 — Quill Vehicle System Report, Volume II, 31 March 1965: Approximately three months after the highly successful single flight of the Quill experimental radar imagery satellite, LMSC delivered a three volume assessment of the experiment. Volume II is the engineering assessment of the program. The volume provides engineering details and performance summaries of all major Quill subsystems including electrical power, altitude control, command and control, and structural elements. The report also provides engineering analysis of the radar payload and radar antenna, two critical components for the system. The volume discusses basic Doppler theory in relation to space-based radar imagery, the thermodynamics associated with the space vehicle, and the testing approach for the program. Finally, the report discusses the handling and processing of the radar data obtained from the experiment for processing into radar imagery. This volume contains a number of engineering drawings of various subsystems and components as well as photographs of some of those items. The volume also has a rich store of data tables and information related to the program.

Document 16 — Quill Vehicle System Report, Volume III, 31 March 1965: Approximately three months after the highly successful single flight of the Quill experimental radar imagery satellite, LMSC delivered a three volume assessment of the experiment. Volume III is the flight performance assessment of the program. The report was developed to describe orbital performance data for the Quill spacecraft. The volume also includes assessments of the subsystems, thermodynamic conditions, vacuum gage responses, and the Satellite Control Facility. LMSC notes that the satellite radar payload operated for a total of 32.91 minutes during 14 orbits. Like the other two volumes from LMSC evaluating the Quill experiment, volume III contains engineering drawings and a significant amount of test data for evaluating the system's performance.

Document 17 — Quill Program Report, Volume I, 1 April 1965: The Goodyear Aerospace Corporation was responsible for developing the radar payload for the Quill experimental radar imagery satellite. On 1 April 1965, a little more than three months after the highly successful single test flight of Quill, Goodyear released a two volume program assessment. The first volume describes the design process and development of the radar payload, and testing of the payload, while the second volume describes the actual flight testing of the radar payload. Volume I's introduction includes a general overview of the program along with the program's design philosophy, basic vehicle configuration, system parameters, and an operational summary. The introduction also includes a chronology related to the radar payload development. This volume includes the important description of Doppler theory in relation to the radar imaging mission of Quill. Goodyear included a lengthy systems analysis including integration of the antenna design, power requirements, mapping coverage, and resolution capabilities. Space is a harsh environment and the section on environmental system analysis recognizes this by summarizing efforts to analyze thermal factors, component stress limits, vibration effects, and shock effects on the Quill system. The report also contains very detailed information on the radar subsystem's design, mechanical elements, and component integration.

Document 18 — Quill Program Report, Volume II, 1 April 1965: The Goodyear Aerospace Corporation was responsible for developing the radar payload for the Quill experimental radar imagery satellite. On 1 April 1965, a little more than three months after the highly successful single test flight of Quill, Goodyear released a two volume program assessment. The first volume describes the design process and development of the radar payload, and testing of the payload, while the second volume describes the actual flight testing of the radar payload. Volume II includes a very important review of the ground infrastructure that was built to receive data downloads from the Quill satellite as well as control the test flight. Like all complicated technical programs, Quill program personnel encountered problems and undertook corrective actions to address those problems. Goodyear's volume II provides insight into this important dynamic. Goodyear's volume II also includes detailed analysis of the radar subsystem as well as the entire system during the flight of the satellite. Goodyear includes in this volume a summary of program results, recommendations for the future of radar imagery in space, possible future applications of the technology, and a chronology of Goodyear's involvement in the radar imagery experiment.

LIST OF QUILL FLIGHT VEHICLE ASSESSMENT DOCUMENTS

Loggerd

AC-04306
VOLUME I
31 March 1965
Copy No. 3

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Quill

RADAR

PROGRAM [redacted]

VEHICLE 2355 SYSTEM REPORT (U)

VOLUME I – SUMMARY

Quill

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LOCKHEED MISSILES & SPACE COMPANY

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AC-04306
Volume I
31 March 1965

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PROGRAM [redacted]

VEHICLE 2355 SYSTEM REPORT (U)

Volume I - Summary

Contract [redacted]
Supplemental Agreement Number 13

Quill

Prepared:

[redacted]

[redacted]
Chief Operations
Program [redacted]

Approved:

[redacted]

[redacted]
Manager
Program [redacted]

Approved:

~~David D. Bradburn~~

David D. Bradburn
Lt. Colonel, USAF
SAFSP

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AC04306

FOREWORD

This report covers the span of time from the inception of the first satellite borne radar system through the final evaluation of the on orbit performance of the first flight. An objective review is attempted, of the complete scope of activities associated with bringing a new system into being and of the system performance during an essentially nominal and troublefree mission.

From this review, it is hoped that the systems management and program control parameters which were found to be effective may be properly recognized and thereby enhance the organization and conduct of similar future activities.

The system definition and resulting configuration is reviewed in retrospect, together with the problems associated with this Program development and testing.

The engineering management concept and the test philosophy which were applied are outlined and restated, with the objectives of first recording these, and then attempting to objectively analyze them for areas susceptible to improvement. The Air Force - LMSC - Associate Contractor team is defined, as it existed during the development, testing and operation of Vehicle 2355.

The system performance from launch through recovery and thence to battery depletion is evaluated from the primary aspect of payload operation.

System performance is compared against predictions, and the performance accomplishments and achievements are enumerated.

The report is therefore, in addition to a flight report, a total summary of the composite effort associated with the preparation and operation of this system. From the system evaluation certain conclusions and recommendations are formulated which are intended to be useful for later work on similar systems.

Through the medium of the detailed information contained in this report, it is intended to properly acknowledge the efforts of all those who were instrumental in managing and conducting a program which produced a completely successful mission with the first flight of a new payload vehicle system.

AC04306

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PART I

Table of Contents

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LOCKHEED MISSILES & SPACE COMPANY

1.2 Program Organization

1.2.1 Program Management - Background

Based on an earlier proposal to the Air Force, Lockheed Missiles and Space Company was awarded a contract in November 1962, to place in orbit a coherent, side-looking radar system. The contract specified that Lockheed (System Associate Contractor) would provide overall systems engineering and technical direction of the program, as well as the Agena and its various subsystems (power, command and control, telemetry, etc.). [redacted] (Eastern Associate Contractor) was made responsible for designing the experiment, designing and constructing the optical correlator for processing the raw radar data, and evaluating the data obtained from the experiment. Goodyear Aerospace Corporation (Associate Contractor) was assigned the task of providing the payload hardware as well as participating in the experiment design, test and operation. The contract specified that two vehicles should be launched (2355 and 2356). The payload for 2357 was to be prepared. The payloads of each of the vehicles were to be essentially identical; the first vehicle originally was scheduled to be launched in April 1964. Figure 1.2.1.1 depicts the program management structure.

1.2.2 Contractor Responsibilities

1.2.2.1 Lockheed - System Associate Contractor - was assigned the responsibility of providing System Engineering and Technical Direction to the P-40 Program, subject to the overall management of the Secretary of the Air Force, Special Projects (SAFSP).

In addition to system management the Program Office was responsible for

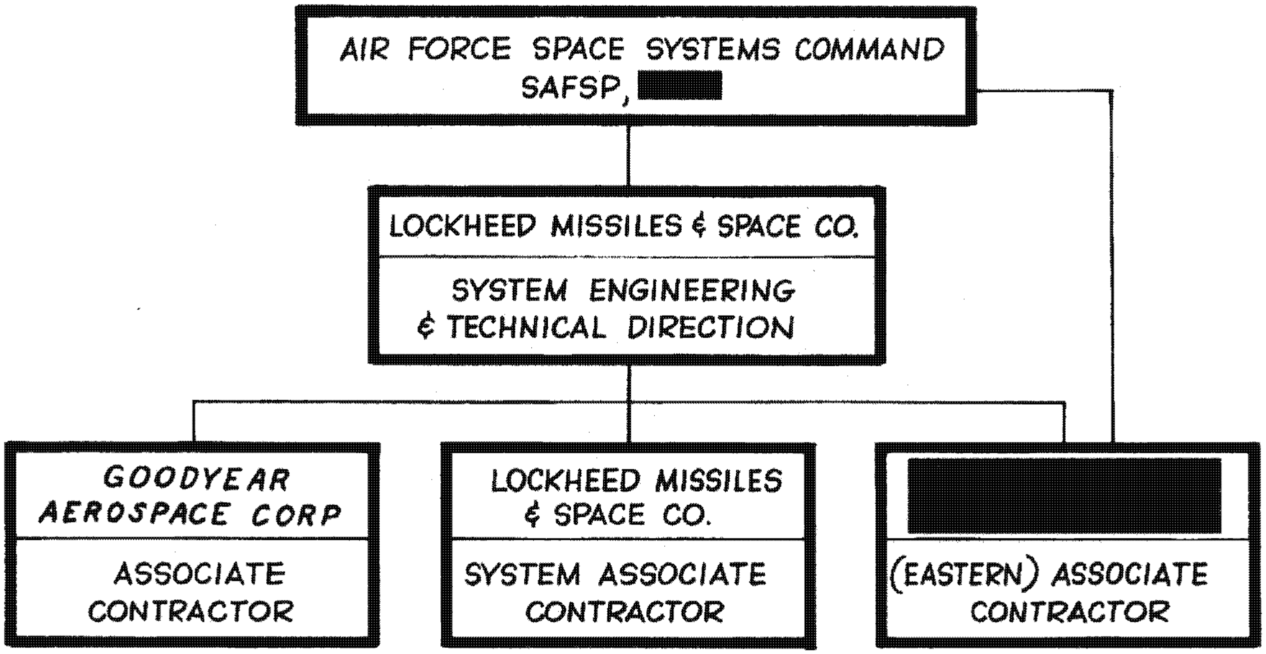

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Figure 1.2.1.1 Program Management

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coordinating all activities of the three Associate Contractors to insure a technically compatible program to meet planned objectives.

Responsibilities assumed by Lockheed to integrate all activities as necessary to achieve all flight objectives included, but were not limited to, the following:

- o Perform technical direction and engineering management within the parameters as established by SAFSP.
- o Determine system requirements and establish system performance through a coordinated study and analysis endeavor.
- o Recommend to SAFSP, the required research, development and experimentation to achieve program objectives.
- o Prepare the requirements for, and evaluate the Design Control Specifications, Acceptance Test Specifications, Engineering Analysis Reports, Test Procedures, and Specifications, by coordinating total effort with the Associate Contractors.
- o Analyze and make recommendations to the Air Force, as required, on System, Subsystem and Component development and test programs.
- o Establish a Systems Engineering and Technical Direction (SETD) capability to conduct continuous evaluation of equipment performance to determine the degree of compliance with all system functional and operational requirements.
- o Hold SETD meetings with Associate Contractors to coordinate latest changes necessary to meet program objectives, by performing technical evaluations of requests from the Associate Contractors for

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design or performance waivers on components, subsystems, end item equipment, and ground support equipment, making recommendations to SAFSP regarding approval of changes.

- o Review, analyze and make recommendations to achieve interchangeability and compatibility of associated subsystem and equipment designs formulated by Associate Contractor.
- o Review the reliability programs established by the Associates to assure consistency, quality and adequacy of effort.
- o Assist Program management in determinimg Program milestones, design parameters, procurement techniques and releases.
- o Integrate AGE, GHE, Spares and all necessary flight support equipment to provide flight test vehicle and flight vehicle readiness.
- o Perform the necessary techniques for integration of GAC Radar equipment with LMSC payload antenna.
- o Perform qualification tests on payload system consisting of radar subsystem, space structure subsystem and recovery subsystem.
- o Provide the necessary assistance in pre-flight planning and programming, in-flight support analyses, post-flight T/M analyses and preparation of preliminary and final ephemeris.
- o Prepare and release a final System Report.

1.2.2.2 Goodyear Aerospace Corporation was assigned responsibilities as an Associate Contractor to fulfill the following requirements to meet the P-40 Program objectives:

- o Perform the necessary functions to accomplish the design, develop-

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ment, procurement, manufacture, and development testing of the radar subsystem, not including the antenna, takeup reel, data link, interconnecting cabling, or the waveguide.

- Design, develop and provide the necessary ground support equipment to meet the Program objectives, including all payload test equipment for payload units and system test sets for the payload as a subsystem.
- Participate in the radar subsystem acceptance at LMSC facility.
- Perform the retrofits, modifications and maintenance of the radar subsystem.
- Recommend readiness and provide certification of the radar subsystem prior to systems test and launch.
- Furnish wooden mock-ups for LMSC integrated mockup.
- Perform the development and acceptance testing of the radar subsystem.
- Assist in the qualification testing of the payload system in regard to the radar subsystem at Lockheed. Perform the necessary payload qualification at Goodyear.
- Recommend and provide the necessary spares for the radar subsystem to give adequate backup to the Program.
- Determine the need for, and provide the necessary tools, jigs, and similar items needed to install, check and adjust all components, subassembly, and assembly of the radar subsystem during the subsystem assembly and checkout.
- Provide film recorders for tracking station data link recording.

- o Assign field personnel to LMSC to assist in performing the necessary modifications and tests to assure technical integrity and technical capability of the radar subassembly and payload vehicle.

1.2.2.3 [redacted] was assigned responsibilities as an Associate Contractor to perform the following tasks:

- o Provide technical advice and assistance to Lockheed Missiles and Space Company and Goodyear Aerospace Corp., in the areas of payload design and establishment of system requirements for flight operation.
- o Design and build an advanced optical correlator for processing the payload data.
- o Process (correlate) the payload data from the recovery capsule and the wideband data link.
- o Perform payload data analysis and evaluation, including system performance evaluations against predictions.
- o Issue a comprehensive report covering all work performed.

1.2.3 Security

The Program requirements for security were established by SAFSP [redacted] and are graphically portrayed in Fig. 1.2.3.1, Security Concept, on the next page.

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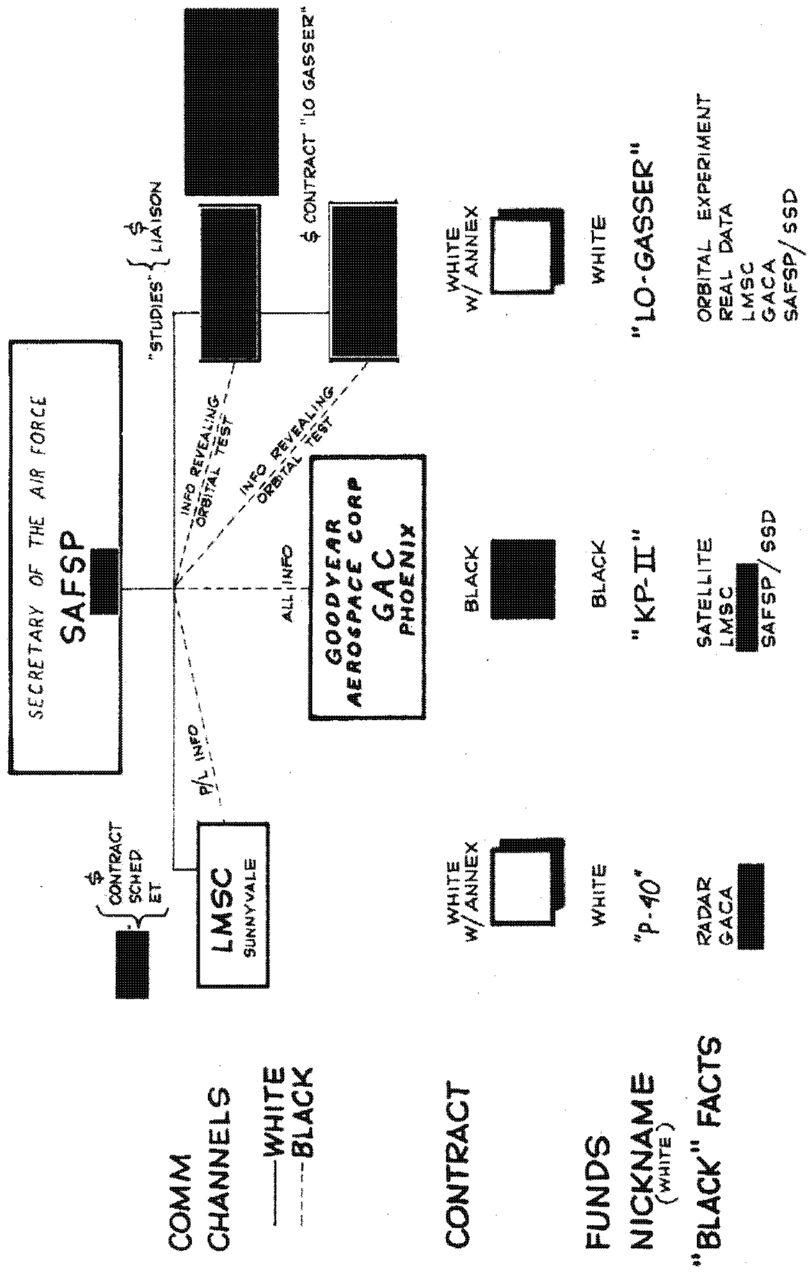

Figure 1.2.3.1 Security Concept

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1.3 Program Objectives

Primary Mission Objective The primary objective of the orbital flight was to demonstrate that a fine-resolution radar strip map of a portion of the earth's surface can be generated through use of a satellite-borne synthetic-aperture radar system. For the purpose of this demonstration a resolution goal of 50 feet in azimuth and in slant range was established.

Secondary Mission Objectives A number of secondary objectives of scientific and/or engineering significance were also established. Among these are the following:

- o Quantitatively evaluate the performance of the radar system, with emphasis on azimuth-dimension behavior:
- o Determine the performance limits imposed by:
  - Payload design parameters
  - Payload in-flight performance
  - Vehicle attitude behavior
  - Atmospheric conditions
  - WBDL design and performance
- o Determine the reasons for any observed anomalous performance of the system:
- o Collect data on target-field reflectivity.
- o Develop engineering data useful for aerospace radar system designs.
- o Demonstrate the capability of the ground recording equipment to record useful data received via the WBDL.

Primary Vehicle Objectives The launch phase primary vehicle test objective was to inject the Agena (SS-01A) into a near circular orbit so that the satellite altitude would be 130 ± 13 nautical miles when passing between 30°N and 70°N geodetic latitudes with an orbit plane inclination of 70 ± 0.25 degrees.

The orbit phase primary vehicle test objectives were:

- o To maintain, during the minimum orbit life of 65 orbits, a stabilized horizontal attitude with the following tolerances (-Z axis up and -X axis forward):
  - Deadband 0.15 ± 0.07 degrees, all axes
  - Bias uncertainty ± 0.4 degrees, all axes
  - Maximum pitch rate 0.002 degrees/second
  - Maximum roll rate 0.005 degrees/second
  - Maximum yaw rate 0.003 degrees/second
- o To yaw the vehicle to a bias angle of 2.44 ± 0.3 degrees to the left and to the right in response to commands.
- o To provide electrical power to sustain payload and vehicle life for a minimum of 65 orbits.
- o To command and control vehicle and payload operation.
- o To obtain data required for the generation and verification of commands to control vehicle and payload operation.

The recovery phase primary vehicle test objectives were:

- o To orient the SS-01A to a proper nose down attitude, separate the recovery capsule at the proper time and provide retro-thrust to

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the capsule so that its re-entry trajectory falls within a predetermined recovery area.

- To recover the recovery capsule with its payload by air or surface units deployed for that purpose.

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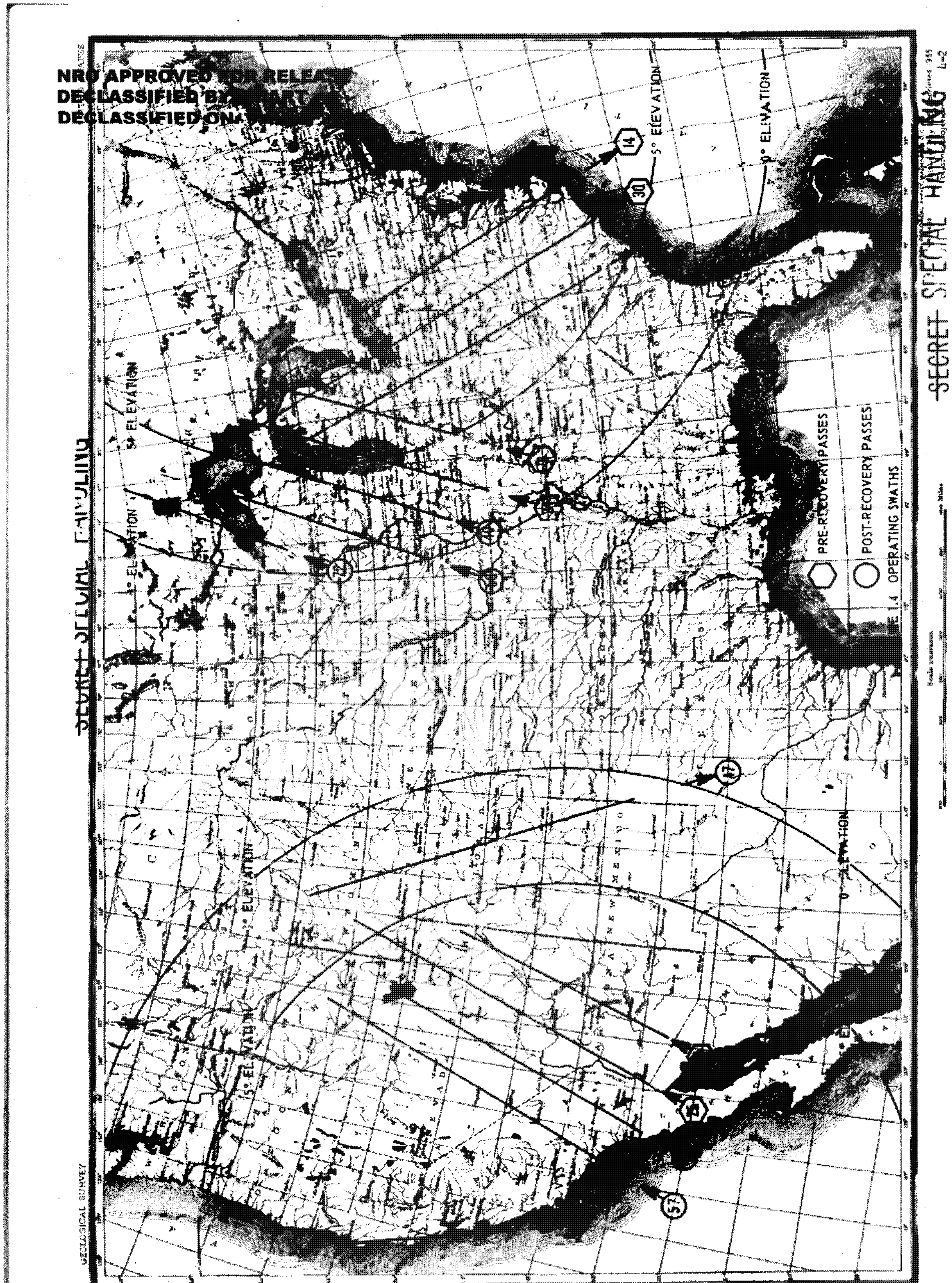
1.4 Mission Description

The mission of Vehicle 2355 was to place in orbit a coherent X-Band, side-looking radar system payload in order to obtain a high resolution terrain map. The payload was to be operated in realtime under command of the Vandenberg and New Hampshire Satellite Tracking Stations. Operation of the payload was to be limited to the Continental United States. The SS-01A vehicle was to be injected into a near circular orbit so that the altitude over the areas to be recorded would be approximately 130 nautical miles. Precise attitude stabilization of the vehicle would then orient the radar antenna so that the main lobe of the radar beam would be at a fixed depression or look angle of 55° from the horizontal, thereby illuminating a swath approximately 10 nautical miles wide at a distance of 93 nautical miles to the left of the satellite ground track.

The data obtained from the payload was in the form of target echoes which were synchronously demodulated to preserve both phase and amplitude of the signals. These signals, which constitute the raw radar map Data or doppler history of the illuminated terrain, were recorded photographically on film in a recoverable capsule aboard the satellite. Simultaneously, these signals were transmitted over the Wide Band Data Link to the tracking stations where they were again recorded photographically on film by ground based recorders and also electronically on wide band magnetic tape recorders. The film recorded in the satellite was to be recovered in the Pacific Ocean area by means of air catch of a recovery capsule. Figure 1.4 portrays the payload operating swaths and the tracking stations zero and five degrees elevation circles of coverage.


5° ELEVATION
0° ELEVATION
PRE-RECOVERY PASSES
POST-RECOVERY PASSES
OPERATING SWATHS
14
30
57

1.5 System Description

The satellite vehicle utilized for this mission consisted of the following subsystems:

Subsystem A (SS/A) - Structural

Subsystem B (SS/B) - Propulsion

Subsystem C (SS/C) - Electrical

Subsystem D (SS/D) - Guidance and Attitude Control

Subsystem C & C - Command and Control

Payload Subsystem

Recovery Subsystem

The above subsystems are described in some detail in Part II, Para. 2.1, Satellite System Engineering; Para. 2.2, Radar Payload; and Para. 2.3, Test, for the Recovery Subsystem. Since the Recovery Subsystem was GFE, the effort was limited to test on that subsystem, and the configuration description is confined to the information considered necessary for understanding of system operation.

The satellite structure forward of the standard Agena vehicle interface housed and supported the guidance system components, the radar payload and associated power equipment and the recovery capsule.

The radar payload was developed for satellite application by Goodyear Aerospace Corporation from the AN/UPQ-102 side looking doppler radar utilized in the RF-4C aircraft. The radar components include: (1) a Transmitter-Modulator, which is basically a high power R.F. pulse amplifier; (2) an RF-IF unit, which generates a low power RF pulse

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for the transmitter and receives and compresses the reflected radar pulse; (3) a Reference Computer which generates timing and control signals, RF pulses for transmission, synchronously demodulates the received intermediate frequency to provide video data and performs electronic beam steering to a zero doppler position; (4) a Power Control Unit, which controls and switches power and generates regulated voltages necessary for the radar; and (5) a Recorder which records the received video from the Reference Computer on film by exposure from the face of a cathode ray tube. The film, containing the doppler history of each target, is returned by the recovery capsule. Simultaneously the video data from the Reference Computer is transmitted by means of an R.F. data link to the tracking stations, and recorded in a similar film recorder.

The high power output pulse of the radar was transmitted through a flat, phased array, antenna mounted on the side of the satellite with the beam oriented perpendicular to the vehicle longitudinal axis and at a 55 degree depression angle below horizontal. The beam width was .346 degrees in the azimuth direction and 2.9 degrees in the vertical direction at the half power points. The satellite was rotated 180 degrees after injection into orbit (positioned for recovery pitch down) and was stabilized in a horizontal plane. During the payload operating passes the horizon sensors were disconnected and the satellite was precisely stabilized under fine attitude control by the inertial reference package gyros. The system was supplied electrical power by three silver-zinc batteries, the output of which was converted and regulated as required. The electrical capacity of the batteries limited the duration of the mission. The vehicle was commanded through an S-Band beacon and returned data through two VHF telemetry links and the wide band UHF data link.

After separation of the recovery capsule the vehicle was re-stabilized in the horizontal plane and the payload was operated through the data link until power depletion on orbits 72 - 73. The orbit decayed and the vehicle re-entered on orbit 333 at 1027Z, 11 January 1965.

1.6 System Performance - The system performance was faultless throughout the orbital mission, until battery depletion on Orbit 72 - with the exception of minor unexplained voltage disturbances on Orbits 8 and 9. This section presents the significant payload operating information, radar imagery samples and discussions of the payload performance, preceded by a brief summary of system parameters and performance.

Launch

Date: 21 December 1964 Time: 1908:56Z

Location: Launch Complex 75-1-1, Vandenberg AFB

Vehicle: LV-2A #425 SS-01A #2355

Orbit	Predicted	Actual
Period (MIN)	89.44	89.66
Perigee (N.M.)	130	135.82
Apogee (N.M.)	154	157
Inclination (deg.)	70.0	70.11
Eccentricity	.003	.0036
Active Orbits	65	73
Recovery	65	33
Payload Operations	13	14

Area recorded as fine resolution radar imagery:

approximately 70,000 square miles (nautical).

1.6.1 Evaluation of Radar Imagery

General Comments - An extensive amount of recorded video data was generated by the flight of vehicle 2355; this data has been processed to generate fine-resolution radar imagery. Examples of this imagery have been selected for the purpose of illustrating the radar-appearance of various cultural targets and non-cultural terrain areas which fall within the imaged swaths, as well as to illustrate system phenomena of engineering interest. A detailed evaluation of the results of the radar experiment which culminated in the 2355 flight is being prepared under separate cover by The [redacted] the results presented in this volume are of a preliminary nature and therefore somewhat incomplete. In examining the incorporated imagery, the reader must keep in mind the fact that the photographic prints in this report do not permit the full azimuth resolution and dynamic range capabilities of the system to be preserved; these are considerably better preserved in the high-quality photographic transparencies which have been generated during the program, and are at their very best at the output of the optical data processor prior to photographic recording. The processor output may be viewed by the user of the radar imagery, without recording, in situations where the full resolution and dynamic range must be preserved.

