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**RAND's Role in the Evolution
of Balloon and Satellite
Observation Systems and
Related U.S. Space Technology**

Merton E. Davies, William R. Harris

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40 Years
1950-1990

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of Balloon and Satellite
Observation Systems and
Related U.S. Space Technology**

Merton E. Davies, William R. Harris

September 1988

Commemorating the 40th Anniversary of The RAND Corporation

40 Years
1948-1988

RAND

"Ah, but a man's reach should exceed his grasp,
or what's a heaven for?"

Robert Browning, *Andrea del Sarto* (1855)



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FRONTISPIECE—RAND's first home at Fourth Street and Broadway in Santa Monica

PREFACE

This report, prepared as part of RAND-sponsored research, was originally intended to commemorate the fortieth anniversary of Project RAND (now Project AIR FORCE), a long-term research effort that began in April 1946 with a study of the utility and feasibility of space satellites. RAND research on space technology continued, for the next two decades, to emphasize the primacy of photoreconnaissance and the communication to earth of remotely sensed data. Without the ability to observe and communicate, other applications of space technology appeared infeasible. As a direct consequence of this continuing focus on the potential of space for reconnaissance and arms control verification, the writing and security clearance of the present report have not been a simple matter either for the authors or for the U.S. government. Hence, a project begun two years ago to commemorate the fortieth anniversary of Air Force Project RAND, in 1986, shall now serve to commemorate the fortieth anniversary of the creation of The RAND Corporation itself (with an interest-free loan from The Ford Foundation) as an independent non-profit corporation in 1948.

The U.S. Army Air Force, soon to become the U.S. Air Force, initiated a project on Research AND Development (RAND) under contract with the Douglas Aircraft Company in March 1946. Project RAND's initial study, completed in a "crash" effort that mobilized both staff and consultants for three weeks in April 1946, resulted in the publication on May 2, 1946, of RAND's first report, *Preliminary Design of an Experimental World-Circling Spaceship* (SM-11827).

The first Project RAND report identified a range of potential applications of space technology. In 1946-47, and following the incorporation of RAND in 1948, members of the RAND staff investigated potential space technologies—or impediments to the development of such technologies. They assisted in the formulation, in the 1950s and later, of space missions for reconnaissance and arms control verification, weather forecasting, mapping and geodesy, communications, planetary and interplanetary exploration, and other purposes.

The present report attempts to capture the breadth of interests, the diligence of effort, and the synergy of multidisciplinary applications that contributed to achievements for the United States and for the scientific community worldwide in the exploration of planetary and interplanetary space.

The roles of the RAND researchers were diverse. The staff initiated research projects that might contribute to the national security; they identified potential USAF system requirements and developed concepts to achieve these requirements; and they facilitated the transfer of ideas into the educational institutions and industrial firms that might pursue technological innovations. But RAND did not build weapon systems, or balloons, or reconnaissance satellites, or rocket launchers. Many of the concepts that RAND explored depended on other institutions for successful implementation.

This history emphasizes the role of the U.S. Air Force in deciding whether and how to implement RAND's research findings and recommendations. The Air Force, in this period, was the principal source of RAND's funding. But other government institutions implemented programs that, for whatever reason, the Air Force could not accomplish. It was the National Aeronautics and Space Administration (NASA) that ultimately operated the TIROS weather satellite system in 1960 and thereafter; the original concept and requirements study (RAND Report R-218) resulted from exclusive Air Force sponsorship in the early 1950s. The Central Intelligence Agency (CIA), established under the National Security Act of 1947, kept abreast of much of the Air Force-sponsored research on high-altitude reconnaissance systems. In particular, Philip G. Strong, a retired Marine colonel who served as CIA's Assistant Director (Collection) for Scientific Intelligence after 1950, participated in meetings of the Air Force Scientific Advisory Board with various RAND participants. Colonel Strong brought promising developments to the attention of Richard M. Bissell, Jr., who in 1954-59 served as a Special Assistant to the Director of Central Intelligence.

The following account of RAND's activities does not attempt to particularize the accomplishments of the CIA. The scope of what is treated here does not imply that only RAND, or only the Air Force, was involved in successful program implementation. Further, the building of rockets, satellites, and other space system components depended upon existing industrial firms and, downstream, upon the creation of new industrial firms that brought many of RAND's concepts to fruition. The authors have followed security guidelines, it should be noted, that have the effect of minimizing references to the intelligence-related activities of other organizations whose accomplishments were essential to success.

Certain aspects of RAND's contributions to astronautics remain classified. Because of RAND's formative role in the space program, a special effort has been made to summarize or to obtain the release of as much background information as possible.

RAND documents that have been externally distributed are identified in this history by title and by date, even in those instances when documents are not presently approved for unlimited public release. These citations provide historical references, and may illuminate the context and sometimes the impact of RAND's research. Some of them have not been approved for public release because no requests have been made and no release decisions sought. Other documents have been approved for release in sanitized form, or have been summarized in unclassified bibliographies. But some works cited to provide an historical overview are not releasable in whole or in part.

The authors of this study bring a diverse experience to their review of RAND's early research on space technology and its applications. Merton E. Davies, trained as an engineer and mathematician, came to RAND in 1947 after eight years at the Douglas Aircraft Company. In recent years he has participated in the exploration of the solar system as a member of the imaging science experiment teams for missions to Mercury, Venus, Mars, Jupiter, Saturn, and Uranus. He contributed to RAND's Project FEED BACK studies on space reconnaissance in the early 1950s; and after Amrom H. Katz, a photoreconnaissance expert, arrived at RAND in 1954, he worked with Katz and others to facilitate the development of space-based reconnaissance systems that many dismissed as impossible. Davies played a recurring role in identifying potential uses of space reconnaissance to minimize the risks of surprise attack, in drafting U.S. submissions on verification capabilities for the Geneva Surprise Attack Conference of 1958, and later in devising ideas to make arms control initiatives feasible.

William R. Harris, an international lawyer at RAND since 1972, has worked on many aspects of treaty verification. He acquired his initial interest in space technology near the end of the period treated in this report. It was in 1962, at the Woods Hole Summer Study on Verification and Response in Disarmament Agreements, that he learned from RAND's Katz of the mounting potential for "verification by national technical means" to supplement or supplant on-site inspections for the verification of arms control treaties. Formerly a consultant to the Historian in the Office of the Secretary of Defense, and to the Senate Select Committee on Intelligence, Harris has reviewed the roles of over one hundred pioneers of U.S. space technology, with special interest in the activities of members of the RAND research staff.

What follows is not a substitute for an in-depth history of RAND's research on space technology and policy, with access to the remaining archival records and interviews as appropriate. It is only a sketch, and an incomplete one at that. Already many of RAND's pioneers in this field have passed from the scene, and so too have some of the most

important documents on RAND's early work on reconnaissance applications. These were considered sensitive in their day; regrettably, many documents retained in but a single copy are now gone, except for the control logs indicating their retention and destruction.

Over the past decade, official records of the National Security Council and the military services have been declassified in the national archives or through requests under the Freedom of Information Act. Based on these archival materials and interviews with participants, many books and historical articles have been written. Many of these studies, including official histories by Robert L. Perry and others, are listed in the bibliography accompanying this report. Much of the RAND work has already been treated in these studies, often with more detail than is provided in this overview of RAND research on space technology. What the authors hope to contribute is a sense of context, illustrating the impact of multidisciplinary research within RAND and suggesting how the RAND staff and their research findings figured in diverse activities leading to early space operations.

The authors wish to express their appreciation to Amrom H. Katz for his review of drafts of this report, and for his helpful suggestions and observations. The authors also wish to acknowledge the efforts of Stephen M. Drezner at RAND and many U.S. government officials to arrive at solutions to impasses during a multi-phased security review of preliminary drafts of this report as prepared in August 1986, and revised in September 1986, June and July 1987, and February, April, and June 1988. Many government officials devoted time to review the manuscript and the security-review issues arising in connection with its preparation. The authors wish to note with special appreciation the careful readings and suggestions of Colonel William L. Griego, USAF (Ret.), and Mr. Donald E. Welzenbach, an historian, and the monitoring of the review process by the Associate Counsel to CIA's Publications Review Board, Anne M. Fischer.

From the inception of research to final type composition, our editor, Malcolm A. Palmatier, has suggested organizational and procedural solutions that have enabled us to present our story, while adhering to security guidelines. We are grateful for his commitment to the publication of RAND history. Mrs. Jean Renner provided word-processing services through many drafts with patience and care; Wendy B. Anderson proofread our latest drafts; and Jean I. Houston and Patricia Tisher did the typesetting.

The authors alone are responsible for the final contents of the history and for any errors that may remain.

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Part I

**THE EVOLUTION OF SPACE SATELLITES FROM
HIGH-ALTITUDE RECONNAISSANCE SYSTEMS:
THE INITIAL PHASE, 1946-1954**

I-1. PROJECT RAND

After one reviews the breadth of activities at RAND with respect to space technology and its applications, a question that comes to mind is, "Why RAND?" Many of the ideas that RAND research staffers—"RANDites"—pursued had no constituency in the Washington bureaucracy. And many were but a gleam in the analyst's eye, disparaged even within RAND. Yet the ideas survived and ultimately found a home in research projects, in development programs, and in operational systems or policy innovations. Why did this happen, and what kinds of policies will encourage this kind of intellectual ferment and innovation in the future?

This is a subject larger than the topic of this report, but it is germane to any explanation of why RAND was able to take on the tasks that it did, and why it was so often successful in bringing ideas together, in honing policy recommendations, and in facilitating practical implementation.

The fact is that RAND, from its infancy, operated in an environment that facilitated and rewarded creativity, multidisciplinary research, the application of knowledge to important issues of national security, and the artform of what some have later called "implementation research."

The Deputy Chief of Staff (Development) of the U.S. Air Force, Major General Curtis E. LeMay, saw part of his job as protecting the Project RAND staff, and RAND as an institution, from short-term diversions from the long-term research mission that the Air Force had assigned it. General LeMay committed himself to give RAND at least five years of benign neglect, allowing it to structure its staff and research agenda so that it could serve long-term needs of the Air Force and the nation.

Also involved with RAND in this beginning period was John H. Carter, an Air Force officer assigned to Wright Field¹ in 1946-50. Thereafter, Colonel Carter became a deputy to Colonel Bernard A. Schriever in the Office of Development Planning. In these capacities Colonel Carter became familiar with RAND's satellite concepts, as did Colonels Richard S. Leghorn and Richard W. Philbrick. Within RAND this meant that there was latitude to innovate, to build research alliances among staffs with diverse training and work habits picked up

¹In the context of this historical sketch, the authors retain the familiar expression "Wright Field." The official name "Wright-Patterson Air Force Base" was adopted on January 13, 1948.

at the universities, from which many RANDites came. At the universities, before the infusion of federal research funds, cross-department research was seldom encouraged and often proved unhelpful to career development. The intellectual ferment at RAND yielded many publications, but it also resulted in RAND's developing a role as a facilitator, an honest broker of new ideas (or old ideas long forgotten) ready for policy implementation.

RAND was not a publish-or-perish place. It facilitated the application of innovations to solve important national, and especially national security, problems. An illustration of RAND's role as a broker of innovations, treated later in this report, involves the concept of the panoramic camera as one especially suited for space photography, and the transfer of suggested means of adapting this concept to another non-profit enterprise (within Boston University), which in turn modified the RAND concept in the redesign of high-altitude cameras. Merton Davies' idea was to take advantage of a spinning spacecraft (spun for stabilization) to perform a panoramic scan with a narrow-angle lens. This opened the possibility of achieving higher resolution in the course of wide-angle scanning with a narrow-angle lens. A variant of this successful formula—wide-angle coverage with narrow-angle lens—has been shown to be successful. Stimulated by the work of Fred Willcox at Fairchild Camera and Instrument Company, Davies' concept was to utilize a panoramic camera with 12-in. focal length mounted in a spinning spacecraft. It was Amrom Katz who passed Davies' concept along to Walter Levison of the Boston University Physical Research Laboratories. Levison thereafter redesigned a camera—while lying in a hospital bed with back pain—that applied the concept of a panoramic camera with long focal length, although his concept involved an oscillating rather than a spinning camera lens.

If it were not for a carbon copy of a letter and a later memorandum, there would be no trace of this particular illustration of RAND's role as a facilitator of innovation. Many other ideas that facilitated technology applications occurred without the written traces that historians would prefer. But early RAND bridged the worlds of basic research, applied research, and policy innovation without worrying excessively about its written trail.

RAND's first president, Frank R. Collbohm, played a major role in structuring the atmosphere at RAND that encouraged creativity and self-initiated research. But the U.S. Air Force deserves much of the credit also.

General Hoyt S. Vandenberg, Chief of Staff of the Air Force, approved Air Force Letter 80-10 on "Air Force Policy for the Conduct of Project RAND," on July 21, 1948. Several of the policies enunciated there contributed to RAND's effectiveness:

- A. The Air Force will support Project RAND to the fullest possible extent.
- B. Project RAND will continue to have maximum freedom for planning its work schedules and research program.
- C. Adequate fiscal support will be provided to insure the continuity of the Project so as to permit maximum effectiveness in programming and to provide for economy of operation. The broad assignment of work and the extremely high caliber of personnel required to conduct this background research dictates that the Project be unusually stable to be effective.

.....

- G. The use of Project RAND to accomplish specific "crash program" staff work will be minimized. RAND is not conceived nor is it staffed as an organization to provide "quick answers" for current staff problems. . . .
- H. "The RAND Corporation" will be free to undertake supplementary work for agencies other than the Air Force, or jointly for the Air Force and other agencies. . . .
- I. RAND will be supplied by all agencies of the Air Staff all information including such classified data which is necessary for the prosecution of the Project.

In a supportive and cooperative environment, Project RAND undertook exploratory research on many aspects of aerial warfare with implications for space technology and on potential space technology applications.

Amrom Katz, who came to RAND in 1954, has reflected on the unwritten rules regarding the scope and limits of RAND research:

The RAND environment was fascinating and the "rules of engagement" largely unwritten. One developed his own feel for the problem and the constraints on what was feasible and what was out of bounds. Shortly after I came to RAND, I discovered (and it was not hidden) that RAND led the country in the calculation of the specific impulse of a large number of possible rocket fuels. The RAND team numbered three or four—a mathematician, a chemist, a computer aide, and a secretary. I wondered how this could be. After a while the explanation was clear. RAND worked on this problem before industry did. It was a not-yet-profitable activity. When it became profitable for industry, they could outweigh and outcalculate RAND. The frontier was no longer the frontier. Hence the important distinction between an unprofitable activity and one which is not yet profitable. As soon as industry occupies the RAND forward bunkers, RAND goes off in search of new frontiers.

I-2. RAND'S FIRST REPORT—A WORLD-CIRCLING SPACESHIP

RAND emerged from the Santa Monica-based research laboratories of the Douglas Aircraft Company almost immediately after World War II. Located in leased buildings at Fourth and Broadway in Santa Monica (Frontispiece), before new facilities were built closer to the Pacific ocean in the early 1950s, Project RAND began with an intensive three-week study of the feasibility of launching and utilizing a space satellite. RAND's first President, Frank R. Collbohm, headed the project himself, together with his deputy, J. Richard Goldstein. Both the Army Air Force leadership and the project managers envisioned Project RAND as an advanced planning organization for the Air Force, with plans for operations analyses as well as investigations of future roles for aircraft and missiles in the U.S. Air Force.²

Despite plans for long-term studies, Project RAND started with a "crash" effort resulting from perceived needs of the Army Air Force to demonstrate independent competence in analyzing the feasibility and potential applications of space technology, in advance of an interservice review with representatives of the U.S. Navy in May 1946. Major General Curtis E. LeMay, then Director of Research and Development for the Army Air Force, considered space operations to be an extension of air operations, and viewed both as the exclusive domain of the Air Force. Hence, he had rejected a joint development program with the Navy even before turning to Project RAND for the Air Force's first study. (Perry, 1962, p. 11; Stares, 1985, pp. 24-25; Hall, 1963)

A May 1945 report by Werner von Braun reviewed German views on the potential of rocket-launched space satellites. This report echoed the interests of a German scientist, Hermann Oberth, whose book, published in 1923, stimulated interest in space exploration and in the formation of a German Society for Space Flight (in 1927). Oberth developed the concept of an artificial satellite of the earth, assuming the need for manned systems and underestimating advances in guidance, control, and automation.

The Von Braun report stimulated Navy interest and a Navy proposal of October 3, 1945, to develop a space satellite. An initial Navy Bureau of Aeronautics (BuAer) report followed in November 1945. (Lancaster, 1945)

²For background information on the origins of Project RAND, see Bruce L.R. Smith, *The RAND Corporation: Case Study of a Nonprofit Advisory Corporation*, Harvard University Press, Cambridge, Mass., 1966, chapters 2 and 3, pp. 30-92.

This initial Navy report preceded (1) a December 1945 Navy request for a satellite feasibility study, and (2) Air Force interest, expressed in both a report of General H. H. Arnold in November 1945 (design of a space ship "is all but practicable today") and a December 1945 Air Force Scientific Advisory Group study, the Von Karman report, which considered long-range rockets to be feasible and satellites to be a "definite possibility." (Perry, 1962, p. 9; Augenstein, 1982, p. 3)

Before Project RAND began operation, Dr. Vannevar Bush had ridiculed the recommendations of General "Hap" Arnold in testimony before the U.S. Senate, and the Navy had proposed, on March 7, 1946, the establishment of an interservice space program. This concept came before the joint Army-Navy Aeronautical Board of Research and Development on April 9, which resulted in a decision to reconsider the matter at a meeting on May 14, after the Army representatives could consult with General LeMay. The latter, possibly upon the intervention of the Commanding General of the Army Air Force, General Carl Spaatz, insisted upon an independent Army Air Force study to demonstrate an independent competence in space technology and to retain primary responsibility for any military satellite vehicle in the Army Air Force. (See Perry, 1962, pp. 10-11.)

General LeMay asked the Douglas Aircraft Company in Santa Monica, California, to have its advanced concepts group, Project RAND, undertake a feasibility study of a space satellite with a three-week deadline so that the Army Air Force could "meet a pressing responsibility." The first Project RAND study, SM-11827, was available after Douglas review on May 2, 1946. After minor revisions, it was forwarded to Major General Laurence C. Craigie at Wright Field and to General LeMay at the Pentagon, where it arrived on May 12, just two days before the May 14 review with the U.S. Navy. (Perry, 1962, p. 12, citing Memo, Ch., BuAer to JRDB, "Earth Satellite Vehicles," January 24, 1947; Lee Bowen, ms; Project 1115 Background, December 1954)

The initial Project RAND report (Fig. 1) contained a multi-authored scientific and engineering review of the feasibility of launching and controlling a space satellite. Concepts reviewed included propulsion, multi-stage launch vehicles, the risks of meteors to mission performance, methods of analyzing trajectories, and problems of recovering space payloads upon entry (now known, mysteriously, as "re-entry") into the atmosphere.

Professor Louis N. Ridenour of the University of Pennsylvania's Nuclear Physics and Electronics Department served as a consultant on Project RAND's initial study. Ridenour was one of the nation's foremost experts on radar technology. Considering the specialized focus of his work in World War II, the breadth of his vision in his brief

DOUGLAS AIRCRAFT COMPANY
SANTA MONICA PLANT
ENGINEERING DIVISION

presents

PRELIMINARY DESIGN OF AN
EXPERIMENTAL WORLD-CIRCLING SPACESHIP

Report No. SM-11827
Contract W33-038 ac-14105

May 2, 1946

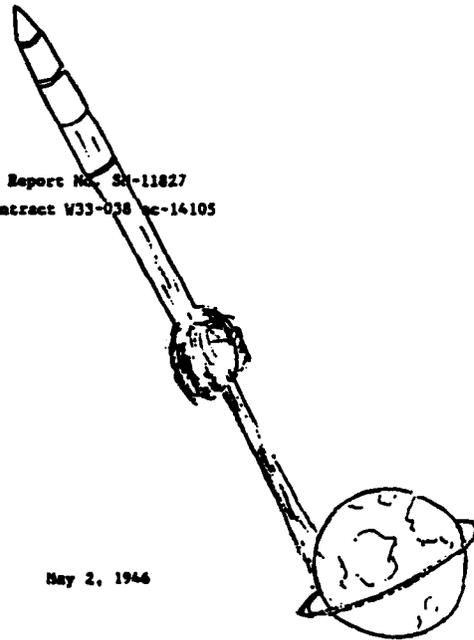


Fig. 1—Title page from RAND's first report

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work for RAND in April 1946 is remarkable. Ridenour wrote Chapter 2 of SM-11827 on the "Significance of a Satellite Vehicle." Among the missions that he identified were: satellites to guide missiles, satellites as the missiles themselves, satellites as "observation aircraft," satellites for attack assessment, satellites for weather reconnaissance, and satellites for communications. But the participants in this study understood the necessary limits of their vision:

In making the decision as to whether or not to undertake construction of such a [space] craft now, it is not inappropriate to view our present situation as similar to that in airplanes prior to the flight of the Wright brothers. We can see no more clearly all the utility and implications of spaceships than the Wright brothers could see fleets of B-29s bombing Japan and air transports circling the globe.

It was the combination of technical feasibility assessments and the Ridenour overview of potential missions which captured the interest of the Air Force and maintained that interest until satellites were an operational reality. Hence, the following testimony occurred before the Senate Committee on Armed Services in January 1958:

Senator Stuart Symington: "The satellite situation: Is the Air Force interested in satellites?"

Maj. Gen. Bernard A. Schriever: "Well, we have been interested in satellites since 1946, actually, when we started The RAND Corporation."

I-3. THE 1947 LIPP REPORT ON SATELLITES FOR OCEAN SURVEILLANCE, RECONNAISSANCE, AND GEOSTATIONARY COMMUNICATIONS

In 1946-47 Project RAND pursued the feasibility issues identified in the May 1946 report. James E. Lipp, head of the Project RAND Missiles Division, managed the continuation of the study on space satellites. A second six-month effort began in July 1946 with the objective of achieving

a design study sufficiently complete so that product contracts can be made for actual [satellite] vehicles of this type. (*Project RAND Second Quarterly Report, RA-15004, September 1, 1946, p. 3*)

RAND's Satellite Study Section staff included, in 1946: James E. Lipp (the Satellite Study Section Chief), F. J. Krieger, G. H. Clement, R. W. Krueger, G. Grimminger, W. C. Peters, Y. M. Claeys, E. Tieman, R. S. Paulson, I. Munson, and B. L. Dodge.

Project RAND's second quarterly report contained an overview, *Status of Satellite Study*, RA-15006, dated September 1, 1946. RAND's work in the aftermath of the May 1946 report required a decoupling of imagination from the experience with high-altitude technology in World War II. In a war replete with breathtaking technological advances, the United States had experienced only modest incremental development in rocket technology and in high-altitude reconnaissance systems. Hence, RAND recommendations in 1947-51 that assumed a potential for rapid development of rocketry and reconnaissance technologies should be interpreted against the backdrop of limited wartime technological progress in these areas.

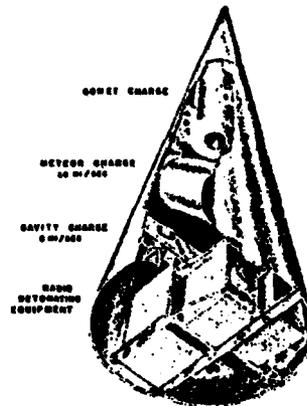
Also contained in RAND's second quarterly report was a summary of the COMET Project. (See RA-15004, September 1, 1946, pp. 36-40.) This project was an outgrowth of an earlier RAND idea to use a V-2 rocket to "shoot the moon" by launching into the moon's gravitational field. The COMET variant would eject particles from a high-velocity shaped-charge. These would create a cometlike object that could be observed from the earth's surface and that might be compared with the phenomena of actual comets. (See Fig. 2.)

It was the February 1947 RAND report, and not the May 1946 report, that first analyzed the potential of satellites for reconnaissance missions. From a 1980s perspective, there is no novelty in this emphasis upon the special potential of space reconnaissance rather than upon other potential uses of space satellites. But in 1947 an act of faith was required in the capacity to make dramatic improvements in high-resolution photography to anticipate the utility of space-based imaging of the earth.

Compared with the development of technology for radar, atomic weapons, and computers, the advances in photographic reconnaissance technology during World War II had been modest. Aerial photoreconnaissance, developed in World War I, was generally viewed as an operational function and not a technology development during World War II. Photographs were required immediately, and research tended to focus upon small improvements that could be brought to operational readiness in a matter of days or months, not years.

Amrom Katz addresses the lack of significant progress during World War II in improving the quality of photographic images:

September 1, 1946



V-2 WARHEAD FOR COMET PROJECT

POINTS FOR HIGH VELOCITY CHARGES TO BE BLOWN OPEN
OPPOSE DIRECTIONAL VELOCITIES OF THE VERTICALLY MOUNTED

FIG. 15.

The trajectories of the ejected material are shown in Fig. 16. The vertically mounted charge will shoot out a cloud of matter in the direction in which the V-2 is pointed at the peak of its trajectory. It is calculated that this matter will not be appreciably decelerated by the atmosphere above an altitude of 100 miles if the particles are larger than .001 cm. in diameter. It is estimated that when illuminated by the sun this material would have an equivalent reflective area of about 1 square meter and would be visible against the night sky for a distance of a few hundred miles. Its trajectory and velocity may be measured by means of two standard rotating shutter meteor cameras.

Fig. 2—A page from Project RAND Report RA-15004,
September 1, 1946, describing the COMET payload

Put simply, World War II standards for aerial photographic performance were of the order of 10 lines per mm. Under favorable conditions . . . cameras in the hands of skilled laboratory personnel based in the United States could achieve 20 or 25 lines per mm. But this wasn't achieved uniformly. . . .

By and large, lens performance matched the then available film, which was principally Kodak Aerographic Super XX, a relatively fast, coarse-grained, low-contrast film, with a speed rating that amounts to about ASA 100.

... One must inquire deeply into the reasons for lack of progress (during the course of the [second world] war) in improving lenses, resolution, and general quality of the photographic image.

The main reason seems to have been that cameras developed in World War II were direct and linear descendants of cameras available at the beginning of that war. The essentially square or rectangular format, flat film, essentially standard mountings, etc., and especially standard film magazines, prevented novel cameras from being introduced. Furthermore, the fact [is] the film itself imposed a serious limit on image performance and image definition, and precluded making giant steps in lenses. Besides, World War II was, as more recent experience shows, fairly brief (except, of course, to participants therein). The current great popularity, well deserved, of panoramic cameras leads one to inquire how come there were no panoramic cameras developed during World War II. The reasons lie in the complex production operations, inventories, standardization of equipment, viewers, processors, etc., that go to make up a standard operational package.

... It is a curious fact that the panoramic camera, at least 100 years old ... was invented specifically because lenses of 100 years ago were resolution limited, and could not cover a wide angle. In the effort to get a wide angle, the lens was scanned across a semicircular piece of film, as in the familiar photographs taken at picnics, class reunions, graduating ceremonies, and the like. Thus, a lens which could inherently cover only a small angle was made to sweep out a large angle giving acceptable definition over the entire field.

... To a new generation of workers accustomed to this extremely high resolution, it may come as a shock to realize the desperate clawing and fighting that was required to increase resolution from 10 to 20 lines per mm, from 20 to 40. High resolution is an extraordinarily fragile commodity; it can be lost by temperature gradients, vibration, mechanical errors, and even requires special handling once it is brought into the laboratory. ... (Katz, 1970, pp. 1, 4, 5, 10, 11)

On February 1, 1947, Project RAND published a series of documents intended to assist contractors in preparing their own preliminary designs and analyses. These reports were:

1. *Flight Mechanics of a Satellite Rocket*, RA-15021
2. *Aerodynamic, Gas Dynamics and Heat Transfer Problems of a Satellite Rocket*, RA-15022 (limited distribution)
3. *Analysis of Temperature, Pressure and Density of the Atmosphere Extending to Extreme Altitudes*, RA-15023 (superseded by RM-841)
4. *Theoretical Characteristics of Several Liquid Propellant Systems*, RA-15024 (withdrawn)
5. *Stability and Control of a Satellite Rocket*, RA-15025 (withdrawn)
6. *Structural and Weight Studies of a Satellite Rocket*, RA-15026 (withdrawn)

7. *Satellite Rocket Powerplant, RA-15027* (limited distribution)
8. *Communication and Observation Problems of a Satellite, RA-15028*
9. *Study of Launching Sites for a Satellite Projectile, RA-15029*
10. *Reference Papers Relating to a Satellite Study, RA-15032*

A summary report, *Proposed Type Specification for an Experimental Satellite, RA-15013*, was also published. (See Fig. 3.)