The first eleven examples of radar imagery, Figures 1.6.1 through 1.6.11, have been selected to show a reasonably wide variety of cultural and terrain features. Their image quality is typical of the entire mission; these samples have been selected because their content is representative of areas of potential military interest. These first eleven images were all generated from the physically-recovered video data. Corresponding U. S. Geological Survey maps are presented with the radar imagery in instances where this is useful.

Figure 1.6.12 is generated from video data transmitted via the WBDL coincident in time with the generation of the data film used to generate Figure 1.6.11; this comparison permits the effects of the data link on image quality to be observed. Figure 1.6.13 was generated from the same video data which had been stored, upon reception via the WBDL, using the AMIE tape recorder, and then played back onto the same ground-based photographic recorder used in the generation of the Figure 1.6.12 data. The comparison of Figure 1.6.12 and 1.6.13 permits an evaluation of the effects of the AMIE to be made.

Figures 1.6.14 through 1.6.20 illustrates effects which are primarily of engineering interest in providing data for the efficient design of future systems. One of these also shows the effects of severe weather on the radar performance.

A brief discussion of the effects of certain system behavior on image quality is necessary, prior to presentation of the image samples.

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Payload Behavior - The radar payload itself performed within nominal specification limits during the generation of the imagery presented in this section. The payload variables which were the key factors in determining image quality were:

- o Time coincidence of the CRT sweep with the returns from the most strongly illuminated portion of the terrain; that is, from the terrain lying between the upper and lower 3 db directions of the illuminating beam. Adjustment of the prf is used to effect this coincidence;
- o Behavior of the clutterlock oscillator in response to initial attitude of the vehicle at turn-on, and to subsequent angular rotations and accelerations of the vehicle; and
- o Behavior of the AGC circuit in response to various target distributions.

Image quality is of course also dependent upon local terrain reflectivity and atmospheric conditions, but these are not controlled payload variables.

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Vehicle Attitude Behavior - The attitude orientation of the vehicle at the time of payload turn-on and its subsequent behavior during the payload operating time affect image quality, part of the effect being somewhat indirect. Roll behavior manifests itself in a different manner than do pitch and yaw behavior.

Since the radar is sidelooking, to within a few degrees of normal to the local inertial velocity vector, the roll attitude determines the ground swath which is illuminated. In the payload subsystem as implemented, one is then faced with the problem of selecting a prf appropriate to the resulting slant range from vehicle to swath center, in order to have return video coincidence with the range gate of the receiver and recorder. Roll excursions which are small compared with the elevation beamwidth are of little consequence once the correct prf is established, and larger roll excursions can be tolerated if one is willing to make a prf-adjustment. The prf-setting problem will be covered in further detail in a later paragraph.

The pitch and yaw attitudes of the vehicle at payload turn-on determine the position of the doppler spectrum of the video return. It is necessary to control the position of the spectrum center in order to guarantee proper sampling of the doppler-shifted video while minimizing the generation of ambiguous target responses; this is effected through use of a voltage-controlled oscillator driven by the output of the clutterlock integrator. At turn-on, the random yaw and pitch biases in general cause the doppler spectrum to be misaligned with respect to its proper location, and the voltage-controlled oscillator responds to correct the error. Similarly, this oscillator also responds to pitch and yaw velocities and accelerations subsequent to turn-on. Because the electrical phase center of the antenna is close to the vehicle's mass center, the angular motions of the vehicle do not directly inject phase errors into the video return; therefore no direct degradation of resolution or image signal-to-noise ratio results from the vehicle rotations. The degradations appear as a consequence of the steering of the voltage-controlled oscillator; this is discussed in the next paragraph. The vehicle attitude control is analyzed in detail in Part II, Par. 3.3.

Clutterlock Behavior - The output of a voltage-controlled oscillator (VCO), whose frequency is determined by the instantaneous output of the clutterlock integrator, is injected into a single sideband (SSB) modulator in the receiver along with the video, the SSB output* then being applied to a synchronous demodulator. The purpose of the clutterlock and VCO is to keep the doppler spectrum of the (corrected) video centered about a predetermined offset frequency. When the instantaneous pitch and yaw orientations of the vehicle are such that the doppler frequency is too large, the VCO is commanded to reduce its frequency to compensate the data, and vice versa. In doing so, it injects a phase error into the target returns while correcting the spectrum position. If the VCO output frequency is constant or changing linearly over the pass length, no deleterious effect on resolution is observed. The output of the clutterlock is constrained from varying rapidly, through use of an integrator with a time costant of the order of a few seconds. The time constant of the integrator is determined on the basis of expected vehicle rotation and angular acceleration rates, the widths of the 3-axis limit cycles, and the radar parameters; the two values available in 2355 were 2.5 and 5 seconds, the former being used in the primary

*the upper sideband being employed.

operating mode.

At payload turn-on the initial misalignment of the antenna beam with the zero-doppler direction causes the VCO to be driven toward the correct compensating frequency, at a rate determined by the integrator circuitry as well as the magnitude of the initial error. If the rate of change of frequency is approximately linear at this time then the following occurs:

- The doppler spectrum is gradually translated, at a constant rate, to its proper position, and unambiguous imagery develops; and
- The VCO injects a quadratic phase error into the target histories; a processor adjusted for optimum processing on the basis of the video data being collected at this time is then improperly adjusted for later times for which the rate has changed, and defocusing occurs unless a subsequent processor adjustment is made.

Once the initial misalignment error is compensated by the oscillator, the VCO behavior will be dominated by the following factors:

- The vehicle rotates in 3 axes within certain deadbands; the pitch and yaw rotations translate the doppler spectrum, the clutterlock senses the error and the VCO attempts to compensate for it;

- o Unbalanced torques on the vehicle will cause angular accelerations within the deadbands;
- o Gas-pulse firings at the edges of deadbands will introduce impulsive angular accelerations; and
- o A slow VCO frequency shift is required to correct for earth rotation as a function of latitude.

The rotations and accelerations associated with the deadband behavior will cause phase errors which are relatively high-frequency in nature to be injected into the target histories. The first-order effect will be image defocusing in the azimuth dimension, with attendent resolution degradation unless the processor is appropriately readjusted.

The examination of imagery to determine the effects of vehicle motions and clutterlock behavior is still in process; the results will be covered in the forthcoming [redacted] report to be published separately.

<u>Comments on Resolution</u> - A key purpose of the 2355 flight was to demonstrate the realization of fine azimuth resolution using an orbital synthetic-aperture radar system; a great deal of attention was therefore devoted to minimizing errors which would unnecessarily degrade azimuth resolution. The radar system had the inherent potential to achieve resolution somewhat finer than 10 feet in azimuth, provided that atmospheric conditions and system malfunctions did not inject excessive degradations. Range resolution, on the other hand, was limited by the bandwidth of the electronics, which had been patterned after the AN/UPQ-102 radar system for reasons dictated by expediency; the most optimistic estimate of achievable slant-range resolution was of the order of 36 feet, which in turn implied a ground-range resolution of 60 feet at the design depression angle. Improvement of the range resolution to make it comparable with the expected azimuth resolution was not warranted, since it would not have affected the demonstration of the synthetic-aperture feasibility, and would have entailed considerable expense and delay.

The radar imagery generated from video data collected during the 2355 flight has a ground-range resolution of approximately 75 feet, and an azimuth resolution of the order of 10 feet when the processor is optimally adjusted for the particular target area being viewed. As explained above, the behavior of the clutterlock, which in turn responds to vehicle attitude motions and initial conditions, may necessitate repeated readjustments of the processor. In situations where the processor was focused only once near the start of the pass, overall azimuth resolution is typically of the order of 15 to 30 feet. The resolution figures quoted here are applicable to the imagery as recorded, directly at the processor output, on photographic transparency material. The photographic prints shown in this report are limited by the characteristics of the paper to a resolution of the order of 6 lines per mm; at the scales chosen for most of the figures, ground-range resolution is degraded to about 150 feet, and azimuth resolution is degraded to 90 to 100 feet.*

Two independent measures of achieved resolution are available. The first of these is obtained from the imagery of Pass No. 8 itself--a test array of radar corner reflectors at [redacted] fell within the mapped swath. The image of this array showed that azimuth resolution of roughly 10 feet, and ground-range resolution of roughly 75 feet, were

*The two figures are different because of the difference in the azimuth and ground-range scale factors in the print.

achieved. The second determination was made via a measurement of the two-dimensional response of the system to a strong isolated target which was imaged near the southern end of Pass 30. The system impulse response determined directly at the output of the optical processor, had a half-power width of 10 feet in azimuth and 72 feet in ground range.

The test-array measurement will be discussed further in Par. 1.6.2 below.

Positioning of the Reflected Energy in the Range Gate - In order to preserve full azimuth resolution and avoid the superposition of undesired azimuth-ambiguous imagery on the desired radar image, it was necessary to employ a radar-repetition rate of the order of 8500 pps, to within a tolerance of perhaps 5 per cent. A pulse was therefore transmitted once every 120 microseconds, to within a few microseconds depending upon the precise value of the prf. At the instant of transmission of any pulse, the previous one had travelled only about 20 nautical miles from the radar en route to the target field, which was typically at a one-way slant range of 170 nautical miles from the vehicle. Under these conditions, about 16 or 17 pulses were making the round-trip between radar and target field at any instant of time; the precise number was dependent upon the precise values of prf and slant range. In a properly designed non-ambiguous system, the return reaching the radar at any instant can only have originated from one particular pulse, not two; this is guaranteed through a proper restriction on the elevation-beamwidth of the radar antenna. Through a slight adjustment of the inter-pulse period (hence the prf) one may arrange to have the "dead-time" between the arrival of return from two consecutive pulses coincide with the time of transmission of a (later) pulse. In the 2355 system, this was done by choosing one of the 16 available prf steps, which essentially provided a vernier adjustment on the inter-pulse period. It was furthermore convenient to trigger the CRT sweep in the recorder from the same source which controlled the transmitter timing. The sequence of events was as follows: the radar transmitted a pulse, the receiver and recorder waited 25 microseconds, and the CRT was then swept for 73 microseconds; the system then repeated the cycle after an additional wait of 16 to 24 microseconds (depending on the choice of prf). When the prf was at its optimum value, signal return from the slant range corresponding to the lower half-power point of the elevation beam (the near-edge of the swath) started arriving as the CRT-sweep started, and video from the upper half-power point (the far-edge of the swath) had completed its arrival 73 microseconds later as the sweep was about to be completed.

On certain occasions, the sweep started a few microseconds before the return from the near-range arrived; the imagery corresponding to these occasions lacks contrast and SNR at the near edge, but is better at the far-edge. Conversely, the opposite occured when the sweep was late in starting. On still other occasions, the sweep was begun as the return from the far-edge was arriving, continued while the instantaneous return power level passed through its minimum, and was almost completed by the time return from the near-edge began to arrive; under these conditions, the CRT was inoperative for the major portion of the return, and two strips, inverted with respect to each other, were imaged by the system. Examples of these two classes of situations are shown later. In either event, a slight readjustment of the interpulse time (hence prf) sufficed to re-establish the proper synchronization between the time of arrival of reflected radar energy and the time of initiation of the CRT sweep. The pulse positioning is described pictorially, with additional discussion in Part III, Par. 3.4.4.

AGC Effects - The radar reflectivity of patches of terrain, which vary in character and may or may not include collections of cultural targets, varies over a wide range of values. The spread from the strongest to the weakest reflectivity depends upon the size of the patch one wishes to consider; a typical spread might be of the order of 70 db (i.e., seven orders of magnitude). This 70 db "dynamic range" of the target-field reflectivity distribution exceeds the dynamic range of currently available components in the receiver and recorder chain by some 40 to 50 db. A simple fixed-gain receiver having a necessarily-insufficient dynamic range can be adjusted to operate somewhere between two limiting situations, one in which "strong" targets are handled linearly but "weak" targets and ground-painting are lost, and one in which ground-painting is preserved at the expense of overdriving the circuitry when strong targets are present, this overdriving in turn leading to such undesirable effects as false-target generation and SNR degradation. An AGC provision permits one to adjust gain to match local reflectivity conditions, thereby recapturing some of the advantages of a larger-dynamic range fixed-gain system. The performance of the AGC-equipped radar falls short of that of the latter, however, when very strong and very weak targets are in close azimuth-proximity to each other; the return from the strong targets induces a receiver gain-reduction, and ground-painting and weak targets at nearby azimuth locations are lost. Examples of this effect will be seen later in radar imagery of shorelines. The lack of sufficient dynamic range will also be evident in imagery which contains agricultural areas close to a strong industrial target complex.

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Weather - Radar imagery was generated under a wide variety of atmospheric and ground-surface conditions during the 2355 flight. Generally speaking, the northeastern part of the U.S. was experiencing rain, snow, some freezing rain, heavy overcasts and some high clouds during the operation. The ground was wet or snow covered in many areas. Frontal activity was generally weak where present; some imaging through turbulent clouds occurred on Pass 25. In the central Atlantic states the ground was generally drier, although fog and haze were frequently present. Heavy rainfalls were in progress during Pass 16 in Northern California, and had been for several days previously; the ground was flooded in some areas along this pass. In the Southwestern portion of the country, the air was generally clear with the ground in its usual dry state.

As a consequence of this synoptic weather situation, a sampling was obtained of most of the lower-atmosphere phenomena which tend to degrade radar performance. In particular, the presence of widespread light precipitation goes largely undetected in the imagery, and the heavy precipitation along the California coast does not severely obscure underlying structure. The reduction of terrain reflectivity resulting from the wet and snow-covered surfaces was not sufficient to cause obscuration of surface details, although the ground-painting signal-to-noise ratio was undoubtedly reduced as a result of these conditions. One notable omission in the sampling of weather conditions stems from the fact that no strong frontal activity or unstable air masses were present along the flight paths; effects which might be associated with summer storms were therefore not observed.

A more detailed analysis of the weather situation will be presented in the final evaluation report to be released by [redacted]

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1.6.1.1 Typical Imagery - The following examples of imagery were generated from physically-recovered video data, and are typical of the recovery results obtained on the first seven operating passes. The processor was optimized for each image to the extent possible. The remarks made earlier with respect to resolution and dynamic range must be repeated here: the paper prints degrade resolution in both dimensions for the scale factors appropriate to this report, and cannot preserve, at any scale factors, the dynamic range available in the optical image at the processor output prior to recording, or in the photographic transparencies generated by this optical image.

The imagery presented in this section is intended for viewing with orientation shown in Figure 1.6.0; it can easily be seen through an examination of Figure 1.6.6 that this orientation preserves a natural appearance of relief in mountainous regions. Increasing system time corresponds to motion from right to left along the image*. The times of various events have been established to within 0.1 second relative to the system time.

*The increase of system time from right to left is a necessary consequence of illuminating a swath to the left of the vehicle's ground track, if we also wish to preserve the usual clockwise sequence of the North, East, South and West cardinal directions. A system which looked to the right and preserved the clockwise sequence would generate imagery with increasing time from left to right.

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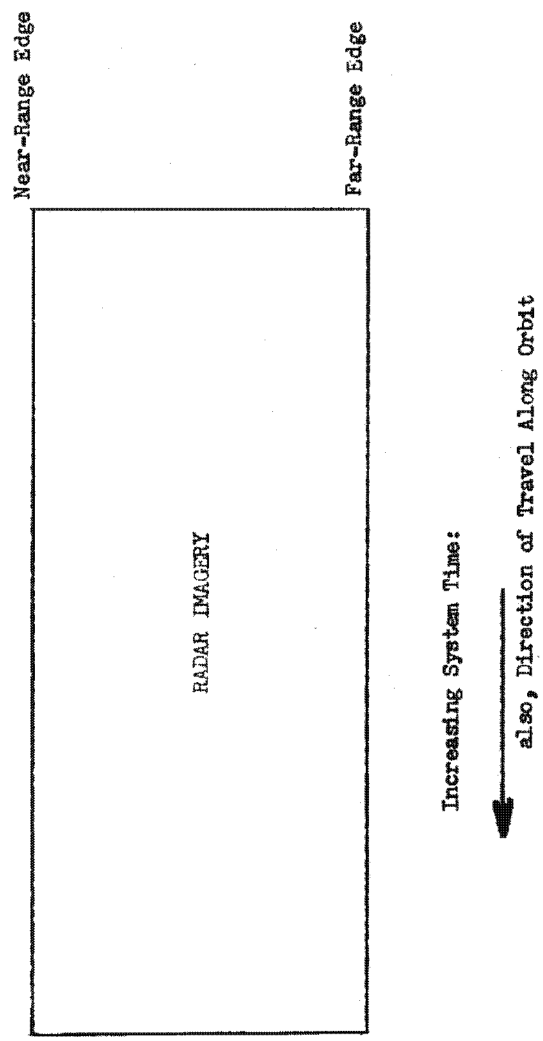

Figure 1.6.0 Image Orientation for Proper Viewing

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As had been stated and is evident from the imagery, the aspect ratio of ground-range to azimuth scale factors is not 1:1; instead, the azimuth dimension appears to have been "stretched" by roughly 66 per cent. This is a consequence of the preservation of a 1:1 aspect ratio of slant range to azimuth scale factors at the system depression angle.

Several of the images are accompanied by U.S. Geological Survey Maps bearing an arrow designating true North. The swath between the inner edges of the shaded lines matches the swath imaged by the radar. Each image is also accompanied by a summary of pertinent events and highlights of the imagery itself. The combination of the U.S.G.S. map and the radar imagery constitutes the figure as numbered under the radar image. It is to be recalled that the motion of the satellite is from the right to the left of the radar image-as viewed by the reader.

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Figure 1.6.1 Summary

Richmond, Virginia: Pass 14

System Time: 57968.6(ON) - 57973.0(H.V. ON) secs ZT, 22 December 1964

Local Time and Date: 11:06 A.M. EST, 22 December 1964

Local Surface and Weather Conditions:

Ground damp to dry. Overcast, tops of clouds at 2500 to 4500 ft. No frontal activity.

Vehicle Attitude Behavior:

Pitch: Slowly negative-going near center of deadband.

Roll: Holding constant at center of deadband.

Yaw: Has just completed approach to negative edge of deadband, holding constant at edge.

Clutterlock Integrator Behavior (F-60):

On the basis of analog data only, the clutterlock output held roughly constant over this time interval.

RF Signal-to-Noise Ratio (Computed from F-53):

The RF SNR was 14 to 15 db during generation of the image.

PRF Adjustment Status:

The radar prf was 8449 pps during generation of this image (P/L Step 8). On the basis of the image intensity

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1.7 Conclusions and Recommendations

Conclusions The major conclusions that have been drawn from the flight of Vehicle 2355 are summarized as follows:

- The orbital flight satisfied the primary program objective by demonstrating that a satellite-borne synthetic-aperture radar system could generate a fine-resolution image of a portion of the earth's surface. All the program secondary objectives were also satisfied.

- The radar-image characteristics were very close to those predicted from the insertion of orbital-system parameter values into an analytic model whose validity had been confirmed previously with aircraft-borne systems.

- Because of the satellite's smooth trajectory, the imagery exhibited consistently fine azimuth resolution and uniform scale over image lengths of hundreds of miles. The achieved 10-foot azimuth resolution implies the realization of the large synthetic apertures required at the long ranges which are characteristic of orbital operation.

- The system proved its expected ability to produce radar imagery of a consistently high quality by day, by night, and through a variety of weather conditions; the conditions which prevailed in most of the swath areas would have prevented successful photographic or infrared imaging.

- The experiment did not produce any evidence of phenomena which would prevent future systems from realizing azimuth and ground-range resolutions on the order of 10 feet.

- The satellite-radar imagery contains many identifiable terrain and cultural features of likely value for strategic reconnaissance.

- The flight data strongly indicates that comparable radar images would be generated by aircraft-borne and satellite-borne radars which have similar resolutions and signal-to-noise ratios, and operate at similar depression angles. In particular, satellite borne systems are not subject to the resolution limitations normally imposed by platform instability in aircraft.

- Data recovered via a wide-band data link produced radar imagery which was only slightly degraded with respect to that produced from physically-recovered data.

- The criteria used in the design of the radar system provide a firm basis for the design of future satellite radar systems offering improved performance.

- The use of an electronic clutterlock for steering the synthetic beam was proven to be highly successful.

<u>Recommendations</u> It is recommended:

- That designs of future satellite-borne radar systems be based on the type of analytic model used successfully for

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this design, and upon the data obtained during this orbital flight.

- That future systems be designed to provide ground-range resolution more nearly equal to azimuth resolution, and to produce output images of higher signal-to-noise ratio.

- That the dynamic range requirements of elements of future systems be carefully reviewed on the basis of data collected during this experiment.

- That an evaluation be made of various means for post-launch adjustment of the radar beam's depression angle, in order to provide for viewing of pre-selected target areas.

- That future orbiting systems utilize improved techniques to assure time-alignment of the returning radar energy with the recorder range-gating.

- That an evaluation be made, with respect to their implications for orbiting systems, of various means for obtaining acceptable imagery over wider range intervals.

- That future experimental orbiting systems incorporate power sources which are adequate for extended-duration missions, as required for operational applications.

- That all future systems be provided with film time-coding to facilitate data evaluation.

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- That the next flight of an orbiting system be instrumented to permit more frequent sampling of received signal levels and of clutterlock behavior, and more accurate monitoring of certain receiver and transmitter functions.
- That future systems incorporate available state-of-the-art improvements to provide an even more stable platform for radar imaging.

The reader is referred to the Goodyear Aerospace Corporation report recommendations for further specific comments pertaining to the radar payload.

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VOLUME II
31 March 1965
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RADAR

PROGRAM [redacted]

VEHICLE 2355 SYSTEM REPORT (U)

VOLUME II – ENGINEERING

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VEHICLE 2355 SYSTEM REPORT (U)

Volume II - Summary

Contract [redacted]
Supplemental Agreement Number 13

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Program [redacted]

Approved:

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Manager
Program [redacted]

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Lt. Colonel, USAF
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FOREWORD

This report covers the span of time from the inception of the first satellite borne radar system through the final evaluation of the on orbit performance of the first flight. An objective review is attempted, of the complete scope of activities associated with bringing a new system into being and of the system performance during an essentially nominal and troublefree mission.

From this review, it is hoped that the systems management and program control parameters which were found to be effective may be properly recognized and thereby enhance the organization and conduct of similar future activities.

The system definition and resulting configuration is reviewed in retrospect, together with the problems associated with this Program development and testing.

The engineering management concept and the test philosophy which were applied are outlined and restated, with the objectives of first recording these, and then attempting to objectively analyze them for areas susceptible to improvement. The Air Force - LMSC - Associate Contractor team is defined, as it existed during the development, testing and operation of Vehicle 2355.

The system performance from launch through recovery and thence to battery depletion is evaluated from the primary aspect of payload operation.

System performance is compared against predictions, and the performance accomplishments and achievements are enumerated.

The report is therefore, in addition to a flight report, a total summary of the composite effort associated with the preparation and operation of this system. From the system evaluation certain conclusions and recommendations are formulated which are intended to be useful for later work on similar systems.

Through the medium of the detailed information contained in this report, it is intended to properly acknowledge the efforts of all those who were instrumental in managing and conducting a program which produced a completely successful mission with the first flight of a new payload vehicle system.

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PART II

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PART II (Cont.)

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2.1 Satellite System Engineering

The subsystems of the satellite vehicle which required engineering development, study or program peculiar applications are discussed in this section. Included also are sections on radar antenna development, thermodynamics and a thorough review of the work which was directed toward control of high voltage breakdown in a vacuum. A brief discussion of vacuum measurements is included due to the early considerations of the possibilities of high voltage breakdowns on orbit and a requirement to measure pressures in the payload vehicle.

The thermodynamic work which was done on this payload vehicle; accommodating the energy dissipated by the payload and during a time period when battery temperatures were under critical review; yielded a new level of quality in on-orbit thermal control. All engineering efforts which are reviewed in this section resulted in the complete and correct operation of the total satellite vehicle through the prescribed mission, setting an enviable standard of excellence in the first flight of a new payload system. This mission was conducted to a duration which exceeded predictions without a failure of any type aboard the satellite vehicle.

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2.1.1 Structural Subsystem

2.1.1.1 Requirements and Design Concepts

The first definition of the philosophy to be followed in engineering of the spaceframe indicated certain major areas where the design approach would be nearly unique for Vehicle 2355. The primary task was to install in a space vehicle, equipment normally associated with conventional aircraft, and to achieve orbit of this vehicle in such a manner that the equipment could operate normally in the acquisition and storage of data. Additionally, Subsystem "A" was to provide the mounting and ejection mechanisms for the capsule which would eventually return the stored data to the ground.

The initial approach envisioned hard-mounting of payload items in structure which was to be as light as possible consistent with the requirements dictated by predicted ascent loads and heating. This resulted in the design and/or installation of seven items tailored to the payloads and to the mission: (See Figure 2.1.1.1)

- Recovery Capsule
- Conical Payload Rack
- Cylindrical Payload Rack
- Ejectable Fairing for the C&C Antenna
- Guidance Auxiliary Rack
- Ejectable Fairing for the Radar Antenna
- Lifeboat Equipment

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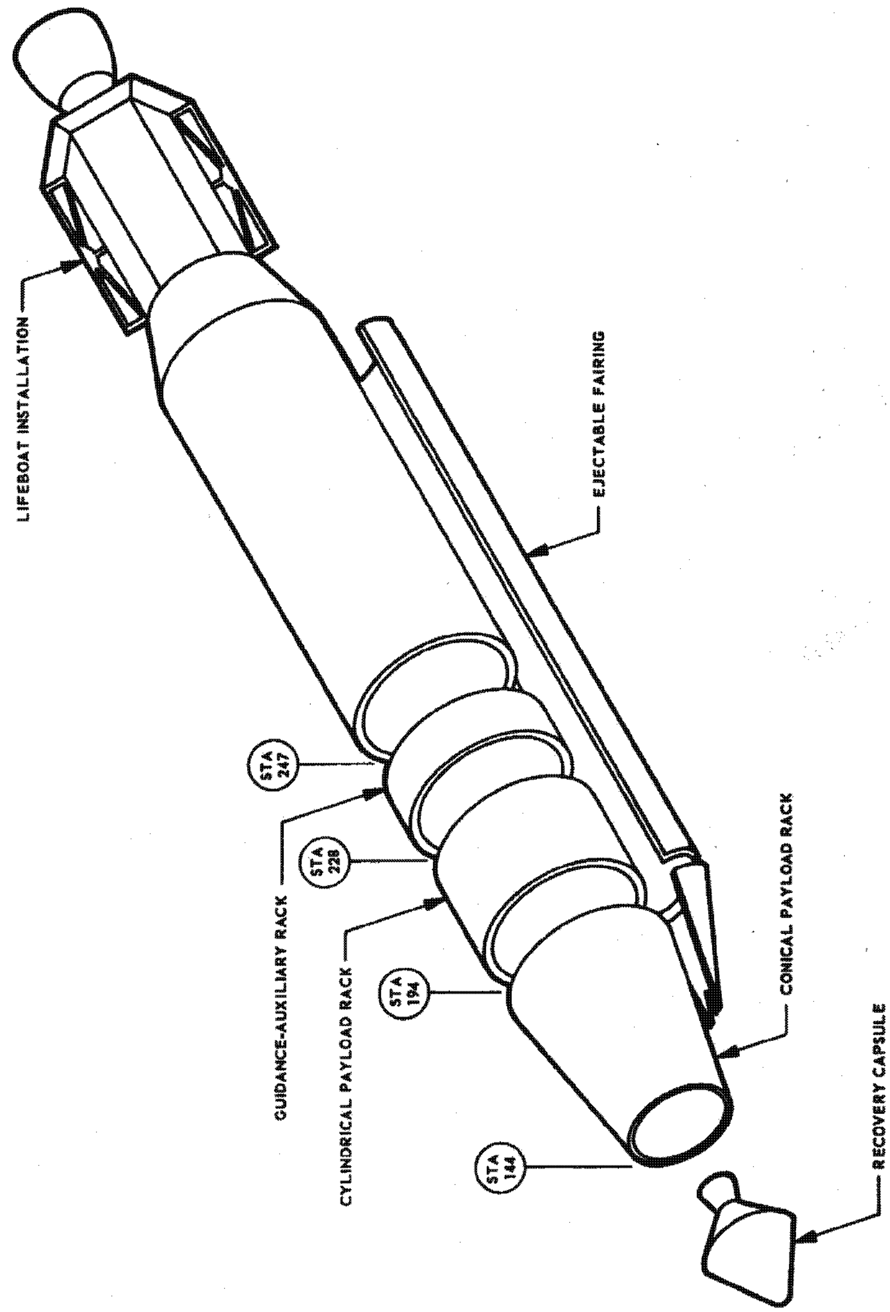

Figure 2.1.1.1 - Major SS/A Components

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2.1.1.2 Configuration - Basic Concepts

Recovery Capsule. This capsule in its entirety was available as GFE. It housed the storage container for the raw data film and served as the nose cone during ascent. Since this recovery capsule had been used in other applications, its characteristics were known quantities requiring only incorporation into the 2355 System. A program peculiar installation had been made to accommodate the film takeup mechanism.

Conical Payload Rack. This structure was located just aft of the recoverable capsule and included mounting provisions for the capsule. The structure was a straightforward design comprising seven rings and a magnesium skin riveted together in the form of a truncated cone. The space inside this rack was allocated to Payload Box #7. Radiation protection for the raw data film feeding from Box #7 to the recoverable capsule was provided in the form of a thermal-tape-covered shield standing off from the inside of the forward portion of the rack. (See Figure 2.1.1.2).

Cylindrical Payload Rack. The third structure item was designed to mount to the forward face of the Guidance Auxiliary Rack, to provide mounting for the Conical Payload Rack, and to accommodate Payload Boxes 1, 2, 3, 4, 5, and 6. The structure comprised three rings, eight longerons, two torque boxes, eight doors, and eight access holes.

The floors of the two torque boxes, on which the payload boxes

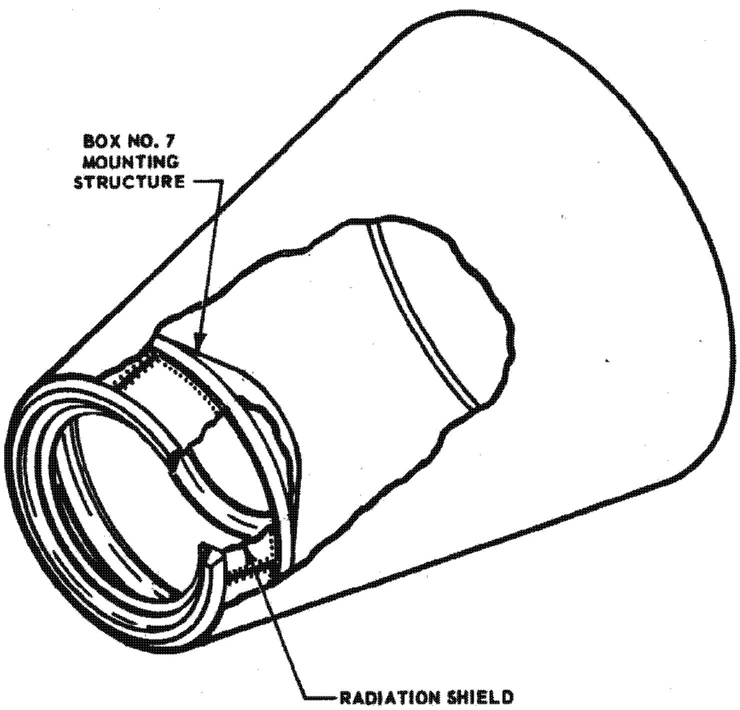

Figure 2.1.1.2-Cone and Thermal Shield

mounted, were located longitudinally between two longerons and over a third, with a web running from this middle longeron to the middle of the floor base. The magnesium skin connecting the three longerons completed each torque box. To offer access to the payload mounting devices, four access holes were located in suitable positions in the magnesium skin.

The remaining space was enclosed by four doors on each side of the rack providing access to all payloads mounted in the rack. (See Figure 2.1.1.3)

Ejectable Fairing for the C&C Antenna. The original design concept called for the Type 7 C&C Antenna to be mounted on the surface of the skin covering the Cylindrical Payload Rack. Protection for the antenna in this location would have been provided by a fairing mounted over it, secured to the outside of the vehicle by tension bolts and pinpuller assemblies. At a suitable time this fairing would have been ejected, permitting proper operation of the antenna.

The launch configuration of Vehicle 2355 did not carry the ejectable fairing. Reasons for this decision are covered in the Design Development section of this report.

Guidance Auxiliary Rack. The Guidance Auxiliary Rack structure comprised two rings, eight longerons, two floors for mounting guidance components, a web joining these floors, and a skin in

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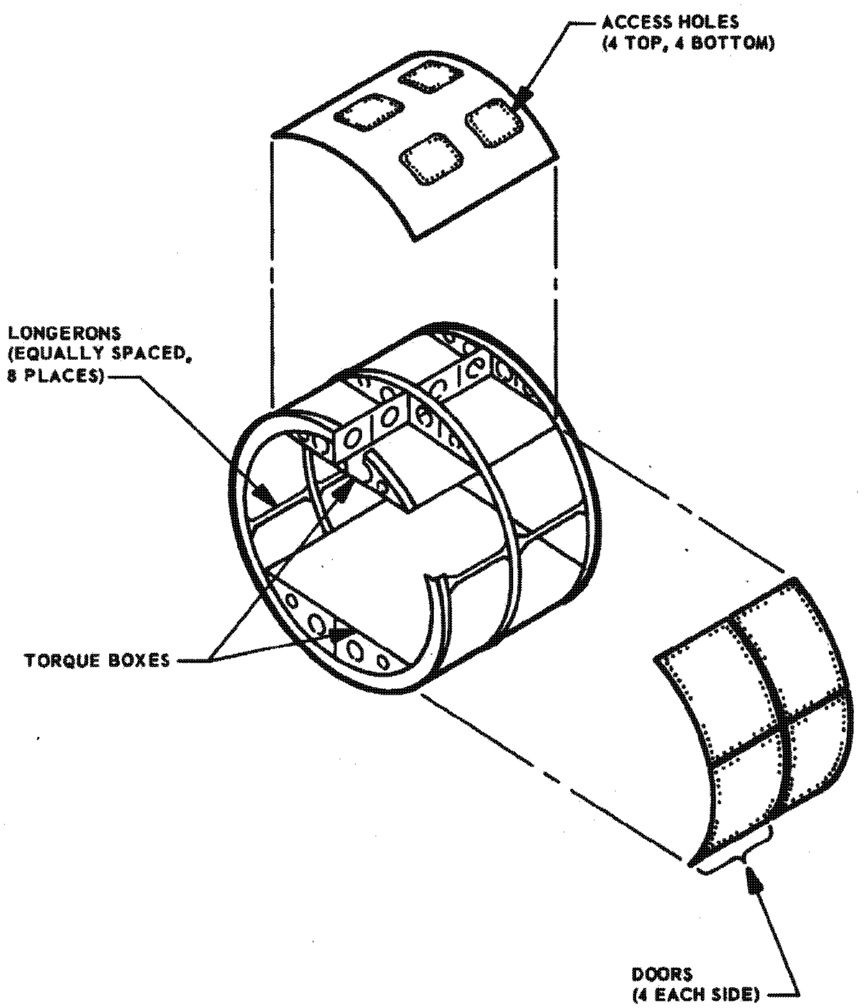

Figure 2.1.1.3 Cylindrical Payload Rack

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the form of removable doors which permitted access to all equipment located in the rack. As in the equipment rack, the floors joined two longerons located ninety degrees apart with an additional web running from the center of the floor to the central longeron.

The floors extended from station 247 forward to approximately station 231, leaving a three-inch space aft of the ring at station 228 for the wave guide installation in the forward portion of the rack. (See Figure 2.1.1.4)

<u>Ejectable Fairing for the Radar Antenna</u>. This fairing comprised a 27-inch wide channel, six inches deep, approximately 226 inches long. It was mounted longitudinally on the skin of the vehicle in the +Y+Z quadrant, and provided aerodynamic and thermodynamic protection for the radar antenna during ascent.

The ejectable portion of the fairing, 187 inches long extending from the forward edge of the cylindrical rack aft to station 381, was secured to the vehicle by longitudinal forward-facing retainer pins (five on each side of the fairing). These pins fitted into matching sockets secured to the vehicle, thereby providing radial and transverse stability for the fairing. Longitudinal stability was provided by a tongue extending forward from the face of the ejectable portion of the fairing into the fixed portion where it was secured by a pinpuller assembly.

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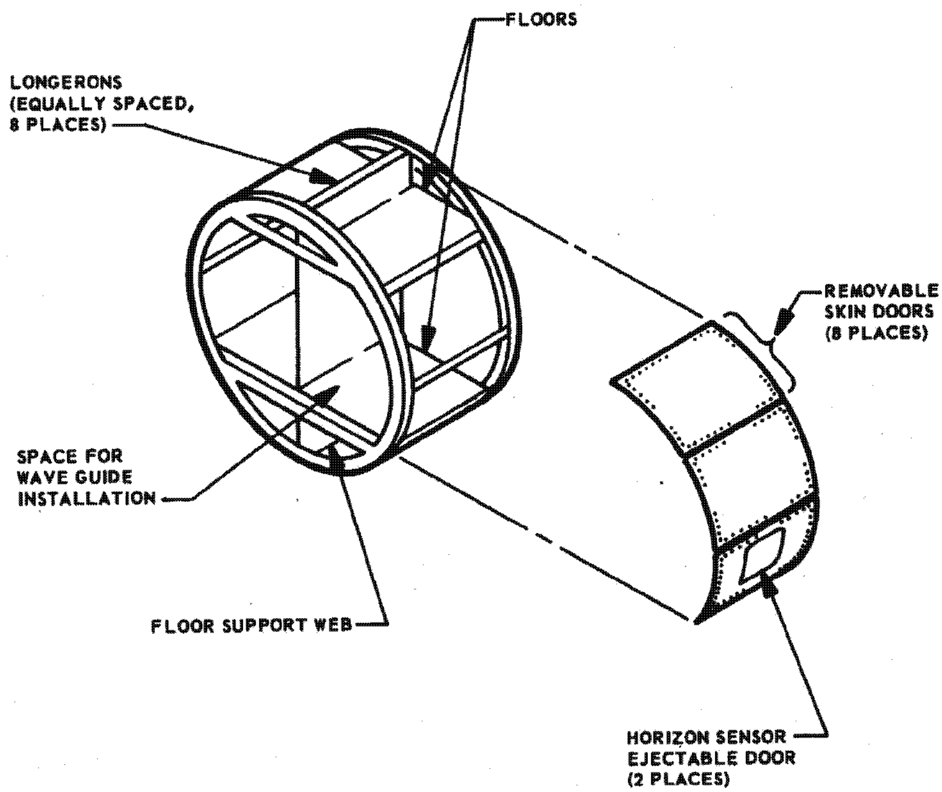

Figure 2.1.1.4 Guidance Auxiliary Rack

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Lifeboat Equipment. This equipment was installed on the aft structure of the SS-01A. Since installation and functioning of the equipment had been developed and proven by other programs, a nearly identical installation was utilized for the 2355 vehicle.

2.1.1.3 Equipment Installations — Basic Concepts

Recovery Capsule. As with the Lifeboat equipment, the capsule itself, together with its attachment and separation mechanisms, had been utilized and proven by other programs. Rather than embark on a development program, the already-proven design was utilized for 2355.

Payload Units - Excepting the Recorder. These payload units were contained in the cylindrical rack. All equipment was secured to the floors of the torque boxes through hard mounting points. Traditional hardware (clips, angles, brackets, etc.) was utilized to take advantage of the structural stiffness of the rack and to carry the predicted loads back through the secondary structure into the primary structure.

Film Recorder. This unit had to be mounted in the conical rack in a manner which would permit feeding of the raw data film forward into the storage container housed in the recovery capsule. The unit was L-shaped with its base pointing forward. The mounting structure employed for the front end of this box was a truncated cone with the small diameter facing aft. The large diameter was secured to the conical rack ring at station 152.

The base of the L-shaped recorder was secured to the mounting structure with three uniball bearing assemblies.

The original concept for the mounting of this unit called for the aft end of the payload to be secured by a device which would restrain it during ascent. After the vehicle had attained orbit, this device was to release the aft end of the box from all restraint.

The design specified four legs extending inboard from the ring at station 194 toward the aft end of the payload. These legs terminated in a plate directly behind the payload. This plate was then secured to the payload with a pin which could be withdrawn upon receipt of the proper signal. In this way the payload was to be rigidly supported during launch and ascent, and free of restraint at the aft end during orbital operations. (See Figure 2.1.1.5.)

<u>C&C Antenna Fairing Ejection Mechanism.</u> The fairing covering the C&C antenna was to be secured to the outer skin of the vehicle by two tension bolts in pinpuller assemblies, one located at the aft end of the fairing, and one located at the forward end. To provide for longitudinal and transverse shear, pins mounted to the rack protruded through holes in the fairing.

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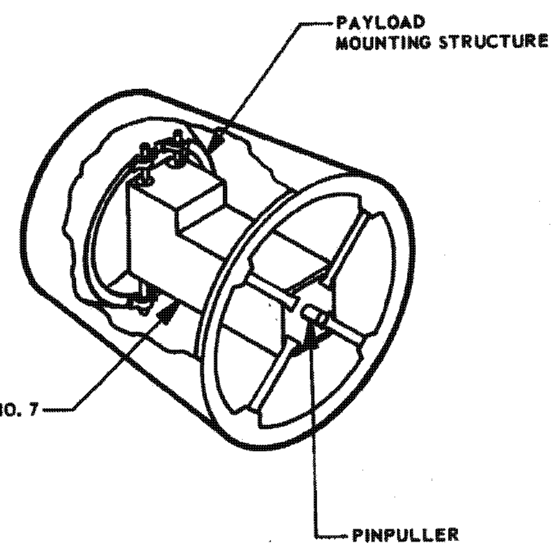

Figure 2.1.1.5 Box #7 Installation

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Motive force for ejection of the fairing was provided by two compression spring assemblies between the vehicle skin and the fairing. One spring was located approximately ten inches aft of the leading edge of the fairing, and the other incorporated the aft pinpuller bolt.

Upon receipt of the proper signal the pinpullers would have retracted and the fairing would have been jettisoned, exposing the C&C antenna.

Vehicle Fairing Ejection Mechanism. Upon receipt of the command to eject this fairing, the pinpuller retracted. This permitted four compression spring assemblies mounted between the ejectable and fixed portions of the fairing to thrust the ejectable portion aft. As soon as the retaining pin cleared their sockets a radial thrust vector was imparted to the fairing by six ramps (three on each side of the fairing) riding on six needle-bearing rollers attached to the vehicle. The resultant separation was in a +X-Y direction with the fairing remaining essentially parallel to the vehicle (See Figure 2.1.1.6)

2.1.1.4 Design Development

Following the original concepts discussed above, design proceeded in a normal manner. Despite the fact that some of these concepts were relatively new, structures and equipment installation engineering was normal in relation to state-of-the-art techniques. Problems with

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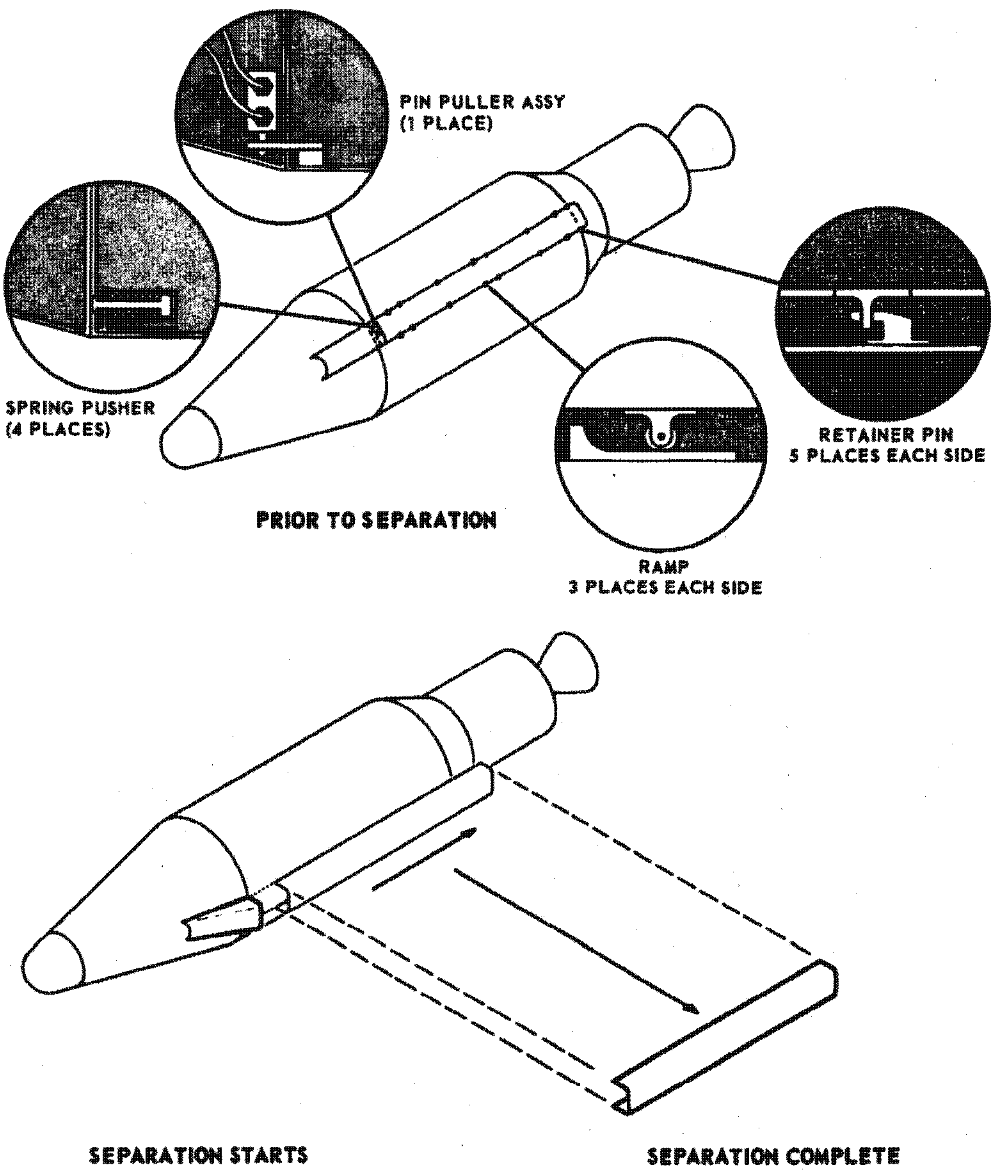

Figure 2.1.1.6 Vehicle Fairing Separation

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components or changes to original design occurred in the following areas:

- Payload Mounting Vibration Difficulties
- Corona in the Transmitter/Modulator
- Wave Guide Heating (Ground Conditioning)
- Thermodynamic Requirements Changes
- Film Recorder Mounting
- Installation of Pressure Transducers
- C&C Antenna Change--Ejectable Fairing Deletion

Payload Mounting Vibration Difficulties. In accordance with the initial design approach the cylindrical rack was tailored to mount the payload boxes and to provide access to them in such a manner that the structure would be the lightest possible consistent with stress requirements. Upon completion, this design was passed to Manufacturing for fabrication and a copy of the engineering documentation was furnished to Goodyear Aerospace Corporation.

Goodyear, however, in conducting confidence tests on payload components discovered that the hard mountings originally planned could result in degradation of payload performance, particularly in light of the stringent vibration requirements called out in LMSC Spec 6117, Revision "D". Goodyear, in order to increase the confidence level in payload survival, dictated that shock mounts be utilized to isolate the critical items from vibration. The vibration isolation mounts were installed on the payloads by

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Goodyear and these payloads furnished to LMSC for proper mounting in the rack.

The precision tailoring of the original design precluded the use of these mounts on a simple substitution basis. As a consequence, the cylindrical rack went through a redesign which saw a complete redistribution of equipment in the rack, and suitable modifications made to the secondary structure to provide the required structural stiffness.

Subsequent testing of the redesigned rack with the payloads restrained in the new shock mounts showed that the required confidence level had been attained.

Corona in the Transmitter/Modulator. Concurrent with the vibration difficulties outlined above, an unrelated problem was discovered in the transmitter. During testing by Goodyear a corona effect was observed inside the unit. Various possibilities for correction were considered; and, Goodyear's proposed solution of encapsulating the transmitter in a pressure vessel was started as an alternative to potting. This pressure vessel in turn was to be mounted in the cylindrical rack.

The eventual solution to the corona problem proved to lie in the potting techniques for components in the transmitter rather than in pressurization of the complete unit. This entailed only removal of the pressure vessel in the final installation since the

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mounting provisions remained the same.

Wave Guide Heating (Ground Conditioning). A modification to the original design arose in connection with the wave guide installation. A Program Office directive was received which required the addition of a device for heating the wave guide during the pre-launch phase of operation.

This requirement was fulfilled by laying heater strips on the wave guide, wrapping these strips to the guide with insulation, and providing power to the heater strips from the electrical umbilical which was disconnected at launch. The wave guide heating facilitated the outgassing of the wave guide during ascent, since the wave guide was warmed at liftoff.

Thermodynamic Requirements Changes. As the design progressed and the thermodynamic characteristics of the vehicle could be more accurately predicted, changes were initiated to assure the correct thermal environment for all components.

In response to these developing requirements Subsystem "A" revised the mounting of Payload Unit #1 (battery) by changing the insulating strips which were located between the mounting pads and the battery itself. Additionally, a radiation shield was installed over the battery; however, as thermodynamic analysis continued, it was determined that this shield should be deleted from Vehicle 2355.

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Film Recorder Mounting. As outlined above, it was planned that this unit would be hard-mounted at the forward end and secured by a pinpuller to spider-legs at the aft end, the plan being to release this pinpuller after orbit injection to permit the aft end of the recorder to be unrestricted. Subsequent analysis, however, indicated that the firing of the pinpuller with its attendant shock was more likely to result in recorder malfunction than would the slight torsion effect resulting from expansion of the unequal spider-legs. As a consequence, the final design called for hard-mounting both forward and aft ends of the recorder.

Installation of Pressure Transducers. At the direction of the Program Office, vacuum measuring instruments were installed in the cylindrical and conical racks. A total of five were installed, one transducer located on the recorder, one on the transmitter, one between the transmitter and the RF-IF, in the high power wave guide, one on a structural ring at the -Y axis, and one on the same ring at the +Y axis.

Installation of the transducers was in accordance with current state-of-the-art techniques, and was problem free.

C&C Antenna Change—Ejectable Fairing Deletion. The ejectable fairing to cover the C&C Antenna was designed as outlined above. However, difficulties were arising in connection with the pattern

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of the Type 7 Antenna which had been planned for installation on Vehicle 2355. These difficulties were such that a substitution of antennas was required. The Type 4 C&C Antenna was selected and was installed.

Since the Type 4 Antenna is flush-mounted with the skin of the vehicle, the requirement for ejection of a fairing was obviated.

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2.2 Radar Payload

Introduction The radar payload furnished by the Goodyear Aerospace Corporation consisted of five components:

- Transmitter-Modulator
- R.F.-I.F. Unit
- Reference Computer
- Control Unit
- Recorder

This section of the report discusses the radar payload to a limited degree, to permit general understanding of the fundamentals of doppler side looking radar by the reader. As indicated elsewhere in this report, Goodyear maintained full responsibility for the radar when not installed in the system. Accordingly, the complete engineering details of the radar are to be found in the Goodyear report, entitled Program Report, KP-II Orbital Doppler Radar, Thor/Agena Satellite Program, Control Number AKP-II-596, dated 1 March 1965. The contents of this section are generally excerpts from that report, included in the interests of completeness of the system report, and the permission for the use of this materials is gratefully acknowledged. The reader is referred to the above Goodyear Aerospace Corporation report for further information pertaining to the radar payload utilized in this mission.

2.2.1 Basic Doppler Theory

General Concept The beam-sharpening process used in a doppler, high resolution, side-looking radar may be described by means of a physical antenna analog. As the vehicle travels its orbital path a series of pulses is transmitted. Successive pulse transmissions are identified with the elements of an array of dipoles. The spacing between elements is the distance traveled by the vehicle between pulses. Each transmission is made with a controlled phase. The amplitude and phase of the reflected energy from the terrain at all ranges and angles within the physical beam width of the antenna is recorded on the data film.

The length of the antenna synthetically generated is basically limited to the distance instantaneously illuminated on the ground by the physical antenna. By the technique of optical processing, the amplitude and phase of the returns from the successive pulses are vectorially added to create the narrow synthetic beam. The results of these data are then recorded on a final film. Thus, the resolution equivalent to that of an antenna hundreds of feet in length is achieved with a small physical antenna.

Basic Equations The basic equations of a high-resolution radar are most easily developed if the analysis is restricted to the slant-range plane of a single-point target. Figure 2.2.1.1 shows the geometry involved. R is the distance to the target from the antenna at time t. At time $t = 0$, R_1 is the distance to the target. The angle θ_o is measured in the slant-range plane to the center of

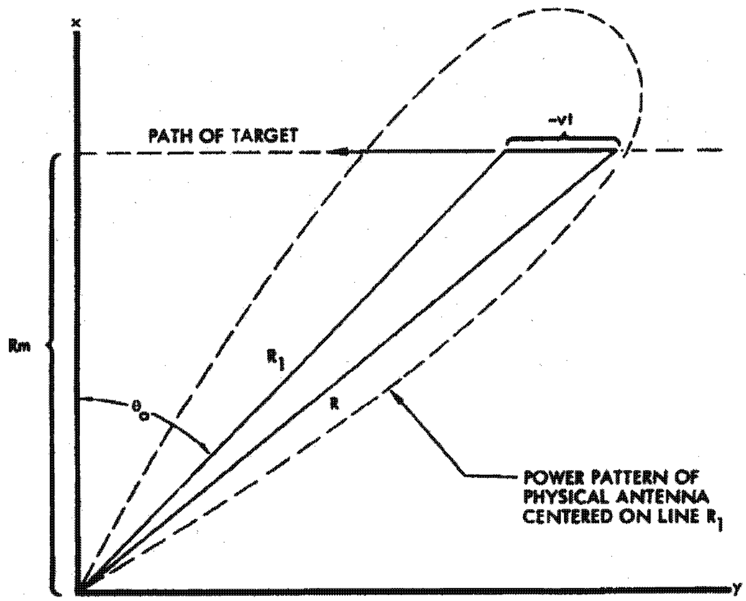

FIGURE 2.2.1.1 - Geometry of a Point Target in the Slant Range Plane

the antenna beam at slant range R_1. Several combinations of pitch and yaw will yield the same angle θ_o. From the geometry of Figure 2.2.1.1 the instantaneous range R to the target is

$$R = \left| R_1^2 + (vt)^2 - 2R_1 vt \sin \theta_o \right|^{1/2} . \qquad (1)$$

As the beam width of the physical antenna is small, the range during the period when the target is illuminated may be closely approximated by taking the first few terms of the binomial expansion of Equation (1):

$$R \approx R_1 \left(1 - \frac{vt \sin \theta_o}{R_1} + 1/2 \frac{(vt)^2}{R_1^2} \cos^2 \theta_o \right) . \qquad (2)$$

The range dependence on time is reflected in a phase dependence on time of the return signal. The dependence of phase 0 of the return signal on time is

$$\phi = 2\pi f_o t - \frac{4\pi R}{\lambda} + \phi_o \qquad (3)$$

where

f_o = the transmitted frequency

λ = the wave length of the carrier

ϕ_o = the phase change caused by reflection.

Equations (2) and (3) may be developed into

$$\phi = 2\pi f_o t + \frac{4\pi}{\lambda} vt \sin \phi_o - \frac{2\pi (vt)^2}{R_1 \lambda} \cos^2 \phi_o + \phi_1 \qquad (4)$$

where

$$\phi_1 = \phi_o - \frac{4\pi R_1}{\lambda} .$$

The return signal is synchronously demodulated with respect to some reference frequency to remove the carrier. It is desirable for the reference frequency to be the frequency of the return signal when the target is at the center of the beam. The phase of the return signal when the target is at the center of the beam and at range R_1 is given by

$$\gamma = 2\pi f_o t - \frac{4\pi R_1}{\lambda} + \phi_o . \tag{5}$$

The frequency will be

$$f_r = \frac{1}{2\pi}\frac{d\gamma}{dt} = \frac{1}{2\pi}\left(2\pi f_o - \frac{4\pi}{\lambda}\frac{dR_1}{dt}\right) . \tag{6}$$

From Figure 2.2.1.1, however,

$$\frac{dR_1}{dt} \equiv \frac{dR}{dt}\bigg|_{t = 0} . \tag{7}$$

Therefore, from Equation (2)

$$\frac{dR_1}{dt} = -v \sin \theta_o . \tag{8}$$

Then, substituting into Equation (6),

$$f_r = f_o + \frac{2v}{\lambda} \sin \theta_o . \tag{9}$$

Therefore, f_r is the frequency that will be used for synchronous demodulation. The synchronous demodulated signal will have the form

$$S(t) = A(t) \mathrm{Re}\left[e^{-j2\pi f_r t}(e^{j\phi})\right] \tag{10}$$

$$= A(t) \cos\left(\frac{2\pi(vt)^2 \cos^2 \phi_o}{R_1 \lambda} - \phi_1\right) \tag{11}$$

where A(t) denotes the amplitude of the return which is a function of the reflectivity of the target and its position in the antenna beam. When

$$\phi_1 = n(2\pi)$$

$$0_o = 0$$

and

$$A(t) = K$$

Equation (12) reduces to the familiar expression

$$S(t) = K \cos\left(\frac{2\pi(vt)^2}{\lambda R_m}\right) . \tag{12}$$

The signal recorded on film at range R_m will be of the form

$$S(x, R_m) = T_b + K' \cos\left(\frac{2\pi x^2}{\lambda R_m}\right) \tag{13}$$

where

T_b = the transmissivity of the film

K' = some constant times K.