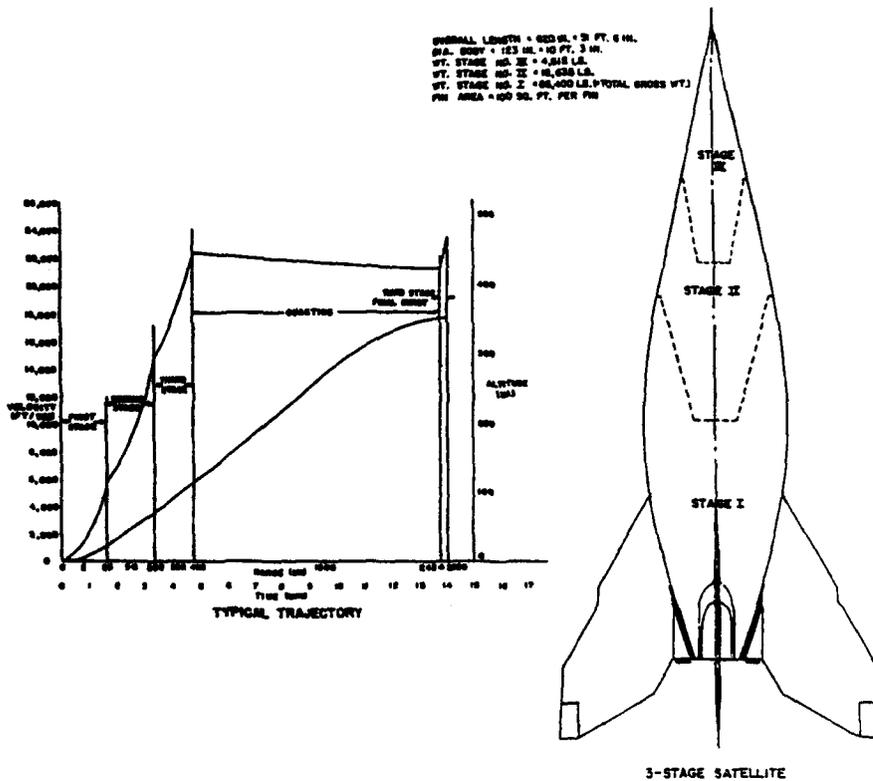


Fig. 3—Schematic of three-stage satellite launcher and typical trajectory from *Proposed Type Specification for an Experimental Satellite, RA-15013*, February 1, 1947

James E. Lipp's *Reference Papers Relating to a Satellite Study*, RA-15032 (item 10, above), contained papers by RAND consultants Lyman Spitzer, Jr., Luis W. Alvarez, Leonard I. Schiff, and Bruno Rossi treating perturbations of satellite orbits, methods of navigation and control, use of nuclear energy in satellites, establishment of missile trajectories, determination of satellite orientation in space, and cosmic ray research. Two papers commented on the potential significance of reconnaissance satellites.

Professor Lyman Spitzer, Jr., a Yale University astronomer, discussed "tactical uses of a satellite in naval warfare" and "problems involved in attacking or defending a satellite." (Lipp et al., 1947, pp. 39-40)

Assuming significant limits in resolving objects on the earth from a space satellite, Professor Spitzer proposed an ocean-surveillance mission:

An important property of a satellite is that it provides a platform from which a very wide expanse of the earth can be viewed. While small objects, especially on land, could probably not be distinguished from a point many hundreds of miles away, a ship at sea could, in principle, be detected. A ship 25 feet wide would subtend an angle of 2 seconds of arc at a point 500 miles away. Thus a telescope of 4 inches aperture, with a resolving power of one second of arc, should be able to detect such a ship, provided the weather were clear. . . . A satellite travelling over the poles, with a period of about one and a half hours, would scan the oceans at least once every day. . . .

Another potential advantage which a satellite might provide is that of a relay station for communications with naval vessels when radio silence was imperative. . . .

It is evident that some interest attaches to the problem of destroying an enemy satellite or of protecting a friendly one. Periodic changes in a satellite orbit would probably exhaust fuel rather rapidly, and thus a satellite orbit must probably be assumed fixed, except for calculable perturbations. Hence any satellite which has been detected could readily be attacked with considerable accuracy from another satellite sent up especially for the purpose. Such an attack satellite might be a relatively small and inexpensive weapon.

While the odds of such a battle in space are not readily forecast, it is evident that concealment would be a primary defense of a satellite. . . .

Professor Spitzer's proposed application of astronomical telescopic concepts to space satellites, undertaken in 1946-47 as a RAND consultant, encouraged the adaptation of long-focal-length sensing systems for observation of the earth, and, over the next four decades, the development of space telescopes for astronomical observation outside

the mantle of the earth's atmosphere. Various space telescopes have already been operated successfully, and the largest, NASA's Hubble Space Telescope, now awaits launch by a U.S. space shuttle. (See Homer E. Newell, *Beyond the Atmosphere*, NASA, SP-4211, 1980; Armin J. Deutsch and Wolfgang B. Klemperer, editors, *Space Age Astronomy*, Academic Press, 1962.)

James Lipp of the Project RAND staff wrote the final section of the February 1947 report, "The Time Factor in the Satellite Program." Lipp proposed that a cost of about \$75 million for the first satellite in orbit (about \$425 million in 1987 dollars) could be reduced by waiting for advances in fuels, materials, and techniques. He relied upon a companion cost projection by J. H. Gunning, *Cost Estimate of an Experimental Satellite Program*, Project RAND, RA-15030, also published on February 1, 1947.

Lipp explored four classes of benefits to be derived from a satellite program: (1) development of long-range rockets, (2) value in military planning and operations, (3) scientific research, and (4) psychological and political factors.

He noted two characteristics of satellites, apparently without knowledge of their earlier identification by the science fiction writer Arthur Clarke in 1944: the concept of the polar orbit for recurring reconnaissance coverage; and the less obvious concept of very-high-altitude orbits for geostationary location compensating for the rotation of the earth:

A number of satellites at great altitude (thousands of miles) could act simply as communications relay stations. By using microwave frequencies the present difficulties with unreliable long-range communications would be avoided. It has been stated by eyewitnesses that such difficulties constituted a major handicap to operations in the Pacific theater during World War II. If a satellite could be placed high enough (about 25,000 miles) to have a 24-hour period of revolution, it could be associated with a fixed ground station at the equator. Three such stations could broadcast to most of the globe. This idea is not as wild as it sounds. The initial gross weight, with several additional stages, would be about four times the weight of a 300-mile altitude vehicle of equal payload.

This reference to geostationary satellites to relay communications appears to have been the first engineering proposal for development of this concept. (The earlier suggestion by science fiction writer Clarke was not in the mainstream of engineering literature, and thus was less likely to be noted by Lipp and his staff.)³ Two years later, another

³See Arthur C. Clarke, "A Short Pre-History of Comsats, or: How I Lost a Billion Dollars in My Spare Time," in Clarke, *Voices from the Sky: Previews of the Coming*

member of the RAND staff, Richard S. Wehner, published RAND Research Memorandum RM-603, *Satellite-to-Surface Communication—Equatorial Orbit*, further developing the Lipp concept of equatorial orbiting communications satellites.⁴

For the first time in a paper on satellites, the February 1947 Lipp report addressed the potential use of satellites to obtain electro-optical images and to transmit them using television-like technology:

By installing television equipment combined with one or more Schmidt-type telescopes in a satellite, an observation and reconnaissance tool without parallel could be established. As mentioned previously in various reports on the subject, a spaceship can be placed upon an oblique or north-south orbit so as to cover the entire surface of the earth at frequent intervals as the earth rotates beneath the orbit.

Also for the first time, the Lipp report proposed the use of relay satellites for microwave communications:

A satellite in the ionosphere would require microwave communication, which is effective only for line of sight distances and cannot be received halfway around the world. This trouble can be overcome by using a relay system involving both satellite and ground stations. . . . If the satellite could accumulate information on film or wire and televise the record rapidly when interrogated by the ground station, a workable system would result. The period of revolution of the satellite is about 1-1/2 hours, so that its successive tracks over the earth would be about 1500 miles apart at the equator. If it is assumed that scanning to a distance of 100 miles on each side of the track is feasible, then a complete coverage of the earth would require about a week, depending upon a proper choice of altitude to give the right orbital period. For more rapid coverage, two or more vehicles could be placed in a "rat race" equally spaced around the same orbit. Obviously, scanning and recording would only be done over areas of interest in order to conserve power and space in the vehicle.

A decade before Sputnik, the same report foresaw the symbolism of innovation in the exploration of space:

Although trips around the moon and to neighboring planets may seem a long way off, the United States is probably in a better position at present to progress in this direction than any other nation.

Space Age, New York, 1965, pp. 119-128. John R. Pierce of the Bell Laboratories, writing under a pseudonym in *Amazing Science Fiction*, suggested a comsat system in 1952. See also Delbert D. Smith, *Communications via Satellites: A Vision in Retrospect*, 1976.

⁴Wehner's RM-603 was classified Secret when published in July 1949. It was republished in April 1951 as a technical companion to RAND Reports R-217 and R-218 on reconnaissance and meteorological satellites. It was declassified before being withdrawn from further distribution in December 1952.

Since mastery of the elements is a reliable index of material progress, the nation which first makes significant achievements in space travel will be acknowledged as the world leader in both military and scientific techniques. To visualize the impact on the world, one can imagine the consternation and admiration that would be felt here if the United States were to discover suddenly that some other nation had already put up a successful satellite.

Lipp ends his report with these observations:

In conclusion it is hardly necessary to point out that most of the reasons for beginning a satellite development program cannot be assigned values in terms of dollars and cents lost in each year of delay. It is equally clear that some of the items discussed are of sufficient importance that the probable cost of the project becomes insignificant. It is therefore desirable that a satellite development program should be put in motion at the earliest possible time.

The Air Force apparently deferred a formal assessment of Lipp's work until September 25, 1947, one week after the official creation of the U.S. Air Force, itself. The Air Staff directed the Air Materiel Command (AMC) to assess the RAND work. AMC reported to the Air Staff in December 1947 its concurrence on the feasibility of space satellites, but questioned their practicality. It proposed, however, the establishment of a project to prepare Air Force requirements and specifications for satellites, recognizing at the same time that the development of guided missiles had higher priority. On January 15, 1948, General Hoyt S. Vandenberg stated that the USAF "has logical responsibility for satellite[s] . . ."; the next day, the U.S. Navy withdrew its claim for control of space satellite development. (Perry, 1962, p. 2; Augenstein, 1982, pp. 4-5)

Merton Davies recalls this period under Douglas Aircraft, during RAND's transition to independence as a separate non-profit corporation:

I arrived at RAND in 1947 just after the publication of this study and worked on missile and satellite structures under George Clement.

RAND was an exciting place. Three major breakthroughs had emerged from World War II which were bound to change the course of history: radar, nuclear bombs, and jet and rocket propulsion. Rocket propulsion was the only area in which the United States had no experience, and we were trying to correct that. We studied the design and experience of the German A-4 (V-2) missile, as well as the A-9 glide version and the long-range A-10 design. RAND made a major study of the capabilities and costs of long-range glide missiles.

The Air Force had contracted with a number of the aerospace firms to make studies of missile design and cost. Typically these were the

MX-770 with North American Aviation (which emerged as the Navaho missile), the MX-773 with Republic Aviation, the MX-774 with Convair (which led to the Atlas missile), etc. RAND kept informed with the thoughts, designs, and capabilities developed in these contracts. Since RAND was part of Douglas Aircraft, a direct competitor of most of these firms, a special proprietary classification was instituted within RAND to assure that these particular company ideas did not drift to other parts of Douglas. Because of this special care, we have always had excellent communication with the aerospace industry. After a while, it was apparent that RAND should cut all ties with Douglas. . . .

In November 1948, Douglas Aircraft Company transferred Project RAND to an independent non-profit corporation, The RAND Corporation, founded on May 14, 1948, with an initial interest-free loan from The Ford Foundation. The Articles of Incorporation, dated May 10, 1948, established The RAND Corporation:

To further and promote scientific, educational, and charitable purposes, all for the public welfare and security of the United States of America.

Thereafter, the institution assumed a broader mission. With regard to satellite feasibility studies, RAND took the lead in exploring satellite missions and feasibility, but with the mission of supporting triservice needs, thus reflecting the assignment of the satellite mission to the Air Force as a triservice responsibility. RAND had authority to sub-contract research studies.

In January 1949, the *Bulletin of the American Meteorological Society* published an article by Major D. L. Crowson, "Cloud Observations from Rockets" (Vol. 30, pp. 17-22). The Crowson article suggested that even low-resolution imagery would assist in weather forecasting. Richard S. Wehner, at RAND, pursued the option of utilizing television technology from outer space, with an unprecedented detail of analysis. The video orthicon television developed at RCA was of special interest to Wehner. His interest in 1949 spread to others at RAND. Wehner was one of three lead authors of RAND's still-classified Report R-217, *Utility of a Satellite Vehicle for Reconnaissance* (U), in 1951, and indirectly influenced the Project FEED BACK report of March 1954.

In 1949, RAND sponsored a conference on the utility of space satellites, including a satellite equipped with "photographic and television equipment." The fact that a satellite "could not be brought down with present weapons or devices" was one of its attractions for both peacetime and wartime observation. (Hall, 1963, pp. 430-431; Stares, 1985, p. 29)

In connection with the 1949 reconnaissance study at RAND, Wehner prepared an internal document entitled "Inquiry into Feasibility of Satellite Television," July 15, 1949. He also published, in July 1949, Research Memorandum RM-603, *Satellite-to-Surface Communication—Equatorial Orbit* (later withdrawn), evaluating an initial plan for equatorial satellites orbiting at an altitude of about 500 miles, with planned relay of communications from electro-optical sensing satellites via a set of at least three ground stations.

In the years before the Korean War, work at RAND proceeded without any apparent sense of urgency to develop improved reconnaissance platforms and sensors.

At a symposium in Topeka, Kansas, in November 1948, Air Force Colonel Richard Philbrick had mentioned the possibility that space satellites might serve as reconnaissance platforms. This was an exceptional vision in that period. The next year, for example, Colonel Richard S. Leghorn (then retired) met with the Assistant Chief of Staff of the Air Force for Intelligence, Major General Charles P. Cabell, who later served as Deputy Director of Central Intelligence under Allen Dulles. Leghorn wrote General Cabell on February 23, 1949:

I want to thank you again for the opportunity you gave me to try to explain certain views. . . . I was of course discouraged to find that you feel that reconnaissance and photography as they now exist in the Air Force are essentially adequate and that the present organization by itself will make further improvements and corrections as required. . . . I still can't bring myself exactly to share this view . . . for the relative importance of air reconnaissance as an instrument to collect intelligence about a system such as the Russian is very great indeed.

I-4. HIGH-ALTITUDE BALLOONS

The work at RAND preceding the Korean War indicated the desirability of space-based reconnaissance systems. But this work also indicated the infeasibility of obtaining and processing electro-optical data that would provide photographic resolutions adequate for military photointerpretation. Consideration of what to do with low-resolution imagery led to an exploration of balloons as an alternative or transitional platform for remote sensing of the earth.

The Korean War, initiated by North Korean forces on June 24, 1950, encouraged a hard look at prospects for strategic reconnaissance.

Members of RAND's Electronics Department, including William W. Kellogg, provided a brief overview on this subject in July 1950. Kellogg, together with Stanley Greenfield, had been intrigued by reports of the Japanese experience with balloon operations in World War II. The Japanese balloons, however, were not optimized for reconnaissance missions but for incendiary and psychological ones. The Japanese launched paper balloons with incendiary payloads. Some of these balloons did reach the U.S. mainland and started forest fires; however, in general they caused little damage because U.S. rangers were already prepared for fires caused by lightning. Moreover, press censorship minimized reports of those incendiary balloons that actually reached the United States; the Japanese thereafter concluded that the campaign had been ineffective, and ceased it altogether.

What especially intrigued Kellogg and Greenfield was the Japanese understanding of upper atmospheric meteorology required to plan a long-distance balloon campaign. The Korean War encouraged both the Air Staff and RAND to consider every alternative to obtain, before the expansion of hostilities, overhead reconnaissance of denied areas in the Soviet Union and China. Peripheral aerial reconnaissance was of limited utility, and direct overflight by manned aircraft in peacetime risked hostile fire and diplomatic unpleasanties.

Kellogg had initially investigated the potential of high-altitude balloons in monitoring the dispersion of radioactive particles from atomic tests. Working at the University of California at Los Angeles (UCLA) under contract to the U.S. Atomic Energy Commission, Kellogg experimented with high-altitude balloons launched from Holloman Air Force Base in New Mexico. Here in the summer of 1949 he had met Stanley M. Greenfield, then a student at New York University. NYU was developing and experimenting with high-altitude balloons. Kellogg recruited Greenfield to RAND in 1950, and they worked together over the ensuing seventeen years.

Kellogg and Greenfield paid a visit to the Photo-Reconnaissance Laboratory at Wright Field, Ohio, under Colonel George W. Goddard. Katz recalls Kellogg and Greenfield asking whether the Photo-Reconnaissance Lab staff had considered the employment of high-altitude balloons as platforms for photoreconnaissance. The RAND visitors were surprised to learn that the Photo-Reconnaissance Lab had already flown a high-altitude balloon reconnaissance mission to learn what could be done with upper-atmospheric photography.

This experiment resulted from George Goddard's approach to experimentation. Goddard asked his staff to perform faster, longer, etc.—and higher was one of those dimensions. Otto C. Winzen, the former chief balloon designer of the Aeronautical Laboratories of General Mills, had

established the Winzen Research Company in Minneapolis. Winzen had flown a polyethylene balloon to an altitude of over 100,000 ft, carrying a K-18 camera with 36-in. lens. The result was 9- x 18-in. photographs in both black and white and color. This experiment demonstrated that a balloon made a suitably stable platform for high-altitude photography. The findings encouraged the RAND researchers to consider alternative balloon reconnaissance programs, as well as a meteorological research program. It would be necessary to predict the paths of the high-altitude jet streams, in part by instrumenting polyethylene balloons so that their flight could be tracked.

Kellogg and Greenfield decided, on their own initiative, to explore the potential of high-altitude balloons as platforms for photographic reconnaissance. Kellogg recalls having participated, together with James Lipp and others, in briefing General LeMay, then Commander in Chief of the Strategic Air Command. LeMay asked the RAND team to help him obtain intelligence for SAC targeting. Back at RAND, Kellogg talked with Greenfield about using altitude-stabilized balloons for photoreconnaissance. In the summer of 1950, they explored concepts that were later to become the "requirements" for Project GOPHER: unmanned, high-altitude, altitude-stabilized, recoverable photoreconnaissance platforms. The altitude had to be so high as to exceed the air defense capabilities of target nations. And the balloons should be, insofar as possible, invisible to the naked eye and to radar sensors.

At about this time, the U.S. Air Force accelerated its experiments with high-altitude balloon systems, tested mainly by the 6580th Test Squadron (Special) at Holloman Air Development Center in New Mexico. (See the 6580th Test Squadron, Special, *Flight Summary, Non-Extensible Balloon Operations . . . June 1950 to October 1954.*) Air Force personnel launched their first polyethylene balloon on July 21, 1950, following civilian experimental launches conducted since July 1947. (Bushnell, 1959, xiii) Polyethylene balloons were lighter and became more reliable than rubber balloons; moreover, they could both achieve and sustain high-altitude flight, appropriate for reconnaissance missions and for the development of techniques later to be applied to space satellites and the recovery of their payloads.

In the fall of 1950, as the United Nations forces in Korea required reinforcements, the Soviet government mounted measures in Central Europe that were indicative of preparations for a European war. These measures caused a war scare within the U.S. government and forestalled the movement of troop reinforcements to Korea. The events were a reminder of the necessity for improved peacetime reconnaissance over the Soviet Union and Eastern Europe.

An Air Force Intelligence summary of the situation on October 3, 1950, indicated that balloons offered the best short-term opportunity to update photographic coverage of the Soviet Union:

The present AF holdings of USSR photography are both out of date and extremely incomplete. [Regarding means of reconnaissance:]

a. Use of airplanes to perform day photographic reconnaissance. This must be ruled out since the use of manned airplanes over USSR prior to hostilities is considered an act of aggression. b. Use of guided missile SNARK will not be available until 1953. c. Use of satellite vehicle. This will probably not be practical for several years. d. Use of balloons. All of the "hardware" needed is available. Some meteorological problems must be solved but if program is properly phased these problems appear soluble. It is believed that balloon surveillance can be in operation in 1951. (Memorandum for the Record, October 3, 1950, RG 341, Entry 214)

When Air Force Vice Chief of Staff Nathan Twining advised President Truman of a Joint Chiefs of Staff (JCS)-backed plan to undertake balloon-reconnaissance overflights over the Soviet Union, the President authorized the program that fall. (Beschloss, 1986, pp. 77-78, 432 Notes)

Air Force review led to the establishment, as noted, of Project GOPHER—designed to develop polyethylene balloons for high-altitude reconnaissance—on October 9, 1950. (See the declassified Project GOPHER records in the National Archives.)

At Holloman Air Force Base:

A significant number of [balloon] flights have been concerned with high-altitude photography, including the development of photoreconnaissance systems. . . .

Holloman balloon flights have played a part in the development of special instrumentation for the United States' satellite program. (Bushnell, 1959, pp. 18, 19)

As an historian of balloon operations explains:

Balloons and satellites both demand instrumentation with minimum size and weight and with other similar characteristics. Hence balloon instrumentation pioneered some instrumentation techniques of the type now used in satellite work. . . . (Bushnell, 1959, p. 101)

At RAND, Kellogg produced Research Memorandum RM-494, *Balloon Reconnaissance*, in December 1950. This report encouraged the Air Force initiative to establish a balloon research program, Project MOBY DICK, at the Air Force Cambridge Research Center in 1951. (See Fig. 4.) This and related research programs hastened the development of high-altitude, constant-level balloons. (Bushnell, 1959, p. 19)

The experience in operating reconnaissance balloons in the 1950s facilitated the development and operation of space satellites for both reconnaissance and meteorological purposes.

I-5. THE 1951 RAND REPORTS ON SATELLITES FOR METEOROLOGY AND RECONNAISSANCE

In August 1950, during the course of this work, Professor Louis N. Ridenour (MIT) was the first of the RAND researchers to address—in what came to be known as the “Ridenour Memorandum of 1950”—the necessity to design an information system to manage, retrieve, and display the vast quantities of data to be derived from space-based electro-optical observation and relay systems:

Display and Handling of Information

Perhaps it will be best to begin a discussion of this topic with some general considerations bearing on the over-all design of the terminal equipment. . . . The information-rate is therefore about 5 million bits/sec. Supposing that lighting requirements and horizon limitations leave only 8 hours per day usable for significant transmissions, the daily rate of information collection will be 1.4×10^{12} bits/day. . . . *The satellite (if it works) is collecting for us the informational equivalent of 10^6 books.* [Emphasis in the original]

Merton Davies recalls:

The RAND engineers were confident that an operating satellite could be built and launched into orbit. This led to studies of the utility of satellites: Why should they be built? It was recognized that a satellite program would be expensive, and there was no national interest in proving that it could be done. Of course, there were scientific reasons but these could not hope to justify a project of this magnitude. If photographic and television cameras were incorporated into the payload, the satellite would have an observation and reconnaissance capability. This mission should be of interest to the Air Force. In November 1950 the Air Force authorized further research to demonstrate the utility of satellite reconnaissance. In April 1951 a formal recommendation went to the Air Force to proceed with advanced research into specific capabilities of a satellite vehicle.

In 1951 two reports were published: one on the use of a satellite for meteorology and weather prediction (by William W. Kellogg and Stanley Greenfield), and one on the use for reconnaissance (by James Lipp, Robert Salter, and Reinhart Wehner).

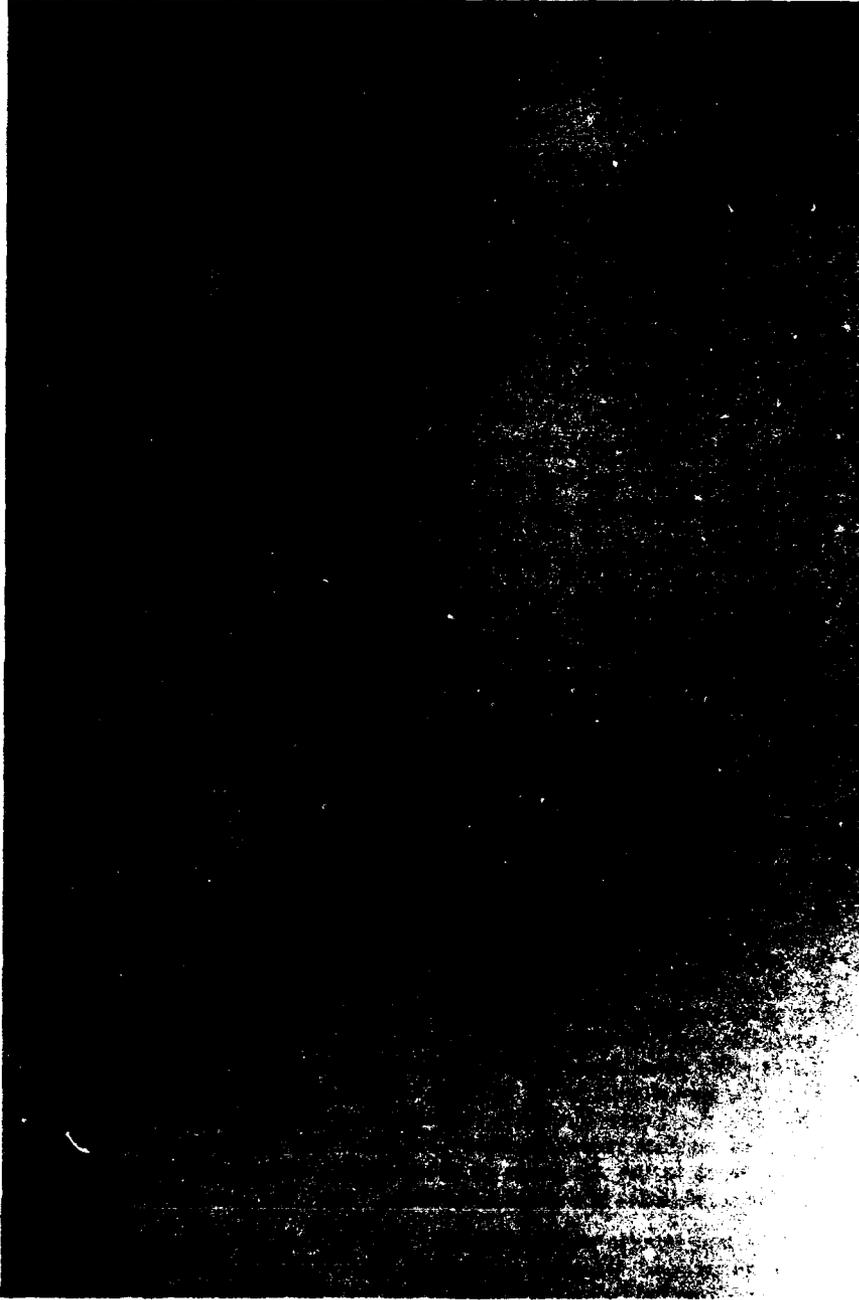


Fig. 4—Photograph of a high-altitude MOBY DICK balloon taken shortly after launch

The two reports resulting from the work in 1950-51, are identified, together with short unclassified descriptions, in a RAND bibliography published in 1958 and revised in 1959. (RAND, 1959) James E. Lipp, Robert M. Salter, Jr., and R. S. Wehner were the lead authors⁵ of Report R-217, *Utility of a Satellite Vehicle for Reconnaissance (U)*, classified Confidential, April 1951. Stanley M. Greenfield and William W. Kellogg were the authors of the companion report, R-218, *Inquiry into the Feasibility of Weather Reconnaissance from a Satellite Vehicle*. R-218 grew out of the RAND work in 1950-51 to develop a TV-sensing reconnaissance satellite, as reported in R-217. Greenfield and Kellogg considered what *could* be done with the imagery at scales in the range of 1 to 1,000,000 or 1 to 1,500,000. If the types of clouds could be identified, and if broad regional weather could be monitored, then space-derived weather forecasting might be feasible. RAND Report R-218 laid out the requirements for a functional weather satellite system. The TIROS-1 satellite that was launched nine years later had almost identical system requirements and was the world's first successful weather satellite.

But in 1951 Greenfield and Kellogg were disappointed that the Air Force did not pursue the weather satellite concept. Scientists involved in the International Geophysical Year took an interest in the weather satellite in the mid-1950s. With the establishment of the Advanced Research Projects Agency (ARPA) in 1957, Kellogg was asked to head an advisory committee that incorporated the requirements of RAND Report R-218 into the TIROS program.