From Equation (9) it is seen that all scatterers at an angle θ_o and with velocity v will have the same frequency. It follows that the locus of all possible scatterers whose returns have the same frequency is one nappe of a right circular cone with semi-apex co-angle θ_o whose axis contains the velocity vector.

The locus of points on the earth can be visualized if the intersection of the above doppler cone with a plane tangent to the earth at midmapping range is considered. Since the range interval mapped is small, the mathematical model so described is a good approximation near the point of tangency.

Ambiguities Two types of ambiguities - range and azimuth - are inherent in a coherent high-resolution radar and provisions must be made to avoid them. The range-ambiguity problem is common to all pulsed radar and is usually avoided by lowering the prf so that the so-called "second-time-around" targets are not seen by the radar. However, the consideration of azimuth ambiguities yields another set of constraints on the choice of prf.

For a processor operating about zero doppler the information spaced at $\pm \gamma_n$ from zero doppler is ambiguous. This angular spacing is given by

$$\gamma_n = \frac{n\lambda F}{2v} \qquad (14)$$

where

n = a positive integer, 1, 2, 3, . . .

λ = carrier wave length

F = prf

v = radar velocity.

The focused processor used with this system operates about an offset of prf/4 and is unable to distinguish between positive- and negative-going frequencies so that the ambiguity spacing is given by

$$\gamma_n = \frac{n\lambda F}{4v} \qquad (15)$$

For most high performance radars it is desirable to choose a prf such that the first azimuth ambiguity is placed in the vicinity of the first null of the physical antenna azimuth pattern. This choice of prf places an upper bound on the size of the mapped interval. This constraint in turn dictates the antenna height, since from the range-ambiguity standpoint the vertical antenna pattern is employed to avoid range ambiguities. It is readily deduced that ambiguity constraints are a determining factor in choosing antenna dimensions for a satellite radar. These considerations will be discussed further in Para. 2.2.3.

2 .3 Test

2.3.1 Test Philosophy

2.3.1.1 The incorporation of a radar system into a satellite vehicle, while not involving any fundamentally new tenets of a good test philosophy, did necessitate a carefully planned test sequence, guided by certain basic considerations which are an integral part of a proper testing approach. It is the purpose of this discussion to consider, in retrospect, the test philosophy parameters which were implicit in the handling, test and flight preparation of vehicle 2355, and in so doing, to attempt to bring to focus and to record the elements of an effective test philosophy. The launch and orbital performance of this vehicle, or any vehicle, are the result of the design, manufacturing, engineering, test, handling and pre-launch checkout efforts of large numbers of personnel. The resulting quality of performance of the vehicle is therefore determined, incrementally, by each of these endeavors.

2.3.1.2 The roles of the testing organisations in the preparation of a satellite vehicle are to fulfill several very specific requirements, among which are:

a) Prove by demonstration that the hardware, as designed, will perform as expected.

b) Establish, by sufficient operation in the correct test environment, that the hardware will survive and has adequate reliability, when operating as a system, to satisfactorily accomplish the mission requirements.

c) Establish the functional compatibility of all systems and subsystems in all possible operating modes, including specifically the assigned mission.

d) Conduct a mission simulation with the complete launch system in the launch environment.

e) Finalize the flight preparations and conduct the countdown.

The foregoing building block approach to testing, if it is to be thoroughly objective, can accept no prior conclusions as to inherent quality. These conclusions as to quality may be the product of a number of identical or similar systems operations, resulting in some modifications to the test approach on later vehicles, as opposed to the utmost rigour on the first vehicle. The sequence, described above in general terms of the requirements to the test organisations, is more explicitly defined by these respective examples:

a) Proving the design involves principally component or unit tests to exercise every design function to the design tolerances. This was accomplished on every Goodyear Corporation payload unit, as a first article. Tests on each succeeding unit utilized the design approval test parameters to the maximum extent realistically possible.

b) Proving the hardware survivability, repeatability and reliability includes vibration, thermal and vacuum component testing. This was done on the payload unit level in accordance with LMSC 6117D - Environmental Specification. It also fundamentally involves extensive, repeated operation in accordance with the mission profile. This was done at ambient as a satellite system and in a thermal-vacuum environment with the payload vehicle.

c) Establishing the subsystem and system functional compatibility in all modes involves the operation of every possible electrical and mechanical function in all normal and failure mode combinations. This was done on a payload vehicle basis in the test laboratory, and on a satellite vehicle basis in the first systems test, in the Anechoic Chamber, in the second systems test and in the launch complex simulated flight.

d) The mission simulation in the launch environment provides a cross check against all previous testing, wherein a deficiency may have been obscured by virtue of a different test environment, but more importantly, it completely revalidates the satellite system at a late point prior to launch and establishes a new benchmark of confidence in being ready to enter the launch countdown. This test - the pad simulated flight - must produce performance which is completely beyond question or compromise before the vehicle can be considered ready to enter the launch countdown.

e) The launch countdown establishes the flight configuration (propellants, gases, power and guidance settings and program peculiar command and control/payload configurations), rechecks the performance as established during pre-launch tests, and results in lift-off of a flight ready system.

2.3.1.3 The application of this test philosophy therefore produces two primary results:

a) A rigorous proof by demonstration that the design is correct and compatible for the operations of the assigned mission, that the manufactured and assembled system is in strict accordance with the design, that the design and hardware together are compatible with and correct for the operating environment, and that the system reliability is adequate for the mission.

b) The launch of a system which is determined to be flight ready as a result of all prior testing and as a result of a complete and correct system operation in the launch environment.

Each of the above results are necessary if a satellite system is to be realistically considered flight ready. A good test philosophy does not challenge the design - the task is to validate the design. In so doing, it must be able to reveal and identify design weakness or functional incompatibilities. The test sequence is not intended to establish qualification status or provide reliability data for the components, but it must be able to establish system reliability - in a manner which is not possible on a component basis.

2.3.1.4 The test sequence on Vehicle 2355 is discussed against the guidelines of the previous paragraphs - in terms of particular examples where applicable.

The test philosophy attempted to preclude any payload component or system failures by requiring each payload component to pass an Acceptance Test Procedure immediately prior to installation. Each item of LMSC furnished power conversion equipment (inverters, converters, junction boxes, etc.) was installed after a determination that the item had successfully passed the required acceptance tests. The wiring was checked, pin to pin against the wiring drawings, during which manufacturing errors were corrected. The payload as a system was thus brought to a point of readiness for power application. Power loads were applied and measured in increments, and system functional utility was determined - item by item - as further described in succeeding paragraphs.

This approach to establishing correct system operation on a subsystem by subsystem basis was maintained throughout the test span, wherein the system would be exercised first in sequence of testing and recording the engineering parameters in all modes, then proceeding into the operational configuration for operation in all modes. The significant differences between these types of tests are tabulated in the following examples, which assist in the description of the test philosophy.

	Test Item	Engineering Tests	Operational Tests
(a)	Power and Loads	Shunt Boxes - Breakout Boxes and Test Cabling allowed.	Flight Configuration only.
(b)	Unregulated Voltage Range Testing	Electronic Power Supply utilized.	Flight Batteries & Flight Cabling only - Mission simulation.
(c)	Telemetry Checks	Test Plug Hardline Monitoring.	RF Telemetry Links only.
(d)	WBDL Evaluation	RF Coax Monitoring.	RF Link monitoring.
(e)	Command System Checkout	Umbilical and Hardline Command Control.	RF Command Link.
(f)	Orbital Programmer Test Mission.	Test Tape Program.	Flight Tape Program.
(g)	Satellite Vehicle Test	Breakout Cables - Test Complex C-12	Anechoic Chamber - Flight Configuration.

The 2355 test sequence progressed through the detailed engineering tests required to validate the systems functional performance. The principal tests which are termed engineering tests are:

- Payload Laboratory - [redacted]
- Preparations for Altitude Test - Temperature Altitude Chamber
- Preliminary Systems Test - Complex C-12
- Final Systems Test - Complex C-12
- Pad Horizontal Simulated Flight - VAFB 75-1-1

These tests were in some cases conducted in an engineering (breakout) configuration, instead of a more complete operational configuration, as a result of security requirements (Preliminary and Final Systems Tests and Pad Simulated Flight) and because of physical handling limitations (Pad Simulated Flight). In each test of this type, the extent of the required compromise from the operational configuration was carefully evaluated to determine the effect on the test validity.

As a result of the fact that many tests are of necessity conducted in less than the full operational configuration, certain tests were included in the 2355 test sequence which were in the complete operational configuration, to the extent possible. These tests validated the total system, specifically including those interfaces which were non-operational in the engineering tests. These tests are listed and described as follows:

<u>Test</u>

(a) <u>Anechoic Chamber Test</u> (2355 and 2356)

These two vehicles, of identical configuration, were tested in the Anechoic Chamber. Vehicle 2356 was tested prior to the 2355 flight.

<u>Configuration</u>

Flight Batteries
Radar Antenna installed
Flight Cabling
Test Program and Flt. Program (Orbital Pgmr.)
RF Air Link Commands
RF Air Link Data
Flight Pyro Simulators
No Test Plug Umbilicals
No Main Umbilical
Gas Supply - Gas Valve Operation

<u>Results</u>

System compatibility was demonstrated - operating in an orbital configuration.

(b) Temperature-Altitude Chamber

This test operated the payload vehicle in an orbital environment of temperature and altitude programmed in accordance with the mission.

Configuration

The payload vehicle was in an orbital configuration forward of Sta. 228, excepting for pyros and flight battery.

Results

The temperature altitude testing produced repeated failures of the payload components, which are further discussed in Para. 2.3.2.5. These failure items were redesigned accordingly. The payload vehicle, after multiple component redesigns and component retests, operated through the programmed mission without failure. The payload vehicle was subjected to extensive, repetitive testing - through a failure regime until repeated successful operation was achieved.

(c) R-3 Launch Stand Payload Vehicle Test

This test followed the pad simulated flight.

Configuration

Complete flight configuration, including batteries and pyros, but prior to final attachment of the radar antenna.

Results

This test successfully exercised every interface function, power, ground, data circuit and command circuit between the payload vehicle and the Agena. It validated the final flight configuration of flight batteries. In the course of performing every payload function, the entire satellite vehicle was essentially validated in the launch configuration.

2.3.1.5 The Associate Contractor (Goodyear Aerospace Corporation) performed a vital role in the test series on this vehicle. An initial procedure was established for acceptance of payloads from Goodyear which involved the participation of LMSC personnel in the final

Acceptance Test Procedure on each system. The data was then reviewed jointly, together with the final deliverable hardware status. Based upon these results, the System Associate Contractor recommended hardware acceptance to the Air Force, or as circumstances dictated, recommended further action and another payload system test prior to acceptance. After receipt of the payload at LMSC, a unit Acceptance Test Procedure was conducted on each payload unit as a final validation on the box level prior to installation in the payload vehicle. Joint responsibilities were defined and documented, briefly as follows:

a) Goodyear maintained responsibility for all payload units when not installed in the payload vehicle, and established an acceptable test status just prior to installation.

b) Goodyear participated in all tests which involved any operation of the payload, during which veto power was in force as to continuance of each test.

c) Goodyear and LMSC jointly conducted test data evaluation and reached a joint determination on test acceptability.

d) Lockheed maintained responsibility for all systems operation, including the operation of the system test equipment.

e) System log books were maintained by Lockheed and individual payload unit log books were maintained by Goodyear. Lockheed Quality Assurance was responsible for both payload and system while at Lockheed facilities.

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f) Lockheed provided all necessary support for the Goodyear field operation.

g) Neither system testing nor unit testing were to be conducted unless both contractors were present.

The foregoing operating procedures were defined in a letter dated 8 November 1963, Subject, "Operating Procedures and Responsibilities for the Conduct of P-21 Checkout and Testing".

The Goodyear personnel were included, as a normal function, in all System Associate Contractor-technical reviews, staff meetings and routine testing planning and status meetings. The result of the early planning efforts and of the integration techniques evolved between Lockheed and Goodyear, were very effective and compatible working relationships. It is considered that the Goodyear participation in the testing, and the complete support of the test philosophy described herein, were essential elements in reaching a flight-ready status and in the successful conduct of the mission.

2.3.1.6 Summary

The prior discussion outlines the applicable test philosophy. The implementation of a proper test philosophy involves the intangible aspect of an understanding of the philosophy, and mental acceptance of the objectives, by the personnel accomplishing the tests. Adequate test planning and test execution require stringent disciplines to avoid the acceptance of questionable or unverified results, and the necessity to be sufficiently thorough and methodical to guarantee completeness. In short, testing requires experts in the field, properly trained, experienced and motivated. Certain parameters are considered significant enough to warrant specific identification:

a) Detailed, documented planning, expressed in completely unambiguous terms.

b) Thorough understanding of the technical aspects of the systems involved - termed professional competence.

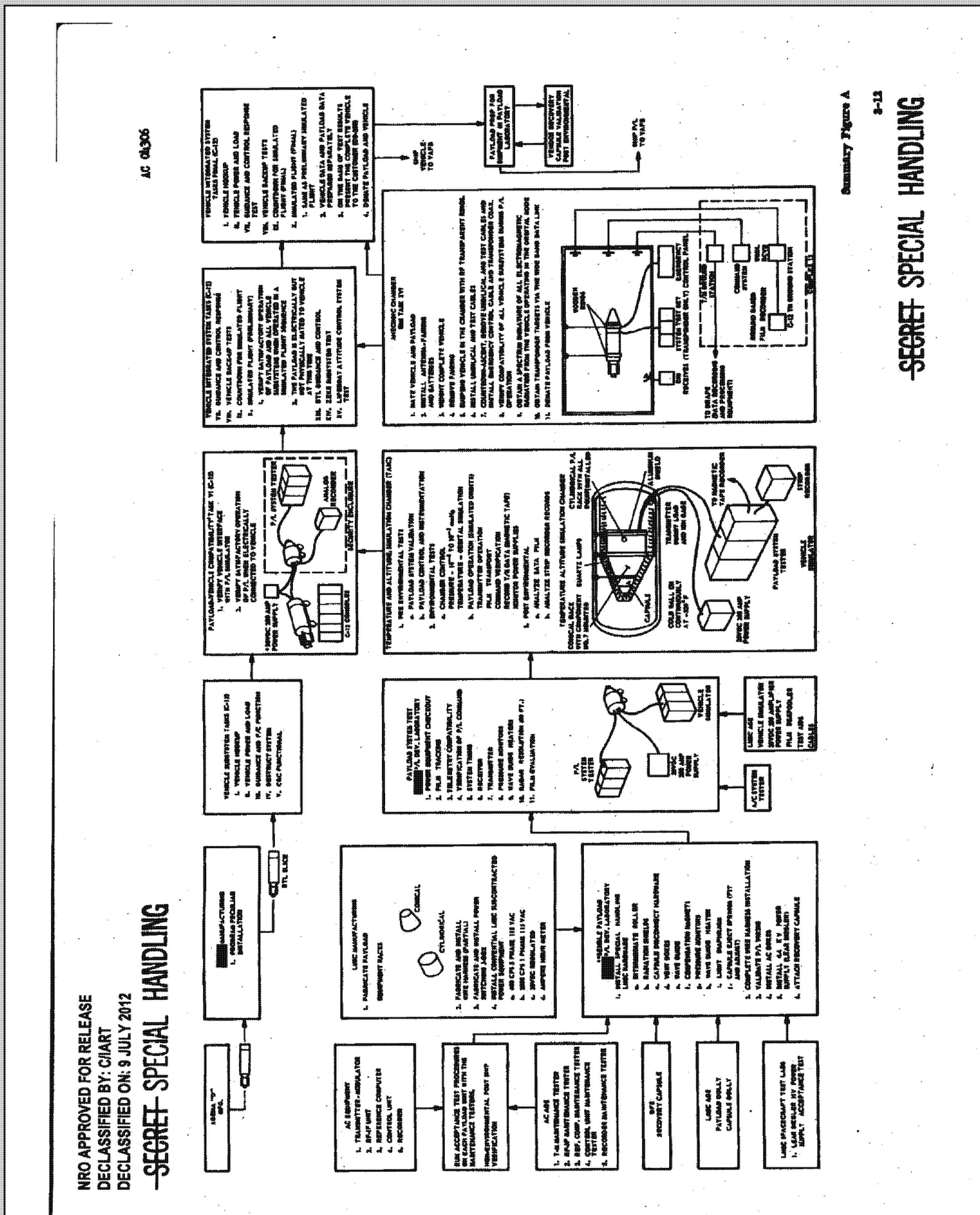
c) A thorough and direct understanding of that status which is correctly termed launch-ready for a satellite system.

d) The mandatory requirements that each system be operated in the orbital configuration - through representative times and cycles - in the orbital environment - as realistically as is possible.

e) A step by step subsystem to system validation process (building block approach) wherein the thorough engineering tests involving the demonstrated and recorded performance of every design parameter are followed by progressively more complete and realistic operational configuration tests.

f) Rigid configuration control of the components, subsystems and systems, as progressively validated.

The planned and actual test sequences on Vehicle 2355 are further discussed in the remaining sections of Para. 2.3 together with the results. The planned test sequences for Sunnyvale and Vandenberg AFB are pictured in sequential block diagram form in Summary Figures A and B respectively, pages 3-12 and 3-13. Summary Figure C, page 3-14, shows the actual test sequence insofar as it differed from the planned sequence.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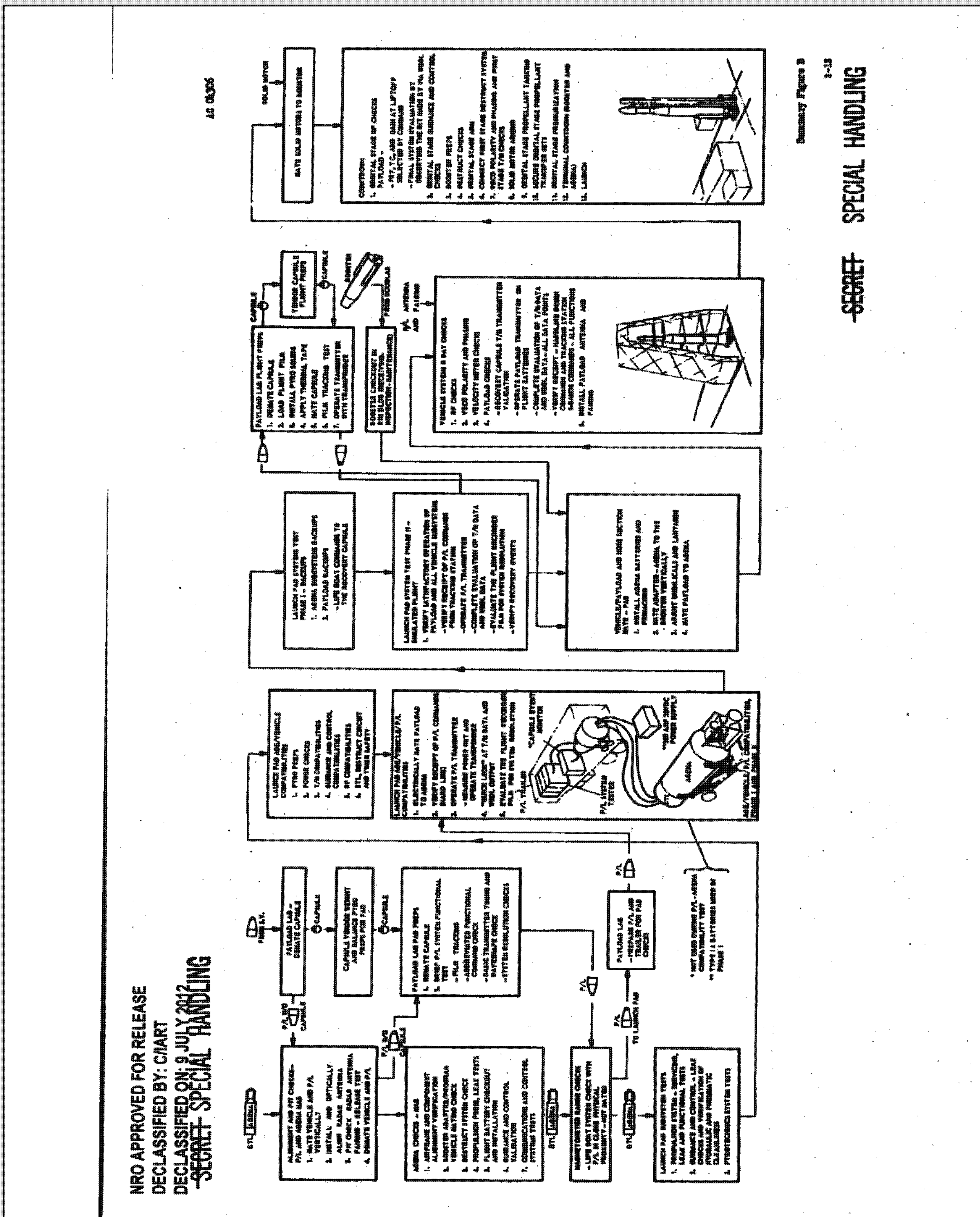
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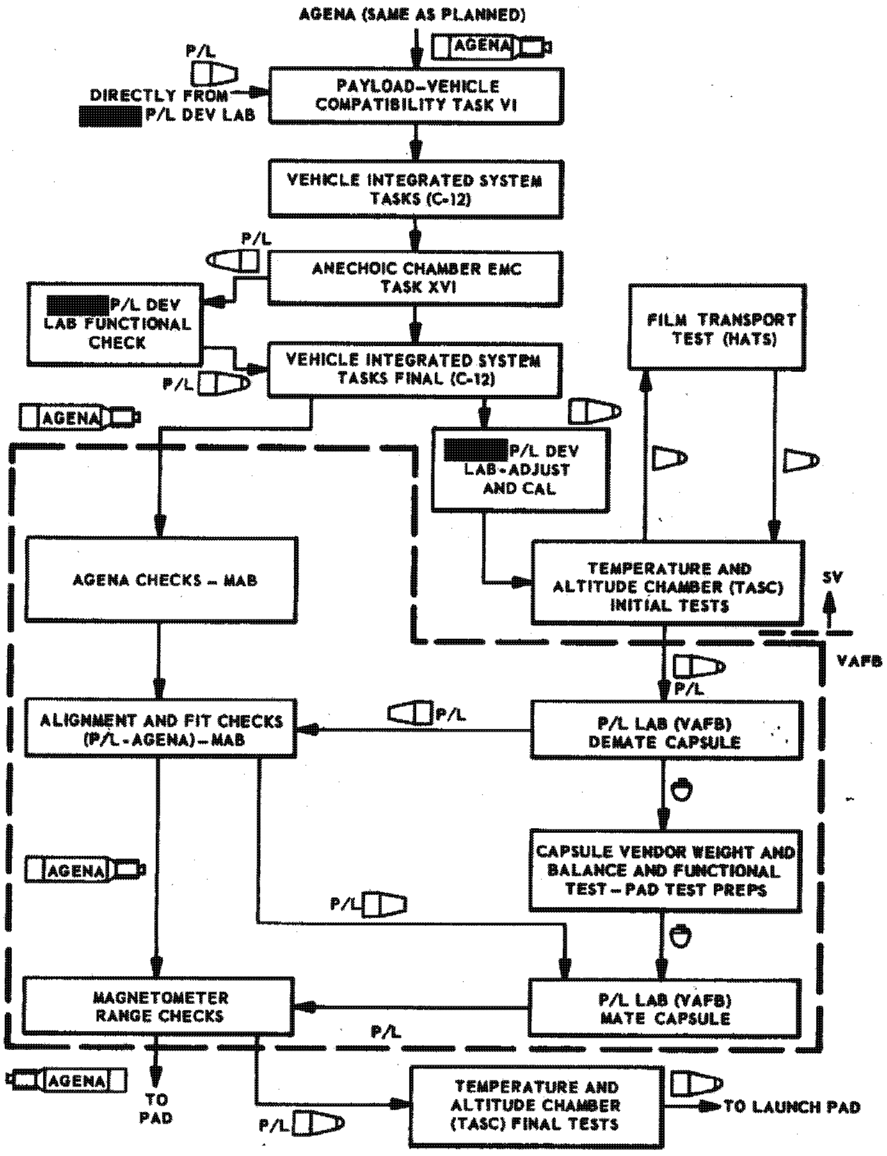

SUMMARY FIGURE C

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2.3.2 Payload Vehicle Testing

Summary

The payload tests defined in the Planned Test Sequence (Para. 2.3.3 of this Section) were completed and the primary objectives met. The scope of testing was enlarged to include a special test of the film transport system in a vacuum environment (HATS). Testing order was altered to permit downstream testing to continue, where practical, during periods when a complete set of flight components were not available.

Malfunctions of payload components in the temperature and altitude chamber (TASC) during the Qualification payload tests and Vehicle 2355 payload tests caused the TASC tests to be altered, repeated and the start and completion to be delayed. (Refer to Para. 2.3.3 of this Section). The final TASC run was a complete and continuous test which verified system compliance to all of the initial objectives.

Payload compliance to specifications was demonstrated in the following configurations:

a) Payload Vehicle System (Non-environmental)
  - o Power supply simulating flight batteries.
  - o Test console simulating Agena commands and radar targets.
  - o Vehicle telemeter simulator monitoring telemeter signals.
  - o Transmitter terminated in a dummy load.

b) Payload Vehicle System (Environmental)
  - o Basic equipment used same as Item a) above with the payload in a simulated orbit pressure and tempera-

ture environment.

c) Agena - Payload Integrated Systems Tests (Non-environmental)

- o Payload electrically, but not mechanically mated to the Agena.
- o Power supply simulating flight batteries.
- o Commands from the Agena (hard line from test complex).
- o Telemeter and "hardline" data used to evaluate system performance.
- o Transmitter terminated in a dummy load.

d) Agena - Payload System (Anechoic)

- o Payload electrically and mechanically mated to the Agena.
- o Payload radar antenna installed and transmitting.
- o Power supplied by flight type batteries.
- o Commands from the Agena (air link from test complex).
- o Telemeter (air link) data used to evaluate system performance.
- o Payload data by air link to ground receiver and recorder.
- o Emergency control and monitoring maintained with a minimum number of electrically isolated hardlines.

e) Agena - Payload System (Launch Pad Horizontal)

- o Payload electrically but not mechanically mated to the Agena.
- o Power supply simulating flight batteries.
- o Commands from the Agena (air link from tracking station).
- o Telemeter (air link to ground station) and hardline data

used to evaluate the performance. (Telemetry and payload video data).

- o Recovery capsule energized and evaluated.
- o Transmitter terminated in a dummy load.

f) Booster - Agena - Payload System (Launch Pad Vertical)

- o Payload-Agena-Booster Adapter-Booster mated.
- o Flight batteries installed.
- o Commands from the Agena (air link from tracking station)
- o Telemeter (air link to ground station) used to evaluate system performance.
- o Simulated targets evaluated with the wide band data link only.
- o Transmitter terminated in a dummy load.

At the conclusion of payload testing the following items were out of limits as specified by the Test Procedures:

a) Transmitter power was 0.7 db low.

b) The sensitivity time control (STC) video waveform was 2.2:1 maximum to minimum and should have been a maximum of 2.0:1.

c) Delay from "ON GATE" to the start of STC was 35 microseconds and should have been 31 microseconds maximum.

d) The accelerometer in the Transmitter-Modulator unit was inoperative.

During the TASC tests unexplained transients were observed on the -2KV and +4.5KV power supply monitors. Instrumentation indicated, and analysis verified that the transients on the two power supplies were not related. The 2KV problems was localized to the RF-IF Unit. This unit was removed after the TASC test was completed and operated through a special test at Goodyear. The spiking was determined to be occurring in an output filter capacitor in the -2KV supply and was not of a potential failure nature. The -2KV problem and the four (4) out-of-limits items listed in this section were all acceptable to Goodyear to Lockheed and to the Air Force as flight worthy conditions. The +4.5KV transients appeared in the first four (4) of the thirteen simulated orbits in the TASC test. They did not appear in the last nine simulated orbits in TASC or in any of the subsequent testing. Refer to Par 2.1.2 and Par. 3.1 of this report for a more detailed discussion.