After the establishment of the National Aeronautics and Space Administration in 1958, the Department of Defense transferred the TIROS weather satellite program to NASA in April 1959. NASA launched the world's first weather satellite, TIROS-1, on April 1, 1960. (Snyder et al., 1976, p. 64) Publication in August 1960 of the initial Greenfield-Kellogg report recommending a weather satellite program, slightly sanitized (but with the same title) as RAND Report R-365, established a visibility for this pioneering study.

In 1960 the American Meteorological Society presented Greenfield and Kellogg with a special award for this work. And, during the twenty-fifth anniversary (1985) of global weather satellites, the Department of Commerce also honored them for their work at RAND leading to the TIROS weather satellite.

RAND Report R-217 is not as yet declassified, but its contents are generally known. (Perry, 1962, pp. 31-32) As previously described (Augenstein, 1982, p. 5):

⁵Other co-authors were R. R. Carhart, C. R. Culp, S. L. Gendler, W. J. Howard, and J. S. Thompson.

These reports [R-217, R-218] discussed "pioneer reconnaissance" with extensive earth coverage at resolution (utilizing TV) of between 40 and 200 feet, in a 1000 pound payload and at a vehicle weight of 74,000 pounds. A new U.S. awareness of Soviet military potential—reflected in atomic weapons and related vehicle developments, for example—had posed new requirements for technical intelligence-gathering, so the RAND reports were published at an opportune time.

The U.S. Air Force, with Research and Development Board (RDB) approval, authorized RAND to recommend development work in reconnaissance satellite programs—now known as Project FEED BACK—in 1951.

RAND Report R-217 carried within its title a proposition that most of the report's readers did not share. This was not the result of a lack of care or thoroughness. RAND's Missiles Division, under James Lipp, prepared the report with underlying documentation, photographs, charts, and appendixes. It also considered rocket launch systems, orbital options, effects of guidance and control errors on satellite drift, communications requirements, power requirements, delays in acquiring remotely sensed data, and alternatives to television sensing and data relay.

The report organized elements of the system requirements for an effective space reconnaissance satellite into a single study. It indicated the potential utility of a space satellite for remote observation of the earth. What R-217 was unable to do was to convince experienced photoreconnaissance experts that there was utility in the development and procurement of an operating reconnaissance satellite. Even if the RAND satellite system were to work as well as hoped, even if all of the subsystems supported it as calculated, the resulting limited image-quality and area that could be surveyed diminished interest in procuring a reconnaissance satellite. What RAND's Missiles Division did was to consider a wide array of variations in satellite systems in the hope of identifying a combination of subsystems that would optimize system performance. RAND analysts rejected the storage of images on film and the recovery of film, in part because of the enormous weight of the film that would be required to provide coverage of areas that could be surveyed by television. RAND researchers considered film-based storage, with delayed data relay, but this also imposed weight penalties of film storage that appeared excessive at that time, or it depended upon the (unlikely) invention of a reusable film. Black and white television imaging with data relay was the prime candidate for data acquisition.

The image orthicon television system of the Radio Corporation of America (RCA) was the basis for the RAND calculations and

simulations. The R-217 authors noted that innovations were under way that might result in the availability of television images with more than the 1000 lines per inch they assumed for the RAND satellite system. With the assistance of television station KNBH (an NBC network station in Los Angeles), RCA engineers in Camden, New Jersey, and the Fairchild Aerial Survey Company, RAND analysts developed a photographic mosaic of the Los Angeles harbor area. Working from a KNBH television studio in Los Angeles, the RAND team simulated the image quality of alternative TV-sensed and relayed data that might be associated with a variety of satellite orbits and image scan rates.

At an altitude of about 350 miles, an image orthicon TV system was estimated to be capable of producing images with a swath width of 800 miles as the satellite circled around the earth. This would yield images with at least 20 percent contrast and a ground resolution of 70 to 80 feet. A "spotting" variant could produce images with a ground scanning width of 80 miles, but this would require a longer scanning period. Opting for higher resolution would preclude the production of a continuous imaging strip of the earth. It would provide a set of image samples, taking ten times the scan time of the continuous strip. Using the TV sensing system in its survey mode, the satellite system could operate over the areas of reconnaissance interest for about three hours per day, and would produce about 350,000 images in a 30- to 35-day period that would be required to provide full coverage of the land areas to be surveyed. This would amount to nearly 4 million images per year over the land areas of interest.

The central problem was that of image quality. Images of the earth yielding a ground resolution of 200 to 80 feet, or even 40 feet in the aftermath of technological progress, were unlikely to yield the detail to which photointerpreters had become accustomed in World War II. (Commercially available electro-optical satellite images of EOS, SPOT, and other providers may be purchased in the 1980s with ground resolutions in the range of 5 to 10 meters or better, but even these are inadequate for some purposes.)

A ground resolution of 200 to 80 feet would suffice for analyzing cloud formations, but this was the subject of the companion report, R-218. Experienced photointerpreters were simply uninterested in image quality with ground resolutions in the range of 80 to 40 feet.

Several of the RAND participants in the research leading to R-217 visited Wright Field in Dayton, Ohio, and introduced the concept of a space satellite to the various departments. Katz, then the chief physicist at the Reconnaissance Laboratory, remembers the visit of Lipp and others in 1951, which coincided with a visit from reconnaissance experts at Boston University's Physical Research Laboratories. Hence,

the Lipp briefing introduced both the Wright Field staff and the Boston University (BU) staff to satellite reconnaissance concepts. Present, in addition to Katz, were Duncan Macdonald, Head of the BU Optical Research Laboratories; Walter Levison, then an Assistant Director of BUORL; Colonel Richard W. Philbrick, the Air Force liaison officer to BUORL; and others.

Jim Lipp and Bob Salter of the RAND satellite study team came out to Wright Field to brief their satellite study. Lipp had a nearly zero batting average; no one was interested. A few of us from the Recce Lab gave him a hard time and he was delighted. The fact that we thought that his scheme was not going to deliver usable results was not as important to Lipp as was the fact that we were interested!

We formed an ad hoc committee [Walt Levison, Duncan Macdonald, Col. Richard Philbrick, and Amrom Katz]. We were going to prove that this proposed project was ridiculous. Mind you, we didn't know or care about the incidental problems such as making the launch rocket, achieving stability in orbit and all the other important parts of the system. We were fastened on the proposed scale to be delivered to the TV sensor—about a million or a million and a half.

It should be remembered that we were engaged in trying to take photos of railroad ties from 40,000 feet and this was very difficult. A full account of this experiment is yet to be written. It would show why we listened to Lipp with a heavy dose of "skepticoccus." None of the lenses available to us was small enough to use in attempting to simulate the performance of this rotten TV sensor cruising at 300 miles altitude.

The first experimental effort to simulate the utility of images comparable to those that might be derived from the RAND-proposed satellite system occurred at Wright Field in November 1951. This was fully seven months after publication of R-217, with its photographs of TV images of Los Angeles harbor.

The concept of attaching a camera to a rocket has been traced back to at least the year 1888, before the invention of the airplane. A French designer, Amedée Denisse had sketched and patented a rocket-mounted camera. So had the Swedish inventor, Alfred Nobel, in 1897. Alfred Maul had made the first known camera-mounted-on-rocket experiment in 1906. In the aftermath of World War II, the Navy experimented with a camera mounted on an A-4 (V-2) rocket in 1946. This camera produced photographs at 30, 45, 60, and 65 miles altitude (Fig. 5). These experiments had indicated that synoptic photography was possible, but they had not achieved the resolution of features on the ground that could be obtained by photography from airplanes.

Probably in late 1951, Amrom Katz of the Wright Field Reconnaissance Laboratory arranged for a round of overflights designed to simulate the prospects for satellite reconnaissance. He writes:



Fig. 5—Photograph taken by a camera mounted in a captured V-2 rocket launched from White Sands Proving Ground in 1946, showing the Gulf of California and Baja California

I ran into Dave Goldstein, President of Elgeet Optical in Rochester. He had a couple of lenses made for 8mm movie cameras. These two lenses were 7.5 and 15mm focal length. But more important for our intended use, they had a long back focus (the distance from the rear surface of the lens to the focal plane).

Dave volunteered to mount these lenses on the flanges that would fit my 35mm Leica camera. In short, he did, and I flew this camera at 30,000 feet, using coarse grain film, developing the film in nearly hot developer. This shows what we thought of TV at that time. The photos taken with the 7.5mm lens were at a scale of 1,200,000, and I was confident that nothing could be seen on the enlargements.

The pictures of Dayton taken by Katz with the modified Leica (Fig. 6) represented a scale that approximated the scale proposed earlier in 1951 by Jim Lipp for a satellite TV reconnaissance system. The streets and bridges of Dayton, Wright Field, and other key landmarks could be detected. These experimental simulations of satellite reconnaissance removed Katz's prejudice against space satellites.

A subsequent flight test with the modified Leica and 7.5mm Elgeet lens occurred on February 26, 1952, aboard an XR-12 aircraft that flew an experimental transcontinental reconnaissance flight from Long Beach, California, to LaGuardia Field in New York.

Although these pictures simulated the scale of satellite pictures, they were not taken through the entire atmosphere. Pictures from higher altitude had been taken by cameras mounted in rockets since 1946. However, in general the results were rather poor. In 1954 the Navy's Viking II took excellent pictures from altitudes over 150 miles (Fig. 7), demonstrating that atmospheric attenuation was not more serious at that height than it was at high-altitude-aircraft or balloon heights.

I-8. COLONEL RICHARD S. LEGHORN AND USAF REQUIREMENTS FOR STRATEGIC RECONNAISSANCE

The return of Colonel Richard S. Leghorn from Rochester, New York, to active duty during the Korean War brought an integrative thinker into the decisionmaking process for reconnaissance systems. As a reconnaissance pilot during World War II, Leghorn had taken photographs in preparation for the Normandy landing.

Colonel Richard W. Philbrick, assigned to the Boston University Optical Research Laboratories had recommended recommissioning Colonel Leghorn; with the support of Colonel George Goddard, he

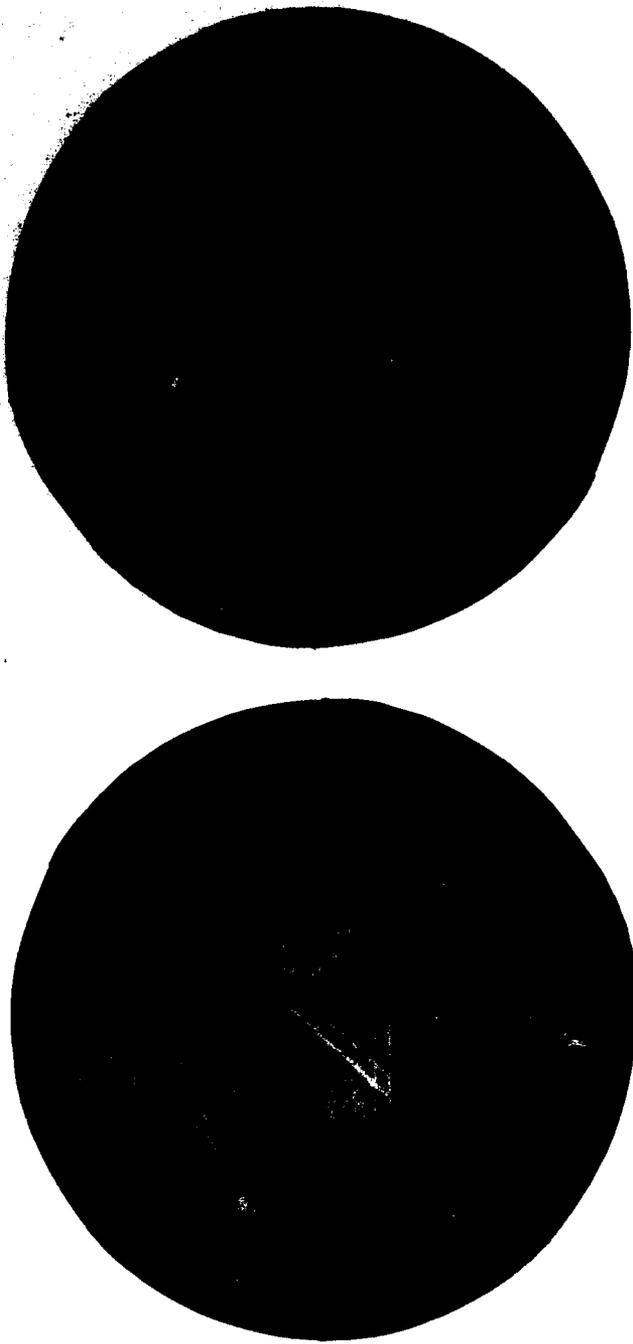


Fig. 6—Photographs of Wright Field and downtown Dayton taken with a Leica camera with a 7.5mm-focal-length lens from 30,000-ft altitude to simulate photography from a satellite

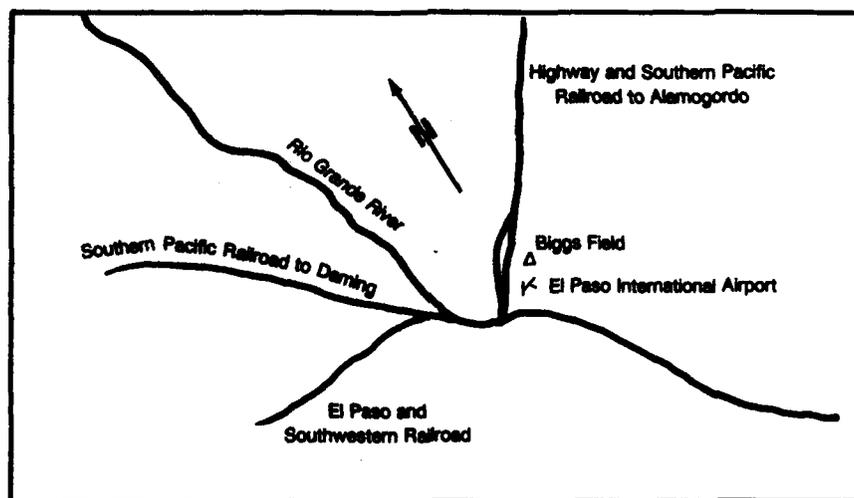


Fig. 7—Photograph of regions of Mexico, New Mexico, and Texas, including El Paso, taken by a K-25 camera with a 16mm-focal-length lens mounted in the Viking 11 rocket from an altitude of 158 miles, launched May 24, 1954

returned to active duty at Wright Field in April 1951. Assigned to a weapon systems procurement office, Colonel Leghorn became chief of the Reconnaissance Systems Branch, where he set about to survey the requirements for reconnaissance and candidate systems for procurement by the U.S. Air Force. He sought a better matching of reconnaissance requirements and capabilities, as is indicated in a Leghorn memo of July 10, 1951, on pre- and post-"D"-Day reconnaissance requirements and the platforms that might best perform reconnaissance missions.

In 1952 Colonel Leghorn focused upon possible modifications to the British Canberra bomber so that it could perform reconnaissance missions at 65,000 to 70,000 ft, or higher. Leghorn worked with some of the principal civilian scientists in Colonel Goddard's "Recce Lab," including the chief physicist, Amrom Katz, and Walter J. Levison, a camera designer who had worked on optical systems at Boston University after World War II.

By the fall of 1952, Colonel Bernard A. Schriever had been assigned as Director of the Development Planning Office of the Air Staff in the Pentagon. His office prepared development planning objectives—DPOs—on various subjects, such as strategic warfare and tactical warfare. At the urging of Katz, who had worked with Leghorn under Goddard at the Wright Field Recce Lab in World War II, Schriever interviewed Leghorn and thereafter requested the latter's transfer to the Pentagon to integrate Air Force defense planning objectives for intelligence and reconnaissance. In the midst of the Korean War, principal emphasis was placed, as in World War II, on short-term improvements in combat reconnaissance. Colonel Leghorn's broader vision encouraged him to address what he called the problem of "pre-D-Day intelligence," and the development of a technical and political strategy to meet reconnaissance requirements of the Air Force.

The contribution of Colonel Leghorn to RAND's work on aerial and space reconnaissance cannot be overemphasized. Together with others, he founded the ITEK Corporation in September 1957 (see *The Itek News*, Special Tenth Anniversary Issue, No. 10, 1967). The fact is that RAND needed a focal point in the Pentagon to make research in Santa Monica effective; for two crucial years—1951 to 1953—Colonel Leghorn was that focal point.

At that time, the Air Force organized its planning activities into three elements: operational planning, for current and prospective military operations; procurement planning, for force acquisition; and development planning, to match long-range requirements with the Air Force research and development effort.

It was during the military conflict in Korea that Colonel Leghorn articulated a strategic rationale for pre-hostilities reconnaissance. Before returning to civilian life in January 1953, he summarized his views in a memorandum for General Vandenberg (through Colonel Schriever and General Craigie), "An Air War Strategy of Disarmament, and Obsolescence of the 'Strategic Offensive'."

This memorandum . . . attempts to summarize factors which . . . argue strongly for an air strategy of disarmament, including a discontinuance of the strategic offensive in the World War II sense. . . .

The term "an air strategy of disarmament" is used to signify the following:

- a. Primary use of atomic-thermonuclear air power during the military decisive phase against military forces-in-being and military stocks. . . .
- b. Use of atomic air power against the Soviet logistics system.
- c. Suspended use of atomic air power against the Soviet economy . . . during the military decisive phase. . . .

. . . Our war strategy must permit meaningful utilization of our atomic superiority and must endeavor to draw his atomic sufficiency to another target system. This requires a counterforce type war, which we have only begun to embrace in our planning. . . .

Current development planning indicates the probable technical feasibility of such a disarmament concept. Our qualitative intelligence and reconnaissance capabilities constitute the primary problems, and without extraordinary action, these might delay adoption at operational planning levels of strategies with emphasis on counterforce operations. (Leghorn, Draft Memorandum, January 27, 1953, Formerly Secret, declassified March 24, 1972)

Colonel Leghorn's proposed counterforce strategy—voiced nearly a decade before Secretary of Defense Robert S. McNamara's Ann Arbor speech in 1962—implied a state of peacetime knowledge of a potential adversary's strategic assets. Hence, the key recommendation in Colonel Leghorn's memorandum was for a vigorous program to strengthen U.S. peacetime reconnaissance capabilities:

. . . Immediate and vigorous steps [should] be taken to strengthen air intelligence and reconnaissance capabilities, which will be necessary before any sort of a disarmament strategy can be contemplated. Because of the demonstrated inability of [the] air intelligence and reconnaissance community to pull itself up by its own bootstraps, extraordinary action will be required directly by the Chief of Staff. (Leghorn, Draft Memorandum, January 27, 1953, p. 7, Formerly Secret, declassified March 24, 1972)

Understandably, primary emphasis was placed upon aerial reconnaissance, long practiced and well understood. Merton Davies convinced Colonel Leghorn to include the role of the reconnaissance satellite within the framework of Air Force requirements. This was a critical but undocumented event. Colonel Leghorn's impact upon RAND research continued long after he left the Air Force in January 1953. Colonel Bert Smiley was to replace Colonel Leghorn as the principal liaison officer with RAND on long-range requirements for reconnaissance, with emphasis on tactical reconnaissance in conflict. The Leghorn legacy, a commitment to improve peacetime reconnaissance, remained as part of the reconnaissance and intelligence requirements.

In 1953 RAND moved its operations from downtown Santa Monica to its present headquarters at 1700 Main Street in the City Hall area, near the Pacific Ocean (Fig. 8).

I-7. THE BEACON HILL STUDY: RECONNAISSANCE WITHOUT SATELLITES

Colonel Leghorn presided over a review of long-range Air Force development requirements for intelligence and reconnaissance. One of the elements of the Air Force planning process involved the BEACON HILL study conducted under the auspices of MIT between July 1951 and the issuance of a final report on June 15, 1952, *Problems of Air Force Intelligence and Reconnaissance*.

The Air Force contacted MIT in May 1951 for the purpose of initiating Project LINCOLN, under the chairmanship of Dr. Carl F. J. Overhage. A study of intelligence and reconnaissance requirements and capabilities became the first Project LINCOLN study. It is notable that, despite multi-institutional representation, no member of RAND served on the steering committee that planned a series of briefings for early 1952, and that supervised the drafting of the BEACON HILL report of June 1952. Despite Air Staff receipt of the April 1951 RAND reports on reconnaissance and meteorological satellites, not a single BEACON HILL briefing considered the potentials of satellites for electro-optical or weather reconnaissance, subjects under consideration at RAND for the previous several years. This was not the result of security compartmentation, because no special compartmentation affected those RAND studies at that time. The Steering Committee membership for the BEACON HILL study was drawn exclusively from educational and industrial firms in New England.

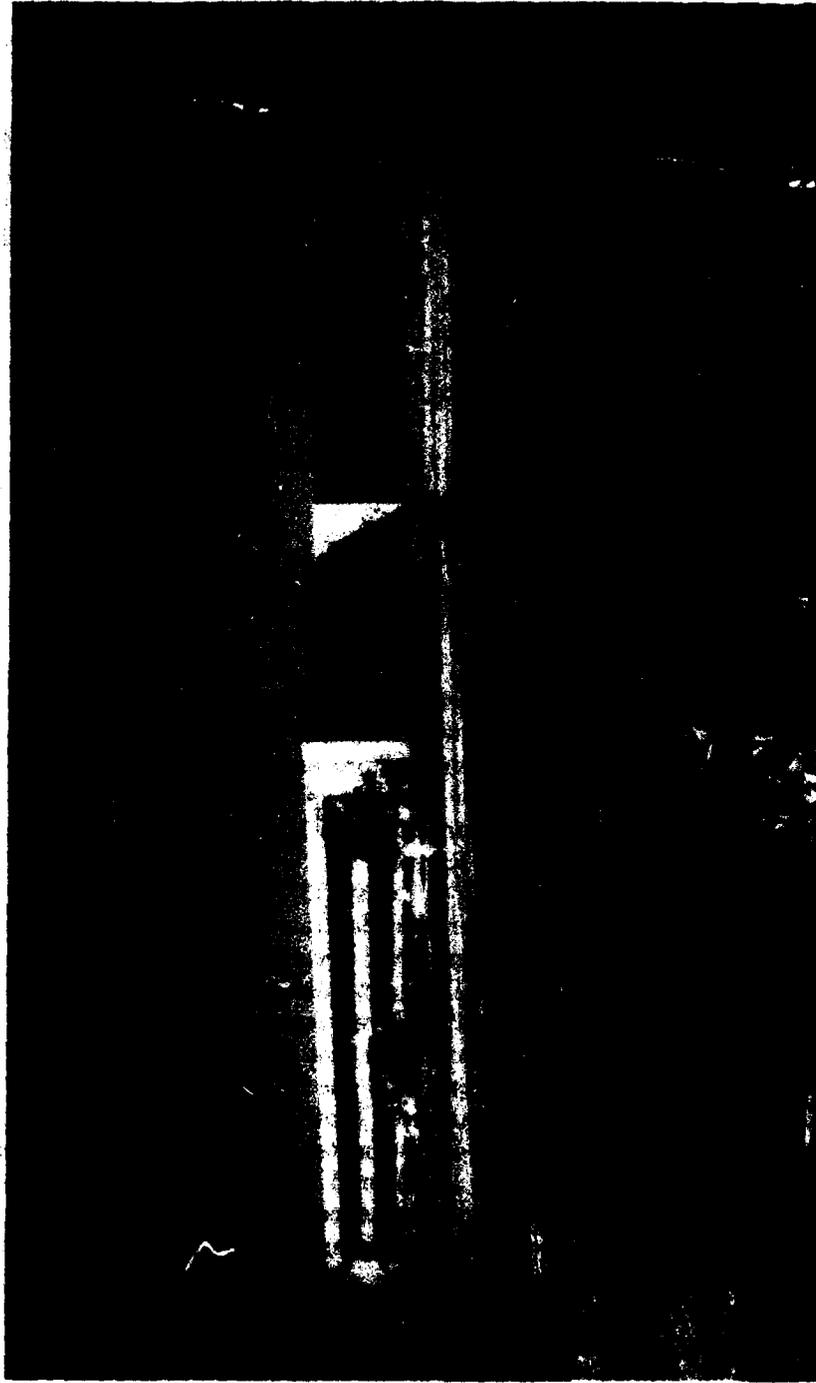


Fig. 8—In 1953 RAND moved into its new building at 1700 Main Street, Santa Monica

About the time of the initial organization of the BEACON HILL study in July 1951, Colonel Leghorn prepared a five-page document (mentioned above): "Comments on Intercontinental Reconnaissance Systems, 1952-1960."

Recent analyses have established that certain objectives must be sought in reconnaissance systems. These objectives fall broadly in two groups. . . . Pre-"D"-Day Reconnaissance and Post-"D"-Day Reconnaissance. A short intense campaign as contemplated by SAC requires the collection of as much planning information as possible prior to "D"-Day. As the SAC striking capability improves with improved development and production of atomic weapons and high performance, invulnerable vehicles, need for Pre-"D"-Day intelligence assumes even greater relative importance.

. . . Vehicles for Pre-"D"-Day Reconnaissance must meet the following requirements:

1. Minimum chances of detection.
2. Minimum chance of interception.
3. An unmanned vehicle is greatly preferred.
4. The vehicle configuration must lend itself readily to a "cover plan" excuse such as a scientific or weather mission gone astray.

Whether or not the State Department will acquiesce in the use of any of these vehicles, the Department of the Air Force must fully develop a technical capability for Pre-"D"-Day Reconnaissance. . . . (Leghorn, 1951, p. 1)

Just three months after the April 1951 publication of RAND Report R-217 on electro-optical reconnaissance satellite concepts, Colonel Leghorn proposed delaying the shift of satellite vehicles from concept studies to development work, while proceeding with development of balloons, guided missiles, drone aircraft, and manned aircraft to achieve Air Force reconnaissance needs. This was an important precursor of the BEACON HILL report of June 1952, which recommended Air Force funding for all of the candidate platforms for intercontinental reconnaissance except space satellites. In his July 1951 memorandum, Colonel Leghorn summarized his views of "vehicle possibilities":

1. Earth Satellite

The earth satellite concept does not offer sufficient promise today to justify the expenditure of development funds by the Air Force. This is particularly true in view of the great promise of Project GOPHER. Although the earth's satellite concept justifies limited and continued studies, development work does not appear justified as yet.

2. Project GOPHER

Project GOPHER has perhaps the greatest potential for Pre-"D"-Day Reconnaissance. Because of its extreme importance, maximum

budgetary support is required. The nature of the GOPHER [high-altitude balloon] vehicle is such that photography is the most promising data collecting technique. . . .

3. Guided Missiles

Next to GOPHER, the Snark Missile, succeeded by the Navaho Missile, offers good possibilities. . . . Photographic techniques offer best promise, with thermal and radar techniques having limited possibilities.

4. Drone Aircraft

Drone aircraft might have promise as an interim system to Snark.

5. Manned Aircraft

The RB-47 and subsequent manned aircraft operating at high subsonic or supersonic speeds can possibly be developed into Pre-"D"-Day Reconnaissance Systems with operational capabilities in lightly defended areas. . . .

6. An intercontinental capability can be arranged for any of the above vehicle systems through either B-36 air launching or through refueling with interim tankers such as the KB-29, the KB-36, or the KC-97. (Leghorn, 1951, pp. 1-2)

The systematic disregard of space reconnaissance options by the BEACON HILL study was, in some measure, a setback for development of a space satellite system, in part because the BEACON HILL participants and final report favored the commitment of additional resources for various airplane, cruise missile, balloon, and other reconnaissance systems. It was understandable that the BEACON HILL participants did not include space-based television reconnaissance as an option of the five-year period, 1952-56. But the BEACON HILL participants omitted satellite systems from their consideration of "pre-D-day reconnaissance" in the period after 1956, even while noting the inadequacy of high-altitude observation from the periphery of Soviet territory, and while remarking on the policy concerns regarding overflight by aircraft.

James S. Thompson of the RAND staff was a regular visitor to the BEACON HILL briefings during February 1952, and a regular participant in the RAND Project FEED BACK studies of electro-optical reconnaissance from space satellites. But Thompson was not temperamentally inclined to interject a subject of discussion that was not otherwise tabled.

Merton Davies did not attend the BEACON HILL study, but he did interject the concept of space reconnaissance into the long-term planning of Colonel Leghorn and his element of Colonel Schriever's research plan. Colonel Leghorn recurringly sought RAND assistance in the development

of a never-ending *Defense Planning Objectives (DPO): Requirements for Strategic Reconnaissance (1952)*, in later versions, *DPO: Intelligence and Reconnaissance*. Colonel Leghorn brought to this mission a keen awareness of the need for "pre-hostilities reconnaissance," or "pre-D-Day reconnaissance." Over time, this concept evolved into what is now generally regarded as "peacetime reconnaissance."

But the broader and continuing DPO review under Colonel Leghorn provided an opportunity for Davies to advocate consideration of space satellites within the USAF reconnaissance program. He recalls:

I was sent to Washington to discuss with Leghorn the capabilities and use of satellites and perhaps to write a section for his DPO. He was not familiar with RAND's satellite work. We spent the morning talking; then the afternoon. We went to dinner and then continued our discussions until after 11:00 p.m. For me, it was exciting and enjoyable to find someone so capable and interested in the studies on which we had spent so many years. Before long, Brigadier General Bernard Schriever moved to the West Coast to set up the Western Development Division (WDD) of the Advanced Research and Development Command (ARDC) to run the Air Force's ballistic missile program.

I-8. DEVELOPMENT OF BALLOON-RECONNAISSANCE SYSTEMS DURING THE KOREAN PERIOD

It was the informal assessment of Air Force planners in 1951-52 that the RAND electro-optical satellite concept, without plans for direct recovery of data payloads, could not make a near-term contribution to the improvement of pre-hostilities reconnaissance of denied areas. As a consequence, Air Force Intelligence placed greater emphasis upon developing balloon-reconnaissance systems than satellite-reconnaissance systems during the Korean War. This had a fortuitous effect upon the development of satellite reconnaissance programs: balloon platforms encouraged the design of lightweight, durable subsystems, even though balloons were able to carry heavier payloads than early space satellites. The balloon-reconnaissance programs provided a technology bridge from the reconnaissance systems mounted in aircraft during World War II to the reconnaissance systems flown and retrieved from space satellites.

RAND researchers, primarily those in the Electronics Division, evaluated alternative balloon-reconnaissance concepts in 1951-52, even

while other RAND staff pursued electro-optical satellite systems. By the summer of 1951, RAND had initiated Project SINBAD (memorandum July 13, 1951, C. G. Habler, RAND Dayton Office, to W. W. Kellogg; memorandum J. E. Lipp to E. W. Paxson, August 24, 1951). This resulted in a *Revised Study of Photo Reconnaissance by Balloon* (U), RAND Research Memorandum RM-979, published as Top Secret in November 1950, and in Research Memorandum RM-692, *SINBAD* (U), published as Top Secret in September 1951 and withdrawn in September 1971.

The RAND work, completed in the fall of 1951, contributed to the development of two related Air Force-sponsored balloon development programs: Project GOPHER, which involved experimental development of alternative plastic and mylar balloon materials for high-altitude, large-payload transportation; and Project MOBY DICK, which involved research on the prediction of meteorological effects and on launch procedures for high-altitude balloons. Project GOPHER, under way in 1951-52, established design criteria to carry a 500-pound payload, operating above 70,000 feet, for a period of 14 days. (See General Mills, Inc., Aeronautic Research Laboratories, *Project GOPHER Status Evaluation*, April 6, 1952.) Project GOPHER "involved sending heavy specialized equipment on [balloon] flights lasting up to two and a half days." (Bushnell, 1959, pp. 87-88)

The Air Force Cambridge Research Center initiated Project MOBY DICK in September 1951, with field operations conducted primarily at Holloman Air Force Base in New Mexico, and later at operational sites in California, Oregon, Missouri, and Georgia. MOBY DICK was "much the most ambitious balloon-borne research activity up to that time, requiring an unprecedented number of flights, constant-level trajectories of several days' duration, and instrument payloads too heavy for normal meteorological sounding balloons." (Bushnell, 1959, p. 25)

In 1952 the staff at Holloman AFB developed the so-called COVERED WAGON balloon-launching technique, which permitted inflation and release of balloons even in winds of 20 to 25 knots, as part of an effort to sustain on-schedule launches for Project MOBY DICK. (See USAF Air Development Center, *Summary Report on Project MOBY DICK COVERED WAGON Balloon Launcher Development and Test Results, 6 Dec 1951 to 15 Sep 1952*, Holloman Air Force Base, New Mexico, Report HDT-21, December 12, 1952; Bushnell, 1959, p. 26 and pp. 37-38, Notes 27-30.)

In the second half of 1952, personnel and equipment from Holloman Air Force Base moved to three sites designated for the operational phase of Project MOBY DICK: Edwards Air Force Base, California; Vernalis Naval Air Station, California; and Tillamook Naval Air Station, Oregon. (Bushnell, 1959, p. 27)

In December 1952, in conjunction with plans to deploy operational balloon reconnaissance payloads, Kellogg at RAND provided Colonel Leghorn of the Air Staff with RAND's estimates for performance of the Project GOPHER balloon systems.

Kellogg and Greenfield explored alternative concepts of recovering photographic payloads from high-altitude balloons. The best of the Project GOPHER cameras was a large, heavy, trimetrogon camera. Kellogg and Greenfield initiated experiments carried out by the Air Force in El Centro, California. There they developed the idea of mid-air recovery of the photographic payload. When they visited Wright Field and the Pentagon, Air Force officers literally laughed at the concept. The Fairchild "Packet" C-119 air transport offered the possibility of access through a 9- x 9-ft rear cargo bay. Outfitted with a clamshell device, the C-119 became an aerial recovery vehicle. Wright Field personnel developed a grappling hook system. After a near crash, Colonel Paul Worthman at the Air Force Cambridge Research Center took charge of the aerial recovery system. As so often happened, RAND developed a concept, but other institutions modified it so that it would work in actual operations.

In parallel with this technical evaluation, RAND explored the political dimensions of high-altitude reconnaissance in peacetime. The BEACON HILL report of June 1952 had focused attention upon the risks and consequences of authorizing high-altitude overflights of the airspace of other nations in peacetime. Particularly because the satellite was not seriously considered by the BEACON HILL participants, a decision to forgo overflight of other nations' airspace had important consequences for gaps in peacetime reconnaissance. During the BEACON HILL reconnaissance study, in September 1951, RAND established a project, "Detectability-Vulnerability Study of Pre-Hostilities Air Recce Techniques," for Colonel Richard Leghorn. (The project description in a RAND Washington Office memorandum dated September 10, 1951, originally Top Secret, has been destroyed.) RAND staff considered means of reducing the detectability of high-altitude balloons, and the residual physical and political vulnerabilities of sustained overflight programs. Following various preliminary studies, Alexander L. George, a pioneer of content analysis techniques, and Joseph M. Goldsen, a RAND political scientist, collaborated on an assessment, "Political Factors Affecting USAF Pre-Hostilities Reconnaissance," in December 1952. Both RAND and Colonel Leghorn developed an understanding in this period of the uncertain acceptability of high-altitude overflight and of the need to parallel technological development programs with a political strategy to develop international support for remote-sensing programs.

The RAND work on the political environment for high-altitude reconnaissance had proceeded from Paul Kecskemeti's Research Memorandum RM-587 of October 1950 (since withdrawn), *The Satellite Rocket Vehicle: Political and Psychological Problems*, to assessments of the high-altitude balloon reconnaissance systems that later appeared to be technologically mature, and likely to be in operation before satellite systems. George and Goldsen focused their attention on balloon overflight, with George applying content analysis methodology to Soviet public communications regarding overflights, an adaptation of a technique of analysis earlier applied by the Office of Strategic Services to German public broadcasts in World War II.

The RAND studies on the political risk of high-altitude overflight had a lasting effect upon, among others, Colonel Leghorn. While a civilian in 1954-55, he advised Governor Harold Stassen on overflight risks precedent to development of President Eisenhower's "Open Skies" proposal of 1955. Subsequently, Colonel Leghorn assisted Richard Bissell of CIA in efforts to anticipate and offset political resistance to aerial and satellite reconnaissance during the U-2 and satellite development activities of the late 1950s.

Project MOBY DICK entered its operational phase in January 1953. From January 1953 through August 1954, Project MOBY DICK personnel launched 640 balloons from three operating bases in California and Oregon, and later from bases in Missouri and Georgia. The 1110th Balloon Activities Group (formerly the Air Support Group) at Lowry Air Force Base, Colorado, organized a plotting and control facility. "[It] finally took over the MOBY DICK Program, and it . . . continued to conduct MOBY DICK-type balloon operations for long-range weather reconnaissance and for similar purposes." (Bushnell, 1959, pp. 31, 123)

Project GOPHER, the reconnaissance companion to Project MOBY DICK, ran into technical difficulties, as indicated by the operations of 1953. With the exception of trial overseas balloon operations that failed to reach the target areas in 1954, it was not until 1956 that the Air Force was prepared to proceed with actual balloon reconnaissance operations, under Project GENETRIX. (Crouch, 1983, pp. 644-647; Memo, "Future Development Action, GOPHER Project, June 17, 1953; U.S. Air Force, *Final Report, Project 119L*, p. 8, declassified 1979)

Nonetheless, in a study conducted in 1952-53, reportedly for President Truman, Professor Aristid V. Grosse of Temple University recommended orbiting an inflatable balloon that would, to the naked eye, appear as an "American Star" rising in the West. This could precede the development of space satellites that would be important for science, reconnaissance, and the psychological competition with the

Soviet bloc. (McDougall, 1986, pp. 118-119 and 482, Note 15, citing A. V. Grosse, "Report on the Present Status of the Satellite Problem," August 25, 1953, in the Harry S Truman Library)

The secrecy respecting the actual operating missions of Project GOPHER, and later Project GENETRIX, contributed to the "flying saucer" speculations of the publics of many nations:

A further advantage, or disadvantage, of plastic balloons is that from a distance they look remarkably like flying saucers. When floating at ceiling altitude, their configuration is somewhat saucer-shaped; and they can either hover for a week over much the same spot or cruise at 250 miles an hour in the jet stream. They can be seen with [the] unaided eye glistening at altitudes above 100,000 feet. . . . In addition, metallic masses of more than a ton may be lifted by these vehicles, thus giving radar returns not usually associated with balloons.

In the early days of plastic ballooning, in fact, it was sometimes possible to track a long-distance flight from Holloman or from some other center of balloon operations such as Minneapolis-St. Paul simply by following flying saucer reports in the daily papers. (Bushnell, 1959, p. 73)

I-9. CONTINUING RESEARCH ON SPACE SATELLITES

RAND assessments of the Project SINBAD, Project GOPHER, and Project MOBY DICK balloon experiments reinforced the ongoing interest in acquisition of observation satellites. If feasible, these would be relatively immune from the vagaries of weather, and would be far more predictable regarding their orbits than high-altitude balloons.

Davies recalls:

During this period, certain characteristics of the satellite system emerged. Because the costs of development would be high, the satellite must have a long life to be cost-effective. At this time, the copper heat-sink design re-entry vehicle was considered the most reliable for guided missiles or recovery from space. Because of the heavy weight of this design, the observation satellite should return imaging data by telemetry. Cost was related to weight so every effort was made to minimize mass.

The RAND scientists were now beginning to become impatient and frustrated. First they demonstrated feasibility, then utility; still there was not enough support within the Air Force or the Defense Department to start development. RAND was to make one more study, called Project FEED BACK. This project was to design an observation satellite with sufficient detail to prepare a development plan. RCA was given a subcontract to design the television system and a video tape recorder (not too different from those we now have in our homes). Robert Salter and James Thompson spent a good deal of time in Camden, N.J., working with RCA on the design. I also went with them on a few trips. James Lipp was in charge of the overall project, and Bob Salter was his deputy. Richard Frick designed the stabilization and control systems. My primary contribution was in the interpretation of simulated TV images working with a consultant, Richard Churchill.

By September 1952 Colonel Leghorn had completed a special project on intelligence and reconnaissance, in the course of which RAND researchers worked, in the fall of that year, on various peripheral aircraft and balloon alternatives, and on longer-range options for satellite reconnaissance to improve pre-hostilities intelligence.

In the aftermath of the BEACON HILL study, Colonel Leghorn sought and obtained support to adapt various bombers—the B-36, the British Canberra, and the Comet Mark II—and other candidate systems for high-altitude peacetime reconnaissance. In November 1952 Leghorn briefed the USAF Air Council, CIA, and the National Security Council on reconnaissance requirements and programs.

In the aftermath of the publication of RAND Report R-217 in April 1951, the Air Force authorized RAND to make specific recommendations for the design of a reconnaissance satellite development program, an effort then called Project FEED BACK. (Perry, 1962, p. 33, citing Memo, Col. J. A. Dunning, Assistant Chairman, War Plans Division, Director/Plans, to Director/Plans, DCS/Plans and Programs, USAF, "USAF Satellite Program," October 28, 1957)

By November 1951, the Air Force had arranged for the Atomic Energy Commission (AEC) to provide RAND with a separate research contract for the purpose of exploring the feasibility of small nuclear reactors to meet the electrical requirements of earth satellites. This work ultimately resulted in a broadening of RAND research sponsored by the AEC on nuclear and thermonuclear processes, nuclear test detection, the safeguarding of nuclear reactors from diversion of weapon-usable materials, and the direction of the Soviet atomic energy program.

In this round of RAND research on the feasibility of reconnaissance satellites, RAND entered into subcontracts with various airframe and electronics firms. In March 1952 RAND subcontracted with North

American Aviation to study orbital guidance and control, and sensing systems. North American Aviation designed a stable-attitude satellite for reconnaissance in NAA Report AL-1564, November 1952. How it compared with the RAND concept of April 1951 is not ascertainable at RAND, which no longer retains the North American Aviation report.

By June 1952 preliminary results indicated that nuclear reactors could provide the energy source for satellite operations. In that month, RAND subcontracted with the Radio Corporation of America (RCA) to study sensor systems for satellites, including optical, television, radiation detection, recording devices, presentation techniques, and reliability aspects of satellite reconnaissance subsystems. (Perry, 1962, p. 34)

By December 1952, it was understood in the Air Staff that RAND was to "prepare a detailed specification for the optimum satellite in the light of present knowledge," taking into account political and psychological problems and the utility of the satellite for reconnaissance. (Memorandum for Deputy Chief of Staff, Development, [Deleted] Satellite Vehicles," December 18, 1952, RG 341, Entry 214, National Archives)

I-10 RELATED RAND RESEARCH ON BALLISTIC MISSILE DEVELOPMENT

Within the RAND staff, much other relevant research aided in concept developments for space technology. RAND's Missiles Division under James Lipp compared a wide array of surface-to-surface and air-launched missiles, commencing with a set of nine reports published in 1950. R. W. Krueger and J. E. Lipp published a summary report, R-174, *A Comparison of Long-range Surface-to-surface Guided Missiles and Ramjet Missiles* (limited distribution). This summarized the results of Reports R-175 through R-182. Ramjets and boost-glide rockets appeared more attractive than ballistic missiles in the early 1950s, before recognition of the potential to miniaturize nuclear weapons so that they could be carried on ballistic missiles.

Several studies in the period 1952-54 contributed to the growing realization of the vulnerability of U.S. strategic forces without improved peacetime reconnaissance and a radical restructuring of the basing and operating philosophy of the Strategic Air Command. These studies had an indirect impact upon the formulation of national policy objectives by President Eisenhower in March 1954 to reduce U.S. vulnerability to surprise atomic attack.

A related RAND research activity was to have a significant impact upon the timing and means for delivery of thermonuclear weapons. This was the work of Bruno W. Augenstein at RAND, and the Strategic Missile Evaluation (TEAPOT) Committee chaired by Professor John von Neumann, to bring to fruition the development of intercontinental ballistic missiles. The ICBM would facilitate a surprise attack at intercontinental range, thus exacerbating the problem of pre-hostilities intelligence. But, at the same time, the ICBM would, once a commitment to its development had been made, reduce markedly the projected cost of launching space payloads. This in turn would reduce the costs of reconnaissance systems designed for the physical recovery of photographic film, as an alternative to reconnaissance systems using nonrecoverable electro-optical means, which RAND had proposed in 1951 and was to reemphasize in Project FEED BACK during 1951-54.

Augenstein, in September 1952, began to explore prospects for the development of intercontinental ballistic missiles, and concurrent development of nuclear weapons amenable to delivery by ballistic missiles. It was this work, briefed by Frank Collbohm, RAND's President, to various audiences in the summer and fall of 1953, and ultimately briefed by Augenstein to the TEAPOT Committee in December 1953, which strengthened the committee's confidence that it was time to recommend full-scale development of the ICBM (February 1954). Augenstein published his recommendations in RAND Special Memorandum SM-21 on February 8, 1954, then Top Secret (but later declassified). It proposed that the Convair Atlas ICBM (MX-1593) could be operational by the early 1960s if performance criteria were relaxed, and if funding and program priority were accelerated. Atlas was then the only U.S. ICBM under development. Two days later, the TEAPOT committee published its recommendations, paralleling those of SM-21. In June 1954 the Air Force established ARDC's Western Development Division, effective July 1, 1954, under Brigadier General Bernard Schriever. WDD, since 1957 a part of the Air Force Ballistic Missile Division, took primary responsibility for ballistic missile and space system development. (Snyder et al., 1976, pp. 1-2)

**I-11. RAND'S RECOMMENDATION FOR
SYSTEM DEVELOPMENT OF A
RECONNAISSANCE SATELLITE
(SEPTEMBER 1953)**

The expectation that development of the ICBM was a practical option gave a new impetus to studies on space missions and space vehicles. The work at RAND and elsewhere proceeded on the assumption that the Atlas ICBM, or an intermediate-range ballistic missile (IRBM) such as the Thor or Jupiter system together with an upper stage, would ultimately provide the capability to launch a satellite into earth orbit. It was not until 1957, with the first successful test of the Thor IRBM on September 20, with Soviet launch of the first space satellite, Sputnik 1, on October 4, and with the first successful launch of the Atlas ICBM on December 17 that the means of launching space payloads could be demonstrated to exist.

In May 1953, ARDC planners obtained Air Staff endorsement of the concept that ARDC should take responsibility for "active direction" of the Project RAND study of satellite reconnaissance, FEED BACK, by June 1, 1953. The Atlas ICBM was then seen as the logical boost vehicle for a reconnaissance satellite payload. (See Letter, Major General D. N. Yates, Director, Research and Development, DCS/D, USAF, to Commanding General, ARDC, "Project FEED BACK," May 22, 1953, cited in Perry, 1962, p. 39.) ARDC staff visited the RAND "Satellite Office." Lieutenant Colonel Victor L. Genez returned from his initial RAND Satellite Office visit in August 1953 convinced that an immediate effort should be made to orbit a satellite, even if the reconnaissance subsystem was not as yet available. (Lieutenant Colonel V. M. Genez, Director/Intelligence, Deputy for Development, ARDC, Memo for the Record, "Conference with RAND Corporation re: FEED BACK Program," August 13, 1953, cited in Perry, 1962, p. 39)

On September 8, 1953, James Lipp, head of the Satellite Section at RAND, forwarded to the Air Research and Development Command RAND's preliminary recommendation for development of a space satellite. (J. E. Lipp, "Interim Recommendations for Project FEED BACK," September 8, 1953, cited in Perry, 1962, p. 39) RAND recommended that ARDC establish a reconnaissance satellite design contract within one year, thereafter proceeding to full system development, "perhaps immediately following the completion of experimental component tests."

In December 1953, ARDC established Project 409-40, "Satellite Component Study," and gave the advanced reconnaissance system an

innocuous-sounding system number, Weapon System WS-117L. By January 1954, Project 1115 (see below) acquired the unclassified designator "Advanced Reconnaissance System," and an engineering project designator, MX-2226, identifying the activity as an Air Force, rather than a Project RAND, enterprise. Funding authorization was to await documentation and summarization of the Project RAND FEED BACK report in early 1954. (Perry, 1962, p. 36)

I-12. STRATEGIC VULNERABILITY AND STRATEGIC WARNING

Meanwhile, RAND staff assessed the strategic situation for the 1950s, during which the main threat appeared to be the delivery of atomic and thermonuclear weapons by aircraft. From assessments of U.S. strategic force vulnerabilities came a renewed appreciation of the importance of pre-hostilities reconnaissance. RAND's contribution to a better understanding of the mounting vulnerabilities to surprise attack came from assessments not of Soviet military capabilities but of the potential interaction of Soviet and American strategic forces. RAND analysts had been addressing the problem of surprise attack and its implications for rethinking strategic objectives and the redesign of U.S. strategic forces. On June 1, 1952, RAND issued Report R-235, *The Cost of Decreasing Vulnerability of Air Bases by Dispersal—Dispersing a B-36 Wing* (limited distribution). On November 1 of that same year, Albert Wohlstetter and Harry Rowen published Research Memorandum RM-975, *Elements of a Strategic Air Base System*, a forerunner of Report R-266, which recommended restructuring SAC basing systems to reduce vulnerability to surprise attack while performing SAC's deterrence mission.

It should be remembered that the Korean War had come as a surprise in June 1950, but this would not explain the resurgence of interest in means of coping with surprise in 1953-54, as the Korean War came to a close. Development of thermonuclear devices and their testing in both the United States and the Soviet Union in 1952-54, and the expanded production of nuclear weapons and their means of inter-continental delivery, raised concerns regarding the war-fighting consequences of a surprise Soviet attack. In particular, Soviet production of TU-4 long-range bombers, and Western projections of Soviet submarine-launched aircraft-delivery of atomic weapons, encouraged a reanalysis of the role of strategic warning in deterring and defending against surprise attack in the nuclear age.

Three RAND studies undertaken in 1952-54 had a considerable impact upon the restructuring of U.S. strategic forces and an indirect effect in highlighting the importance of improving the reliability of warning of the initiation of nuclear war.

One study, prepared by Andrew W. Marshall and James F. Digby, analyzed the contribution of intelligence warning of attack to the performance of military forces in war. RAND issued Special Memorandum SM-14 in April 1953 and a revised version of a then-Top Secret document, entitled *The Military Value of Advanced Warning of Hostilities and its Implications for Intelligence Indicators*, in July 1953. This study recommended attention to short-term indications of dynamic preparations of a Soviet attack, and a willingness to accept force readiness based, at times, upon false alarms. If warning of impending attack were sufficiently unambiguous to form the basis for all-out-alert orders, it was estimated that within 12 to 48 hours after an all-out alert, military effectiveness could reach about 90 percent of its maximum value.

This study attributed to the USSR the possibility of striking without warning, perhaps after deceptive and placatory moves. It attributed to the Soviet Union an ability to conceal its immediate intentions more completely than has generally been possible at the initiation of past wars. The study anticipated the increasing decisiveness of the early moves of a war as a result of plentiful atomic bombs, long-range air forces for their delivery, and highly mobile ground forces. Hence, even if a deceptive, surprise attack were not judged to be the most likely way for war to begin, this was an important possibility for which to prepare, because the Soviet Union was projected to have that capability and because the success of such an attack would have disastrous consequences for the West. This report recommended the restructuring of a system to collect indications of impending war, rapid transmission of data, development of analytic systems that commanders trusted for purposes of mobilizing resources, willingness to accept false alarms, and realism regarding political constraints upon the mobilization of strategic forces. This study did not address the need for specific intelligence collection systems to improve the reliability of pre-hostilities warning.

A second study, prepared by RAND's Plans Analysis Section, reported the *Vulnerability of U.S. Strategic Air Power to a Surprise Enemy Attack in 1956*, in a 112-page document, together with a six-page summary, RAND Special Memorandum SM-15, April 15, 1953.

Top Secret when issued, it was declassified in May 1967. Fifteen members of the RAND staff contributed to its preparation.⁶

Special Memorandum SM-15 estimated the effect of a surprise Soviet attack on the combat potential of the Strategic Air Command in 1956. It considered three types of attack: submarine-launched, manned aircraft; TU-4 bombers penetrating radar warning nets at low altitude; and TU-4 bombers penetrating at high altitudes, with atomic bombs of 40 KT and 100 KT. The study estimated that with no more than 50 aircraft launched from submarines, or 50 TU-4s achieving surprise with low-altitude flight and carrying only 50 atomic bombs, the Soviet Union could destroy two-thirds or more of SAC's bombers and reconnaissance aircraft. But "[the] degree to which the enemy succeeds in making an effective attack depends upon his capability to mount an attack and reach the radar network without giving enough advance warning to allow full-scale execution of SAC's evacuation plan. . . ."

SM-15 alluded to the parallel work reported in SM-14 (Marshall and Digby):

A substantial reduction in vulnerability would result from advance indications of enemy activity *provided these could be translated into sufficiently unambiguous states of alert*; but from the limited data now available at RAND, the probability of such action appears to be small. (SM-15, p. iii) [Emphasis in the original]

Moreover:

The programmed 1956 radar network does not provide enough warning at most SAC bases for either evacuation to occur or for fighter defenses to be effectively brought to bear.

Indeed, most of the SAC aircraft and bases which survive do so owing to the failure of the enemy carrier to reach the target because of operational difficulties and the range limitation imposed on the sub-launched aircraft. The situation is especially bad in overseas areas, where two-way TU-4 missions of relatively short duration are possible and warning times are quite short. (SM-15, p. iii)

Two out of eight recommendations for immediate action were: (1) "Relocation to interior areas of all programmed ZI [Zone of the Interior] SAC bases now planned for areas with little warning and not yet under construction," and (8) "filling of gaps in the low-altitude warning net in the southern states."

⁶H. I. Ansoff, W. W. Baldwin, R. L. Belzer, E. Boehm, J. C. DeHaven, C. B. Dougherty, R. H. Frick, W. H. Fleming, Col. T. A. Holdiman, H. S. Rowen, Jr., F. M. Sallagar, J. T. Schneider, Mrs. A. L. Skogstad, R. L. Stewart, Jr., and C. V. Sturdevant, III.

SM-15 recommended as a performance goal, without specifying the means of accomplishing it: "Provision of substantially more warning at ZI SAC bases coupled with a corresponding reduction in SAC evacuation times." (p. vi)

The same Special Memorandum reported that, without even equivocal warning, about 73 percent of SAC bomber bases would have all of their aircraft on the ground at the time of Soviet release of atomic weapons over the bases. With equivocal warning of 60 minutes or longer, some of the SAC bombers would escape destruction on airfields. But the main requirement was to redesign the basing system for SAC, rather than to depend upon unequivocal warning of impending attack:

The general conclusion to be drawn from these considerations is that the present ZI radar network and the SAC base location do not seem to be properly matched and, unless a very high attrition level can be inflicted on the enemy, heavy damage is to be expected from enemy attacks. . . . [While] improvements in SAC evacuation procedures [are] certainly desirable, any real improvement in the evacuation picture would have to come through increase of the net warning time . . . provided to SAC.

So far the warning situation has been discussed for the ZI base complex. On the overseas bases the picture is considerably worse. It is estimated that all areas except the UK will get virtually no warning against the submarine-launched and low-altitude attacks, and about 30 minutes against the high-altitude attacks. . . . It can therefore be concluded that *all wings on rotation overseas will be caught on the ground.* (SM-15, pp. 25-26) [Emphasis in the original]

The short-term impact of SM-15 upon requirements for warning of impending attack involved improvements in radar coverage of access to the United States, and "anti-submarine detection measures in order to insure all-around protection." (SM-15, p. 82) Moreover, "[there] ought to be a clear-cut and relatively unambiguous set of ground rules for translating indications of enemy activity (equivocal warning) into corresponding states of U.S. alert. . . . The circumstances attending Pearl Harbor and the initiation of the Korean War show that the mere existence of indicators of enemy activity does not necessarily guarantee that these will be translated into adequate states of national alert." (SM-15, p. 83) For purposes of this operationally oriented study, it was impractical to project improvements in reconnaissance systems that might be available in the 1960s.

The immediate requirement was an improvement in SAC's warning and operating posture in the 1950s. Nonetheless, studies of strategic force vulnerability indirectly contributed to a broadening of awareness of the value in obtaining timely and reliable synoptic reconnaissance

coverage of the Soviet Union, its allies, and their war preparations in peacetime.

A third study paralleled these first two in its origins, but continued for another year (1953-54). It ultimately became one of RAND's best-known research studies, *The Selection of Strategic Air Bases*, Report R-266, April 2, 1954, by A. J. Wohlstetter, F. S. Hoffman, R. J. Lutz, and H. S. Rowen. This report drew upon related studies of the vulnerability of U.S. strategic forces as they existed, and projected alternative strategies to enhance deterrence in the nuclear bomber and missile age. The 426-page study, originally Top Secret, was declassified on June 28, 1963. As with most of the important RAND studies, its main policy impact resulted from briefings, special memoranda and other preliminary documents, and informal discussions preceding its formal publication.

Albert Wohlstetter and Harry Rowen published their preliminary review of air base vulnerability in RAND Research Memorandum RM-975, November 1952. Two months later, Wohlstetter began briefing preliminary concepts for the selection of a more appropriate basing strategy. By March 1953 there was a 48-page draft, "The Selection of Strategic Air Bases." Extensive briefings commenced after the completion of a 148-page draft study on September 1, 1953, at the Strategic Air Command, within the Air Staff, to the Air Force Scientific Advisory Board, and in early 1954 to the Air Force Advisory Council.

The RAND studies complemented formal national intelligence estimates (NIEs) on projected Soviet atomic weapons and delivery capabilities. But the RAND studies, unlike the NIEs, examined the interaction of strategic forces and called for a fundamental rethinking of strategy in the nuclear bomber, and potentially the nuclear missile, age. It is beyond the scope of the present report to trace the indirect effects of these RAND studies, and of independent studies contributing to the President's concern that the nation address the problem of surprise attack. But from the reactions to the briefings preceding publication of R-266, it is clear that a recognition of the importance of improving both pre-hostilities and attack warning was, by the spring of 1954, widespread.