2.3.2.1 [redacted] Payload Development Lab, Lockheed

a) General

The payload system was assembled and checked out in the [redacted] payload development lab at Lockheed-Sunnyvale. Components of the payload system were obtained from Lockheed-Goodyear and the Recovery System Vendor. Goodyear supplied five (5) flight radar components with mounting hardware and the AGE required to check each component individually and interconnected as a system. A system for recording the wide band data link (WBDL) video was also supplied by Goodyear, termed a ground based recorder. Lockheed provided the payload airframe, flight antenna and waveguide, power conversion equipment, pyro system, compensation magnets and equipment necessary to interconnect, monitor and control the payload system. Lockheed also supplied the AGE required to handle the capsule and payload, a battery simulator, a vehicle telemeter simulator, and payload test aids.

The Recovery System Vendor supplied the recoverable nose section including all of the flight equipment contained within the capsule.

b) Acceptance Tests of Goodyear Components

Goodyear personnel performed acceptance tests on the radar flight components. These components were, 1) Transmitter Modulator (Box #3), 2) RF-IF Unit (Box #4), Reference Computer (Box #5), the Control Unit (Box #6) and the Recorder (Box #7). Each Box had its own Maintenance Tester which was used initially

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RADAR

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VEHICLE 2355 SYSTEM REPORT (U)

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VEHICLE 2355 SYSTEM REPORT (U)

Volume III - Flight Performance

Contract [redacted]
Supplemental Agreement Number 13

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Prepared:

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Chief Operations
Program [redacted]

Approved:

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Manager
Program [redacted]

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David D. Bradburn

David D. Bradburn
Lt. Colonel, USAF
SAFSP

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FOREWORD

This report covers the span of time from the inception of the first satellite borne radar system through the final evaluation of the on orbit performance of the first flight. An objective review is attempted, of the complete scope of activities associated with bringing a new system into being and of the system performance during an essentially nominal and troublefree mission.

From this review, it is hoped that the systems management and program control parameters which were found to be effective may be properly recognized and thereby enhance the organization and conduct of similar future activities.

The system definition and resulting configuration is reviewed in retrospect, together with the problems associated with this Program development and testing.

The engineering management concept and the test philosophy which were applied are outlined and restated, with the objectives of first recording these, and then attempting to objectively analyze them for areas susceptible to improvement. The Air Force - LMSC - Associate Contractor team is defined, as it existed during the development, testing and operation of Vehicle 2355.

The system performance from launch through recovery and thence to battery depletion is evaluated from the primary aspect of payload operation.

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System performance is compared against predictions, and the performance accomplishments and achievements are enumerated.

The report is therefore, in addition to a flight report, a total summary of the composite effort associated with the preparation and operation of this system. From the system evaluation certain conclusions and recommendations are formulated which are intended to be useful for later work on similar systems.

Through the medium of the detailed information contained in this report, it is intended to properly acknowledge the efforts of all those who were instrumental in managing and conducting a program which produced a completely successful mission with the first flight of a new payload vehicle system.

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PART III

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PART III (Cont.)

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PART III

System Performance During Orbital Operations

Introduction

This section of the report - Part III - is designed to contain a maximum of orbital performance data. The subsystems, the thermodynamic conditions which prevailed, the vacuum gage responses and the performance of the Satellite Control Facility are each discussed.

The payload subsystem operation, as recorded in Para. 3.4, was evaluated by Engineering personnel relatively inexperienced in evaluation of photographs or of radar imagery. The basis of the evaluation was:

- All telemetry data considered pertinent.
- The recorded video data transparency.
- The correlated radar imagery for the full length of all operating passes. (An unrefined copy)

The resulting observations and comments provide a total evaluation of the payload data and radar imagery accumulated in 32.91 minutes of operation throughout the 14 orbits of payload operation - with the qualifications indicated above.

The entries made for each pass may form a basis for further evaluation - if required - without recourse to extensive research through retired data records.

3.4 Radar Payload Subsystem

General The satellite vehicle was programmed by means of the orbital programmer to operate for 80 orbits. The payload was programmed to operate through a warmup and a preoperate cycle whenever the satellite was in sight of the Vandenberg AFB or the New Hampshire tracking stations, and when the ground mapping swath was within the Continental United States. The recovery was originally planned for Rev 65. Due to interference with other operations a decision was made to effect recovery on Rev 33. The seven payload operating passes prior to Rev 33 were utilized to acquire a maximum of recovered film data of highest quality. Accordingly, the only payload control which was conducted during these Operate periods consisted of adjusting the PRF. Automatic gain control was used for all passes prior to recovery, as was Clutterlock Integrator (In) and Time Constant #1. Engineering experiments as indicated herein, were conducted during the seven passes following recovery. The objective of this section of the report is the recording of a maximum of payload operating data and performance parameters which would permit subsequent and more detailed evaluation of the system -- as desired.

This section consists of the following paragraphs:

3.4.1 Pass Summary Log (Verbal Reports to STC During Operation) This log contains a quick reference source of all payload operations during this mission, by pass, with operating times per event and cumulative. (Not complete.) Refer to Para. 3.4.2 for specific event details.

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3.4.2 Pass Analysis

This paragraph contains the basic data taken from telemetry records, doppler data film and correlated radar imagery, arranged in a time sequenced format for each of the fourteen active payload passes.

3.4.3 Telemetry Schedule

This paragraph contains a basic telemetry listing.

3.4.4 Telemetry Data

This paragraph contains basic telemetry data.

3.4.5 Positioning of the Return Pulse in the Range Gate.

3.4.6 Terrain Reflectivity.

3.4.7 Direct Monitoring of Payload Radiation.

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3.7 RECOVERY SUBSYSTEM

3.7.1 The recovery subsystem, as described in Para. 2.3.2.10 above, performed the payload on-orbit functions of maintaining film tension during nonoperate periods, taking film up into the recoverable cassette, with a constant tension, during operate periods, cutting the film prior to separation and providing a light-tight and protected environment during re-entry.

In addition, the capsule takeup mechanism maintained film tension during ascent. The takeup motor gear drive was prevented from unwinding by a ratchet. During ascent the ratchet (anti-backup) was held by solenoid action in the disengaged position to prevent ratchet damage from ascent vibration.

The capsule status on orbit was evaluated by the following telemetry points:

F-91	Footage Potentiometer (Cassette Hub Diameter)
F-93	Water Seal Position and Continuity Loop
F-97	Cassette Temperature
F-99	Takeup Idler/Cassette Commutator

The other capsule telemetry points were temperature monitors and recovery battery signal monitors:

F-92	Retro Temperature (Rocket)
F-94	Thrust Cone Temperature
F-95	Recovery Battery #2 Signal (V_oH)
F-96	Recovery Battery #1 Signal
F-98	Forebody Temperature

The capsule status telemetry point displays for F-91 and F-99 are shown in Para. 3.4. These indicated normal film transport operation. The cassette temperature was controlled by two 10-watt heaters in series, yielding 5 watts power dissipation, with a thermostat setting of 82°. The cassette temperature, monitored by F-97, was 73°F on Rev. 8 and decreased to 44°F on Rev. 25.

3.7.2 Weights

The capsule weight was increased to 120 pounds parachute suspended weight, as described in Para. 1.6. The capsule weights were:

Separation Weight	306.85 lbs.
After Retro Weight	223.25 lbs.
Weight on Parachute	120.00 lbs.

The corresponding descent rates on the parachute were:

Altitude (Feet)	Descent Rate (Ft/Sec.)
54,300	Parachute Deployment
35,000	32.5
30,000	29.5
25,000	27.0
20,000	24.9
15,000	23.0
10,000	21.2
5,000	19.6
Surface	18.0

3.7.3 Recovery

The recovery events and performance are given below in Table II. The predicted impact point was 24°N and 143° 38' W. The actual air catch was made at 23° 38' N and 143° 45' W, approximately 23 nautical miles South-Southwest of the predicted impact point.

The recovery area plot, and two views of the recovery positions, predicted versus actual for views up range and looking across range are given in figures 3.7.1, 3.7.2 and 3.7.3 respectively. The variations from actual prior to entering the atmosphere are due to minor variations in alignment from optimum during retrorocket thrust and to minor differences in total thrust value.

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RADAR

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KP-II ORBITAL DOPPLER RADAR
THOR/AGENA SATELLITE PROGRAM

VOLUME I - DESIGN AND DEVELOPMENT

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SECTION I - INTRODUCTION

1. GENERAL

In January, 1963, Goodyear Aerospace Corporation, Arizona Division, was contracted by the Secretary of the Air Force Special Projects Office (SAFSP) to participate in an Agena Vehicle Satellite Program. The primary objective of the program was to demonstrate the feasibility of obtaining doppler high-resolution radar imagery of the earth's terrain from an orbiting satellite. To accomplish this objective, it was proposed to base the radar system, wherever practical, upon the existing designs of the Goodyear-produced AN/UPQ-102 side-looking doppler radar.

Initial studies and proposal efforts on this program had previously begun in the latter part of 1962 when a number of meetings were held between Goodyear Aerospace, Lockheed Missile and Space Company (LMSC), and the [redacted] to discuss system parameters, design concepts, and vehicle configuration. Actual work on the radar portion of the program began at Goodyear Aerospace on January 15, 1963. Twenty-three months later on December 21, 1964, successful completion of the first orbital radar test was achieved.

This program report is divided into two volumes. This volume — Volume I — documents the initial system analysis, design, and development of the Goodyear KP-II side-looking doppler radar system. Volume II describes the ground tests to which the system was subjected, and presents the results of the orbital flight test.

2. DESIGN PHILOSOPHY

To accomplish the program objective, extensive changes were required to the existing designs of the AN/UPQ-102 doppler radar. The KP-II radar was required to operate at 20 times the ground speed and 16 times the altitude of the AN/UPQ-102 radar. The KP-II radar was required to scan one side only; the AN/UPQ-102 radar scanned on both sides and used two receiving and recording channels. In the AN/UPQ-102 radar, the film speed and prf were slaved to ground speed; in the KP-II radar they would be constant. Additionally, the AN/UPQ-102 radar incorporated many modes of operation, such as moving target indication and variable mapping intervals, which were not included in the requirements for the KP-II radar. Finally, the more difficult vibration and pressure requirements of the satellite environment would necessitate an extensive repackaging of the radar units.

It was decided that specialized parts, such as klystrons, traveling wave tubes, cathode ray tubes, and frequency multipliers, would be procured from previously established vendors wherever possible. To ensure that these specialized parts would meet all requirements, new specification control drawings were made and the components procured to these specifications.

It was also decided that the payload would be instrumented in such a manner that flight performance and failure mode data could be obtained from narrow band telemetry information.

3. CONFIGURATION

The KP-II radar payload equipment which was designed and built by Goodyear Aerospace consists of the following units: Transmitter, RF-IF, Reference Computer, Control, and Recorder. The equipment, with the exception of the recorder, is installed in the forward barrel section of a standard Agena D vehicle. The recorder is installed in the conical nose section directly behind the film recovery capsule. The radar antenna, built by LMSC, is attached to the side of the Agena vehicle and is a two-dimensional slotted wave guide array. The antenna is 15 feet long, 1.8 feet in height, and is uniformly illuminated in both directions.

4. SYSTEM PARAMETERS

The radar payload is designed to operate at an altitude of 130 ±13 nautical miles. The orbital inclination angle is 70 degrees. A fixed radar depression angle of 55 degrees is used. The radar maps a slant range interval of 5.95 nautical miles which is independent of altitude variation. This slant range interval corresponds to a ground range interval of approximately 10 miles.

The design value for peak transmitter power is 30 kilowatts and the average transmitter power is 262 watts. The length of the transmitter pulse is 1.0 microsecond. By the use of pulse compression techniques this is reduced to an effective pulse width of 0.06 microsecond. The minimum acceptable resolution for the system is 50 feet slant range resolution and 50 feet azimuth resolution. Actual system performance was found to be better than these minimum acceptable values.

The pulse repetition frequency (prf) has a 16-step variable range from 8215 to 8735. Changes in prf are accomplished via the payload command system. A grey code is used to allow a one-step change in prf to be accomplished by a single command. During flight, change of prf from its preprogrammed position was made on the basis of the radar data received at the tracking station.

The total power consumed by the radar system in the operate mode is 2500 watts. The total weight of the five payload components is 348 pounds.

5. OPERATIONAL SUMMARY

The payload was launched by a thrust-augmented Thor booster and had a useful orbital life of approximately four days.

Radar radiation was confined (1) to the limits of the continental United States, and (2) to the limits of control of the Vandenburg and New Boston tracking stations. Doppler radar data were recorded simultaneously by the recorder unit contained in the vehicle and also by a ground-based recorder located at the tracking station. The data were transmitted to the controlling tracking station via a wide-band data link. There were a total of 14 mapping passes within the four-day period. The time interval for each pass varied from 1.4 to 3.7 minutes. The total mapping time was 32.91 minutes. The unprocessed vehicle data film was returned to earth in the recovery capsule. The resulting high-resolution imagery from the data films confirms the feasibility of doppler high-resolution radar techniques for space application.

6. CHRONOLOGY OF PROGRAM HISTORY

To give chronological perspective to the design and development phases of the program, a summary of events on a monthly basis is included as Appendix I to this volume.

SECTION II - BASIC DOPPLER THEORY

1. GENERAL CONCEPT

The beam-sharpening process used in a doppler, high-resolution, side-looking radar may be described by means of a physical antenna analog. As the vehicle travels its orbital path a series of pulses is transmitted. Successive pulse transmissions are identified with the elements of an array of dipoles. The spacing between elements is the distance traveled by the vehicle between pulses. Each transmission is made with a controlled phase. The amplitude and phase of the reflected energy from the terrain at all ranges and angles within the physical beam width of the antenna is recorded on the data film.

The length of the antenna synthetically generated is basically limited to the distance instantaneously illuminated on the ground by the physical antenna. By the technique of optical processing, the amplitude and phase of the returns from the successive pulses are vectorially added to create the narrow synthetic beam. The results of these data are then recorded on a final film. Thus, the resolution equivalent to that of an antenna hundreds of feet in length is achieved with a small physical antenna.

2. BASIC EQUATIONS

The basic equations of a high-resolution radar are most easily developed if the analysis is restricted to the slant-range plane of a single-point target. Figure 1 shows the geometry involved. R is the distance to the target from the antenna at time t. At time $t = 0$, R_1 is the distance to the target. The angle θ_o is measured in the slant-range plane to the center of the antenna beam at slant range R_1. Several combinations of pitch and yaw will yield the same angle θ_o.

From the geometry of Figure 1 the instantaneous range R to the target is

$$R = \left[R_1{}^2 + (vt)^2 - 2R_1 vt \sin\theta_o\right]^{1/2} . \qquad (1)$$

As the beam width of the physical antenna is small, the range during the period when the target is illuminated may be closely approximated by taking the first few terms of the binomial expansion of Equation (1):

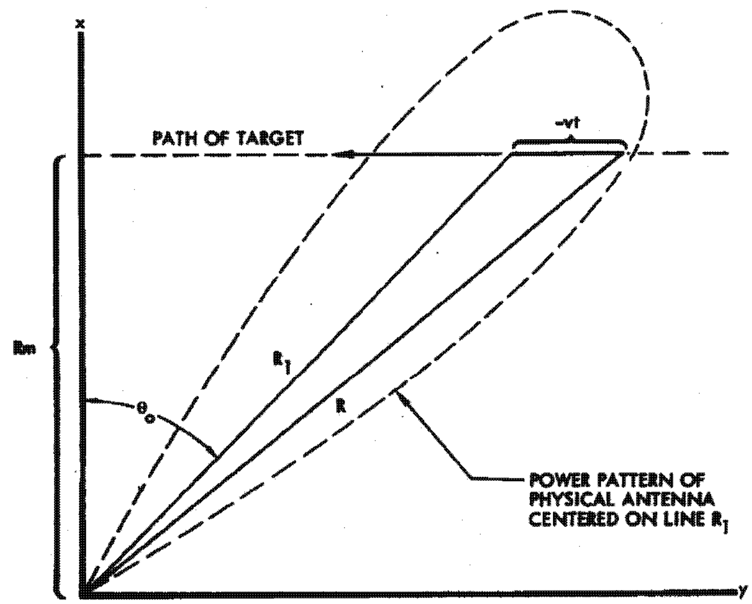

Figure 1 - Geometry of a Point Target in the Slant Range Plane

$$R \approx R_1\left(1 - \frac{vt \sin \theta_o}{R_1} + 1/2\,\frac{(vt)^2}{R_1^2} \cos^2 \theta_o\right) . \quad (2)$$

The range dependence on time is reflected in a phase dependence on time of the return signal. The dependence of phase ϕ of the return signal on time is

$$\phi = 2\pi f_o t - \frac{4\pi R}{\lambda} + \phi_o \quad (3)$$

where

f_o = the transmitted frequency

λ = the wave length of the carrier

ϕ_o = the phase change caused by reflection.

Equations (2) and (3) may be developed into

$$\phi = 2\pi f_o t + \frac{4\pi}{\lambda} vt \sin \phi_o - \frac{2\pi (vt)^2}{R_1 \lambda} \cos^2 \phi_o + \phi_1 \quad (4)$$

where

$$\phi_1 = \phi_o - \frac{4\pi R_1}{\lambda} .$$

The return signal is synchronously demodulated with respect to some reference frequency to remove the carrier. It is desirable for the reference frequency to be the frequency of the return signal when the target is at the center of the beam. The phase of the return signal when the target is at the center of the beam and at range R_1 is given by

$$\gamma = 2\pi f_o t - \frac{4\pi R_1}{\lambda} + \phi_o . \quad (5)$$

The frequency will be

$$f_r = \frac{1}{2\pi}\frac{d\gamma}{dt} = \frac{1}{2\pi}\left(2\pi f_o - \frac{4\pi}{\lambda}\frac{dR_1}{dt}\right) . \quad (6)$$

From Figure 1, however,

$$\frac{dR_1}{dt} = \left.\frac{dR}{dt}\right|_{t = 0} \quad . \tag{7}$$

Therefore, from Equation (2)

$$\frac{dR_1}{dt} = -v \sin \theta_o \quad . \tag{8}$$

Then, substituting into Equation (6),

$$f_r = f_o + \frac{2v}{\lambda} \sin \theta_o \quad . \tag{9}$$

Therefore, f_r is the frequency that will be used for synchronous demodulation. The synchronous demodulated signal will have the form

$$S(t) = A(t) Re\left[e^{-j2\pi f_r t} (e^{j\phi})\right] \tag{10}$$

$$= A(t) \cos\left(\frac{2\pi (vt)^2 \cos^2 \phi_o}{R_1 \lambda} - \phi_1\right) \tag{11}$$

where A(t) denotes the amplitude of the return which is a function of the reflectivity of the target and its position in the antenna beam. When

$$\phi_1 = n(2\pi)$$

$$\theta_o = 0$$

and

$$A(t) = K$$

Equation (12) reduces to the familiar expression

$$S(t) = K \cos\left(\frac{2\pi(vt)^2}{\lambda R_m}\right) . \tag{12}$$

The signal recorded on film at range R_m will be of the form

$$S(x, R_m) = T_b + K' \cos\left(\frac{2\pi x^2}{\lambda R_m}\right) \tag{13}$$

where

T_b = the transmissivity of the film

K' = some constant times K.

From Equation (9) it is seen that all scatterers at an angle θ_o and with velocity v will have the same frequency. It follows that the locus of all possible scatterers whose returns have the same frequency is one nappe of a right circular cone with semi-apex co-angle θ_o whose axis contains the velocity vector.

The locus of points on the earth can be visualized if the intersection of the above doppler cone with a plane tangent to the earth at midmapping range is considered Since the range interval mapped is small, the mathematical model so described is a good approximation near the point of tangency.

3. AMBIGUITIES

Two types of ambiguities – range and azimuth – are inherent in a coherent high-resolution radar and provisions must be made to avoid them. The range-ambiguity problem is common to all pulsed radar and is usually avoided by lowering the prf so that the so-called "second-time-around" targets are not seen by the radar. However, the consideration of azimuth ambiguities yields another set of constraints on the choice of prf.

For a processor operating about zero doppler the information spaced at $\pm\gamma_n$ from zero doppler is ambiguous. This angular spacing is given by

$$\gamma_n = \frac{n\lambda F}{2v} \qquad (14)$$

where

n = a positive integer, 1, 2, 3, . . .

λ = carrier wave length

F = prf

v = radar velocity.

The focused processor used with this system operates about an offset of prf/4 and is unable to distinguish between positive- and negative-going frequencies so that the ambiguity spacing is given by

$$\gamma_n = \frac{n\lambda F}{4v} \quad . \qquad (15)$$

For most high performance radars it is desirable to choose a prf such that the first azimuth ambiguity is placed in the vicinity of the first null of the physical antenna azimuth pattern. This choice of prf places an upper bound on the size of the mapped interval. This constraint in turn dictates the antenna height, since from the range-ambiguity standpoint the vertical antenna pattern is employed to avoid range ambiguities. It is readily deduced that ambiguity constraints are a determining factor in choosing antenna dimensions for a satellite radar. These considerations will be discussed further in Section III.

4. DATA PROCESSORS

The most successful type of high-resolution processor thus far is the optical correlator.* Considerable insight into the optical processor is possible if

*These devices are commonly known as correlators because the original conception, developed at the University of Michigan, was an optical cross-correlator.

the properties of a sine wave diffraction grating are considered. Figure 2 shows the three principal emergent rays from a sine-wave diffraction grating resulting from an incident plane wave of coherent light. The angle θ is defined thus:

$$\sin \theta = \lambda' f \tag{16}$$

where

λ' = the wave length of the coherent light

f = the spatial frequency of the sine-wave diffraction grating.

Now consider a diffraction grating of the form cos $(2\pi x^2/\lambda' R_m)$. This is of the same form as the demodulated return signal from a point target (Equation (13). Assuming a one-to-one scale factor in recording the demodulated return, the spatial frequency is $2x/\lambda' R_m$. From Figure 3 the distance r to the crossing of the zero axis is given by

$$r = \frac{x}{\tan \theta} \quad . \tag{17}$$

For small angles

$$\tan \theta = \sin \theta = \theta \quad . \tag{18}$$

Then,

$$r = \frac{x}{\lambda' f} = \frac{x \lambda' R_m}{\lambda' 2x} = \frac{R_m}{2} \tag{19}$$

which is to say that the diffracted light focuses on the zero (doppler) axis at a distance $R_m/2$ from the grating (data film).

From Figure 2 it is recalled that there are three principal emergent waves. For the cosine x^2 grating the three waves are defined thus (see Figure 4):

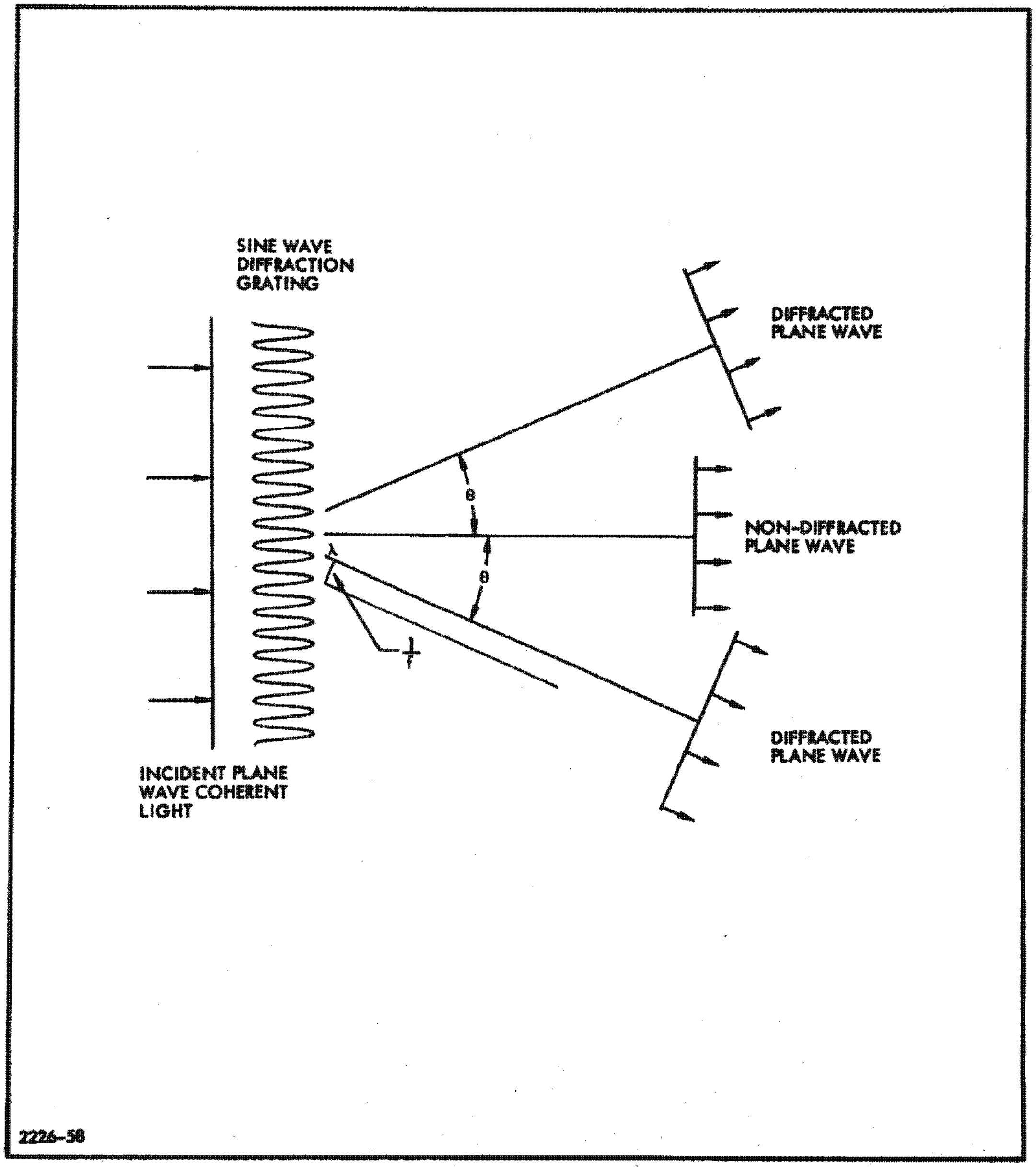

Figure 2 - Geometry Illustrating Fruenhofer Diffraction

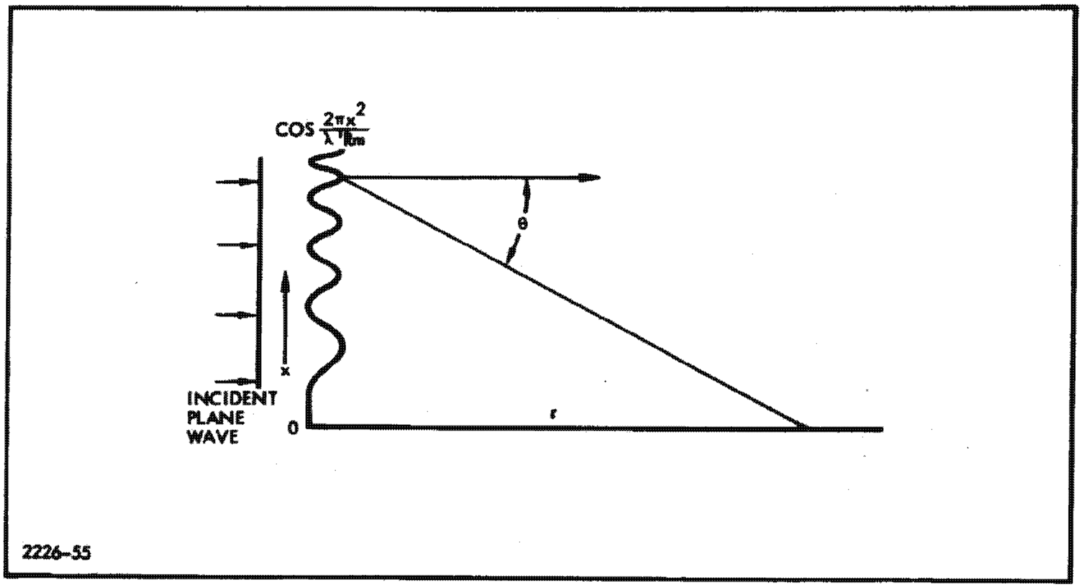

Figure 3 - Diffraction from $\frac{\cos 2\pi x^2}{\lambda' R_m}$ Grating

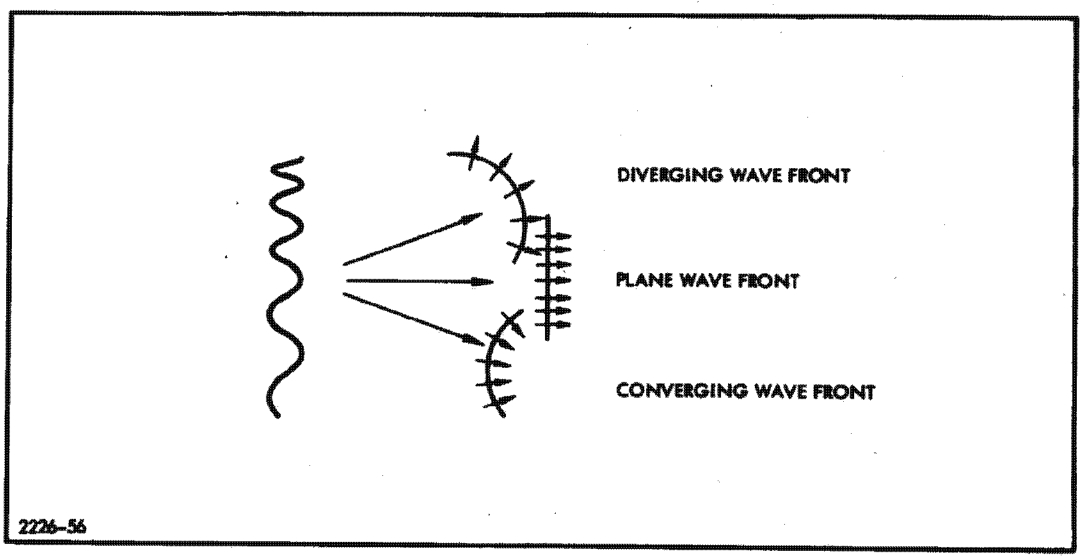

Figure 4 - Three Wave Fronts of a Parabolic Phase History

1. Converging wave front focused at a distance r on the axis
2. Diverging wave front with a virtual image at a distance -r on the axis
3. Plane wave front focused at infinity.