I-13. RAND'S PROJECT FEED BACK REPORT (1954)

In parallel with RAND staff studies of strategic force vulnerability, RAND staff and consultants explored technological possibilities for space-based sensing systems that might, if successful, relay data in near-real-time to ground stations. These nonrecoverable observation satellites would, if feasible, contribute both to the pre-hostilities assessment and targeting requirements of interest to Colonel Leghorn, and to the warning of impending attack of mounting concern to the Strategic Air Command and other Department of Defense elements.

On March 1, 1954, James E. Lipp and Robert M. Salter, Jr., with others, published RAND Report R-262, *Project FEED BACK Summary Report*, two volumes. (R. L. Perry, 1962, p. 32; Augenstein, 1982, p. 7) With some deletions, the Appendixes constituting Volume II of the FEED BACK report have been declassified, and key recommendations of Volume I (still classified) have been summarized in a declassified Air Force history (Perry, 1962).

From the declassified appendixes, it is apparent that the FEED BACK team that reported its findings and recommendations in its two-volume summary report recommended that the Air Force develop an electro-optical reconnaissance satellite. The imaging system visualized in the FEED BACK study consisted of an image orthicon television to be used with a 0.96- × 1.28-in. photocathode and an f/24, 38-in. focal-length optical system. From an altitude of 300 miles, the resolution (2-pixel) on the ground was projected to be about 144 feet. A scanning mechanism was designed to map a strip with a width of about 375 miles, at 300 miles satellite altitude. (Project FEED BACK Summary Report, Vol. II, March 1, 1954, pp. 105-108, declassified 1985)

With the technology foreseen in the mid-1950s, a ground resolution well in excess of one hundred feet meant, as a practical matter, that a satellite of this design could provide cloud cover and other weather information but not the kind of high-resolution imagery that photo-interpreters could obtain from airborne photographic systems. Television and videorecorder technology was not sufficiently advanced in this era to provide the Air Force with the intelligence it sought to identify and target strategic forces. Moreover, a reconnaissance satellite without higher resolution could not contribute the indicators of impending military hostilities of interest to reduce vulnerability to surprise atomic attack.

Thus, RAND's FEED BACK report encouraged the Air Force to plan a competition among industrial firms to develop a higher-

performance system. The FEED BACK studies, and others stimulated by them, later encouraged the development of earth resource satellites for civilian applications. But the ground resolution that could be expected in the mid-1950s was not adequate for most military intelligence purposes.

By comparison, when the civilian space satellite system LANDSAT 1 began its remote sensing in July 1972, it operated at an altitude of 565 miles with a ground resolution (2-pixel) of about 160 meters, or 525 feet. (Doyle, 1978, pp. 155-164) The Project FEED BACK studies completed 18 years earlier had projected somewhat better system performance, taking into account an altitude about half that of LANDSAT 1 and 2 but with nearly four times better ground resolution.

The Project FEED BACK Summary Report provided an overview of engineering issues, the international political repercussions of satellite reconnaissance, a cost projection, and subsystem studies. It was not just another report, but a culmination of several studies, designed to encourage the Air Force to proceed with a major satellite development effort. Robert L. Perry reviews highlights of the FEED BACK summary report in a declassified official history:

Over a period of more than two years, RAND had subcontracted studies to a variety of highly qualified research and industry groups. Several hundred scientists and engineers had a part in the contributory studies and in the final report. In consequence, that report (dated 1 March 1954) contained the validated findings of some of the most highly regarded individuals and organizations in the nation. On the basis of such work, RAND specifically recommended that the Air Force undertake "the earliest possible completion and use of an efficient satellite reconnaissance vehicle" as a matter of "vital strategic interest to the United States." Additionally, RAND urged that the satellite project be "considered and planned" at a high policy level and that it be conducted under elaborate secrecy wraps to prevent dangerous international repercussions. On such a basis, it seemed possible to RAND that the development and initial operation of the satellite could be completed in about seven years and at a total cost "on the order of \$165 million"—although the researchers cautioned that uncertainties inherent in the prediction of development trends might double or treble that cost. (RAND also remarked, with considerable foresight, that "it may be possible to attain the end goal of the program from one to two years earlier at a considerable increase in cost.") (Perry, 1962, pp. 36-37, 39, citing RAND Report R-262, *Project FEED BACK Summary Report*, March 1, 1954, pp. vii, 3-4, 149-150, 164-166)

The FEED BACK summary concluded:

RAND has been working on the satellite vehicle for 8 years. During this period the metamorphosis from a feasibility concept to a useful reconnaissance purpose has occurred. Cognizance is now being turned over to the Air Force with the recommendation that the program be continued on a full-scale basis. (Quoted in Perry, 1962, p. 37)

Following the publication and favorable reception of the Project FEED BACK report in 1954, RAND recruited Robert W. Buchheim, a guidance and control project engineer from North American Aviation, and Amrom Katz, who brought nearly fifteen years of photoreconnaissance and camera experience from his work in General George Goddard's Reconnaissance Laboratory in Dayton, Ohio. The combination of Katz and Davies gave RAND an institutional memory and diverse contacts in the field of high-altitude reconnaissance. These came to be of importance, for the requirements for television-type data storage and retrieval from space systems appeared to be unmeetable in the near term.

I-14. PRESIDENT EISENHOWER'S COMMITMENT TO STRATEGIC WARNING: THE TECHNOLOGICAL CAPABILITIES (KILLIAN) PANEL

In the fourth week after completion of the RAND Project FEED BACK report, but without any discernible relation to it, President Eisenhower initiated a government review of means to reduce the risks of surprise attack. On March 27, 1954, President Eisenhower asked various of his scientific advisers, including James B. Conant and James R. Killian, Jr., to develop a solution to the problem of surprise attack.

Exactly what piqued President Eisenhower's interest in late March 1954, instead of earlier, remains a mystery. Many institutions were coming to grips with the potentiality for surprise attack in the nuclear age. Intelligence estimates in the period 1953-54 emphasized the potential for Soviet mass production of nuclear and thermonuclear weapons, and long-range bombers, including the TU-4, to deliver them to the continental United States. RAND's prior studies of the vulnerability of U.S. strategic forces and the mounting importance of pre-hostilities intelligence affected perceptions within the Strategic Air Command, the military services and the Office of the Secretary of Defense. Special Memorandums SM-14 and SM-15, as well as briefings on SAC vulnerabilities and recommended actions, preceded

publication of the bomber basing study (R-266). These had an indirect impact upon strategic thinking. But there is no directly traceable link to President Eisenhower's directive to his scientific advisers in March 1954 to address the problem of surprise attack.

It has been reported recently (Beschloss, 1986, pp. 73-74) that Trevor Gardner, Assistant to the Secretary of the Air Force for Research and Development, was instrumental in stimulating scientists advising the President to take an active role in identifying solutions to the problem of surprise attack. Gardner had worked on the Manhattan Project at the California Institute of Technology before establishing his own corporation, HYCON, which designed and built reconnaissance cameras. He joined the Eisenhower administration in 1953. At this juncture, it is difficult to ascertain whether he received the Wohlstetter briefing or others prepared at RAND on SAC force vulnerability to surprise attack or the need to modernize the SAC warning and alerting system; but he was in a position where he was frequently briefed on Project RAND findings. Reportedly after a visit with "the cigar"—General Curtis E. LeMay, Commander of the Strategic Air Command—at which the surprise attack problem was considered, Gardner met with the President of Caltech, Lee E. DuBridge, in Pasadena. DuBridge served at that time as Chairman of the Office of Defense Mobilization's Scientific Advisory Committee (SAC). Gardner reportedly told DuBridge that the SAC wasn't worth

a good goddamn. . . . You're abnegating your responsibility to science and the country, sitting . . . in fancy offices in Washington, wasting your time and the taxpayers' money going through a lot of goddamn motions on a lot of low level . . . exercises—all in the name of science. (Beschloss, p. 73)

Gardner reportedly proposed that SAC undertake a study of surprise attack and the U.S. ability to meet it. DuBridge reportedly took the issue to President Eisenhower. After White House consultations in the spring of 1954, the President invited MIT's President Killian to chair a Technological Capabilities Panel, known as the TCP. This panel operated with three project committees, one on offensive forces, one on defensive forces, and one on intelligence. (Beschloss, 1986, pp. 73-74; Kaplan, *The Wizards of Armageddon*, 1983, pp. 127-154)

Edwin H. ("Din") Land, the founder of Polaroid, chaired the Intelligence Committee, known as Project 3. The Land Committee also included James G. Baker, a lens-designing Harvard astronomer; Joseph W. Kennedy of Washington University; Allen Latham, Jr., of Arthur D. Little, Inc.; Edward M. Purcell of Harvard University; and John W. Tukey of Princeton University.

I-15. RAND WORK TO ACCELERATE DEVELOPMENT OF U.S. AIR FORCE RECONNAISSANCE SATELLITES: THE WS-117L PROGRAM

It was later in 1954, after publication of the FEED BACK report in March and after the TCP effort was under way, that the U.S. Air Force authorized a research program to develop reconnaissance satellites, WS-117L. (Stares, 1985, p. 22) Bruno Augenstein explains:

This early period closes with the decision to pursue the WS-117L program, whose main progenitor was the RAND FEED BACK study. . . . The impetus given to satellite work by RAND studies in this era seems mostly forgotten now; but it is doubtful if the program could have obtained a running start without it. (Augenstein, 1982, pp. 1,2)

The RAND project FEED BACK team briefed its study at the Pentagon, at Wright Field, and elsewhere. General (then Lieutenant Colonel) William G. King, Jr., recalls his pleasure at being invited to the Top Secret briefing. But after the briefing was over, no immediate initiative followed to establish a satellite development program. Nonetheless, the RAND FEED BACK report captured the imagination of the Assistant Librarian at Wright Field, Lieutenant Colonel Q. Riepe, who lobbied various ARDC officials to pursue the RAND satellite concept. When ARDC approved the project, Riepe assisted Colonel King, who outranked him, in organizing the development project.

Two months after issuance of the RAND FEED BACK report in March 1954, HQ USAF had directed ARDC to assume responsibility for a study of applications. ARDC, headquartered in Baltimore, delegated responsibility for "Project 1115" to Wright Field, where Colonel King, Colonel Riepe, and others began study of, and documented, the Advanced Reconnaissance [Satellite] System. In July 1954 the Coordinating Committee on Guided Missiles, established to implement the recommendations of the Von Neumann Committee, approved Project 1115 on behalf of the Office of the Secretary of Defense. In August 1954, the authorization to start work on a satellite reconnaissance system reached the Western Development Division of ARDC. (Perry, 1962, p. 41)

An Air Force history, *Origins of the USAF Space Program, 1945-1956*, attempts to summarize the impact of the Project FEED BACK briefings—events that, more than three decades later, are not readily reconstructed:

A number of the presentations of the FEED BACK proposal, largely as defined by RAND, marked the summer and early fall of 1954. Following the Air Research and Development Command's assumption of project responsibility in May, that command began a determined attempt to obtain approval for an expanded industry study effort. Among those who heard and in some degree endorsed the FEED BACK approach were the acting chairman of the [USAF] Scientific Advisory Board, J. A. Doolittle; the Air Force Chief of Staff, General N. F. Twining; and the heads of Strategic Air Command and the Air Research and Development Command—Generals LeMay and Power. General LeMay was quite responsive to the presentation, urging preparation of a formal Strategic Air Command requirements document covering the satellite, but other of the command's officials, notably in its operations analysis staff, urged the greater need for improved refueling techniques and manned bombers. General Putt, who immediately preceded [ARDC Commander General Thomas S.] Power as research and development command chief, strongly supported the satellite program—as did Power himself. (Perry, 1962, pp. 41-42)

In October 1954, Trevor Gardner, Assistant Secretary of the Air Force for Research and Development, asked the ICBM Scientific Advisory Group (an offshoot of the Von Neumann Committee) to consider the possible interaction of satellite programs, other missile programs, and the intercontinental ballistic missile program. On October 15, the ICBM Scientific Advisory Group recommended that the integration of the satellite and missile programs be assigned to the Western Development Division under Brigadier General Schriever. (Perry, 1962, p. 41 and p. 58, Note 5).

There remained, however, widely based skepticism about the utility of satellite system development. On December 17, 1954, for example, Secretary of Defense Charles E. Wilson responded to a prediction that the Russians might place a satellite in orbit before the United States could do so. Wilson replied: "I wouldn't care if they did." (*New York Times*, December 17, 1954)

By November 1954 the Killian Panel, and its reconnaissance committee under "Din" Land, recommended accelerated development of a high-altitude airplane. President Eisenhower approved what became the U-2 project at a meeting of the Killian Panel with the Secretaries of State and Defense, DCI Dulles, and other senior officials, on November 24, 1954. Richard M. Bissell, Jr., of CIA took charge of this highest-priority project, codenamed AQUATONE. (Memorandum, Colonel A. J. Goodpaster of Conference with President Eisenhower, November 24, 1954; Beschloss, 1986, pp. 81-82; Stephen Ambrose, *Ike's Spies*, 1981, p. 268)

Three days later, on November 27, 1954, ARDC issued System Requirement No. 5 to develop a reconnaissance satellite system. Since the Final Report of the Killian Panel recommended development of such a system, it is possible that it was the Killian Panel review of November 24 that indirectly stimulated the Air Force to proceed with a formal requirement:

The appearance of System Requirement Number 5 on 27 November 1954 signaled approval of a clearly defined effort to develop a reconnaissance satellite system, even though the general operational requirement (GOR No 80) did not emerge from Pentagon channels until 16 March of the following year. (Perry, 1962, p. 41)

I-16. PROJECT GENETRIX (WS-119L) BALLOON RECONNAISSANCE OPERATIONS

Concurrently with the U-2 project, the Air Force proceeded from the development to the operational phase of its balloon reconnaissance program in 1955-56, as noted. On March 21, 1955, the Air Force assigned responsibility for aerial reconnaissance of the Soviet Union to the Strategic Air Command, using the codename GENETRIX for the balloon reconnaissance program known as WS-119L. On April 15, SAC established the 1st Air Division (Meteorological Survey).

Meteorological experiments continued under the overt project MOBY DICK, established in 1951 at the Air Force Cambridge Research Center, with primary field experimentation at Holloman Air Force Base in New Mexico.

The transposition from development to operations of overhead reconnaissance programs had two effects upon RAND research. The first was the delimitation of participation by RAND researchers, as reconnaissance systems became operational, together with restrictions upon access to many RAND research studies that had been widely distributed in the past. In May 1955 and thereafter, several of the early RAND research studies on "pioneer" reconnaissance by balloon systems (as it was sometimes termed) were recalled from general circulation, in parallel with the actual commitment to implement these designs and proposals. Included in the May 1955 recall were RM-494 by William W. Kellogg, Stanley M. Greenfield, and D. T. Griggs, and RM-692, by E. W. Paxson, T. E. Harris, and S. M. Greenfield.

The second effect was the tasking of selected RAND personnel to provide analytic support to the reconnaissance operations of SAC,

commencing with WS-119L and continuing with the follow-on project WS-461L.

Davies recollects:

In 1956, a project called GENETRIX (119L) was implemented in which balloons containing cameras were launched from five locations in Europe. They drifted across Europe and Asia, taking pictures, and were recovered from the Pacific when all went well. Levison had designed the duplex camera flown on these balloons. The cameras were produced by five manufacturers. The camera had two six-inch wide-angle lenses mounted so that the two pictures overlapped at nadir and extended to the horizon. (See Colonel Paul Worthman's recollections, in *Rostow, Open Skies*, 1982; USAF Project 119L Final Report, declassified in part in 1979)

Walter J. Levison was the project manager for the Project 119L "Duplex" camera subsystem, designed at the Physical Research Laboratories of Boston University. Levison writes:

The Duplex Camera was designed at the Boston University Physical Research Laboratories specifically for the balloon mission. . . . The camera consisted of two 6" metrogon lenses mounted in a single structure to provide an overlapping field of view at the nadir. Each lens covered a 9" by 9" image. The configuration was an adaptation of the standard tri-metrogon installation that had been used extensively for mapping during World War II. (Letter, W. Levison to D. Dworkin, Curator, National Air and Space Museum, May 29, 1987)

Operational launches of GENETRIX balloons started on January 10, 1956, under inauspicious circumstances. Levison recalls:

The operational mission was delayed and didn't begin until 10 January 1956. For various reasons the operational altitude was decreased to 45,000 feet from a design altitude of approximately 70,000 feet. At that altitude the balloons were quite vulnerable to enemy action. The lower altitude also meant that the wind speed was higher, although that was partially offset by the lower wind velocity typical of January. (Letter, W. Levison to D. Dworkin, Curator, National Air and Space Museum, May 29, 1987)

After many balloons landed over foreign territory, including the Soviet Union, and after some balloons were successfully recovered, the operational flights were discontinued on March 1, 1956, following Soviet protests and a *Washington Post* story on February 10. President Eisenhower instructed Secretary of State Dulles to tell the Soviet government that no further balloons associated with the MOBY DICK research program would be sent over the Soviet Union. (See Attachment to Memorandum for Colonel A. J. Goodpaster, The White House, February 8, 1956; USAF, *Final Report, Project 119L*, p. 8ff; Beschloss, 1986, p. 112.)

Levison recalls:

[The] project was considered to be successful. About 40 balloons made it through and about 2 million square miles were photographed. The net square miles photographed were 1,116,449, which is about 8% of the Sino-Soviet area, at a cost of \$48.49 per square mile. That is significantly lower than the cost of getting mapping coverage in the U.S. then or now. (Letter, W. Levison to D. Dworkin, May 29, 1987, p. 2)

**I-17. U.S. AIR FORCE REQUIREMENT
NO. 5 FOR AN ADVANCED RECONNAISSANCE
SYSTEM, AND THE TRANSFER OF RAND
EXPERTISE TO PRIVATE INDUSTRY**

It was fully a year after submission of the FEED BACK summary reports, and concurrent with a commitment to operation of balloon reconnaissance, that the Air Force issued a formal System Requirement (No. 5) for an Advanced Reconnaissance [Satellite] System on March 16, 1955. (Perry, 1962, p. 41) This followed by just one month the report of the Killian panel to the President.

The Killian Panel's report to the President on February 14, 1955, *Meeting the Threat of Surprise Attack*, included these findings from Project 3's section of the report:

We must find ways to increase the number of hard facts upon which our intelligence estimates are based, to provide better strategic warning, to minimize surprise in the kind of attack, and to reduce the danger of gross overestimation or gross underestimation of the threat. To this end, we recommend adoption of a vigorous program for the extensive use, in many intelligence procedures, of the most advanced knowledge in science and technology.

Killian and Land together briefed President Eisenhower on the specific technological options that could alleviate uncertainties of strategic intelligence. These included systems for aerial overflight by aircraft or balloon and, somewhat further in the distance, satellite reconnaissance systems. Indirectly, the Killian Panel was a major stimulant to Air Force requirements for advanced reconnaissance systems. RAND's role was that of a source of technical expertise on the system concepts that might provide improved reconnaissance capabilities.

General Operational Requirement No. 80 of March 16, 1955 established a requirement for an advanced reconnaissance satellite:

In many respects, as might have been anticipated, it paralleled the earlier RAND studies. It defined as the Air Force objective a means of providing continuous surveillance of "preselected areas of the earth" in order "to determine the status of a potential enemy's warmaking capability." Intended for launch from fixed bases, the reconnaissance satellite was to provide daylight visual coverage in sufficient detail to permit identification of airfield runways, and intercontinental missile launch stations. Additionally, an alternate ability to collect electronic intelligence and to provide weather forecasting data was also specified. Although the "ultimate" required definition ("... capability to detect objects no more than 20' on a side...") was somewhat optimistic in terms of RAND's earlier findings, the required operational availability date (1965) seemed basically sound. (Perry, 1962, pp. 42-43)

During this period many RAND personnel who had worked on advanced reconnaissance concepts left to work in private industry, taking with them many of the concepts that they had developed or had learned about at RAND. While Project FEED BACK concepts were under evaluation in 1953, for example, L. Eugene Root, Head of RAND's Aircraft Division, left to join the Lockheed Aircraft Corporation as Director of Development and Planning. Over the next few years he recruited many of the RAND staff who had worked on advanced reconnaissance issues.

I-18. PRESIDENT EISENHOWER'S "OPEN SKIES" INITIATIVE (JULY 1955)

The Killian Panel's evaluation of requirements to reduce the risks of surprise attack preceded a more broadly based review of verification requirements for arms control and disarmament agreements. In May 1955 the Soviet Union agreed, in principle, to the concept of on-site inspection, but implementation of the principle would require a transformation of the Soviet system of secrecy. In June 1955 Nelson Rockefeller, Special Assistant to President Eisenhower for "Cold War Strategy," convened a panel of experts at Quantico Marine Base to evaluate the role of aerial reconnaissance in achieving disarmament agreements and in averting surprise attack.

Hans Speier of RAND was one of the participants in this review panel, sharing with the participants RAND's evaluations of Soviet reactions to overflight of their territory and concerns about the difficulty of gaining Soviet acceptance. Professor Max Millikan of MIT,

who had recently served a tour at CIA as Assistant Director for Intelligence, proposed an agreement on overflight rights. Speier reportedly considered the proposal too close to plans for the U-2 reconnaissance project (AQUATONE). Based on this review, Rockefeller recommended to President Eisenhower adoption of an "open skies" proposal for a Geneva summit meeting scheduled in July 1955. (Rostow, 1982; Beechloss, 1986, pp. 98-99)

On July 21, 1955, President Eisenhower did propose this "Open Skies" plan, which met with favorable British and French reaction, and with the initial support of Soviet Premier Bulganin. Chairman Nikita S. Khrushchev objected to the plan, denouncing it as nothing more than a device to legalize espionage—although it would have facilitated arms control verification and served as what is now termed a strategic "confidence-building measure." (Rostow, 1982; Ambrose, 1984, 257-259, 262-264)

In the aftermath of Soviet rejection of the "Open Skies" concept, self-help measures of reconnaissance appeared all the more necessary. A National Intelligence Estimate of 1955 projected: "As of 1958, the estimated Soviet nuclear stockpile and delivery capability will be inadequate to 'knock out' the United States." But this special estimate also concluded that "the USSR could damage the United States on a scale unprecedented in human experience," without, however, preventing "the delivery of an even more devastating retaliatory attack." (Quoted in R. K. Betts, "A Nuclear Golden Age? The Balance before Parity," *International Security*, Winter 1986-87, p. 13)

In August 1955 Lieutenant Colonel William G. King, Jr., became the project officer for the advanced reconnaissance satellite program. (Perry, 1962, p. 43) Colonel King recalls a critical meeting at ARDC headquarters in Baltimore. He came from Wright Field to brief the Scientific Advisory Committee on the satellite project. Simon Ramo pointed out to General D. H. Putt that the satellite program was competing for the same launch capabilities and personnel as the highest priority ICBM program. Ramo urged Schriever to move the satellite program to the Western Development Division in Inglewood, California. The resulting decision removed WS-117L from an environment dominated by the aviation-oriented staff of ARDC at Baltimore and Wright Field. In the fall of 1955, General Schriever assigned responsibility for the satellite program to Navy Captain Robert C. Truax. In October 1955, the Air Force consolidated its management of space satellite programs. General Thomas S. Power, Commander of the Air Research and Development Command, transferred responsibility for the advanced satellite system (WS-117L) from the Wright Air Development Center to the Western Development Division of ARDC, already

responsible for IRBM and ICBM development. Also in October 1955, WDD moved from the "old schoolhouse" (also known as the "little red schoolhouse") in Inglewood to a larger complex on Arbor Vitae Avenue near Los Angeles International Airport. (See Snyder et al., 1976, p. 29.) Both facilities were conveniently close for RAND researchers.

The next phase of space satellite development was the organization of a contract competition. By November 1955, 14 basic technical tasks had been defined, approved, and assigned to WDD staff. Under the project name PIED PIPER, the Air Force contracted with Radio Corporation of America, Glenn L. Martin Company, and Lockheed Aircraft for satellite design studies. (Perry, 1962, p. 43)

Davies recalls:

With the publication of the Project FEED BACK reports and a recommendation to the Air Force to initiate a satellite program, action was finally taken and a competition was held between Lockheed, RCA, and Martin for the Advanced Reconnaissance System (ARS). About this time, Gene Root, head of RAND's Aircraft Division, Bob Salter, and about a dozen of RAND's missile engineers left to go to work for Lockheed. Shortly thereafter, Jim Lipp joined Root's corporate planning staff at Lockheed headquarters in Burbank. When Root moved to Sunnyvale to establish Lockheed Missiles and Space Systems Division, Lipp succeeded him at Burbank as Director of Development Planning. Robert Krueger left RAND to organize the Planning Research Corporation and took a few engineers with him. George Clement stayed with RAND to head the Missiles Division and rebuild the organization.

Navy Captain Robert Truax was in charge of the Advanced Reconnaissance System Office in the WDD. He had been involved with rocket experiments and studies since his days at Annapolis. Amrom [Katz] and I were invited to attend the final ARS competition briefings by the contractors at Wright Field, Dayton. This was for information only; we were not involved with the evaluation.

Part II

THE DIVERSIFICATION OF RAND'S SPACE TECHNOLOGY RESEARCH, 1954-1960

In the aftermath of the Air Force requirement for a reconnaissance satellite, RAND rebuilt its staff with a broader range of interests. In the ensuing period, stimulated by International Geophysical Year programs, RAND studies were broadened to include lunar and planetary exploration.

II-1. SCIENTIFIC SATELLITE MISSIONS

On May 26, 1955, the National Security Council, through Directive 5520, established a policy on "peaceful uses of space," and decreed that the U.S. satellite for the International Geophysical Year (IGY) would not employ any missile intended for military purposes. (Bowen, 1960, p. 10; Perry, 1962, pp. 47-48, citing NSC Directive 5520, May 26, 1955) This policy decision resulted in the effective elimination of the Atlas-Thor vehicles of the Air Force, and the Orbiter satellite that depended upon Redstone-Jupiter launch vehicles of the Army and Navy for launch support of scientific payloads. With the Redstone ruled out, the Navy proposed the Viking. This was a forerunner of the Navy's Vanguard satellite launcher, which was ultimately selected. The Air Force remained committed to the Atlas, even though it was vulnerable to elimination because of its military payload. (See Bowen, 1960, citing Robert W. Cairns, Chairman, Coordinating Committee of General Sciences, for Acting Secretary of Defense, "Scientific Satellite Program in the Department of Defense," May 4, 1955; Memo from John Gardner for the Secretary of the Air Force, "Scientific Satellite," May 17, 1955.)

This policy followed more than a decade of intertwined interests in scientific and military missions for space operations. Both the November 1945 Navy and the May 1946 RAND reports had identified more scientific missions than military missions for spacecraft. Many of the findings of the RAND reports of 1946 and 1947 were summarized in the *Journal of Applied Physics* for October 1948, later known as the "Griminger Report." In February 1954, RAND published Research Memorandum RM-1194, by R. R. Carhart, entitled *Scientific Uses for a Satellite Vehicle*. Shortly after NSC Directive 5520 was issued, Hilde K. Kallmann and William W. Kellogg published RAND Research Memorandum RM-1500, *Scientific Use of an Artificial Satellite*, June 1955.

To implement the NSC Directive, the Assistant Secretary of Defense for Research and Development, Donald A. Quarles, established an "Ad Hoc Advisory Group on Special Capabilities," chaired by Dr. Homer J. Stewart, and known as the "Stewart Committee." This committee made specific recommendations on the launch system for a scientific satellite, and continued as a high-level advisory group during the development of observation satellite systems. (See Perry, 1962, p. 48; Hall, 1963)

Merton Davies recalls the work at RAND on international cooperation in exploration of the solar system and the geophysics of planet Earth:

In mid-1955 [on July 29th] the President announced that the United States would launch a small scientific satellite in connection with the International Geophysical Year. A number of proposals had been prepared; however, the two most advanced were the Army's Orbiter and the Navy's Vanguard. The Orbiter was based on the Redstone military missile and the Vanguard was derived from the Viking research rocket. The Air Force "World Series" proposals were not considered because they would interfere with the Atlas ICBM development.

The Department of Defense established the Committee on Special Capabilities (Stewart Committee) with chairman Homer Stewart of Caltech to recommend which path the U.S. should pursue. George Clement of RAND was a member of this committee, and with the departure of C. C. Furnas from the group, Robert Buchheim of RAND was named to the committee. The activities of the Stewart committee continued long after the decision to recommend the Navy's Project Vanguard for the IGY. The Army continued support of the joint Army-Navy Orbiter project, using the Redstone missile together with upper stages of Loki rockets. Eventually the Army launched the first successful U.S. satellite called Explorer, which was an improved version of the Orbiter proposal.