The converging wave front focuses at that angle and at that distance away from the recorded phase history which corresponds to the same angle and the scaled-down distance (proportional to the ratio of light-to-radar wave lengths and aircraft motion-to-film-scale factors) of the radar space where the data were recorded. Unfortunately, in a practical case the ratio is not nearly high enough and a converging lens must be used to bring the desired spot into focus at a convenient distance. Of course the other two wave fronts also come to a focus then but since they lie at different angles they can be blocked off from the final film with an appropriate optical stop. However, from Equation (19), the focal distance is a function of range; therefore, the lens must have a converging power which varies with range, giving rise to a conical shape. A cylindrical lens is also required to maintain target separation in range.

Thus, the basic elements of an optical processor are a coherent light source, optics to focus range and azimuth data onto a single plane, and film drives for transporting both the data and image films.

The optical processor for this system is being provided by the [redacted]

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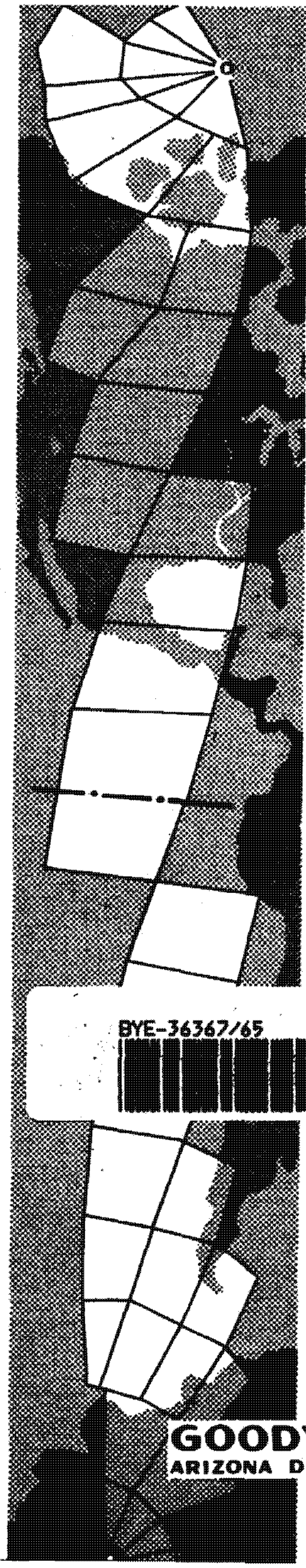

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KP-II

PROGRAM REPORT

KP-II ORBITAL DOPPLER RADAR

THOR/AGENA SATELLITE PROGRAM

VOLUME II - TESTING

AKP-II-596 — 1 APRIL 1965

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SECTION I - INTRODUCTION

The initial design and development phase of the KP-II doppler radar is documented in Volume I of this report. This volume — Volume II — documents the ground test and flight test phases.

The sections on ground testing include a description of the specialized test equipment which was used, the tests that were performed on the equipment, the problems encountered, and the corrective actions that were taken.

The sections on flight testing describe the operations which were carried out during the mission and present a detailed analysis of the radar system performance.

A summary of testing events on a monthly basis is included as Appendix I.

Estimates based on flight data of the radar back-scattering coefficient, σ_o, are presented in Appendix II.

SECTION VI - ORBITAL OPERATIONS

1. MAPPED AREAS

The areas mapped during the flight test are shown in Figure 18. Each trace on the map represents a mapped interval which is approximately 10 nautical miles wide (5.95 nautical miles in slant range) and several hundred miles long. Table X gives the approximate latitude and longitude (determined by examination of the map film in all but one pass) of the start and finish of each pass.

2. PRE-RECOVERY OPERATING MODES

For the first seven payload operate periods (passes 8, 9, 14, 16, 24, 25, and 30), no attempts were made to determine the radar system limits, as the primary purpose of the mission was to demonstrate the feasibility of operating a satellite-borne radar system and early experiments could have placed the primary goal in jeopardy. Immediately after pass 8 the data obtained from the wide band telemetry link were sent by courier to be processed and correlated at the [redacted] This step was taken to verify that the radar was operating properly. During these first seven active passes only OPERATE, PRF and OFF commands were sent to the radar system. The necessary prf commands were determined from the A-scope presentation in the screen room at the tracking stations.

3. POST-RECOVERY OPERATING MODES

On pass 33 the data film from the satellite was recovered. On the next active pass (40), the automatic gain control (agc) circuitry in the radar was commanded off and fixed amounts of receiver (r-f/i-f) attenuation (step 2 and step 3) were selected.

Again, on pass 41, the radar was operated with several steps (0, 3, 4, 5) of fixed attenuation.

No experiments were conducted on pass 46 but on pass 47 the prf was stepped through all of its 16 positions. On pass 56 a command to short the integrator output (clutterlock circuitry) was sent. On pass 57 clutterlock time constant number 2 was selected and on pass 72 additional fixed attenuator settings were selected. Table XI shows the status of the various radar functions, which were subject to commanding from the tracking stations, during the active orbital life of the vehicle. Table XII is a time analysis of the mission.

TABLE X - ORBITAL PASS COORDINATES

Pass no.	Pass direction	Start		End	
		North latitude	West longitude	North latitude	West longitude
8	S-N	38° 56.0'	86° 58.5'	45° 47.5'	82° 52.5'
9	S-N	32° 28.9'	112° 33.5'	39° 46.5'	109° 06.2'
14	N-S	42° 03.0'	79° 51.0'	34° 46.2'	76° 12.1'
16	N-S	41° 27.5'	124° 48.5'	35° 55.1	121° 49.0'
24	S-N	39° 23.5'	88° 49.0'	46° 51.3'	84° 19.0'
25	S-N	33° 11.5'	114° 22.5'	42° 00.9'	109° 24.6'
30	N-S	47° 23.5'	85° 29.8'	34° 09.0'	78° 01.5'
40	S-N	40° 40.1'	90° 08.0'	46° 54.1'	86° 20.5'
41	S-N	32° 42.2'	116° 46.0'	41° 24.2'	112° 27.0'
46	N-S	45° 37.5'	86° 21.5'	34° 06.5'	80° 10.0'
47	N-S	44° 47.5'	108° 23.1'	33° 57.5'	102° 42.5'
56	S-N	41° 41.8'	91° 37.8'	47° 38.2'	87° 58.0'
57	S-N	32° 51.6'	118° 28.7'	43° 34.2'	113° 22.5'
72	S-N	46° 17.5'	90° 50.0'	51° 01.2'*	87° 15.6'*

*S-Look data

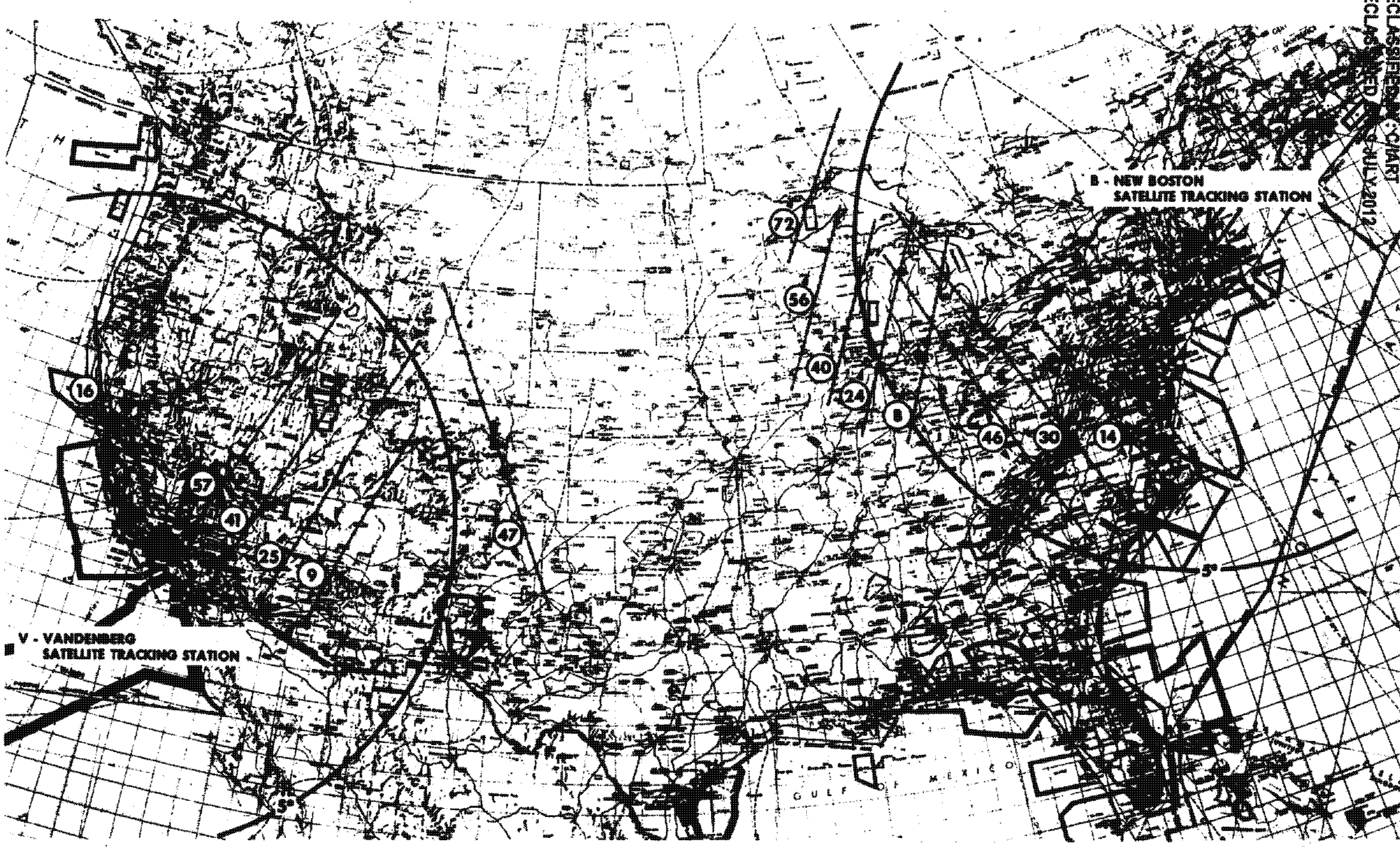

Figure 18 - Traces Depicting Radar Coverage of United States by The KP-II Radar, December 1964

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TABLE XI - STATUS OF RADAR FUNCTIONS

Pass no.	Automatic gain control	Fixed attenuator steps	Prf initial (at OPERATE on) step	Prf changes step	Clutterlock time constant	Clutterlock integrator output
8	Yes	None	14	13-12-11-10	TC No. 1	Normal
9	Yes	None	10	5-6-7-8-9	TC No. 1	Normal
14	Yes	None	10	9-8	TC No. 1	Normal
16	Yes	None	10	None	TC No. 1	Normal
24	Yes	None	11	10	TC No. 1	Normal
25	Yes	None	11	10-9	TC No. 1	Normal
30	Yes	None	8	9-8	TC No. 1	Normal
33	Recovery of Data Film					
40	App. 5 sec	2, 3	8	None	TC No. 1	Normal
41	No	4, 5, 4, 3, 0	9	None	TC No. 1	Normal
46	Yes	None	8	7-6	TC No. 1	Normal
47	Yes	None	6	All 7-15, 0-6	TC No. 1	Normal
56	Yes	None	6	7-8	TC No. 1 (approx 7 sec)	Shorted
57	Yes	None	9	8	TC No. 2	Normal
72	App. 36 sec	0, 7	8	7-6	TC No. 2	Normal

TABLE XII - MISSION TIME ANALYSIS

Active pass no.	Payload warm-up time (T_w) (min)	Payload pre-operate time (T_p) (min)	Operate (time (T_p) (min)	Total payload ($T_w + T_p + T_o$) cycle (min)	Time to next active pass (hr)
8	5.5	2.5	2.0	10.0	1.3
9	4.5	3.8	2.1	10.4	7.7
14	4.5	3.6	2.1	10.2	2.8
16	4.5	2.4	1.6	8.5	11.4
24	4.5	1.4	2.2	8.1	1.3
25	4.5	3.4	2.8	10.7	7.7
30	4.5	2.2	3.7	10.4	14.4
40	4.5	2.4	1.8	8.7	1.3
41	4.5	4.0	2.4	10.9	7.7
46	4.5	2.7	3.2	10.4	1.3
47	5.1	0.2	3.0	8.3	12.9
56	4.5	2.3	1.7	8.5	1.3
57	4.5	4.1	2.9	11.5	22.4
72	4.5	3.3	1.4	9.2	
Totals	64.6	38.3	32.9	135.8	93.5

Total payload cycle time ($T_w + T_p + T_o$) = 2.3 hr
Time from launch to pass 8 = 11.4 hr
Pass time = 93.5 hr

Total orbit time (from launch to end of pass 72) = 107.2 hr

SECTION IX - SYSTEM FLIGHT TEST ANALYSIS

1. GENERAL

This section presents an analysis of the radar system operation during the orbital flight test. The purpose of this analysis is to establish that the radar functioned properly throughout the test. No attempt is made to analyze the radar performance in terms of resolution or to discuss over-all picture quality. These results are presented in a separate report by [redacted]

In the following pages, a short subsection is presented showing some typical radar mapping results of the flight. Following this, various functions which are important from an over-all system standpoint are discussed by reference to the telemetry and radar map data. The radar pictures, unless otherwise noted, are enlarged 2.6 to 1 from the original data film size. The map scale is 3.6 miles per inch in range and 2.2 miles per inch in azimuth.

2. TYPICAL RADAR PICTURES

Figure 32 shows a section of a 1953 topographic map of East Chicago, Illinois. Figure 33 is a picture of the same area made with the KP-II satellite-borne radar enlarged 4.8 to 1 from the data film size. Several landmarks are identified by numbers on the topographic map and by corresponding numbers on the overlay to the radar map.

Figure 34 shows other radar maps taken with the KP-II radar. Figure 34(a) is the radar return from Richmond, Virginia, and Figure 34(b) the return from Wurtsmith Air Force Base on Saginaw Bay in Michigan.

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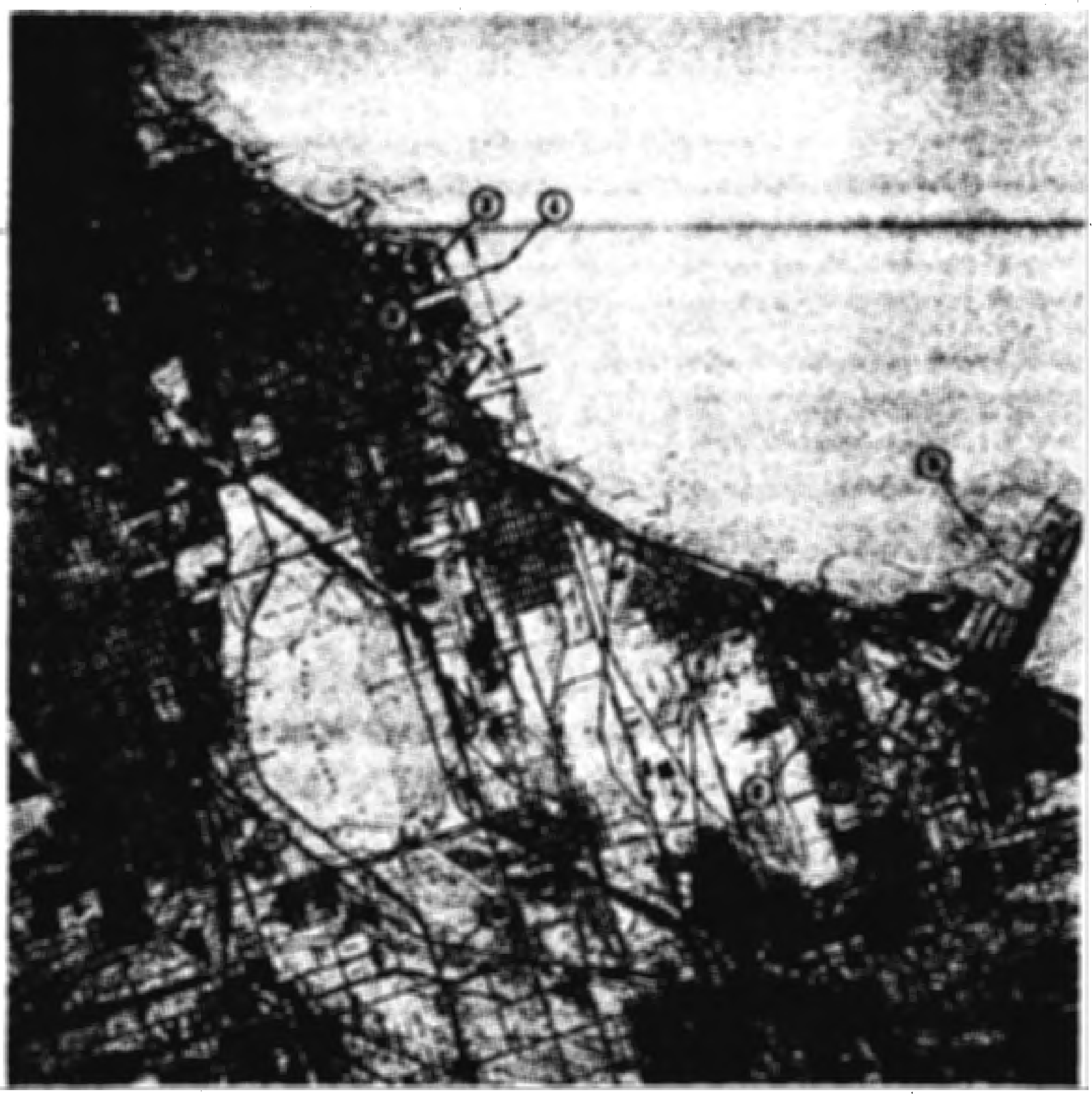

Figure 32 - Topographical Map of East Chicago, Illinois

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1. ILLINOIS CENTRAL RAILROAD
2. OAKWOOD CEMETARY
3. HEAVY INDUSTRY
4. BREAKWATER
5. CHICAGO SKYWAY
6. INDIANA HARBOR
7. LAND FILL
8. OIL STORAGE AREA
9. RIVER BARGE
10. CALUMET FREEWAY
11. TRAIN
12. LITTLE CALUMET RIVER

Figure 33 - Radar Return from East Chicago, Illinois

(A) RICHMOND, VIRGINIA

(B) WURTSMITH AFB, MICHIGAN

1. AIRPORT
2. GRAND CANAL
3. SHOPPING CENTER
4. CENTRAL AVENUE
5. STATE FAIRGROUNDS
6. HIGH RISE BUILDINGS
7. BLACK CANYON FREEWAY
8. GRAND AVENUE
9. THOMAS ROAD
10. ALUMINUM PLANT
11. US HIGHWAY 80
12. OIL STORAGE AREA

4000-37

Figure 34 - Typical Radar Maps

Figure 35 shows a 1953 topographic map of part of Phoenix, Arizona. (Note: Many changes have occurred in Chicago and Phoenix since the topographic maps were made.) Figure 36 is the radar return from the same area, enlarged 7 to 1 from the data film. The upper part of the radar map is somewhat dark as a result of a one-step misadjustment of the prf. This will be discussed further in paragraph 5 following.

3. AUTOMATIC GAIN CONTROL (AGC)

a. General Operation of Agc

The automatic gain control permitted the receiver gain to vary as a function of the amplitude of the signal returned to the receiver from the terrain being mapped. For large returned signals, such as those from residential or manufacturing areas, the receiver gain was automatically reduced. For low signal returns, such as those from desert or sea areas, the gain of the receiver was increased. The dynamic range of the agc was measured prior to the flight and found to be 35 db.

b. Agc Operation During Pass 34

The effect of the agc action on the map film can be seen in Figure 37(a). The increases of receiver gain over open water areas produce lighter areas on the film. These light areas are seen to correspond to the decreases in agc voltage on the graph, Figure 37(b).

c. Agc Operation During Pass 30

Measurements on a non-flight system showed that the agc time constant was 32 milliseconds for a 10-db step increase in received power and 26 milliseconds for a 10-db step decrease in received power. A land-water boundary occurred at system time 57460

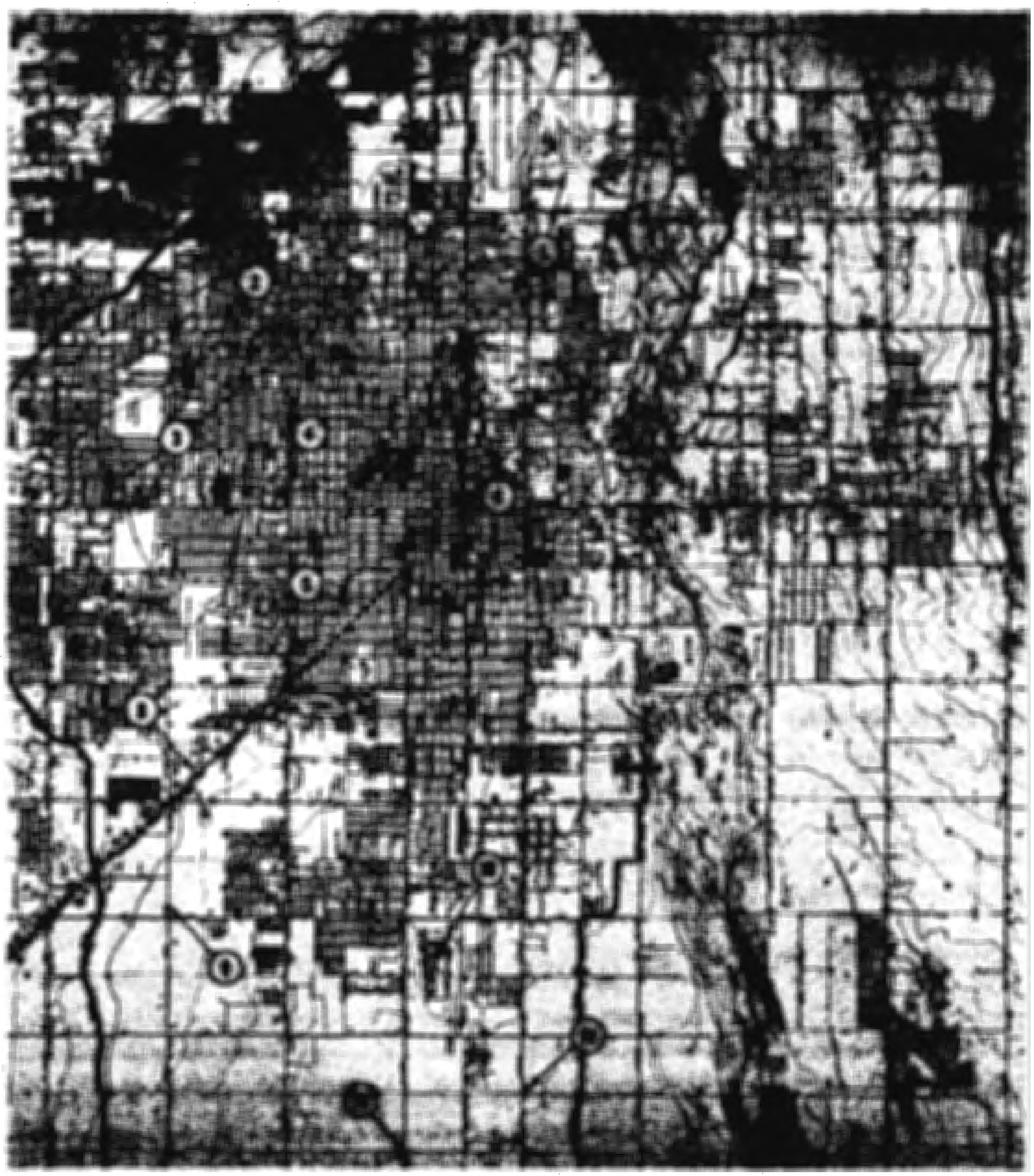

Figure 35 - Topographical Map of Phoenix, Arizona

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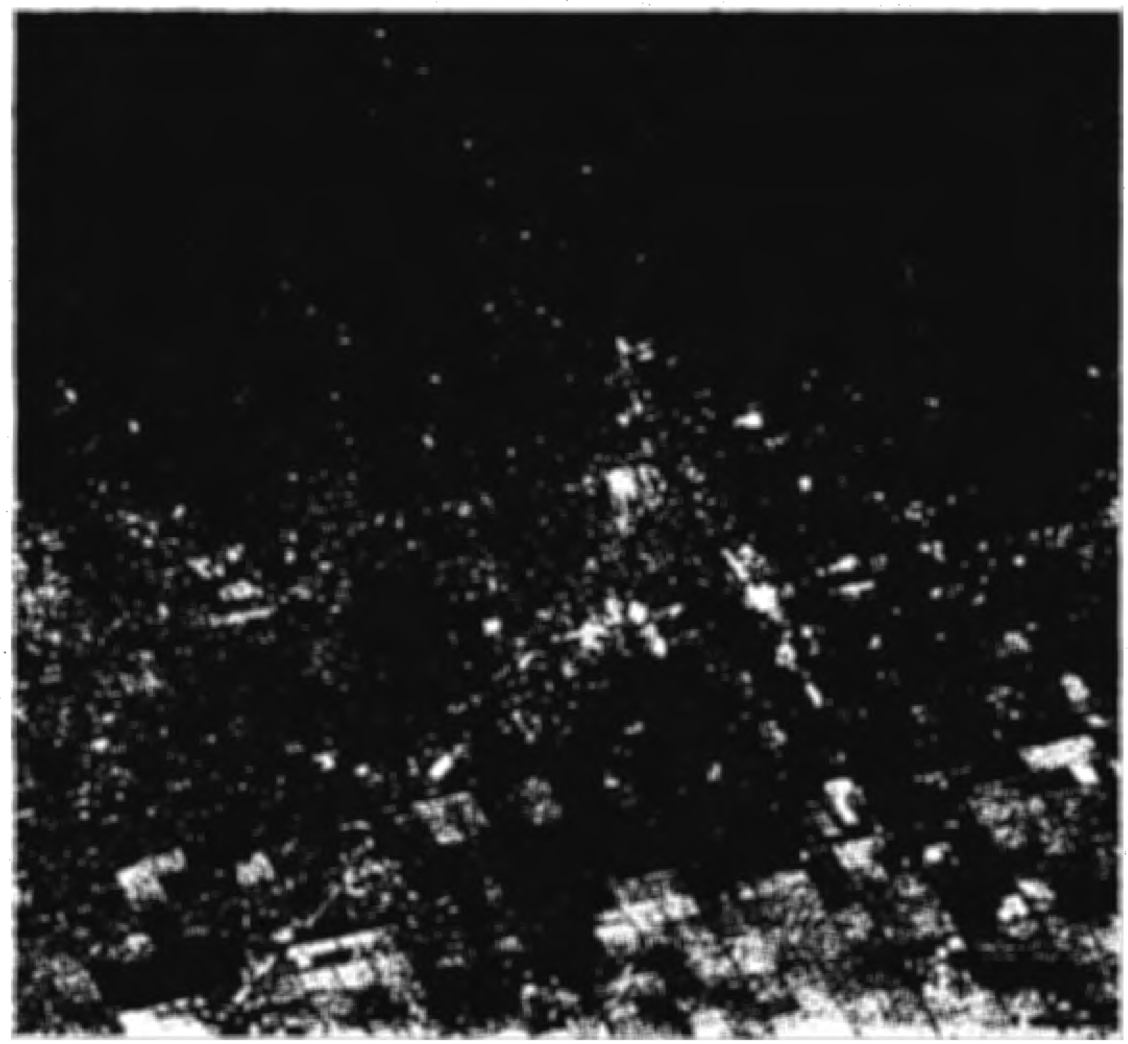

Figure 36 - Radar Return from Phoenix, Arizona

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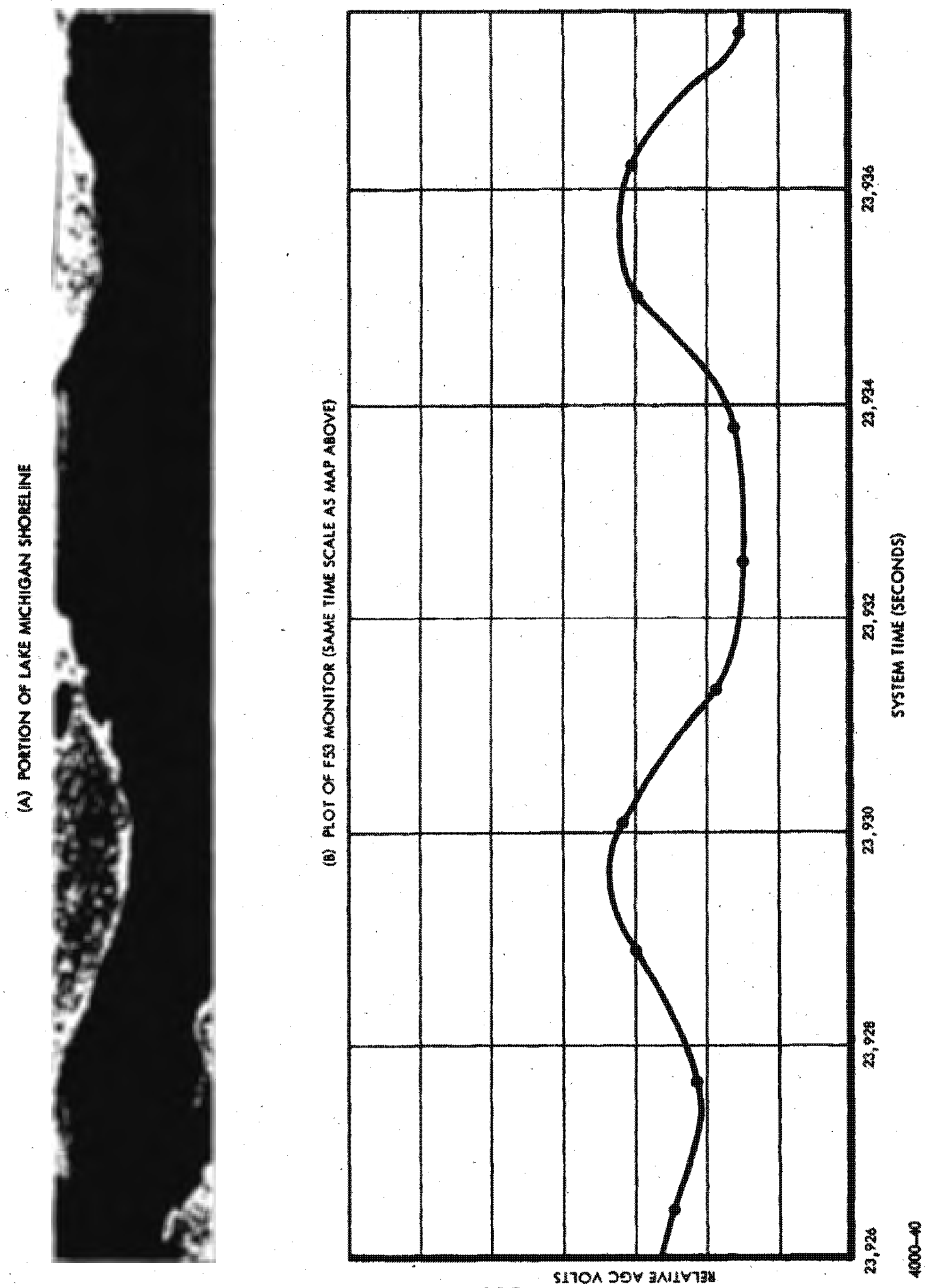

Figure 37 - Automatic Gain Control Operation

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SECTION X - CONCLUSIONS

1. GENERAL

This report has documented the KP-II doppler radar program from inception through completion of an orbital test in an Agena satellite. All of the program objectives were realized during the first flight. The success of the mission in large measure resulted from the extensive environmental testing and the associated corrective action program.

2. PROGRAM RESULTS

The results of the KP-II radar program are summarized below:

1. The use of doppler high-resolution radar for mapping of the earth's terrain from an orbital satellite is feasible within the present state-of-the-art.
2. The performance of doppler radar systems at satellite altitudes compares favorably with the performance of lower altitude aircraft-type radar systems. In particular, satellite-borne systems are not subject to the limitation of resolution normally imposed by platform instability in aircraft.
3. Satellite-borne radar systems, as expected, have the ability to map through all weather conditions and either by night or day, thereby overcoming the main limitations of photography.
4. Wide-band video links and ground-based photographic or tape recording provide practical methods of data recovery.
5. The design criteria used for the KP-II radar have provided a firm basis for design of future satellite radar systems.

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6. The use of clutterlock for steering the synthetic beam was proved to be highly successful.

7. High altitude radar back-scattering coefficients were shown to be in close agreement with previous low altitude data (refer to Appendix II).

3. **RECOMMENDATIONS**

A number of improvements could be developed for incorporation in the present equipment or in future systems. A partial list of these is given below:

1. The present radar signal-to-noise ratio could easily be increased by the use of parametric amplifiers. Presently available units could improve the signal-to-noise ratio by 5 to 6 db.

2. The range interval could be extended by three methods:

   a. By eliminating the azimuth image ambiguity. This would extend the range interval by a factor of two. It could be accomplished by arranging the data processing method so as to eliminate the need for an azimuth offset reference.

   b. By the use of a longer antenna. However, the azimuth resolution is theoretically limited to one-half the physical antenna length.

   c. By the use of multiple channels. This can be done by using separate antennas, each operating at different frequencies, and illuminating different range intervals. Alternately, a single transmitter frequency can be used with multiple antenna sections being used for reception.

3. Range resolution could be improved to be more consistent with the present azimuth resolution. This can be readily accomplished by increasing the system band width and increasing the number of resolution elements of the recorder.

4. On-board magnetic or dielectric tape recorders could be used for delayed read out of doppler data.

5. Automatic circuits could be incorporated in the payload for control of prf selection independently of ground commands. The system could then be programmed for operation during any portion of the orbital period.

6. The system could be repackaged for decreased weight and volume. For a system having the KP-II performance a reduction of weight from 340 pounds to 250 pounds is feasible.

7. Real time electronic correlation and display of selected small areas are possible.

4. FUTURE APPLICATIONS

Satellite-borne radars have wide application to both military and civilian requirements. These include location of military targets, bomb damage assessment, and general surveillance over land and water. Radar data can be used to improve present maps of the Earth, particularly for polar or other remote areas. Detailed mapping of the moon and the planets by orbital satellites using doppler radar is a next logical step.


COURIER CONTROLLED MATERIAL
PROPERTY OF THE UNITED STATES GOVERNMENT
IF FOUND, DO NOT OPEN
TRAILBLAZER 1964:
THE QUILL EXPERIMENTAL RADAR IMAGERY SATELLITE COMPENDIUM
SECTION V:
EVALUATION DOCUMENTS OF THE QUILL RADAR IMAGERY PRODUCTS

The Quill experimental radar imagery satellite produced images for evaluation by intelligence analysts. The question of what organization would evaluate the imagery lingered right after the successful Quill mission. The documents in this section shed light on some of the tension that existed between the Central Intelligence Agency (CIA) and National Reconnaissance Office (NRO) over satellite programs. Eventually the CIA consented to allow its National Photographic Interpretation Center (NPIC) to lead an evaluation effort. The NPIC-led team concluded that based on the Quill results, radar imagery was a promising supplemental source of intelligence to the imagery obtained from the Corona and Gambit programs. The documents in this section also highlight the potential that some saw in radar imagery as a viable source of crisis or quick response satellite imagery. Quill provided imagery data via downlink to a ground station, establishing a much desired characteristic for future imagery programs.

Document 19 — Memorandum from the Director of the National Reconnaissance Office to the Secretary of Defense concerning increasing responsiveness of reconnaissance satellites, 11 January 1965: The Director of the NRO (DNRO), Dr. Brockway McMillan, responded on 11 January 1965 in a memorandum to a request from Secretary of Defense, Mr. Robert McNamara, for quick reaction satellite surveillance capabilities. In his lengthy memorandum, Dr. McMillan reviewed a number of changes underway with the Corona and Gambit photoreconnaissance satellites that could potentially improve the timeliness of photoreconnaissance satellite imagery. He also highlighted a number of NRO initiatives to improve timeliness of satellite imagery as well as the ability to obtain imagery in differing conditions. One effort that Dr. McMillan highlighted was the Quill experiment in radar imagery. McMillan suggested that radar imagery may not reach the resolution requirement specified by the Secretary of Defense, but indicated he would fully explore the potential of radar imagery for quick responses given the results of the Quill experiment.

Document 20 — Memorandum from the Director of the National Reconnaissance Office to the Deputy Director of the Central Intelligence Agency, requesting assistance in evaluating of Quill imagery products, 3 February 1965: After the test flight of the Quill radar imagery satellite, DNRO Dr. Brockway McMillan requested support from the Deputy Director of the Central Intelligence Agency, Lt. Gen. Marshall S. Carter, in evaluating Quill products. Dr. McMillan requested that Lt. Gen. Carter direct the NPIC chair of the evaluation panel to review the Quill program and evaluate imagery from the program. The NPIC chaired panel's study efforts would parallel engineering analysis undertaken by Lockheed Missiles and Space Company as well as Goodyear Aerospace Corporation, the two primary contractors responsible for the Quill system.

Document 21 — Memorandum from the Deputy Director of the Central Intelligence Agency to the Director of the National Reconnaissance Office in response to a request for assistance in evaluation of Quill imagery, 8 February 1965: On 3 February 1965, the DNRO Dr. Brockway McMillan requested assistance from the Deputy Director of the CIA, Lt. Gen. Marshall S. Carter, in assigning members of NPIC to chair an evaluation of the Quill radar imagery program. Lt. Gen. Carter agreed that the potential value of radar imagery for intelligence use should be evaluated. He deferred assigning NPIC until the CIA received a comprehensive briefing on the Quill experiment in radar imagery.

Document 22 — Memorandum from the Director of the National Reconnaissance Office to the Director of the National Photographic Interpretation Center requesting an evaluation of Quill Products, undated: After the test flight of the Quill radar imagery satellite, DNRO Dr. Brockway McMillan prepared a request for assistance from NPIC in evaluating Quill products. Dr. McMillan asked the NPIC, after obtaining support from CIA leadership, to identify the extent to which radar imagery could be interpreted by photo-interpreters, techniques and approaches for radar imagery exploitation, and recommendations for future use of radar imagery systems. Dr. McMillan requested the formation of a study group to address these issues and any others that might be relevant. He requested a final report by 1 July 1965.

Document 23 — Memorandum from the Director of the National Reconnaissance Office to the NRO Staff Director requesting a study of the use of radar imagery in analysis of military targets, 14 April 1965: DNRO Dr. Brockway McMillan requested that the NRO Staff Director, Brig. Gen. James T. Stewart, prepare a study of the use of radar imagery in evaluating military targets. Dr. McMillan specifically suggested evaluating imagery use in determining changes in air and naval order of battle, changes in military transport patterns, and the presence of large military equipment. Dr. McMillan also directed that other studies of radar imagery by the Army, Navy, and Air Force be reviewed as part of this assessment of radar imagery based on the Quill experimental satellite.

Document 24 — Project Quill Exploitation and Evaluation Report by the National Photographic Interpretation Center, 1 August 1965: In the winter and spring of 1965, DNRO Dr. Brockway McMillan requested a review of the Quill experimental radar imagery satellite program and imagery products by the CIA's NPIC. NPIC responded with their Quill evaluation on 1 August 1965. In the report, they reviewed a number of aspects of the Quill program. They reviewed the interpretation value of the Quill products and found that large targets such as aircraft and vessel counts could be achieved. The imagery was limited in providing details about those targets. The NPIC-led evaluation team concluded that technical evaluation of targets such as measurement of distance or of targets themselves was limited due to the lack of resolution in Quill radar imagery. The NPIC-led evaluation team concluded they could exploit the imagery with current equipment, but that their exploitation would be enhanced with radar imaging processing equipment. Finally, the team assessed the intelligence worth of radar imagery and concluded that it would be a very valuable source of intelligence when used in conjunction with photo imagery. The NPIC-led evaluation team recommended an additional study of the facility requirements for radar imagery exploitation as well as a test program to optimize radar imagery collection.

Document 25 — Semi-Annual Report to the President's Foreign Intelligence Advisory Board on the Activities of the National Reconnaissance Program, 1 November 1965 to 30 April 1966: In its semi-annual report to the President's Foreign Intelligence Advisory Board for activities from 1 November 1965 to 30 April 1966, the NRO reported on the Quill experimental radar imagery satellite program and evaluations of the program. The NRO reported that the evaluations indicated that there were potential future uses for a radar imagery program. The NRO also indicated that continued evaluation of the Quill experiment was still underway in order to plan for future radar imagery satellites that would offer both high resolution/small swath and low resolution/wide swath radar imagery capabilities. The satellite studies would be supplemented by aircraft radar imagery studies.

LIST OF EVALUATION DOCUMENTS OF THE QUILL RADAR IMAGERY PRODUCTS

1998000074-02-13

CORONA GAMBIT QUILL

ma f
5.1.1
X Ref 5.1.3
5.2.1.1

DEPARTMENT OF THE AIR FORCE
WASHINGTON

OFFICE OF THE UNDER SECRETARY

January 11, 1965

MEMORANDUM FOR THE SECRETARY OF DEFENSE

SUBJECT: Quick Reaction Surveillance Systems

Reference is made to the following task you recently gave me:

> "Propose a plan to develop the capability for instantaneous satellite reconnaissance with at least G resolution for various uses (particularly in relation to TITAN-III) such as monitoring the arms control agreements, tactical uses, etc."

The stated requirement could be met by day and night photography from a synchronous satellite, reported back in real time electronically. As will be commented on later, this combination of technical capabilities is not likely to be attainable in the foreseeable future.

As a means to approach the desired capabilities, I propose - and indeed have underway - a fairly specific three-phase program: (i) improve existing systems, (ii) incorporate the desired characteristics to the maximum practicable degree in the next generation of satellite systems, (iii) continue studies and hardware investigations looking toward a further generation. Some specifics on each of these phases follow after a brief general discussion. An attached chart summarizes the situation now and at a specific point in the first phase, and sets out for comparison the goals of the first and second phases.

The requirement implied by your task to me is closely related to one enunciated by the Chairman, JCS, in a memorandum to you of March 31, 1964. The attached chart shows that, on missions for which orbits and target programs are prepared in advance, our planned improvements in reaction time will, during the first phase, meet the desired performance in this regard as described by the Chairman's memorandum.

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General Discussion

To approach the kind of resolution stated, we must look to photographic systems operating at medium to low altitudes and limited to daylight photography. For such systems, the daily cycle of the sun limits the times at which desired targets can be covered. The laws of orbital motion and the distribution of desired targets fix the orbit and the rate at which targets can be photographed on a given mission, and thus constrain the times and places at which film or information can be recovered. In addition, bad weather over the target area may preclude photography at the time desired.

In addition to these constraints, which are intrinsic in nature and introduce delays varying with the mission to be flown and with the weather, there are other sources of delay introduced by hardware and by procedures, some of which can never entirely be eliminated. Assuming that a mission is defined by a statement that a particular set of targets must be photographed, a complex sequence of preparatory actions must take place converting this mission into plans for a flight, and then accomplishing the flight. In general terms the actions are of the following kinds, although not necessarily conducted exactly sequentially:

A. Determination of the orbit to be used and preparation of necessary instructions and documentation that are specific to a mission and orbit. These plans define a flight except that they may contain the date of launch as an open parameter.

B. Establishing hardware in a condition for use that is not specific to a particular flight.

C. Preparation of hardware that is chosen specifically for a flight, into a condition specific to that flight but not necessarily specific to a date of launch.

D. Determination of a date of launch.

E. Issuance to the range (WTR) and to the Satellite Control Facility (SCF) of instructions specific to the flight and to the date of launch, and preparation of the WTR and the SCF accordingly.

F. Final countdown and launch, representing the completion of actions initiated in B, C, and E.

An ideal mode of operation is one in which the planning operation, A, is accomplished in a few hours by computer, and steps B through F are then accomplished in a rapid countdown. In practice, I am sure we will always have to undertake B in advance, and depend upon a checked out system standing by in a reasonably ready condition.

Step A, preparation of flight plans, will always have to be accomplished largely in advance of those other than B and D. It can be expedited by computer. Because of the many constraints imposed upon a flight plan by the mission itself, by the requirements of range safety, by the limitations of the booster, and by the characteristics of guidance systems, a great deal of computation and checking by people must be done in this step. I cannot visualize cutting it much below 24 hours even with the most sophisticated of systems. Fortunately, as with ballistic missiles, the likely missions can be anticipated and a library of flight plans prepared in advance. On a mission covered by the library, the time consumed by step A does not contribute to delay.

Step C, commitment of the hardware to a specific flight, and step F, final countdown, depend upon the hardware involved. In principle, at least, they can be cut to a few hours by proper design. In fact, on GAMBIT today they are not controlling; step C will be controlling on CORONA as long as the THOR is used as its booster.

Step E, preparing the range and the Satellite Control Facilities for a specific flight on a specific date, is largely procedural. Many support activities are involved, people must be informed and perhaps even rehearsed, and potentially conflicting requirements must be identified and resolved. Range safety is of major concern. In principle, procedures can be tightened sharply, but in practice it is probably this step and the requirement for daylight over target that will ultimately control the minimum delay between completion of A, the determination of a flight plan, and launch.

Another factor in connection with quick-reaction missions that is of interest, although not directly connected with delay, is efficiency. Short missions necessarily cover fewer targets than long ones, and one would like to get as much intelligence return per launch as possible. In the case of interest here, he would like to do so without compromising quick return of the primary data. Obviously a multiple recovery system helps greatly in this connection. Also, anything that allows a broader or more flexible selection of orbits leads to the possibility of more efficient and more expeditious coverage of desired targets.

There are many detailed changes over present systems and practices that can serve to improve or shorten the preparatory actions A through E discussed above, and can improve efficiency or flexibility of target coverage. Important improvements of degree or kind possible within the framework of CORONA and GAMBIT, and of our present launch and recovery facilities, are:

1. Improve the ability of the hardware to stand in a ready condition for long periods, facilitating or economizing step B.

2. Reduce the time required to prepare new orbits and camera programs, facilitating step A.

3. Reduce the delay in configuring the hardware to match a desired orbit, facilitating step C.

4. Recover in the present recovery area at night and on South-to-North passes, providing for earlier or more flexibly chosen recoveries.

5. Process recovered film while in flight from the recovery area. This attacks a significant source of delay in present operations.

6. Add alternate launch facilities or, alternatively, increased boost capabilities, to permit orbits more efficiently covering areas such as Cuba, the Soviet missile belt, etc.

4 13

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Further improvements can be considered which require significant to major new developments. These are listed below roughly in an order of increasing difficulty and decreasing incremental effectiveness:

7. Develop a multiple recovery system to maintain efficiency in total coverage even if early recoveries are made, say after one day or after one pass.

8. Develop a land recovery system. The reduction in time-in-transit of recovered film may not be particularly useful in the presence of (5), but in general, land recovery will increase the number of recovery opportunities per day. As a simpler step, one could consider deploying our present recovery forces to new bases for special missions. The time required to do this, perhaps a few days, would have to be counted as a preparatory delay. The alternative of setting up permanent recovery forces in many areas would be expensive and inefficient. In fact, the present Hawaiian recovery base is very conveniently located relative to most of the orbits that can be launched from the U. S., and it provides uniformly good weather. Its principal drawback is its distance from Washington, and (5) attacks this problem.

9. Develop a maneuverable land recovery system, further extending the flexibility of selecting recovery times.

10. Add extensive fuel for orbit adjustments to allow somewhat freer selection of targets and of recovery times and places.

11. Develop the capability [redacted] This contributes to efficiency but, in the presence of (1), perhaps not much to elapsed time.

Consideration has several times been given to developing an air-launched satellite system, one of its attractions being flexibility in selection of launch sites, and hence of orbits. Such systems have always been discarded, however, because the payload available has been inadequate to support adequate photographic resolution.

One of the most troublesome problems, practically, in achieving any kind of quick-reaction capability is the reliability of the equipment. Our latest CORONA launch, for example, went through four countdowns before it was finally - and successfully - launched, five days late. I am afraid that a long and difficult period of evolution will be experienced before the theoretical possibilities of any particular quick-reaction system will be regularly realizable in practice. There are no dramatic actions or inventions that can be expected to substitute for the meticulous continuing attention to detail that is required to design and maintain a complex system capable of a high state of readiness.

Improvements to Present Systems

Phase (i) applies to CORONA and GAMBIT, and concentrates on items (1) through (6) outlined in the preceding section. Specific information is given in the paragraphs below, correspondingly numbered.

1. During February, we plan to launch a CORONA that has stood in the R-1 condition for at least 15 days. The criteria defining the limits of this hold condition are not sharp, and we expect to be able to improve beyond this point. I wish to defer experiments with GAMBIT in this direction until actions now under way to improve its recently unreliable performance show results.

2. Preparing flight plans for CORONA is, for accidental but unavoidable reasons, a very clumsy process. Fortunately, the variety of significantly different possible missions is low, so that a useful library of flight plans is practicable. Flight planning for GAMBIT is well automated, and can be done rapidly ab initio, provided one does not ask for optimized coverage of too large a list of targets. On the other hand, a comprehensive library of GAMBIT flight plans could be very extensive.

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We have a small library of CORONA flight plans now, and are working with the intelligence community to identify, in an order of priority, useful additions to it. In the case of GAMBIT, we plan to establish a library of critical missions, and then simply accept the fact that if a new mission must be planned quickly, we cannot expect it to be optimized for ancillary coverage. We are working with the intelligence community to identify the missions most important for this library. By summer I think we can have a useful library for both CORONA and GAMBIT, and will have in operation a regular procedure for keeping it up to date.

3. To configure a THOR for a particular launch trajectory requires physical disassembly of part of the booster and physical changes to its autopilot. During this month, improvements to this process will be effective so that it can be done at day R-8; this is about the limit of improvement short of a major change in the launch vehicle. The ATLAS booster is not handicapped in this way, and is ready to fly on any launch trajectory within its capabilities down to the point that final countdown begins.

4. Recovery forces are training on night recoveries and on recoveries on South-to-North passes at the present time, using air-dropped training equipment. I may later recommend flying an extra CORONA J mission for an operational test of these and other capabilities. Alternatively, we may find it acceptable to test them on a scheduled mission without great risk to the intelligence take.

5. Contractors are preparing bids now to develop a film processor that can fly in a C-135 and process satellite film with satisfactory quality. Use of such equipment would remove about 14 hours of delay that now occurs in transporting film from the recovery area to the processing plant. It will probably be about a year in development, hence not available much before the end of FY 66.

6. Planning for an alternate launch site at ETR is in process and will be reported to you soon. It appears that we may be able to achieve the same results more quickly and at less expense by certain payload and booster changes which will allow a much wider selection of orbits from the present launch sites at WTR. I want to report on this alternative at the same time.

In connection with this last point, there is no question that it is relatively easy to substitute an ATLAS for a THOR booster on CORONA. This would eliminate any real need for launching CORONA from ETR. Equally important for this discussion is the fact that it would permit other changes so that CORONA could have the same pre-launch and on-orbit flexibility as GAMBIT. If this is done, then, CORONA could be expected finally to show the same flexibility as that shown for GAMBIT in the column on the attached chart labelled "GAMBIT Goals." I expect to report to you soon on this possible change of booster for CORONA.

Turning specifically to the chart: the first column shows CORONA as present procedures operate. The improvements in going to the second column are largely procedural, but include an actual change to the THOR to facilitate step C. This column also shows, as a goal, the effects of introducing an airborne film processing plant.

The differences between the two GAMBIT columns are entirely procedural and somewhat conjectural, except for those due to the proposed airborne processing. The most difficult problem is to tighten up the preparatory procedures on the range without sacrifice of range safety (Step E). The 12-hour goal shown is simply a goal and should not be regarded as certain of accomplishment on a regular basis. It is more likely of achievement on a few highly prepared and stereotyped missions than on an arbitrary new and complex mission.

The G3 goals differ from those of GAMBIT only in the hope that the TITAN IIIX booster may permit simpler countdown procedures and longer holding times.

Examination of the chart shows that, even exploiting all of the improvements (1) through (5), and using a pre-determined orbit, at best about 36 hours will elapse between the R-1 condition and the initial reading of a day's photography. For surveillance

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of some areas, one could recover after one pass, in the best case then cutting the elapsed time to 22 hours at the expense of a drastic reduction in coverage. In the worst case, that in which a decision to launch comes too late to meet the first launch window (set by the requirement of daylight over the target), one must add about 22 hours to the figures quoted.

New Satellite Systems

The next generation of photographic satellite systems consists of GAMBIT-3, a high resolution pointing system, and a new search/surveillance system now going through its early definition phase. Both of these systems will incorporate to the best reasonable extent the operating conveniences represented by (1), (2), and (3) above, and can of course take advantage of improvements such as (4) and (5). Flexibility in choice of orbit can be expected because of the capabilities of the TITAN III-X or TITAN III class boosters to be used. Here again, however, a delay of 22 to 60 hours can be expected between the R-1 condition and reading of the first recovered film.

Consideration is being given to incorporating in each of these new systems the option to use multiple recovery vehicles. This does not influence reaction time, but greatly improves the efficiency of operation, measured in coverage per launch, when an early recovery is required.

Among the possibilities for new search/surveillance systems is one that could search the whole Soviet Union, at say 4 feet resolution, in four days. Such a system trades resolution for a very impressive "quick reaction" search capability.

Longer Term Prospects

Ideally, the "instantaneous" requirement calls for a satellite stationed at synchronous altitude, capable of taking pictures day or night, and reporting these pictures back electronically. To achieve the stated resolution of about

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three feet from synchronous altitude would require a lens or mirror more than 80 feet in diameter - some 20 times larger than we are willing to attempt with the required precision today. Consequently, even for the distant future, one must think of systems which fly at much lower altitudes, covering target areas and encountering recovery or read-out stations only periodically. Granting this, some very rough estimates are given below of what may be possible, perhaps after major new developments.

Daylight photography: Using TITAN III-C, and not extending the optical art much beyond that envisioned for GAMBIT-3, one might look forward to a system which flew at about 400 n.m. altitude and provided a resolution of 3 feet on the ground. On each pass over the United States such a system could report back electronically, at the indicated resolution, pictures of a few targets each 10 miles by 10 miles square. Perhaps an ultimate practical read-out speed might permit ten targets per pass per read-out station.

Night and foul weather: Using laser illumination, a capability for night photography at perhaps 10 foot resolution might be achieved on a TITAN III-C. Read-out of several targets per pass over the United States would be possible. Alternatively, a radar system might achieve resolutions almost this good, and would work in foul weather as well as at night. Either of these possibilities would require a nuclear power source for reasonable lifetime on orbit. Both require, and are getting, further study.

Exploratory Program

There are some specific efforts in the NRO program to explore or to develop the capabilities that are critical to the several kinds of capability discussed earlier. The more important activities are listed below.

The NRO budget for FY 66 contains funds earmarked for initiating development of a new recovery system. It is expected that this development will provide for multiple recoveries, returning four to six separate packages of film from a single mission. Requirements will be defined in detail as the characteristics of the new general search/surveillance system are clarified. The objective is to have a multiple recovery system available during FY 1967 as an option on GAMBIT-3 and on the new search/surveillance system.

The START program, funded in the Air Force budget, is presently studying the long-term prospects for development of a highly maneuverable recovery system. Two kinds are under examination, one to return a large payload, and the other, to return a small payload, as might be appropriate for a multiple recovery system. Emphasis is currently on the latter system. Any development that results will be several years in coming, and will require a further definition of requirements appropriate to the sensor systems expected then to be available.

Under the classified code name QUILL, an experimental high resolution radar satellite has just successfully undergone a test in orbit. This is one of the more dramatic milestones in a continuing program of study and development exploring the technology of satellite borne radar systems. Although it seems unlikely that such systems will ever achieve the three-foot resolution suggested in your statement of requirements, I plan, during the next several months, and using the results of the QUILL tests, to try to develop a definitive report on what one might expect to accomplish with a radar satellite, and to relate this to various potential requirements.

Electronic read-out has always been an attractive objective. The SAMOS project included two read-out systems, E-1 and E-2. E-1 flew and successfully returned results in January 1961, with pictures showing about 100 foot resolution. E-2 successfully transmitted pictures from the payload during countdown, but efforts toward flight were stopped after launch failures. The USSR is known to have a read-out system operating at an estimated resolution of about 75 feet.