In the five years from 1951 to 1956 the prospects for space had changed dramatically from paper studies to the actual development of components for the Air Force and IGY Vanguard satellite programs. Moreover, the Army had the Redstone and Jupiter missiles under development, and the Air Force was proceeding as fast as possible to put into production the Thor IRBM and the Atlas and Titan ICBMs. All of these missiles could be used as the first stage of a satellite launcher. Another important development was the use of ablation cooling to carry away heat during the entry of a payload into the atmosphere. This decreased the mass of missile payloads and made practical the physical recovery of satellite payloads and data packages from lunar or planetary missions.

However, in 1956 all was not well. The flight programs were experiencing many failures and setbacks. There seemed to be particular difficulty in achieving reliability in the propulsion systems and in control and stability. At RAND, the philosophy was developing that some programs should concentrate on simplicity of design, establish reliability in operations, and then introduce complexity and precision. This point of view characterized the choice of launch vehicles and performance requirements used in the RAND studies for many years to follow. For this reason, spin stabilization was popular with the RAND engineers.

II-2. RAND'S RECOMMENDATION FOR A RECOVERABLE RECONNAISSANCE SATELLITE (MARCH 1956)

Richard C. Raymond, a physicist who had joined RAND's Electronics Division in 1953, proposed in early 1956 a relook at recoverable space payloads to accomplish reconnaissance missions. Raymond proposed using an Atlas booster plus a solid rocket, together with a vertical strip camera. (See A. H. Katz, memorandum to L. J. Henderson and R. J. Lew, January 3, 1958, pp. 2-3, declassified March 24, 1972.)

Davies recalls:

The simplest and most reliable of the Air Force missiles under development was the Thor. When combined with the second stage of the Vanguard, this system was designated Thor-Able. It could toss a payload to intercontinental ranges; in 1958 a full-range nose cone re-entry test was made. At the time, thought was given to deploying these vehicles as first generation ICBMs. A solid propellant third stage could be added to the Thor-Able to place 300 to 500 pounds in satellite orbit or 85 pounds on a trajectory to the Moon. Launch vehicles of this class were available sooner and were less expensive than the Atlas or Titan. Like the Thor, the Army's Jupiter missile was used for satellites and lunar launches; however, our studies at RAND concentrated on the Thor.

Raymond recalls that the basis for his advocacy of a recoverable film payload was an unpublished comparison of the rates of data recovery from electro-optical satellites versus film-stored images returned from a satellite to earth. Film recovery, Raymond calculated, would yield at least two orders of magnitude more data. Raymond had taught and published papers on information theory at Pennsylvania State University before joining RAND, so he had some confidence in his calculations. He relied in part upon the advice of Carl Gazley, who had joined RAND from General Electric's Space Systems Division. On June 18, 1954, Gazley had issued a then Secret RAND Classified Paper (S-20) on *The Re-entry of Long Range Ballistic Missiles*. Gazley kept abreast of re-entry techniques and helped others studying the recapture of space-launched payloads.

Based upon the Raymond concept, Brownlee W. Haydon assisted RAND's President, Frank Collbohm, in writing a formal RAND Recommendation to the Air Staff for a recoverable reconnaissance satellite system. The then-Top Secret piece, *Photographic Reconnaissance Satellites*, a 20-page document, constituted RAND's approach as of March 1956. Within a matter of weeks, the Air Force issued its plan for full-scale development of advanced reconnaissance satellites.

However, welcome the Recommendation may have been to elements of the Air Staff, RAND soon withdrew it from circulation. This was an unusual procedure for RAND; the specific reasons are not now known, because of the apparent destruction of RAND correspondence with the Air Staff pertaining to the Recommendation to the Air Staff series. Richard Raymond, who served on Duncan Macdonald's Reconnaissance Panel of the Air Force Scientific Advisory Board, recalls that at least some Air Force officials were committed to obtain near-real-time reconnaissance for targeting and warning missions. Storing images on film spools to be recovered from satellites entailed delays far beyond those associated with the FEED BACK (TV) satellite concept.

The specific points of the Recommendation were judged to be premature, perhaps because their feasibility had not been demonstrated; neither had they been systematically compared with FEED BACK alternatives for television-type transmission of near-real-time data. Perhaps the most critical aspect of the Recommendation that remained unproven was the assumption that space-based payloads could be retrieved after entry into the atmosphere at high velocity. Many assumed that the Air Force would solve this problem in the course of developing the intercontinental ballistic missile. Robert Porter of General Electric's Space Systems Division in Philadelphia had published a paper on a promising concept for re-entry of high-velocity payloads into the atmosphere. But in the spring of 1956 the solution to this problem remained theoretical. In the summer of 1955, the Department of Defense had devoted an entire summer study to the problems of atmospheric re-entry under the chairmanship of Professor Robert Bacher of Caltech. The summer study ended without assurance of success. It was not until the conclusion of the second Bacher-chaired summer study in 1956 that it was widely perceived that a solution to the return of missile-launched payloads was in hand. Meanwhile, work at RAND focused on identification of all the requirements for payload recovery.

John H. Huntzicker and Hans A. Lieske investigated the recovery of "such heat-sensitive items as photographic film" in RAND Research Memorandum RM-1811, *Physical Recovery of Satellite Payloads: A Preliminary Investigation* (limited distribution), published on June 26, 1956. (RAND, 1959, p. 9)

II-3. BIRTH OF THE VIDEO RECORDER INDUSTRY

Partly to satisfy Air Force advocates of near-real-time reconnaissance systems, RAND work proceeded with renewed intensity in 1956-57 on electronic feedback systems. But the economics favored physical recovery of space payloads after the Air Force procured ICBM systems and solved the atmospheric re-entry problem.

Even so, RAND helped to spawn an entirely new industry, the videotape recorder industry, while encouraging the government to keep its options open. In the aftermath of earlier RAND subcontracts with RCA, and of Air Force criticisms of RAND's Recommendation for a recoverable satellite system in March 1956, RAND entered into a contract with the Ampex Corporation in 1956 to investigate means of improving the resolution of data stored on magnetic tape as a medium for recording visual data. Ampex had worked on videotape recorders in 1952, and it demonstrated a videotape recorder at the National Association of Broadcasters Convention in 1956. Working under contract to RAND, Ampex researchers found that improvements in the tape head were necessary to store data for 600 lines of television image. Ampex Corporation staff wrote and RAND published Research Memorandum RM-2110 on October 1, 1957, *Wide-Band Magnetic Tape Recorder*. By pushing the state of technology through selective subcontracting, RAND stimulated the development of a commercial videorecorder industry, today a multinational marketplace for video cassette recorders and related equipment.¹

II-4. RAND'S RECOMMENDATION FOR A MAN-IN-SPACE PROJECT (MAY 1956)

In 1956 Robert Buchheim of the RAND Staff proposed using the Thor-Able rocket booster with spin stabilization for lunar scientific missions. The concept of spin stabilization was attractive in part because early space tests had indicated difficulty in stabilizing space objects during flight. The team led by Buchheim undertook a

¹See, for a contemporary account, James Lardner, *Fast Forward: Hollywood, the Japanese, and the Onslaught of the VCR*, New York: Norton & Co., 1987, 344 pp. See also D. Kirk, "Rapid Advances in Video Design and Engineering," *Television*, Vol. 18, No. 2, March-April 1980, pp. 13-15, and Joseph Roizen, "Ampex Home Video Recorder," *Electronics World*, Vol. 75, May 1966, p. 75.

feasibility study for the launching of unmanned scientific satellites and for lunar exploration. The RAND Recommendation for a Man-in-Space project was one of three RAND proposals in that year for development of space launchers and payloads: in March 1956, RAND recommended the Advanced Reconnaissance [Satellite] System (ARS) with a recoverable payload; in May, RAND recommended the Man-in-Space mission; and, in the same year, RAND recommended that the Air Force develop a Ballistic Weapons Research and Support System (BALWARDS) for moon landings and for interplanetary flight to the vicinity of Venus and Mars. The Air Staff approved all three as possible projects in 1956, before funding shortfalls in the spring of 1957 curtailed consideration of the interplanetary mission. (Bowen, 1960, p. 6)

Davies recalls:

A major study on lunar exploration was started at RAND in 1956 under the leadership of Robert Buchheim and continued for many years. This study was very comprehensive, covering performance requirements, trajectories (impact, orbital, return-to-Earth), guidance and control, payloads, and instrumentation. One of the more interesting ideas was a study of the impact loads and feasibility of a survivable, instrumented probe, what we now call a penetrator.

These studies took place under Air Force sponsorship, mostly before NASA was established.

Buchheim published Research Memorandum RM-1720 on May 28, 1956, entitled *General Report on the Lunar Instrument Carrier*, then classified Secret. (RAND, 1959, p. 7) This study, supported by reports on component topics, considered how to place on proper trajectory a vehicle, launched by an Atlas missile, which would deposit a package of scientific and radio equipment on the lunar surface, for data transmission to earth stations. In July 1956, William W. Kellogg published RM-1764 *Observations of the Moon from the Moon's Surface*, which considered measurement of the lunar atmosphere, its magnetic field, and its seismicity. It suggested creation of a visible flash and seismic motion, using an atomic explosion. Also in May 1956, George Clement published *The Moon Rocket*, RAND Paper P-833, and in September Buchheim presented to the International Astronautical Congress in Rome a paper, *Artificial Satellites of the Moon*. By May 1957, the Office of the Secretary of the Air Force had deleted interplanetary missions from the Air Force agenda. The BALWARDS program became, on a tighter budget, a program for rocket development and manned exploration of the lunar environment: the Ballistic Research and Test System (BRATS). In September 1957, Buchheim published a second Research Memorandum, RM-2005, *Outline of a Study of Manned Space*

Flight, which helped in developing national space objectives before the creation of the National Aeronautics and Space Administration in 1958. For the Air Force, Buchheim proposed a missile and space program consisting of ten projects, in a Secret report of September 26, 1957, RM-2002. Five of the ten recommended projects pertained solely to space: the reconnaissance satellites, a cislunar system, interplanetary systems, navigation satellites, and communication satellites. (Bowen, 1960, pp. 6-7 and 49, Note 8, citing Memo for Hq ARDC from Hq USAF, "BALWARDS," May 15, 1957; Memo for Richard E. Horner, Assistant Secretary Air Force (R&D) from Herbert F. York, Chief Scientist, ARPA, "BALWARDS Vehicle," May 13, 1958.)

Davies observes:

In 1958 and 1959 I had published papers describing the operation of a spinning panoramic camera in taking pictures of the Moon. In the early 1960s after the Russian successes, the U.S. responded with the Ranger and Surveyor Lander lunar programs at the Jet Propulsion Laboratory. The Surveyor program was delayed because it required the Atlas/Centaur booster, and the Centaur development was behind schedule. A Surveyor Orbiter was intended to follow the Lander with photographic coverage of the lunar surface.

About this time, Dr. A. K. Thiel, Space Technology Laboratories (STL, now split between TRW and the Aerospace Corporation), delivered a proposal to NASA Headquarters describing how the lunar surface could be photographed with a spinning panoramic camera, with onboard processing of the film, and electronic readout. The important ingredient was that this spacecraft could be launched with the Atlas/Agena and need not wait for the Centaur development. In late 1962 it became apparent that this mission should proceed soon to support the search for Apollo landing sites. This Lunar Orbiter mission was assigned to Langley Research Center and a competition was held. Two contractors proposed using spinning panoramic cameras. They both lost. The winning contractor was Boeing with Eastman Kodak building the camera and CBS the film scan device for the lunar exploration mission. Five Lunar Orbiter spacecraft were flown; all were successful. It was an excellent program.

II-5. THE AIR FORCE DEVELOPMENT DECISION FOR WS-117L

In the spring of 1956 the Western Development Division of ARDC issued a plan for full-scale development of an advanced reconnaissance satellite. General Schriever approved the plan on April 2, 1956, and

General Power endorsed the plan three weeks later. Concerned almost exclusively with military reconnaissance activities, it was based upon the use of Atlas launch vehicles. Full operational capability was projected for the third quarter of 1963 at a research and development cost of about \$115 million. (Perry, 1962, p. 55, citing "WS-117L Advanced Reconnaissance System," April 2, 1956)

Of critical importance is the fact that when the Air Staff approved a development directive for WS-117L in July 1956, ARDC authorized funding of only \$3 million in FY 1957. This was acknowledged to be "inadequate initial funding." (Perry, 1962, p. 56) The low priority for development of the advanced reconnaissance system within ARDC ultimately resulted in the preeminence of civilian managers of U.S. satellite observation systems. From RAND's vantage point, however, what was important was the transition from paper studies to hardware development:

Almost precisely 10 years after its first appearance in the guise of a RAND study, the military satellite had achieved system status. But whereas conservative estimates of program costs had indicated an initial need of at least \$39.1 million through fiscal 1957, the WS 117L program approved in August 1956 was funded at rather less than 10 percent of the requirements level. It was not a particularly auspicious start, but considering the obstacles of funding stringency, skepticism and "policy considerations" that had been overcome in progressing that far, the achievement was not unremarkable. (Perry, 1962, p. 56)

II-6. THE MERGER OF RAND RESEARCH ON BALLOON AND SATELLITE RECONNAISSANCE SYSTEMS IN 1956-57

In 1956, the year in which Robert Buchheim began a project on lunar exploration and instruments to support it, RAND's research staff proposed a de facto merger between research on requirements for high-altitude balloon reconnaissance systems and satellite reconnaissance systems. Balloon reconnaissance programs were then compartmented. See the now declassified 32-page summary of balloon reconnaissance in 1955-56: *U.S. Air Force Final Report on Project 119L*, substantially declassified in 1979.

Davies and Katz were the two members of the RAND research staff who had worked both on the balloon project and on the developmental phase of space observation satellites. Hence, it is not surprising that

they should see the logic in merging RAND's research on balloon and satellite systems, so that RAND could be more effective in analyzing tradeoffs between timeliness and system performance.

Davies and Katz formulated the need for both types of systems in a memorandum of October 12, 1956 proposing a RAND project on "pre-hostilities reconnaissance." This followed a request of Lieutenant Colonel Quentin Riepe, USAF, of General Schriever's Western Development Division, asking RAND "to take on the job of devising an operational concept for the 117L reconnaissance satellite project." (Memorandum, A. H. Katz and M. E. Davies to Ed Barlow, October 12, 1956, p. 1, formerly Secret, declassified March 24, 1972):

We have for some time been mulling around and considering a generalized study of pre-D-Day intelligence and reconnaissance which would simultaneously embrace study of national objectives, intelligence requirements, and proposed collection systems of all types as they are likely to become available in the era just ahead. We have been concerned with defining the problems, examining preferred methods of solution, and the roles of likely gadgetry of the future (such as balloons, missiles, special aircraft, and satellites). Col. [Quentin] Riepe's [proposed project] deals exclusively with the satellite. To proceed, it would be necessary to see which and how many of the intelligence requirements can be satisfied by satellite-collected data, and this would form the basis for answering the detailed questions concerning the required numbers and types of payloads, installations, training, operation, production of data, analysis systems, etc. It has been clear to us for a long time that allocation of jobs and priorities for the satellite cannot and must not be done independently of parallel considerations of other contemporary collection systems. . . .

As explained in a Katz memorandum of June 19, 1957:

Considerable part of this project would have been devoted to a job we were asked to do by BMD's 117L Project Office. This job, briefly, had to do with the formulation of operational concepts, considerations of utility, parceling out of preferred payloads, and similar matters related to the reconnaissance satellite. . . .

This request of BMD's was made more official in a letter dated 20 November 1956 to [RAND's President] Frank [Collbohm]. . . .

We stalled BMD off very neatly with a left jab in the form of a letter dated 26 December 1956. This letter says we are going to do it pretty soon, and said that at some future time we will discuss in detail what we will do . . . a letter, dated 5 February 1957, from Collbohm to [USAF Colonel Charles H.] Terhune [the Deputy Commander for Ballistic Missiles at WDD] . . . says that we will start the project three to six months following the date of the letter. The last paragraph states: "No further formal requests on your part will be necessary to initiate this work."

Shortly after Katz and Davies began comparing alternative means of fielding reconnaissance systems to meet peacetime requirements, the Air Force formally awarded a contract to the Lockheed Missile Systems Division to develop Weapon System 117L, the Advanced Reconnaissance System (ARS). This was known as PIED PIPER, and implemented the RAND recommendations of 1954. Lockheed became the prime contractor for WS-117L and the upper-stage vehicle, later redesignated Agena. (Snyder et al. 1976, p. 36)

RAND prepared, in the spring of 1957, to assist the Air Force in developing specifications for advanced satellite reconnaissance systems in the WS-117L family. This effort paralleled research on advanced balloon reconnaissance concepts, in the aftermath of operation and termination of the GENETRIX balloon program, known as the WS-119L. (See the USAF Project 119L Final Report, substantially declassified in 1979.)

In March 1957 the Western Development Division started "feasibility studies" of a Missile Detection Alarm System (MIDAS), a satellite to provide warning of hostile missile launches. (Snyder et al., 1976, p. 38) This gave further impetus to RAND's effort to integrate its intelligence-related research to accomplish a broad array of intelligence and warning missions.

RAND staff were now engaged in short- and long-range studies of balloon reconnaissance, long-range reconnaissance satellite studies for both film recovery and electro-optical data-relay satellites, and tactical aerial reconnaissance. In his third year at RAND, Katz sought to bring some coherence to the analysis of alternative reconnaissance programs, and their relationships, by posing a fundamental question: what were the requirements for reconnaissance?

Katz first addressed types of requirements for reconnaissance in a lecture, published in May 1957, *Balloon Reconnaissance—Part I: Intelligence Requirements and Reconnaissance Systems*. He later treated four categories of reconnaissance in public writings: (1) large area search, with ground resolution from 50 to 200 feet; (2) limited area search, with ground resolution from 10 to 40 feet; (3) specific objective spotting, with ground resolution from 2 to 8 feet; and (4) technical intelligence, with ground resolution from 0.5 to 2 feet. (Katz, 1960, pp. 7, 33)

Looking back upon a distinguished career, Katz concludes that the most important work he did after coming to RAND in 1954 was not on the means of accomplishing reconnaissance missions, but on the nature of and specification of reconnaissance requirements. Once a requirement was understood and accepted, the means of accomplishing it could usually be created. The Katz writings on requirements for

reconnaissance, in the 1957-58 period, occurred well after Colonel Leghorn returned to civilian life (in 1953), but they supported the Air Force studies of requirements for peacetime reconnaissance established by Colonel Leghorn and continued by General Schriever's organization.

Shortly after this integrative assessment of requirements for reconnaissance, Katz urged that RAND management pursue an outstanding request for assistance from the Project 117 Project Office under Colonel Frederick C. E. ("Fritz") Oder. In June 1957, Katz wrote:

Well, here we are. To rewrite an old fable, it is time to perform or get off the chart. . . . At this particular moment, we know full well through our informal contacts with these people that they were very anxious for us to get into this act.

Now this alone is not enough reason to do so. The project is eminently worthwhile. It fits in extremely well with our own competencies and interests, and, if anything, the general subject of pre-hostilities reconnaissance is becoming of increasing importance to the U.S. Air Force (and therefore at least ought to, to RAND also).

The [RAND] Steering Committee knows we have been very active on Air Force Project 461L [a balloon reconnaissance project subsequent to Project 119L] for the last few months. Though one might not suspect this at first glance, it turns out that there is a good deal of relationship and carry-over between [the] 461L [balloon project] and [the] 117L [advanced satellite project]. The same kind of grubbing around an analysis of requirements, the same criteria for palatability/acceptability, the same types of analyses and performance, what it would do, the data handling problem, the R & D necessary to handle extraordinarily high resolution photography—these problems are in many respects identical between the systems. They differ, of course, in time phasing. It is about precisely this point that we can make the major contributions.

.....

We are therefore proposing that we initiate the project with BMD. . . . In this grab-bag we could consider pre-hostilities reconnaissance in general. We would consider it by levels of reconnaissance, missions, priorities, and time periods, and thus produce a rationale (which we already have as far as 461L is concerned) into which in matrix form all pre-hostilities reconnaissance projects could be displayed graphically and meaningfully.

. . . As a minimum, both Davies and Katz should occupy themselves with 461L and 117L on a full-time basis. . . .

II-7. BROKERING INNOVATION: PANORAMIC CAMERAS

It was in connection with a balloon reconnaissance project, the previously noted Project 461L, that Davies and Katz encouraged the photographic subsystem manager, Walter Levison, to adapt the concept of the panoramic camera to long-focal-length cameras for high-altitude photography. The panoramic camera had been widely used for large-group photographic portraits in the 19th century. George Lawrence had adapted the panoramic camera to balloon-based wide-angle photography over the city of Chicago in 1903. The panoramic camera had been considered, after World War II, for low-altitude wide-angle photography. In 1949, Colonel Richard W. Philbrick, USAF, assigned to the optical research program at Boston University, demonstrated the wide-angle potential of panoramic photography for horizon-to-horizon coverage by synchronizing the passage of film past a slit, together with angular rotation of the lens. (Smith, 1972, p. 2730) At the altitudes of space satellites, a wide angle of coverage was relatively easy to achieve. What was not easy to achieve was ground resolutions that would be possible only with long-focal-length lenses with narrow fields of view. Hence, the concept of a panoramic camera had a special application in space-based photographic systems.

One of RAND's functions on behalf of the Air Force, which in turn served as a triservice sponsor of satellite development programs, was the identification and intellectual transfer of important innovations to elements of the nation's space development program. Davies recalls:

Throughout the 1950s the Boston University [Physical] Research Laboratories carried out a research program on aerial photography sponsored by the Air Force Reconnaissance Laboratory at Wright Field. The laboratory head was Dr. Duncan Macdonald and, of course, Amrom Katz knew well the people at the laboratory and their research program. Amrom and I attended a meeting at Boston University, February 19, 1957, to discuss their research programs and to tell them about our interest in taking pictures from satellites. Among others present were Duncan Macdonald, Dow Smith, and Walter Levison from the laboratory and the independent optical designer, James G. Baker. It was an exciting all-day meeting, exchanging ideas with innovators in aerial reconnaissance.

Walter Levison talked about cameras designed to take pictures from high altitude balloons. Levison described a camera he was designing for use in balloons. The camera was to cover a wide angle, about 120 degrees, with a f/3.5, 12 inch focal length lens. The lens design was to be a modification of the Baker spherical shell lens of World War II. This lens yielded a high resolution image. However, its focal

plane was spherical, leading to difficulty in alignment of film. Levison planned to use 70mm film, so the image format was about 2.5 by 28 inches; the platten which holds the film during exposure was curved to the 12 inch radius. An optical field flattener or other device would be necessary to remove the curvature of the field along the width of the film. The only moving part was the focal plane shutter, which was to move 2.5 inches across the film during exposure. (See Smith, 1972, p. 2730.)

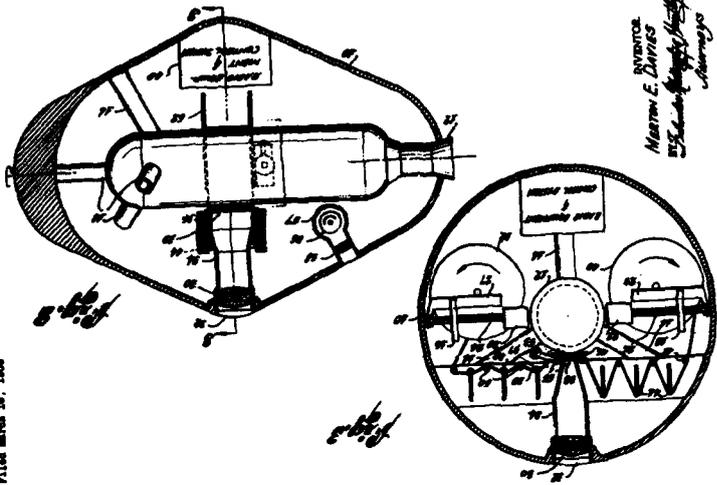
Amrom and I went to the annual meeting of the American Society of Photogrammetry about three weeks after the Boston trip. During a social gathering, we were talking to Fred Willcox, Vice President of Fairchild Camera and Instrument Corp., when he described a new camera, a rotary panoramic design, which his company wanted to build and install in fighter aircraft wing pods. The camera had a 45 degree mirror in front of the twelve inch focal length lens, and the entire camera, film and all, rotated about the optical axis to perform the panoramic scan. A slit was mounted in the focal plane and during exposure the film was moved past the slit to compensate for the rotation. In this way, the slit acts as a focal plane shutter. My first impression was, "What a terrible design to be moving all that mass within a drum." However, after a while I began to recall that most of the spacecraft designs at RAND were spin stabilized, and then I realized that the camera could be fixed to the spacecraft structure and its motion would perform the panoramic scan. Thus was born the idea of the spinning panoramic camera. [See Fig. 9]

The RAND concept of the camera placed the optical axis normal to the spin axis of the spacecraft and moved the film past the focal plane at the proper rate to compensate for the spin. A slit was placed in the focal plane to act as a shutter. The camera was light weight and operationally simple, perhaps elegant.

As the design of this camera was coming together, Amrom telephoned Walt Levison and described the beauty of a panoramic design. The panoramic camera took a wide-angle picture with a narrow-angle lens. It had a flat field, and it was not necessary to have a mirror or prism perform the scan. During a brief illness (lying on a hospital bed with back trouble) and afterwards, Walt designed the elegant HYAC camera. Amrom gave the camera the name HYAC, standing for high acuity. In this design Walt had saved the fixed platten to hold the film from his wide-angle design; the lens and slit structure were the only moving parts. They rocked back and forth, like a pendulum about an axis located at the optical rear nodal point. HYAC cameras with twelve inch focal length were built and flown in high altitude balloons during 1957. [See Fig. 10.] They performed beautifully and took very high resolution pictures [Fig. 11]; later they were flown in high altitude aircraft.

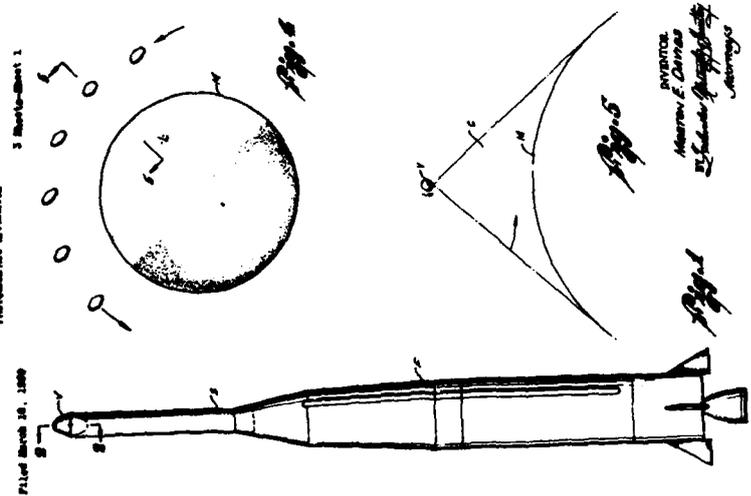
The panoramic camera that the Boston University Physical Research Laboratories designed did not use the spinning camera that RAND proposed, but it did employ the concept of a panoramic camera

Aug. 4, 1964
M. E. DAVIES
PHOTOGRAPHIC APPARATUS
3,143,048
Filed March 16, 1969
Sheet 2 of 2



INVENTOR
MARTIN E. DAVIES
BY *[Signature]*
Attorneys

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Sheet 1 of 2



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Fig. 9—Schematic of spinning panoramic camera photographing the Moon, as described in the 1964 Davies patent

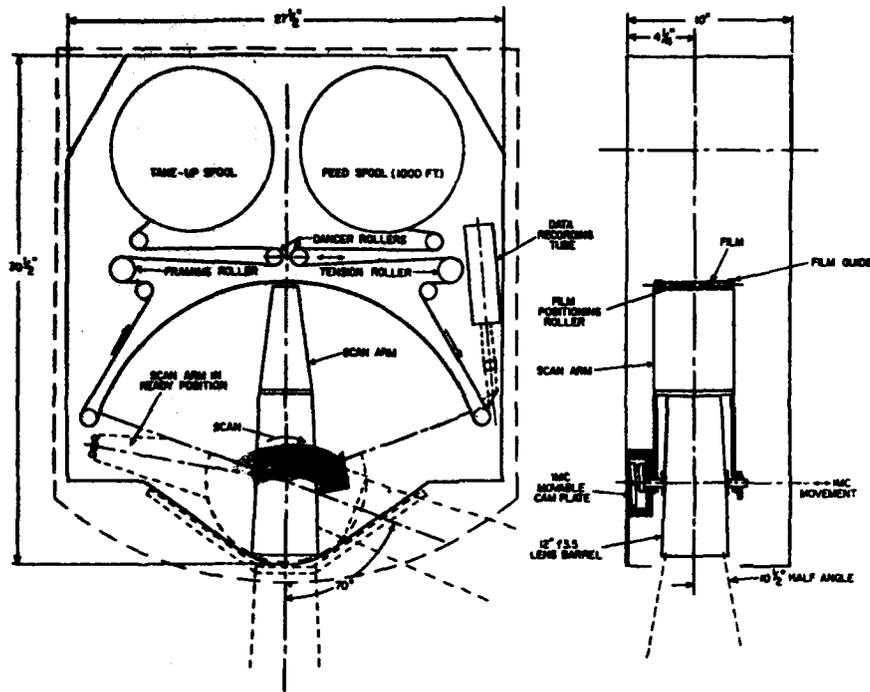


Fig. 10—Schematic of HYAC-1 panoramic camera showing method of scanning

with a long focal length. Hence, RAND brokered a concept that was applied to operational spacecraft, although modified in important ways by Walter Levison and others.