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The NRO continues to support study and development efforts in the technology of read-out systems. The critical limiting factor has always been the actual reading out and transmitting of pictures at a speed high enough to permit a useful return during the time that the satellite is visible from a read-out station. Current technology permits transmitting only about one target per pass per read-out station, and limits the area covered by, or the resolution of, that particular return. Fairly definitive results bearing on future possibilities are now coming out of our NRO studies. An attempt will be made to summarize these and evaluate their implications for several potentially interesting applications, including the application to quick-reaction surveillance systems.

You have recently directed me to undertake studies and hardware efforts related to surveillance systems to be flown at synchronous altitudes. Although such systems, as I noted earlier, cannot be expected to support image forming sensors with three-foot resolution, they may be expected to collect important collateral information for surveillance purposes.

Brockway McMillan
Brockway McMillan
Director
National Reconnaissance Office

Attachment

cc - DepSecDef

12

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~~TOP SECRET~~

SAFSS
1965 FEB 3 14 48

SAFSS/Capt [redacted]/Gen Stewart/29Jan65

[redacted]

MEMORANDUM FOR DIRECTOR OF CENTRAL INTELLIGENCE AGENCY

SUBJECT: Evaluation of QUILL Feasibility Demonstration

On 21 December 1964 the first QUILL feasibility demonstration high resolution radar was successfully orbited. Both readout data and recovered data have been examined. Preliminary analysis indicates that all feasibility demonstration objectives were met.

A detailed engineering analysis of the mission is currently under way by contractors. This analysis will deal with comparisons between readout and recovered data, effects of meteorological conditions, vehicle influence on radar performance, and other factors which, from an engineering sense, are necessary for a complete performance evaluation.

I feel that a parallel analysis should be made to determine the value of satellite-acquired radar imagery as an intelligence source. I feel that NPIC is the best qualified agency to chair a team for this purpose. If you agree, my staff will work out the details with NPIC.

Brockway McMillan
Director
National Reconnaissance
Office

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2. SS-6
3. SS-1
4. RF-1
5. RF-2

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CENTRAL INTELLIGENCE AGENCY

WASHINGTON 25, D. C.

[redacted]

OFFICE OF DEPUTY DIRECTOR OF CENTRAL INTELLIGENCE

1965 FEB 8 16 23

8 FEB 1965

MEMORANDUM FOR: Director, NRO

SUBJECT: Evaluation of QUILL Feasibility Demonstration

1. This memorandum is in response to yours of 3 February 1965, subject as above. It is my understanding that we were to receive a comprehensive briefing on the QUILL system and it would seem timely now that this should be scheduled.

2. I agree that analysis of the potential value to intelligence of this source is an appropriate complement to the engineering analysis which you advise is now under way. Determination of the precise auspices under which this analysis is conducted should await a fuller understanding on our part of the factors involved.

Marshall S. Carter
Lieutenant General, USA
Deputy Director

BYE #0084-65
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Approved for Release: 2022/08/18 C05139542

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MEMORANDUM FOR Director, National Photographic Interpretation Center

SUBJECT: QUILL Product Evaluation

As you know, Project QUILL is an orbital experiment of the use of high resolution radar for satellite reconnaissance purposes. The first feasibility mission was flown in December 1964, and the radar was operated successfully over the continental USA for several days.

A thorough engineering analysis of the results is underway by the Project Office/contractor team. In addition, even though the product (in terms of range, resolution, swath width, obliquity, etc) is not necessarily representative of what one might expect from an operational system, it nevertheless appears desirable to conduct an evaluation of the intelligence worth of satellite radar imagery and its impact on the Community.

In that vein, it is requested that NPIC chair an ad hoc QUILL evaluation team. I will request the DIA to provide you the names and clearance status (QUILL is handled under the BYEMAN system) of up to six people to serve as members of the team. You may appoint such other members as you consider necessary to a well-rounded analysis.

As I see them, major objectives of the ad hoc evaluation team are generally as follows:

a. Determine the amenability of the QUILL High Resolution Radar products to interpretation by trained PI's to include problems associated with target detection, recognition and identification, training and interpretation aids.

b. Determine the techniques, limitations, advantages and special applications of this type of satellite derived intelligence product as a supplement to current photographic reconnaissance sensors and as a separate satellite reconnaissance sensor.

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c. Recommend swath widths, resolutions, and beam depression angle for these applications.

You may wish to modify and/or add to these objectives. I therefore should like to review your evaluation plan shortly after the effort gets underway.

As soon as the team has been assembled, the chairman should contact Colonel Buzard of the NRO Staff, so that necessary arrangements can be completed for briefing the team on the QUILL system and the December mission, and providing the required material for evaluation.

The ad hoc team should schedule its activities so as to present a final report and briefing to me not later than 1 July 1965.

Brockway McMillan
Director
National Reconnaissance Office

cc: Deputy Director, CIA

1. NPIC
2. DepDir,CIA
3. SS-1
4. SS-6
5. RF-1
6. RF-2

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April 14, 1965

MEMORANDUM FOR DIRECTOR, NRO STAFF

SUBJECT: Study of Radar Imagery

You are requested to plan a study of the problem of interpreting imagery from synthetic-array (side looking) radars. The principal interest in these studies is in images having a resolution of 25 feet or better, and in military targets appropriate to that resolution. An important intelligence objective is to sense changes in air and naval order of battle, changes in major transport activity, and the presence of heavy military equipment. Tests should determine how well this objective can be met, and what kind of base of primary data is required.

It will be necessary first to learn what studies have already been made, to determine what imagery is now available - e.g. from [redacted] - for possible further analysis, and what radars are now operating that could be used for gathering further data. Army and Navy sources should be examined, as well as Air Force. When this information is assembled, I will want to discuss plans for such studies as seem required.

Brockway McMillan
Director
National Reconnaissance Office

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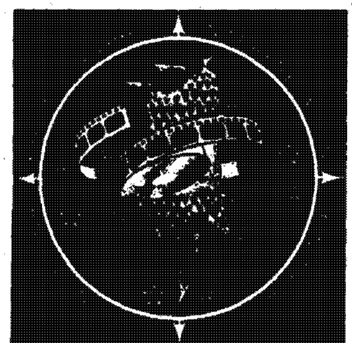

PROJECT QUILL EXPLOITATION EVALUATION REPORT

[redacted]

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PROJECT QUILL

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BYE-41778/65

I. PROJECT DESCRIPTION

A. Purpose

The purpose of the exploitation evaluation of Project QUILL is to determine the intelligence worth of satellite side-looking radar imagery as an information collection system (BYE #36346-65 from Director, NRO, to Director, NPIC, and BYE #41652-65, NPIC Project QUILL Evaluation Plan).

B. Objectives

1. "Assess the amenability of the QUILL High Resolution Radar products to interpretation by trained PI's to include problems associated with exploitation techniques in target detection, recognition and identification, training, and interpretation aids."

✓ 2. "Assess the limitations, advantages, and special applications of this type of satellite-derived intelligence product as a supplement to current photographic reconnaissance sensors and as a separate satellite reconnaissance sensor."

✓ 3. "Assess the benefits to be derived from various swath widths, resolutions, and beam depression angles for those applications unique to radar satellite sensors." (It is emphasized that radar sensors were examined from the point of view of image utility only. Operational problems which may be inherent to this type of sensor were not considered.)

C. Materials for Evaluation

The QUILL evaluation materials were obtained from 14 passes of Mission 2355 made over the United States [redacted] from 21 December to 24 December 1964. The mission was flown for research and engineering purposes and not for intelligence collection purposes. Consequently, some of the flight and system information and data that is required for complete interpretation was not obtained and some types of targets of current intelligence importance were not covered.

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In addition, a limited amount of material was collected employing an airborne high resolution radar to map some of the target complexes contained in the QUILL product. This material was used to supplement the QUILL material employed only in the Intelligence Worth evaluation.

1. Radar Imagery Recorded

The material for evaluation, obtained from the 14 passes, was recorded by 3 methods.

a. Recovered Imagery

Physically recovered from the vehicle in the form of a Doppler History Record and converted to human readable imagery in a correlator. This material was from the first 7 passes only.

b. Transmitted Imagery

Transmitted and recorded as a Doppler History Record and fed into a correlator. This coverage was from all 14 passes.

c. Transmitted and Taped Imagery

Transmitted by data-link, recorded on magnetic tape, and later transformed into a Doppler History Record and fed into the correlator. This coverage was from all 14 passes.

2. Reproductions Received for Evaluation

Radar imagery was received in two forms:

a. Contact print on 70 mm film.

b. 2.6X enlargement on 9.5 inch film.

3. Imagery Evaluated

a. The primary evaluations were made of Recovered imagery.

b. A select sampling was made from all 3 methods of recording and was given a comparative evaluation to determine the relative losses of information.

c. The 2.6X enlargement received a technical evaluation but was omitted from interpretation evaluation because of its degradation and poor quality.

II. DISCUSSION

A. General

This discussion is a summary of the results of the efforts of 5 teams charged with attaining the objectives of the QUILL evaluation. The detailed reports of the teams are included as appendixes A thru E, which also contain results and conclusions beyond the basic objectives of the project evaluation.

B. Interpretation Evaluation (See Appendix A)

The interpretation effort involved the overlapping functional categories of mission plotting and scanning, target indexing, preliminary analysis of significant targets, and the detailed analysis of selected targets.

Mission plotting and target indexing were accomplished without difficulty with the aid of charts and maps. The continuous-scan format, the lack of atmospheric interference, and the photo/map similarity of the QUILL imagery facilitated the performance of these functions.

Target descriptive information of a general nature was readily derived during both the preliminary and the detailed analyses without the use of collateral information. The information derived from the QUILL imagery included the determination of activity levels of ports and rail yards, the occupancy of vehicle parks, and the approximate counts of aircraft at airfields. The use of collateral information and comparative visible spectrum imagery, i.e., KEYHOLE, added considerably to the reliability and the amount of detail derived from the QUILL imagery. Although targets not indicated on maps or in collateral were detected in the QUILL imagery, the derivation of substantive descriptive information was extremely difficult in many instances without the use of comparative visible spectrum imagery. The detailed analysis obtained from visible spectrum imagery was enhanced through its comparison with subsequent QUILL imagery to include target change detection.

Significant target information, such as aircraft and vessel counts, was derived from the QUILL imagery. Although this information is inherently less defined in nature than that obtained from visible spectrum imagery, this factor does not necessarily detract from the significance of the information derived from QUILL imagery.

Similar detail on most of the targets was derived from both the Recovery and Transmitted imagery. However, the degradation of the imagery from the Transmitted-tape format resulted in the loss of significant target detail.

The variables involved in the radar return from a given target and the relatively general nature of the information derived from QUILL imagery affect the accuracy of such information as aircraft and vehicle counts and functional determinations. However, reasonable estimates can be derived. The accuracy of these estimates is improved considerably through comparison with visible spectrum imagery and the maximum use of collateral information.

C. Technical Evaluation (See Appendix B)

The evaluation of the technical aspects of the QUILL material included a study of its characteristics determined by an analysis of the film quality and study of problems associated with plotting, titling, ephemeris data, and general handling.

The mensuration analysis included the determination of scale, the measurement of long distances, and the measurement of target dimensions. The QUILL mission was primarily a research and engineering test mission having no particular regard for target measurement requirements. In the majority of cases, precise measurements from QUILL imagery could not be obtained. This was partly due to the lack of reference data, such as normally received from a satellite reconnaissance mission, and partly due to the peculiarities of radar imagery. This resulted in a technically incomplete mensuration analysis. Nevertheless, the evaluation indicated that the QUILL imagery can be measured with reasonable accuracy from point to point and that the degree of measurement accuracy increases in the longer distances.

Accurate measurement of small targets is difficult because of the lack of sharpness of image edges and because of inaccuracy in establishing the image reference points of positive-return targets which are rarely imaged in their actual configuration.

The absence in the film format of mission reference data similar to that provided in the KEYHOLE program was a serious handicap to mensuration, but it is subject to ready correction through the application of techniques and equipments such as are used in other satellite systems.

D. Equipment Evaluation (See Appendix C)

The exploitation equipment currently on hand in interpretation facilities, such as the NPIC, is capable of handling QUILL mission material when it is exploited in a manner similar to a KEYHOLE read-out.

The development and installation of an in-house optical data processor (correlator) capable of enhancing target imagery detail would considerably improve the exploitation capability with regard to providing flexibility and timeliness to the detailed read-out.

In the event that a requirement for near real-time exploitation capability is generated by the collection system's real-time image transmission capability, the addition of correlating, multiple mission viewing, and automatic information retrieval would be required in the exploitation center. The nature, sophistication, and extent of such equipment would depend upon the real-time requirements, the volume and nature of the imagery of Doppler History Record received, and the type of read-out.

E. Intelligence Worth Evaluation (See Appendix D)

1. The estimated intelligence worth of a radar sensor was established through an evaluation of the following 4 major considerations.

a. The potential information collection capability of such a sensor against selected Essential Elements of Information (EEI) under certain operating conditions.

b. The advantages of the system which supplement photo sensors.

c. System limitations.

d. Special applications of such a system within selected international environments.

The collective evaluation of these considerations indicated that radar sensors could be extremely valuable as a supplemental imagery collection system during Cold War and Crisis situations and would be almost completely satisfactory as a separate system during a General War environment for the purpose of Strike Effectiveness Assessment (SEA).

2. The potential information collection capability was evaluated

for QUILL as well as QUILL-Improved (resolution approximately 10 feet in both range and azimuth) products. Furthermore, each of the preceding was evaluated as separate and supplemental collection systems. It was estimated that QUILL products were, at most, marginal information-producing materials during Cold War and Crisis situations, particularly as a separate system. However, they were estimated to be most productive for SEA during a General War environment, even as a separate system. QUILL-Improved products were considered to have substantially more information potential when compared with QUILL, particularly as a separate collection system for SEA. As a separate system, even these materials have limited information potential during Cold War and Crises; however, when employed as a supplemental system, their potential is significantly enhanced. The evaluation relative to scientific and technical information potential revealed that even QUILL-Improved products held little promise of providing anything of significance. Consideration was also given to a Post Attack Reconnaissance (PAR) mission during General War, and it was determined that the relative information potential would be almost identical to the Crisis situation.

3. The major advantages of a radar system, as a supplement to photo sensors, were considered to be threefold. They would be:

a. An essentially all-weather system.

b. A day-night system.

c. A potentially "quick response" system.

All of these advantages make a radar sensor invaluable where short response time is a major consideration.

4. The evaluation indicated a major limitation as an intelligence collection system. A radar sensor is extremely limited in providing meaningful information on previously unknown targets.

5. There were significant special applications for a radar sensor in each of the 3 international environments considered. During Cold War, changes or new construction activity could be detected, although not identified, in areas where weather or light conditions precluded photo acquisition, thereby increasing the efficiency of the operation of photo sensors for search and surveillance purposes. During both Crisis and General War, the quick-response characteristic makes its application most significant.

F. Collection System Evaluation (See Appendix E)

The objective of the Collection System Evaluation Team was to assess the limitations imposed upon the QUILL imagery as a result of collection equipment characteristics and to determine which characteristics might be improved in order to enhance the intelligence yield of the product.

As a result of this study, a number of system characteristics have been isolated and analyzed with regard to their influence on imagery quality and utility. To a large extent, these analyses have been subjective in nature since a sufficient quantity of QUILL data is not available.

It is clear that in order to proceed with the optimum design and development of an advanced radar system, a better quantitative understanding of the relationships between image utility and the various system parameters must be achieved. The primary parameters which require quantitative, experimental investigation are:

Range and azimuth resolution
Signal-to-Noise Ratio
Depression angle
Dynamic range
Radar frequency and polarization combinations

Although there are other characteristics which require study, it is considered essential that sufficient quantitative data be acquired on these 5 characteristics in order to design a system which would produce optimum imagery.

III. CONCLUSIONS

A. The QUILL High Resolution Radar products are amenable to interpretation by trained interpreters. Interpretation is enhanced by correlation of the QUILL products with collateral.

B. Previously known targets can be located, identified, and described, significant target changes and activities can be discerned, and previously unknown targets can be detected.

C. The analysis of QUILL imagery is enhanced significantly by variable processing with an optical data processor (correlator).

D. The exploitation of QUILL imagery on a near real-time basis with simultaneous comparison of visible spectrum imagery of selected targets is feasible.

E. In addition to the consideration of ground resolution as a separate and important factor influencing the information produced by radar imagery, the factors of dynamic range, look-angle, and frequency spectrum should also be considered.

F. A radar sensor would be of value in supplementing visible spectrum sensors in Cold War for search and surveillance purposes.

G. A radar sensor would be of definite value as a supplement to visible spectrum sensors for indications during a Crisis and for Post Attack Reconnaissance (PAR) during General War.

H. A radar sensor would be of very high value, even as a separate system, during General War for Strike Effectiveness Assessment (SEA).

I. The collection system employed on this QUILL mission represented a significant technological achievemnt. It demonstrated that very good quality radar imagery can be acquired from an orbital system during bad weather and darkness. It also demonstrated that near real-time strategic intelligence acquisition is feasible.

J. Notwithstanding the success of the collection system on this mission, it is highly probable that it can be greatly improved to produce much better imagery.

K. A QUILL-Improved system (10 feet in range and azimuth resolutions) seems justifiable.

IV. RECOMMENDATIONS

These recommendations are based on the assumption that satellite side-looking radar will be used operationally.

A. It is recommended that a thorough study be made of the requirements for the exploitation facility and exploitation procedures to include a near real-time capability.

B. It is recommended that a test program be initiated to investigate various parameters of the collection system in order to optimize the quality and utility of the resultant imagery.

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Project IDEALIST—OXCART—CORONA—GAMBIT—
QUILL—[redacted]—HEXAGON—DORIAN

SEMI-ANNUAL REPORT

TO THE

PRESIDENTS FOREIGN INTELLIGENCE

ADVISORY BOARD

ON THE

ACTIVITIES OF THE

NATIONAL RECONNAISSANCE PROGRAM

1 NOVEMBER 1965 — 30 APRIL 1966

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SEMI-ANNUAL REPORT

TO THE

PRESIDENT'S FOREIGN INTELLIGENCE

ADVISORY BOARD

ON ACTIVITIES OF

THE NATIONAL RECONNAISSANCE PROGRAM

1 Nov 65 - 30 Apr 66

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HEXAGON/QUILL/[redacted]

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I. FOREWORD

The organization and functions of the National Reconnaissance Office remain essentially unchanged since the last Annual Report to the Board, in October 1965. Additionally, there have been few significant changes in USIB intelligence requirements against which the efforts of the National Reconnaissance Program are directed. These items are not included in this Semi-Annual Report but will be covered in detail in the next Annual issue.

Recent significant decisions of the NRP Executive Committee concerning the new general search system (HEXAGON) and the initiation of the [redacted] program are reflected in this report.

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QUILL - The successful QUILL feasibility demonstration in December 1964 established that there is nothing unique in the operation of a relatively high powered radar in a space environment. The subsequent evaluation by a National Photographic Interpretation Center team of the potential of a satellite radar for reconnaissance identified missions where such a system could be of definite value, both as a supplement to photographic coverage and as a separate sensor. These included use in Crisis Indications and Strike Effectiveness Assessment missions.

During the period of this report, the National Reconnaissance Office has been conducting several studies related to further definition of possible operational satellite radars. Testing the remaining QUILL subsystems has been completed. The data obtained are expected to be of value in design and fabrication of any future radar systems. Related design studies for state-of-the-art spacecraft wide band magnetic tape recorders have been completed.

Additional studies still underway and expected to be completed by September 1966 include:

1. Two system studies for long lifetime, variable mode (high resolution/small swath and low resolution/wide swath) satellite radars.

2. Testing of critical experimental subsystems and components.

3. Investigations for readout techniques to overcome some of the limitations in state-of-the-art spacecraft tape recorders.

4. Target signature studies.

This summer, imagery typical of targets for Crisis Indications and Strike Effectiveness Assessment missions will be obtained by an aircraft. (The QUILL feasibility demonstration has shown that aircraft data should not differ from comparable quality imagery obtained from satellites.) This imagery will have various ground resolutions, look angles, signal to noise ratios and dynamic ranges and will be provided to NPIC for determination of the effects of the various parameters on image interpretability. This study activity will continue through September of this year.


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TRAILBLAZER SECTION 1964:
THE QUILL EXPERIMENTAL RADAR IMAGERY SATELLITE COMPENDIUM
SECTION VI:
QUILL PROGRAM CLOSEOUT
DOCUMENTS

Quill would gradually fade into the background as the National Reconnaissance Office (NRO) undertook new efforts to obtain imagery from space. The final documents contained in this compendium represent the closure of the program. By the late 1960s, the only question remaining with respect to Quill was whether or not to maintain strict controls over access to Quill related information. These documents show that those controls were not necessary. Quill was essentially retired with the decision to remove the program from the security controls that governed most other national reconnaissance programs.

Document 26 — Memorandum for the Record concerning dropping Quill from Byeman controls, 28 May 1968: In a Memorandum for the Record dated 28 May 1968, the Chief of the Special Security Center, responsible for Byeman control, indicated that the Central Intelligence Agency (CIA) Deputy Director for Science and Technology had no objections to dropping Quill from the Byeman control system. The Director noted that the Office of Special Programs at CIA also had no objections to dropping the control.

Document 27 — Letter from the Central Intelligence Agency's Deputy Director for Science and Technology to the Director of the National Reconnaissance Office regarding dropping Quill from Byeman Controls, 6 February 1969: The CIA Deputy Director for Science and Technology, Mr. Carl Duckett, wrote to Director of the NRO, Dr. Alexander Flax on 6 February 1969, confirming the Director of Central Intelligence, Mr. Richard Helm's, decision to drop Quill from the Byeman control system.

Document 28 — Security Cable notification of removal of Quill from Byeman Controls, 10 February 1969: On 10 February 1969, the NRO released a cable with instructions that the Quill program was no longer controlled under Byeman security controls. Quill would be identified as a NRO study in future references. Quill imagery would only be released on a "must know" basis, as would be the case for its engineering data. The cable represents a closing chapter for the highly successful Quill experimental radar imagery satellite. The Quill program established a strong foundation for the national reconnaissance satellite development efforts that would follow in the NRO.

LIST OF QUILL PROGRAM CLOSEOUT DOCUMENTS

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SSC-0189-68

28 May 1968

MEMORANDUM FOR THE RECORD

SUBJECT: QUILL

On 28 May 1968, [redacted], C/SMS/DD/S&T called and stated that in connection with subject program, his office has no objection ~~to~~ dropping the QUILL program. After checking with OSP Security, he learned that OSP had no objection to dropping the program.

[redacted]

Chief, Special Security Center

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The Honorable Alexander H. Flax
Director, National Reconnaissance
Office
Room 4E968, Pentagon

Dear Al:

Mr. Helms asked that I convey to you his approval of your request to delete QUILL as a BYEMAN project indicator.

Sincerely,

Carl E. Duckett
Deputy Director
for
Science and Technology

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PRIORITY [redacted]

QUILL, CORONA, DORIAN, GAMBIT, HEXAGON

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EFFECTIVE IMMEDIATELY, THE USE OF THE CODEWORD QUILL AS A SECURITY PROJECT INDICATOR UNDER THE BYEMAN SECURITY CONTROL SYSTEM WILL BE DISCONTINUED. THE SATELLITE RADAR FEASIBILITY DEMONSTRATION CONDUCTED AS PROJECT QUILL WILL HENCEFORTH BE IDENTIFIED AS NRO STUDY [redacted].

THOSE MATERIALS RELATED TO PRLJECT QUILL, PRESENTLY IN POSSESSION OF VARIOUS BYEMAN CONTROL CENTERS, WILL BE RESTRICTED ON A MUST KNOW BASIS TO INDIVIDUALS APPROVED FOR ACCESS TO EITHER CORONA, DORIAN, GAMBIT, OR HEXAGON. THESE MATERIALS WILL CONTINUE TO BE MAINTAINED IN THE BYEMAN SECURITY CONTROL SYSTEM ALTHOUGH APPROVAL FOR QUILLACCESS WILL NO LONGER BE REQUIRED OR BILLETED.

THE IMAGERY PRODUCED DURING THE QUILL FEASIBILITY DEMONSTRATION (WHICH WAS LIMITED TO US ZONE OF INTERIOR) IS RELEASABLE ON A "MUST KNOW" TO INDIVIDUALS HAVING ACCESS TO EITHER TALENT-KEYHOLE, OR BYEMAN PROJECTS CORONA, DORIAN GAMBIT, OR HEXAGON. TALENT-KEYHOLE PERSONNEL MAY HAVE ACCESS TO SELECT ENGINEERING DATA UPON VALID REQUEST. "MUST KNOW"

Quill file

FORM 12-67 2820

(44)

CLASSIFIED MESSAGE

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PAGE TWO [redacted] ~~T O P S E C R E T~~ TALENT KEYHOLE

DETERMINATIONS WILL BE MADE BY THE SIO.

ALL QUILL MATERIALS IN CUSTODY OF BCO'S WILL HAVE THE QUILL COMPARTMENT DELETED AND BE MARKED NRO "STUDY [redacted]". MATERIALS IN THE TALENT-KEYHOLE OR BYEMAN SYSTEM WILL USE THE TERM "RADAR FEASIBILITY STUDY" IN LIEU OF "PROJECT QUILL" IN CONTEXTUAL MATTERS.

IMMEDIATE ACTION WILL BE TAKEN TO DEBRIEF ALL PERSONNEL CURRENTLY AUTHORIZED QUILL ACCESS.

~~T O P S E C R E T~~

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Date	Event
Early 1962	Proposal for satellite carrying radar sensor for imagery developed by Lockheed Missiles and Space Company and Goodyear Aerospace who had previously demonstrated similar sensors on airborne platforms.
Early October 1962	National Reconnaissance Office (NRO) Program A preliminary assessments affirm potential feasibility of Lockheed and Goodyear proposal for radar satellite. Director of the NRO (DNRO), Dr. Joseph Charyk, approves proceeding with additional review of the proposal.
30 October 1962	NRO Program A review team affirms feasibility of radar satellite. Review team recommends using hardware components already available from other projects. Review team also recommends one of its members, Major David Bradburn, to serve as program director, and names the new program Quill.
10 November 1962	Dr. Charyk authorizes Bradburn to proceed with the Quill program.
14 November 1962	Bradburn meets with Lockheed and Goodyear and indicates that the government will proceed with a contract for the proposed radar satellite on a non-competitive basis.
December/January 1963	Lockheed and Goodyear respond with draft proposals and initial cost estimates for the Quill program
Late January 1963	Bradburn meets with Lockheed and Goodyear representatives and approves classified and unclassified contracts for the Quill satellite.
March and May 1963	Bradburn provides status reports to new DNRO, Dr. Brockway McMillan, on Quill.
May 1963	Bradburn resolves issues with Goodyear purchasing government approved items for use in the Quill program.
9 April 1963	Bradburn meets with Corona program representatives and finalizes the agreement for purchasing Corona components for use in the Quill program including the film recovery vehicle.
17 July 1963	Lockheed reports high voltage arcing problem that threatens to delay Quill launch.
Mid September 1963	Lockheed reports on resolution of high voltage arcing problem by pressurizing system components.

Date	Event
Late September 1963	Third Quill vehicle canceled and launch of first vehicle set for 5 August 1964.
Early October 1963	Additional arcing problems identified by Lockheed.
January 1964	Arcing problems again resolved.
January to May 1964	Initial testing of Quill sub-systems undertaken.
March 1964	Program A Director orders readiness review of Quill vehicle.
7 May 1964	Readiness review team confirms Quill on course for fall launch.
Summer 1964	Lockheed and Goodyear carry out additional sub-system and integration testing
September 1964	Transmitter modulator tests reveal failings leading to launch delay.
2 December 1964	Additional transmitter modulator tests reveal reliability after component issues are resolved.
November/December 1964	Problem discovered with reflective materials on the Agena vehicle and efforts undertaken to reinforce reflective material.
21 December 1964	Quill, vehicle 2355, launched from Vandenberg Air Force Base.
22 December 1964	Quill film recovery vehicle recovered.
24 December 1964	Quill film delivered to processing facility.
22-26 December 1964	Quill completes 14 radar passes and transmits data to ground stations for processing.
5 January 1965	Bradburn provides first briefing of Quill experimental program results.
11 January 1965	Quill vehicle deorbited.

Date	**Event**
11 February 1965	Remaining Quill hardware placed in storage pending further analysis of program.
31 March and 1 April 1965	Final reports completed by Lockheed and Goodyear on Quill program performance and engineering assessments.
April 1965	NRO and the Central Intelligence Agency agree to establish review team, led by the National Photographic Interpretation Center (NPIC) to evaluate potential intelligence value of radar imagery based on the Quill experiment.
1 August 1965	NPIC-led team recommends further study of radar as source of imagery and identifies potential contributions from future programs.
10 February 1969	Quill removed from Byeman controls, effectively closing the program.