The HYAC-1 camera served for only limited operational missions as part of balloon flights conducted for Project 461L, but the technology of panoramic, long-focal-length cameras found an enduring application in space reconnaissance systems. Levison has written:

... The HYAC Camera was actually designed for a later project, 461L. . . . Only 40 HYAC-1 cameras . . . were made. All the lenses were made at the Itek Corporation in 1958. . . . Only three of the cameras were flown operationally and none of them were recovered. The launch was delayed to the tail end of the operational window, which resulted in the balloons not getting through the area of interest. They almost made it, but not quite. That camera was a significant departure from conventional aerial cameras. The lens is a 12" f/5 triplet that rotates about its rear node. The image is formed in a



**Fig. 11—Enlargement of a section of a photograph taken by a
HYAC-1 camera from a high-altitude balloon**

cylindrical focal plane and is, so to speak, painted onto the film through the motion of a narrow slit. (Letter, Levison to D. Dworkin, May 29, 1987, pp. 1, 2) [See Figs. 12, 13.]

In a memorandum of May 11, 1959 (formerly Confidential, declassified in 1972), Katz provided a more nearly contemporaneous account of the application of the concept of panoramic cameras to the design of satellite photographic equipment:

In early spring of '57 Davies was doing some preliminary work on what subsequently turned out to be the spin stabilized panoramic camera system of RM-2012. [See Section II-8, below.] At precisely the same time our "large recce group" (Davies and Katz) was very interested in following closely the problems and possibilities of 461L (the balloon reconnaissance system). We were, at that time, in close touch with Walt Levison who headed this project's camera subsystem team at the Boston [University Physical Research] Laboratories.

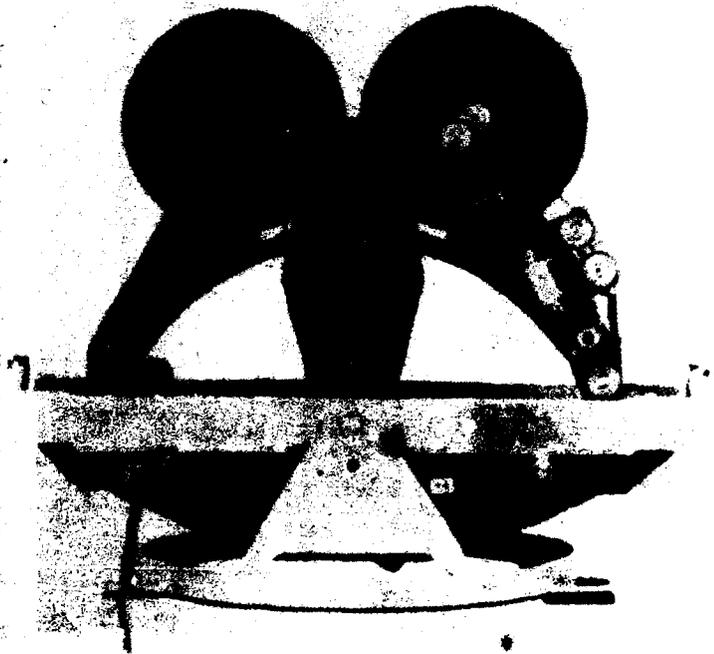


Fig. 12—The HYAC-1 camera in the National Air and Space Museum

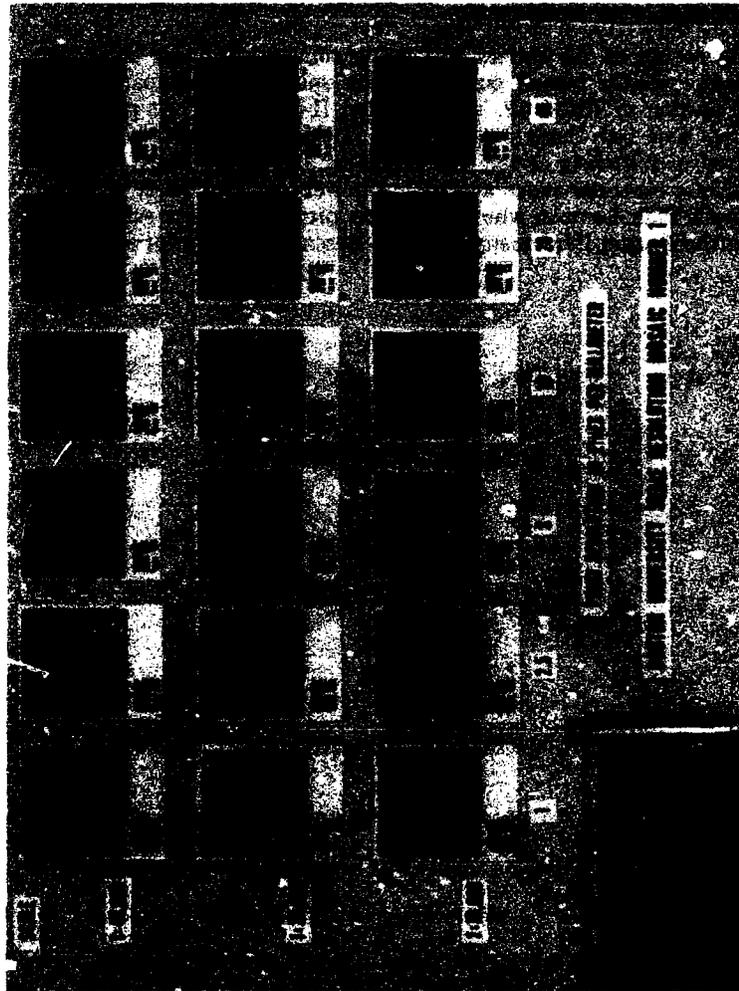


Fig. 13—Chart of scale and resolution of overhead photography, prepared at Boston University's Physical Research Laboratories in 1957. At RAND, Katz and Davies added a single index of interpretability, *ground resolution* (lower left)

The camera which he was considering for application to this problem was a World War II designed Baker camera, which used a spherical shell of film and had a 120 degree spherical lens associated with it. This was a very elegant and beautiful camera, many years ahead of its time. However, we suggested to Levison that this camera would be difficult to build, let alone put into production. This was entirely apart from and in addition to the problems of production rate and of weight which would be associated with this kind of a camera. We pointed out to Levison that we had been looking at panoramic cameras, that Fred Willcox (of the Fairchild Camera and Instrument Corporation) had an interesting idea for an axially-spun panoramic camera which we thought might be applicable to Walt's problem. In fact we suggested that Levison, a good and old friend of Willcox, call him in and have a discussion with him on the feasibility of panoramic cameras for the balloon system.

As it turned out this is exactly what happened and Levison got enthusiastic about panoramic cameras. Proper and extensive credit is due Levison for the particular camera he finally designed. It performed elegantly and superbly and made what I consider to be the finest aerial photographs ever made from extreme altitudes. . . . (A. H. Katz, memorandum, May 11, 1959, p. 2)

II-8. RAND'S RECOMMENDATION FOR ACCELERATING THE ACQUISITION OF RECOVERABLE OBSERVATION SATELLITES (NOVEMBER 1957)

Davies writes:

By the summer of 1957 RAND had completed a satellite design study with the objective of obtaining a photographic capability in a short time. The satellite was to be put in polar orbit with the Thor-Able booster and a small, spin stabilized, solid rocket. The satellite contained a spinning panoramic camera with twelve inch focal length lens and five inch wide film which operated by command and by clock. The satellite also contained a solid rocket which was fired on command from the ground, causing the satellite to deorbit and fall into the Pacific Ocean to await recovery. An automatic radio beacon would aid in the search. (See M. E. Davies, memorandum to A. H. Katz, September 10, 1957, "Progress of Recoverable Satellite Study," 1 p. Declassified March 24, 1972.)

The RAND work was briefed informally to members of the Stewart Committee of the Air Force Scientific Advisory Board. On October 9, 1957, the Ad Hoc Committee on Advanced Weapon Technology of the

AFSAB urged priority for the development of military satellite systems. (Snyder et al., 1976, p. 42)

In November 1957, Davies and Katz completed a key Research Memorandum with the assistance of various RAND co-authors.² Known simply as "RM-2012," this study was declassified in a highly sanitized form in 1984 with the abridged title *A Family of Recoverable Satellites*. RAND's formal Recommendation to the Air Staff, published together with RM-2012 on November 12, 1957 (and declassified without deletions in 1972), indicates a focus on accelerating the development of a class of recoverable reconnaissance satellites.

RM-2012 and accompanying briefings accomplished in six months what Katz had set out to accomplish in June 1957: development of a strategy for high-altitude peacetime reconnaissance that took account of one critical factor, timing, with respect to high-altitude aerial systems (balloon and aircraft) and reconnaissance satellites. In parallel with completion of RM-2012, Davies and Katz developed briefings on alternative means of accelerating reconnaissance satellite programs so as to achieve a scope and reliability of coverage that balloon and aircraft systems (e.g., the U-2) were unable to achieve. Davies and Katz concluded that the Air Force could have better reconnaissance satellites sooner than the WS-117L Program Office expected. The briefings and their technical backup stimulated both Air Force and CIA representatives to accelerate their plans for reconnaissance satellites, but with design differences from those recommended by RAND.

RAND's formal Recommendation to the Air Staff accompanying RM-2012 bore the same date as the report: November 12, 1957. It was on this date that Colonel Frederick ("Fritz") Oder of the Project 117L Program Office presented to the Stewart Committee (meeting at RAND) recommendations of the Program Office for a recoverable satellite reconnaissance program.

Coordination with the Air Staff in the Pentagon may be inferred from the seeming coincidence that, also on November 12, 1957:

Headquarters USAF asked the Defense Department to approve a space program that would provide an early demonstration of space capability and a developmental test vehicle for larger satellite systems. Three Thor IRBMs could be made available. . . . (Snyder et al., 1976, p. 43)

RAND's President, Frank Collbohm, provided the cover letter for the Recommendation: *An Earlier Reconnaissance Satellite System*:

²R. W. Buchheim, T. F. Burke, R. T. Gabler, T. B. Garber, C. Gazley, Jr., E. C. Hefern, J. H. Huntzicker, H. A. Lieske, D. J. Masson.

In the light of recent events, RAND has reviewed national and military intelligence problems, existing and proposed reconnaissance systems, and in particular, the current USAF satellite reconnaissance program (WS-117L). As a result of certain technical and conceptual breakthroughs, it is concluded that efficient satellite reconnaissance systems of considerable military worth can be obtained earlier and more easily than those envisioned in the current 117L program.

The systems proposed in this recommendation differ substantially from the current 117L system concept.

The proposed systems feature a spin-stabilized payload stage. They use a transverse panoramic camera of essentially conventional design, fixed to spin with the final stage, which scans across the line of flight. Either the entire payload or the film is recovered.

The first of the proposed systems uses a 12-inch camera, carrying 500 feet of 5-inch wide film. . . . It will provide sharp photographs of about 60-ft ground resolution. Each exposure, covering some 300 miles across the line of flight, will photograph some 18,000 sq. mi. The 500-ft roll will cover some 4,000,000 sq. mi (almost half the Soviet Union) and show major targets, airfields, lines of communication, and urban and industrial areas. This satellite could weigh about 300 lb and be placed in a polar orbit at 180 miles altitude by a combination of rockets such as Thor plus second-stage Vanguard plus a third-stage small solid rocket similar to the Vanguard's third stage. A one-day operation is envisaged, with recovery by command firing of a braking rocket on the 16th pass, so as to impact in a predictable ocean area.

The next, more sophisticated, system would use a 36-inch camera, carry much more film, [and] do more detailed reconnaissance—with a ground resolution of about 20 feet. This system can possibly be Thor-boosted.

A third system—undoubtedly requiring Atlas-type boosting—would use a 120-inch camera and would have very large film capacity. This system will be able to accomplish very high quality photo reconnaissance and, most important, will do it better than any Air Force system now in development or in prospect will be able to do in the 1960s.

The earliest and simplest of the several systems will collect at least as much information in its one-day operation as the "early" 117L vehicle will in its useful life.

Because of our belief that the first system could be available about a year from start of work, the second in less than two years, and the third in about three years, we recommend that the U.S. Air Force begin work immediately to accomplish this program.

Success in this type of system should result in refocus of the present components of the 117L program to those tasks requiring the communication link and cyclic talk-back facility of 117L—warning, and

daily surveillance of selected targets, being the principal high priority tasks requiring such an operation. Thus this new family of satellites and the type of satellite at present scheduled under 117L program would be mutually complementary and not competitive. (RAND letter, pp. 1-2, November 12, 1957, formerly Secret, declassified March 24, 1972)

The breadth, rationale, and technical backup of the RAND Recommendation doubtless energized the Air Force to achieve earlier recoverable reconnaissance systems than those previously adopted by the Air Force satellite reconnaissance program office. It is perhaps less important that none of the three systems proposed by RAND in November 1957 was, in precisely the form recommended, the system that was in fact successfully developed and deployed in 1958-60.

II-9. SPACE OBSERVATION FOR ARMS CONTROL

As reconnaissance satellites appeared to be a practical option for the decade of the 1960s, RAND's social scientists began to contemplate their uses. Outside RAND, Colonel Richard Philbrick had proposed, back in 1948, aerial reconnaissance for arms control. But this was a little-recognized concept, the conventional wisdom being that on-site inspection was the essential element for treaty verification.

Joseph M. Goldsen completed a then-Top Secret RAND memorandum on March 28, 1957, entitled "Reconnaissance Satellite and Latest U.S. Disarmament Proposal." Regrettably, RAND's record copy of this document has been destroyed, so one can only guess at its contents. From its title, it would appear that Goldsen had linked space observation with improved prospects for arms control agreements. This was not a conceptual linkage that was widely understood in 1957, but by the summer of the following year the potential of space satellites for arms control verification is found in the initial National Security Council paper for "U.S. Policy on Outer Space":

Reconnaissance satellites are of critical importance to U.S. national security. . . . Reconnaissance satellites would also have a high potential use as a means of implementing the "open skies" proposal or policing a system of international armaments control. (NSC 5814, June 20, 1958, formerly Secret, declassified December 9, 1981)

Also in 1958, several members of the RAND staff joined in preparations for the Geneva conference on reducing risks of surprise attack.

Amrom Katz participated in pre-conference planning as a technical adviser, along with Arthur C. Lundahl of CIA and others. In a memorandum to Goldsen on October 22, 1958, Katz predicted:

The most significant feature of reconnaissance satellites, which is of direct application and utility in the forthcoming Geneva talks, is that reconnaissance satellites will make inspection inevitable. As such, I am convinced that they will serve to force agreement on inspection in some degree. (RAND Washington Office memorandum, unclassified)

Merton Davies participated in the actual Conference of Experts at Geneva. Somewhat to his surprise, he found that various "experts" considered the future of satellite observation of the Earth to be speculative and infeasible, hence not suitable for inclusion in the papers that the experts were assigned to prepare. The task fell to Davies to convince others that satellites were a viable means of achieving international inspection. He won the right to include satellite observation within the scope of technical working papers; as a result, he drew the task of summarizing prospects for satellite observation of the Earth. Hence, even before the first space observation system was launched, RAND staffers had achieved inclusion in international negotiations of the potential for satellite verification of arms control and disarmament agreements.

Davies recalls:

Proposals for the use of aerial photography to monitor arms control agreements go back to the late 1940s, and the most famous of these was the "Open Skies" proposal of President Eisenhower in 1955. These ideas were important because they helped develop classes of arms control measures which could be monitored by aerial inspection techniques. Thus, when inspection by satellite became possible, real arms limitation measures could be negotiated.

In late 1958 the Surprise Attack Conference was held in Geneva. Experts from five Eastern Bloc countries and five Western Bloc countries were called together to try to negotiate measures which would decrease the likelihood of one country attacking his neighbor. Amrom Katz participated in the preparations for the conference, and I was sent as a delegate. Albert Wohlstetter, Andrew Marshall, and Harry Rowen of RAND were also delegates. The meeting itself was a disappointment because the East and West could not even agree on an agenda. However, each time we met, each side would table papers. These papers then became the technical forum for exchanging ideas. In the paper describing methods and capabilities for inspection, I did include discussion of the observation satellite. To my knowledge, this was the first mention of the role of the satellite at an arms control negotiation.

In the technical working sessions at Geneva, Davies worked on the satellite observation study, GEN/SA/5, Part I, November 19, 1958, *A Survey of Techniques Which Would Be Effective in the Observation and Inspection of the Instruments of Surprise Attack*. Davies did much of the drafting on space observation systems, working together with Colonel Paul J. Heran, USAF, the group leader, and Lieutenant Colonel Francis J. Cappelletti, USAF.

In a comprehensive and now-declassified memorandum prepared in 1959 (Katz, 1959, p. 1), Katz recapitulated what RAND had done to simplify concepts of overhead photography and to minimize the difficulties of system development. He noted, correctly, the importance of the work undertaken in 1957. That work probably contributed to an awareness in the Air Force that it was more important to obtain an effective operating system than to impose programmatic delays in the interests of an Air Force monopoly. Katz wrote in 1959:

Certainly our major and formal recommendation in the field of reconnaissance and satellites in the last couple of years has been the recommendation [of Davies and Katz] of November 1957 regarding a new family of recoverable reconnaissance satellites. . . . Recoverable satellites are important and complementary to the talk-back type system. . . . The major point we were making in late '57 and early '58 was that 50 feet of ground resolution in '59 is infinitely better than five feet in '65. There is a curious tendency among R&D people to settle for something better later over something reasonably good now. (Katz, 1959, p. 1)

Davies remembers the briefings:

Amrom and I presented this study to the Air Force, sometimes together, sometimes separately. We first went to WDD, then to various offices in the Pentagon, to the Air Research and Development Command, and also to the Air Reconnaissance Laboratory, Wright Field. We felt that it was very important that the Air Force start a new photographic program. . . .

In a November 1957 presentation to the Stewart Committee, which met in RAND's main conference room concurrently with the distribution of RAND Research Memorandum RM-2012, Colonel "Fritz" Oder of General Schriever's staff announced that the Air Force was going ahead with a new program.

This program would incorporate the Thor booster, spin stabilization, and film recovery. We were excited. Early in 1958 contractors were selected and design decisions made. This program to utilize a spin stabilized spacecraft was cancelled and redirected in April 1958.

II-10. THE EVOLUTION OF RAND CONCEPTS FOR RECONNAISSANCE SATELLITES

The evolution at RAND of alternative concepts for reconnaissance satellites may be bounded by the initial study in the spring of 1946 and the formal recommendations of November 1957. At the outset, the Army Air Force sponsored a study to demonstrate expertise and to preserve primary Air Force jurisdiction for space technology. The RAND study team assumed that rocket technology would enable the launching of a spaceship and concentrated on alternative missions that might be performed from spacecraft in earth orbit. Two assumptions of the early work were that the space payload would not be recovered and, accordingly, that the spacecraft would be unmanned.

Refinement of the potential of a reconnaissance satellite in 1946-47 led to consideration of a polar-orbiting satellite for reconnaissance of naval vessels, using a space-based telescope. Use of television to record and relay data was noted in the February 1947 Lipp report. Concurrently, RAND staff proposed deployment of satellites at geosynchronous altitude, where they would appear to be stationary. Three satellites could receive and transmit communications to "most of the globe."

Once the Air Force had established its "logical responsibility" for space satellites, and once the Navy had conceded Air Force primacy in January 1948, Air Force interest in satellite development receded. But the Air Force's sponsorship of Project RAND provided funding for and encouraged RAND initiative to refine satellite concepts in the 1949-51 period.

When General Curtis E. LeMay became CINCSAC in 1949 and invited RAND to address SAC's unfulfilled mission requirements, satellites were not of immediate interest both because there was no extant launch capability and because there was no demonstrated means of recording and relaying data sensed in earth orbit. The initiative of Will Kellogg and Stan Greenfield in 1950 to explore altitude-stabilized balloons for peacetime reconnaissance reintroduced two concepts for high-altitude observation of the earth, earlier applied by Navy experimenters with V-2 rockets in 1946 and 1948: data recording on photographic film and physical recovery of film payloads. Developments in optics, films, and aerial recovery techniques for balloon-borne sensors facilitated the development of satellite reconnaissance more effectively than the concurrent development of aircraft reconnaissance systems.

Before 1954, when the Air Force proceeded with development of the intercontinental ballistic missile and techniques to assure the entry of space payloads through the earth's atmosphere, RAND researchers

emphasized two types of non-recoverable satellite reconnaissance systems: those that utilized television technology and near-real-time relaying of data to earth, and those that utilized tape storage of sensed data, with delayed relaying of data to earth. The ground resolutions then considered to be feasible—in the range of 80 to 200 ft—were adequate to identify areas and types of cloud cover but inadequate for technical photointerpretation of objects on the ground below. Hence, the practical result of the RAND reports in 1951 (R-217, R-218) was the identification of requirements for the world's first weather satellite, using TV-sensors and operated as the TIROS series since 1960. A subsequent study, completed in the spring of 1954 (FEED BACK, R-262), still assumed that recovery of film-stored data was technically and economically unjustified. That report, in two comprehensive volumes, sufficed to encourage a formal Air Force satellite requirement in the spring of 1955. Later that year the TV-relayed data concept found a parallel application in the work of Kellogg and Sidney Passman, who discovered that infrared sensors to provide warning of Soviet ICBM launches might better be positioned aboard satellites than aboard "picket" airplanes on the Soviet periphery, unable to see initial ICBM launches owing to the curvature of the earth. Delayed data recovery was unacceptable if warning of the ICBM launches was to be timely and reliable—hence, the infrared satellite warning system, later named MIDAS.

Even for peacetime ("pre-D-day") reconnaissance, several assumptions precluded the choice of recoverable payloads. In particular, the failure of copper-heat-sink nose-cones in 1954-55 to sustain atmospheric re-entry at the high speeds proposed in ICBM studies of the early and mid-1950s encouraged the perspective that a reconnaissance satellite must await development of better TV or videotape data storage technology.

The assumptions underlying reconnaissance-without-recovery dissipated in the period 1954-56. Augenstein's work on the ICBM in 1952-53 and the parallel work of the TEAPOT committee under Von Neumann led to acceptance of the ICBM as a weapon system in 1954. At RAND, it was only a matter of time before a cost analyst, Milton Margolis, estimated the scale economies resulting from large-scale procurement. With reduced estimates of the costs of space boosters, recoverable payloads might compete for high-altitude reconnaissance missions. Concurrently, Gazley and others proposed using wider and slower-moving re-entry bodies, and monitored progress with ablative surfaces that were judged, by 1956-57, capable of withstanding atmospheric re-entry at ICBM velocities. While still at RAND, Raymond

proposed and Collbohm formally recommended the development of a recoverable reconnaissance satellite in March 1956.

Satellites with recoverable film payloads seemed premature at the time, both because no one (before Huntzicker and Lieske) had demonstrated that film could withstand re-entry through the atmosphere and because the altitudes required to assure satellite longevity would preclude obtaining high-resolution imagery. And by 1956, photointerpreters expected high-resolution imagery of at least the quality obtained in World War II. "Pioneer" reconnaissance at resolutions of 80 to 200 ft could be obtained by sporadic balloon or aerial overflight, without the development of expensive and uncertain satellite systems. In this 1956-57 period, Davies and Katz closely examined the relationship between reconnaissance requirements and the timing of deployable high-altitude balloon and satellite systems. Recognizing a collection "gap" in the early 1960s, when ICBMs were likely to be deployed, they concentrated efforts upon those concepts that would improve the quality of high-altitude imagery on an expedited basis. Recovery of film would avert image degradation through TV sensing and transmission. Spin stabilization would avert the wait for sophisticated satellite guidance and control systems. Panoramic cameras would permit broad area coverage, while allowing the use of lenses with the long focal lengths required to obtain high ground resolution.

In a November 1957 memorandum, "Some Notes on the Evolution of RAND's Thinking on Reconnaissance Satellites," Katz recapitulated:

... About this same time [1955-56], the notion of re-entry became an Okay concept; there were clues that re-entry was possible; there was an ICBM program; the right intellectual framework was available to start talking about bringing data back alive, not sending it back by video. There was a brief flurry of RAND work, back-of-the-envelope-type things of that time, resulting in recommendation for a recoverable film satellite, still based on Atlas but with the elimination of processing of the film in the bird and its subsequent scanning and playback.

This particular recommendation, in spring [of] 1956, had an unhappy history: it went out, and was sort of withdrawn. Shortly thereafter, Dick Raymond, who was the main inspiration behind this recommendation, left RAND. By and large, the work on this kind of subject, which never really got started, dropped to an even lower level. Some of us here still thought the notion of recovering a film payload was a good idea. . . .

In the late spring or early summer of 1957, Davies got a really hot idea. This was the possible use of spin-stabilized panoramic cameras for satellite reconnaissance over the Soviet Union. . . .

Now, by the fall of 1957, not only were the kinds of previously operating constraints removed, but Sputniks I and II [October 4 and November 3, 1957] were added. This permitted the entry of "space flight" and "satellites" in the list of Okay ideas for the military. A sense of urgency developed in the satellite business, and a corresponding sense of increased urgency in the reconnaissance business. Hence recce satellites were doubly Okay.

Thus we see how our thinking has progressed from a climate in which boosters were nonexistent, long-life satellites a must, re-entry impossible, into an era in which re-entry seems assured, boosters will be plentiful, and satellites are no longer an exotic topic to be discussed only on the lunatic fringe, but an important part of our activities.

The time was ripe and right for this kind of a proposal. It was made.

This, briefly, is how we got where we are.

II-11. INCREASED PRIORITY FOR RECONNAISSANCE SATELLITES

On January 6, 1958, Lockheed proposed acceleration of the WS-117L satellite program by using the Thor IRBM booster together with Lockheed's Agena upper stage. (Snyder et al., 1976, p. 47)

Major General Bernard A. Schriever, as Commander of the Air Force Ballistic Missile Division (AFBMD), sought funding to accelerate the development of space satellite systems, but funds were not available even after the uproar over the launch of the first Soviet Sputnik in October 1957.

This may seem implausible to the contemporary reader, for, with hindsight, space observation systems have been an essential component of international security policy over more than a quarter century. Moreover, Soviet protests had caused the President to terminate the GENETRIX balloon reconnaissance program in March 1956, and later balloon reconnaissance programs in 1958. The manned U-2 airplanes operated at such high altitudes that they were temporarily beyond the effective reach of the Soviet air defense forces. But it was widely recognized that aerial overflight, whether by aircraft or balloon, exacerbated diplomatic tensions and left chronological and spatial sampling gaps that were important to close. Why, then, was there no money to accelerate the WS-117L satellite reconnaissance program in the fall of 1957?

The economic recession of 1957-59, together with the fiscal conservatism of Treasury Secretary George Humphrey, resulted in inadequate Air Force funds for any significantly accelerated satellite program. In October 1956, WDD had submitted a proposed FY 1958 budget of \$1.672 billion, but the commitment of the President to achieve a balanced budget, a sentiment reinforced by Secretary Humphrey, resulted in an initial budget for FY 1958 of \$1.175 billion for the ballistic missile program. On August 1, 1957, the National Security Council approved a Department of Defense recommendation to scale back the U.S. ballistic missile programs. Atlas retained its highest priority rating, but Titan's priority was reduced, and the Air Force Thor and the Army Jupiter IRBM programs were combined. (Snyder et al., 1976, p. 40)

On October 5, 1957, just one day after the Soviets launched Sputnik 1, Secretary of Defense Charles E. Wilson approved an AFBMD budget of only \$991 million. (Snyder et al., 1976, pp. 40-41) The ballistic missile programs were on a tight time schedule, and no funds were available to augment the WS-117L satellite program in the aftermath of the budget reductions.

The USAF funding levels assigned for WS-117L, the Advanced Reconnaissance [Satellite] System, for three fiscal years (ending June 30 of the calendar year) were publicly reported (Bowen, 1960, p. 39):

FUNDING FOR WEAPON SYSTEM WS-117L
(In \$ millions)

FY 1956	4.7
FY 1957	13.9
FY 1958	65.8

On January 22, 1958, the National Security Council approved NSC Action No. 1846, assigning the highest priority to development of an operational reconnaissance satellite. (NSC 5814, June 20, 1958, p. 20, citing NSC Action 1846) Finding the funds to accelerate the program was increasingly difficult for the Air Force, particularly after the new Secretary of Defense, Neil H. McElroy, agreed in late 1957 to consolidate key research and development activities in an Advanced Research Projects Agency (ARPA). The impending creation of ARPA stymied Air Force planners who would, in the absence of this new agency, have expanded their requests for advanced satellite systems. Department of Defense Directive 5105.15, February 7, 1958, established ARPA as a new entity to undertake basic research and to direct research and development projects within DOD, as assigned to ARPA by the

Secretary of Defense. As a practical matter, ARPA reassigned many of the pertinent missile and space system projects back through AFBMD; but in the winter of 1957-58 the process of establishing ARPA created a new set of barriers to accelerated Air Force funding of a satellite reconnaissance program.

A nearly contemporaneous Air Force history summarized the situation (Bowen, 1960, p. 19):

[After] February 1958, authority for space projects was centralized in ARPA. The Air Force could do little more than urge funds for long-term projects; work to accelerate the production of Atlas, Titan, and Thor; proceed as swiftly as possible with near-term space projects; and fight for favorable policies at high levels.

On January 24, 1958, the Deputy Chief of Staff for Development, USAF, recommended development of five space programs, with 21 subsystems, assessed as "essential to the maintenance of our national position and prestige." (Memo, Richard E. Horner, Assistant Secretary of the Air Force (Research and Development), to William Holaday, OSD, January 24, 1958, cited in Bowen, 1960, p. 23) The five programs included: (1) WS-604, Ballistic Test and Related Systems, including BRAT and aerial reconnaissance; (2) WS-447, Manned Hypersonic Research System, including the X-15 and advanced R&D for manned space flight; (3) WS-464, Dyna Soar, including a manned capsule with glide interceptor and satellite interceptor, together with global reconnaissance and global bombardment subsystems; (4) WS-117L, the Advanced Reconnaissance [Satellite] System, with recoverable photo-capsule, a multi-satellite system for 24-hour reconnaissance, a manned strategic space station, and a strategic communications station; and (5) WS-499, a Lunar Base System. (Bowen, 1960, p. 23)

General Schriever implied a lack of OSD funding approval for augmented space system development within the Air Force when he testified before the Senate Committee on Armed Services in late January 1958 (U.S. Senate, 1958, pp. 1634-1635):

Senator Stuart Symington: "Could you put up in orbit fairly soon a satellite that you believe you could call down?"

General Schriever: "Yes sir. . . . There was a lot of interest, at different sources in the Government, for an advanced reconnaissance system. But we got no approval for proceeding with this on a systems basis either on the Air Force secretariat level or at the Department of Defense secretariat level until just recently.

On February 1, 1958, Secretary of the Air Force James H. Douglas urged Secretary of Defense Neil McElroy to approve the set of Air Force development programs presented in the previous November. These

included a proposal for USAF use of Thor missiles to boost test satellites into orbit, starting before the end of 1958. (Snyder et al., 1976, p. 48; Bowen, 1960, p. 53, Note 54, citing Memo, Douglas to SecDef McElroy, February 1, 1958, "Requesting OSD Approval of the Air Force Programs Presented 12 November 1957")

On February 3, 1958, President Eisenhower directed the highest and equal materiel priority for the Atlas, Titan, Thor, and Jupiter missiles; the WS-117L satellite; and the WS-224A (BMEWS) early-warning network. (Snyder et al., 1976, p. 48) With ARPA in the planning loop, the identification of development priorities did not necessarily empower the Air Force to include additional funds in the Air Force budget.

Notwithstanding this decision, the Office of the Secretary of the Air Force continued to seek OSD approval to revive its own authority to fund and develop space systems. On February 14, Assistant Secretary Horner renewed the Air Force request for approval of the five astronautics programs previously noted. On February 21, 1958, he sent the Secretary of Defense a memorandum entitled "Request that USAF be Made Executive Agent for Some Aspects of ARS [the Advanced Reconnaissance System]." (Bowen, 1960, p. 53, Note 54) On that same date, Assistant Secretary Horner, in another memorandum to the Secretary of Defense, submitted a "Request for Approval of WS-117L Plans to Put Series of Unmanned Satellites in Orbit." (Bowen, 1960, p. 54, Note 54)

Air Force initiatives to regain primary responsibility for space system development programs were unsuccessful. On March 24, 1958, President Eisenhower authorized ARPA to manage civilian space programs until the creation of the National Aeronautics and Space Administration on October 1, 1958. (Bowen, 1960, p. 24)

When President Eisenhower approved the accelerated satellite program in February 1958, the RAND concept of a spin-stabilized spacecraft carrying a fixed long-focal-length panoramic camera was part of the design concept. Davies and Katz, following the design philosophy of their colleague Robert Buchheim, had placed their priority on early operation of such a system, with an eye toward simplicity of design and operation. Others proposed alternative design concepts. It is reported that in April 1958 a technical review of the project resulted in a change from a panoramic camera fixed in a spin-stabilized spacecraft (the RAND concept) to an alternative development concept. (Mosely, 1978, p. 432; Stares, 1985, pp. 44-45).²

²Fairchild Camera and Instrument Company continued to advocate the employment of a spin-stabilized panoramic camera system, in Report SME-AB-3 of July 25, 1958, *Panoramic Camera System for a Spin-Stabilized Satellite* (recently declassified). Fairchild

In June 1958, the National Security Council approved NSC 5814, "U.S. Policy on Outer Space," establishing a U.S. national space policy. Paragraphs 51 and 55, included in the substantial portions of this historic document that were declassified and released by the Eisenhower Library in 1981, stated:

54. In anticipation of the availability of reconnaissance satellites, [the U.S. should] seek urgently a political framework which will place the uses of U.S. reconnaissance satellites in a political and psychological context most favorable to the United States.

55. At the earliest technologically practical date, [the United States should] use reconnaissance satellites to enhance to the maximum extent the U.S. intelligence effort. (NSC 5814, June 20, 1958, p. 21)

The initial launch of a Discoverer I payload occurred on February 28, 1959. Thor 163, carrying the Agena A upper stage, was the first in a test program to orbit U.S. satellites. (Snyder et al., 1976, p. 63) The launch of Discoverer II on April 13, 1959, resulted in the stabilization of a satellite along all three axes, the first satellite in the world to be stabilized in this manner. (Snyder et al., 1976)

On June 10, 1960, President Eisenhower directed Secretary of Defense Thomas Gates, Jr., to evaluate U.S. intelligence requirements, and the feasibility of meeting them, for the National Security Council. Gates in turn established a committee consisting of the Under Secretary of the Air Force, Joseph Charyk; the Deputy Director of Defense Research and Engineering, John H. Rubel; and the Science Adviser to the President, George B. Kistiakowsky. The recommendations of this committee led, according to an official Air Force history, to

a key decision by NSC and the President which, eliminating previous uncertainties, signalled the start of a highest priority project reminiscent of the wartime Manhattan effort. . . . (Berger, 1966, p. 34)

An official Air Force chronology also indicates that on August 10, 1960, a Thor IRBM with Agena upper stage was launched, from Vandenberg Air Force Base, Discoverer XIII, and that on its seventeenth pass it ejected a "data capsule" that was recovered from the water by a Navy helicopter crew near Hawaii. This was "the first successful recovery of a man-made object ejected from an orbiting satellite." (Snyder et al., 1976, pp. 82, 84) And on August 19, 1960, an Air Force unit based in Hawaii, flying a C-119J "Flying Boxcar," completed the first successful in-air recovery of a capsule ejected from Discoverer XIV. (Snyder et al., 1976, p. 84)

asserted that a spin-stabilized system permitted lower-altitude orbits, hence heavier payloads.

In the period 1946 to 1958, Air Force sponsorship of RAND projects facilitated the development of overhead reconnaissance systems. When the Soviets were finally able to shoot down a U-2 reconnaissance airplane in May 1960, the nation was on the verge of acquiring alternative means of gathering the information needed for survival in the nuclear age.

In 1960, after the deployment of the U-2's follow-on system, a formal USIB [United States Intelligence Board] subcommittee, the Committee on Overhead Reconnaissance (COMOR), succeeded the ARC [Ad Hoc Requirements Committee]. COMOR was responsible for the development and operation of all overhead reconnaissance systems. (U.S. Senate Select Committee with Respect to Intelligence Activities, Report 94-755, Book IV, 1976, p. 59)

The RAND-sponsored studies of the potential of space satellites for reconnaissance and arms control verification persisted over a twelve-year period. These studies stimulated alternative concept and development initiatives. The RAND (FEED BACK) concepts for electro-optical sensing and associated data relay systems were premature. The later RAND-proposed design for a space reconnaissance satellite was in fact canceled in April 1958. RAND's studies served as catalysts, as exemplars, as beacons—facilitating, illustrating, and encouraging others' efforts.

In June 1964, the chairman of the U.S. Senate Space Committee, Clinton P. Anderson, stated: "We are using satellites in the cause of peace. . . . It seems that there is a recognition and acceptance of this amazing new development wrought in space and that we have a new weapon with which to wage peace." (Robert C. Toth, "Use of Spy Satellites Admitted," *Los Angeles Times*, June 12, 1964)

President Lyndon B. Johnson indicated on March 15, 1967, that the U.S. space program was worth ten times its cost (*New York Times*, March 17, 1967):

We have spent between thirty-five and forty billion dollars on space. . . . [What] we have learned from space photographs has made the whole expenditure worth while. We know who has the missiles, how many of them and where they are.

President Jimmy Carter, in remarks at the Kennedy Space Center on October 1, 1978, stated:

Photoreconnaissance satellites have become an important stabilizing factor in world affairs in the monitoring of arms control agreements. They make an immense contribution to the security of all nations. We shall continue to develop them. (*Public Papers of President Jimmy Carter*, 1978, Vol. 2, 1979, p. 1686)

II-12. AN UNSOLVED PROBLEM: WARNING INTELLIGENCE AND THE MISSILE DETECTION ALARM SATELLITE (MIDAS)

In 1955 Sidney Passman, an expert on infrared technology, and William W. Kellogg, an expert on high-altitude observation of the earth, considered techniques for detecting intercontinental missiles during and after boost phase. The baseline platform to carry infrared sensors was a group of "picket airplanes" that would search for missile launches from the periphery of the Soviet Union. But the impossibility of observing much of the boost phase, because of the curvature of the earth, and the risk of detection failure after completion of the powered phase of flight encouraged consideration of space-based infrared detection satellites. This work preceded inclusion of the Missile Detection Alarm Satellite (MIDAS) in the WS-117L Air Force program. Kellogg and Passman wrote (RAND Research Memorandum RM-1572, p. 50):

During the early stages of the (ICBM) takeoff there is more than enough infrared emission, but the earth gets in the way. . . . After burnout there is not nearly enough infrared signal to give detection at any useful range. . . .

The figures . . . lead one to speculate on the increased warning time and perhaps more accurate trajectory prediction that might be possible by getting around this geometrical limitation with a very-high-altitude search station—perhaps with a satellite-borne infrared search set. This is the subject of a separate study at RAND.

RAND staff did not consider that the RAND-proposed imaging satellite, taken alone, made significant progress in augmenting the reliability of warning of surprise attack. Amrom Katz observed, in a memorandum of January 3, 1958:

The warning problem is, of course, the kind of thing . . . which the RAND satellites cannot really contribute to in any meaningful way. . . . (Memorandum, A. H. Katz to L. J. Henderson and R. Lew, January 3, 1958, p. 5, declassified March 24, 1972)

While imaging satellites might contribute to warning of surprise attack, there was no guarantee that imaging data would provide unambiguous warning. For example, a CIA submission to a report of the National Security Council Planning Board stated in 1956:

[It] is possible that the USSR, if it sought full strategic surprise, could launch an attack on the continental U.S. without undertaking any observable preparations which would provide strategic warning.

(NSC 5606, Annex B, p. 25, quoted in Richard K. Betts, "A Nuclear Golden Age?" *International Security*, Vol. 11, Winter 1986-87, p. 24)

In the 1950s, the preeminent emphasis in RAND's research on high-altitude reconnaissance had been to match requirements with systems, and then to facilitate the development of appropriate systems. Some of the RAND work on balloon systems involved studies of non-photographic payloads that had the potential to complement imagery with non-imagery indicators of peacetime preparations for hostilities.

A. L. Hiebert had summarized the work of a RAND conference on electronic reconnaissance in the summer of 1953 (see declassified Classified Paper S-15, August 1, 1953). Thereafter, he and Richard Raymond had considered aircraft and balloon platforms for electronic sensors. By 1955 the prospects for a Soviet ICBM force led to interest in early warning of ballistic missile launches. Hence, as noted earlier, Kellogg and Passman identified infrared techniques that might be applied to the space-based detection of ICBM launches. (See RAND Research Memorandum RM-1572, *Infrared Techniques Applied to the Detection and Interception of Intercontinental Ballistic Missiles* (limited distribution), October 21, 1955.) This work captured the attention of various science advisory committees and precipitated the inclusion of MIDAS in the WS-117L satellite program. The Western Development Division had begun studies of missile launcher requirements for MIDAS in March 1957. Concurrently, RAND committed substantial research effort to the improvement of ground-based radar warning, both for aircraft and for ballistic missiles, the so-called Ballistic Missile Early Warning System (BMEWS).

The Advanced Research Projects Agency took over sponsorship of both the MIDAS and the SAMOS programs from the Air Force in February 1958. The establishment of ARPA, as noted earlier, was a temporary cause of administrative delay in program planning during 1958. In September of that year, ARPA redefined the Advanced Reconnaissance System. The reconnaissance element became Project SENTRY, later renamed SAMOS. The advanced space satellite program included experiments within the Discoverer series. And the infrared sensor system for detection of missile launches became MIDAS. (See Bowen, 1960, p. 32.)

It was not until September 1959 that both MIDAS and SAMOS systems became once again the primary responsibility of AFBMD. MIDAS I, launched on February 26, 1960, failed to achieve orbit. MIDAS II, launched on May 24, 1960, became the world's first early warning satellite to be placed in orbit. (Snyder et al., 1976, pp. 38, 70-73, 80) After an initial launch failure, the Air Force launched (on

an Atlas/Agena rocket) the SAMOS II satellite on January 31, 1961. (Snyder et al., 1976, pp. 70-73, 88, 92, 317)

In connection with the photoreconnaissance system most directly linked to the RAND effort of the 1950s, between February 1958 and the Soviet shootdown of the U-2 reconnaissance aircraft in May 1960, virtually all of the RAND pioneers of space reconnaissance still resident at RAND missed the opportunity to participate in the developmental phase of concepts that were theirs or that were adapted from their work. This did not stop innovation at RAND regarding space technology, but for a time it channeled energies in directions other than the primary one since 1946—reconnaissance.

II-13. MILITARY MAPPING AND SPACE DEFENSE

A discipline related to space reconnaissance was mapping by satellite. In 1958, RAND published Research Memorandum RM-2179, Robert Buchheim's collection of materials on space applications, which included a summary proposal for a space reconnaissance mapping satellite for General Ferguson's office in the Air Force. This led to modification of the USAF reconnaissance requirements document (GOR 80-4) to include mapping reconnaissance missions (Katz, 1959, p. 6). These requirements have, in current times, found an institutional home in the Defense Mapping Agency.

More broadly, the significance of satellites for peacetime reconnaissance and communications, and for the conduct of military operations, encouraged the consideration of countermeasures. In 1958, RAND published two relevant studies, both classified Secret: S. T. Cohen's Classified Paper S-84, *Nuclear Defenses Against Space Weapons* (a quarter century before the Strategic Defense Initiative) and Irwin S. Blumenthal's Classified Paper S-76, *Problems in Defending Against Satellites*. (RAND, 1959, pp. 46, 47)

In subsequent years, RAND staff considered various cooperative measures to provide public notice of space launches through the United Nations and to inspect space payloads before their launching. John J. McCloy, President Kennedy's Special Adviser on Disarmament, established a Disarmament Consultative Group on Outer Space, chaired by Trevor Gardner. In this group, Robert Buchheim floated the idea of agreed rights to inspect even reconnaissance satellites before launch to the extent necessary to assure the absence of nuclear weapons.

In subsequent decades, both the United States and the USSR have constrained their antisatellite efforts essentially to option-keeping hedges, almost surely in recognition of the importance of "Open Skies" reconnaissance, warning, communications, mapping, navigation, weather observation, and verification of arms control agreements.

II-14. TECHNOLOGY TRANSFER FROM MILITARY TO CIVIL SPACE PROGRAMS

Twenty-one months before initial operation of the TIROS-1 weather satellite in 1960, Greenfield and Kellogg published a RAND Paper, P-1402, *Satellite Weather Reconnaissance*, dated June 12, 1958. This paper brought the results of more than a decade of upper-atmospheric experimentation to the attention of the scientific community. It was important to do so at that time, just a month before President Eisenhower signed the National Space Act of 1958.

The initial RAND investigations of upper-atmospheric phenomenology in the late 1940s and early 1950s had supported the development of balloon reconnaissance systems, as we have shown. These, in turn, supported the development of earth-sensing payloads that hastened the design of space satellites for remote observation of the earth. Because balloons could carry heavier payloads than could space satellites launched in the early 1960s, balloon programs, rather than aircraft programs, provided testbeds for the observation systems later carried on space satellites. Work at RAND on the high-altitude observation potential of rockets in the late 1940s, and on high-altitude balloon systems in the early 1950s, led by 1958 to public discussion of the potential for satellite-based observations of cloud cover and upper atmospheric weather patterns, as well as of communications satellites, which became a reality in the 1960s.

On September 4, 1958, the Air Force Ballistic Missile Division formally initiated a program to launch a Television Infrared Observation Satellite (TIROS). The Air Force transferred this program to NASA in April 1959; consequently, the world's first weather satellite, TIROS-1, operated from April 1960 under civilian auspices. (Snyder et al., 1976, pp. 56, 64, 78) See Figs. 14-16.

The Air Force had the vision, and the Congressional backing, to sponsor RAND's studies and later system development of space satellites with a potential for both civil and military applications. RAND researchers supported development of both the civil and the military potential of space systems.

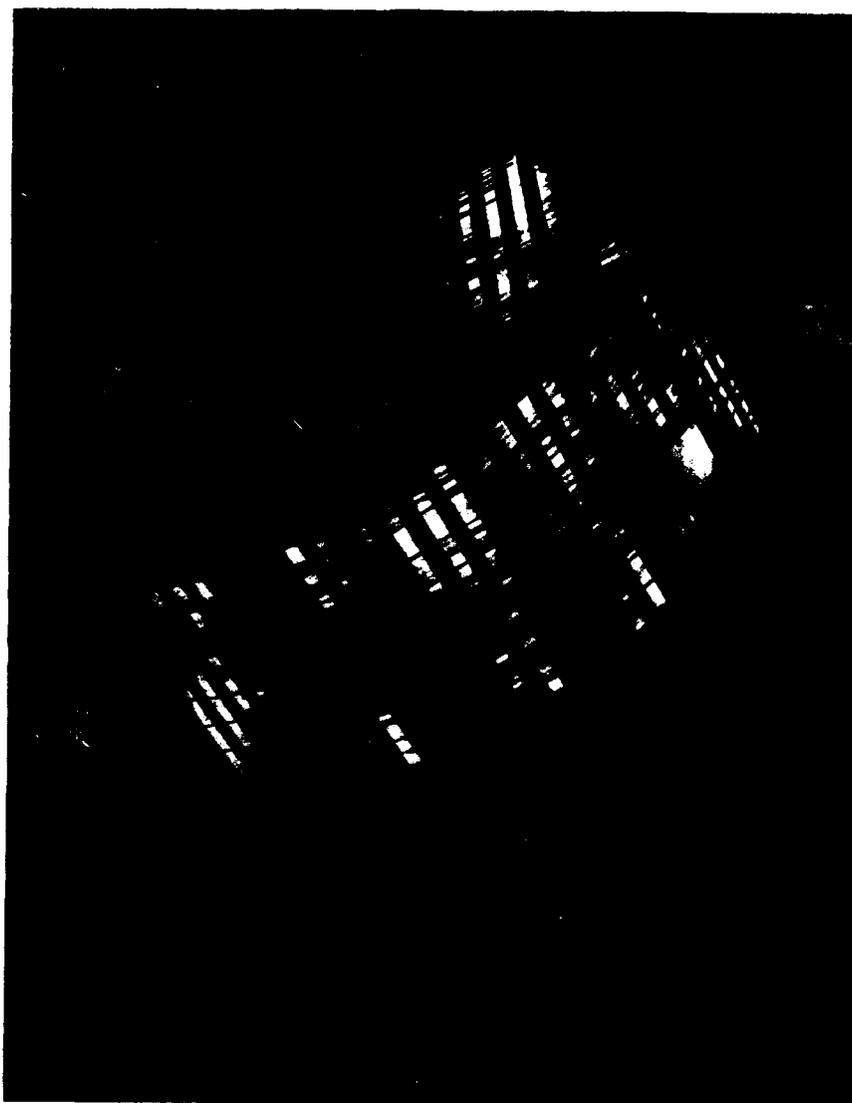


Fig. 14—The first meteorological satellite—TIROS-1



Fig. 15—TIROS-1 was launched on April 1, 1960, by a Thor-Able booster

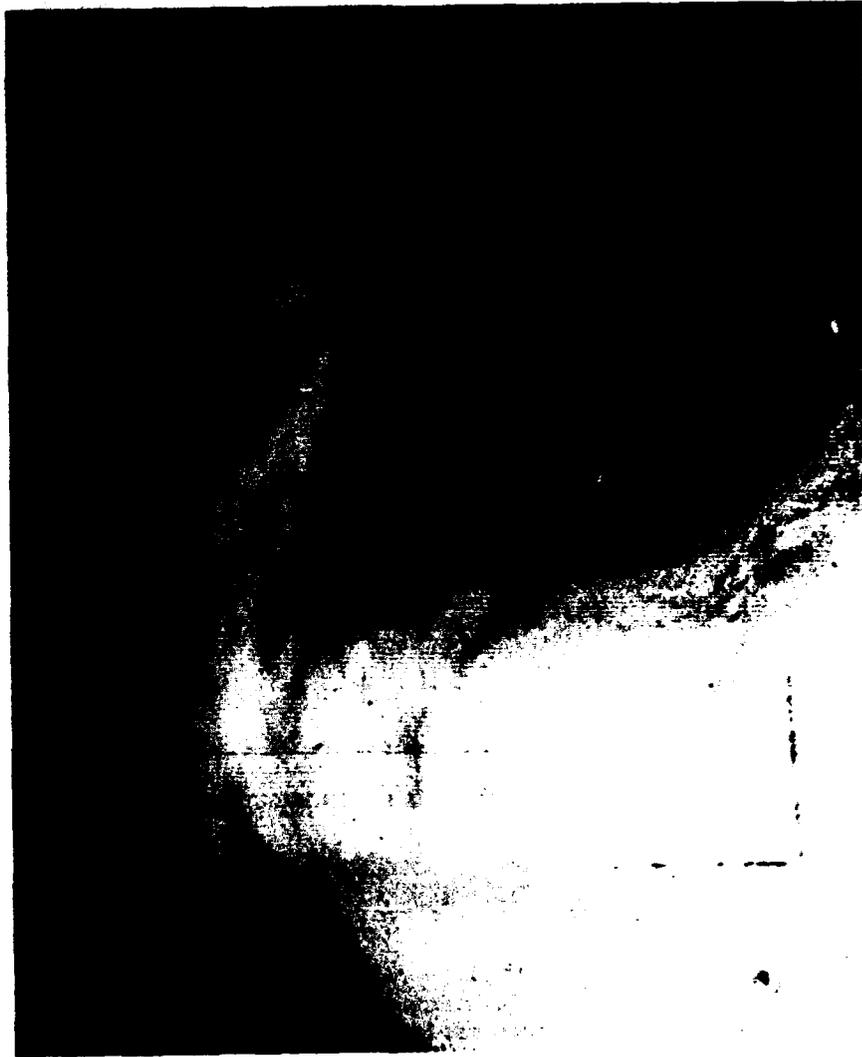


Fig. 16—The first picture returned by the TIROS-1 meteorological satellite

Shortly after the founding of the National Aeronautics and Space Administration in 1958, T. Keith Glennan, its first Administrator, asked RAND to prepare a paper, "Rationale for a Space Program." Designed in part as a starting point for a NASA Advisory Committee, the paper, by Robert Buchheim and Rear Admiral Paul A. Smith (USCGS, retired), emphasized the benefits of cooperation between NASA and military space programs, and the importance of NASA's drawing upon military assets, current and future.

As ambitions for space satellite missions expanded, RAND studied concomitant needs for communication with space vehicles. In February 1958, Cullen M. Crain and R. T. Gabler published *Communications in Space Operations*, RAND Paper P-1394, indicating the feasibility of communicating from ground stations to and from space vehicles at all distances, including lunar and beyond. In 1960, RAND published Research Memorandum RM-2709-NASA, *Communications Satellites: An Introductory Survey of Technology and Economic Promise*, for the fledgling space agency. This study focused NASA's attention on the potential economic benefits of communication satellites.

In parallel with the writing of unclassified publications on the potential for a civil space program, RAND researchers helped organize a "Lunar and Planetary Exploration Colloquium" in the spring of 1958. This brought together experts on disciplines pertinent to the exploration of the moon and the solar system, and it provided a forum for the exchange of ideas and their publication.

The Lunar and Planetary Exploration Colloquium came into being in the aftermath of a lecture by RAND's Richard Holbrook on "Lunar Base Planning" at UCLA in April 1958. N. A. Riley of the California Research Corporation, and Allan L. Jones and James L. Friend of North American Aviation, proposed the establishment of a forum for more systematic discussions. A planning session, held at RAND, led to the initiation of the Colloquium, with North American Aviation (later absorbed by Rockwell) hosting the first meeting in Downey, California. Holbrook and William Kellogg of RAND, together with Riley, Jones, Friend, Frank Press (then director of Caltech's Seismological Laboratory), and Dinsmore Alter (director emeritus of the Griffith Observatory), formed an initial steering committee for the Colloquium. RAND hosted the second meeting, and other institutions hosted subsequent meetings.

At the first session, E. H. Vestine of RAND summarized Research Memorandum RM-2106 in a paper, "Evolution and Nature of the Lunar Atmosphere." Other RAND participants at the first session of the Colloquium were Robert W. Buchheim, Stephen H. Dole, Stanley M. Greenfield, H. A. Lang, and A. G. Wilson. In 1959 Greenfield and

Wilson represented RAND on the Steering Committee. The presentations resulted in formal papers, together with extensive photography, published as a courtesy to the Colloquium by North American Aviation's Aero-Space Laboratories in two volumes for the period 1958-April 1959 and April 1959-December 1961.

In the 1980s some writers have asserted that there is a trend toward the "militarization" of space after its development for civil purposes. This does nothing less than stand history on its head. A recent book on the evolution of space technology, written by Paul Stares of the Brookings Institution, for example, bears the title, *The Militarization of Space: U.S. Policy, 1945-1984*. Does this title fairly summarize the evolution of U.S. space policies and programs?

Reviewing extant records of the classified and unclassified work performed under Project RAND and at The RAND Corporation in all of its programs since 1946, we find a preponderance of "military" space missions that were transformed into civilian applications.

Project RAND's initial task, in the spring of 1946, was to explore the feasibility of reconnaissance satellites for military purposes. RAND staffers together with U.S. government officials advocated the inclusion of space observation systems in the class of observation systems to reduce the risks of surprise attack and to assure adequate verification for potential arms control agreements. Today, primary responsibility for the verification of compliance with arms control agreements rests with civilian organizations, not the military services. The Director of the U.S. Arms Control and Disarmament Agency (ACDA) is technically responsible for verifying compliance and noncompliance with agreements in force and those that are proposed by or to the United States. Under the direction of the Special Assistant to the President for National Security, ACDA and CIA co-chair an Arms Control Verification Committee of the National Security Council. Earth observation satellites support military missions, of course, but they also perform arms control and Earth resource evaluation missions for civil purposes.

Several of the potential space missions explored by the RAND staff under Air Force sponsorship in the 1940s and 1950s came to fruition under civil agency management in the 1960s and 1970s. RAND accepted sponsorship of research from civil government agencies such as NASA, and from non-profit foundations, to identify civil applications of space technology.

The first weather satellite, originally funded by the Air Force, was from its inception operated by NASA. RAND researchers supported this transition from military to civil (NASA) sponsorship. At the same time, RAND continued to work on weather reconnaissance require-

ments for the Air Force. A Defense Meteorological Satellite Program (DMSP) complemented the civilian TIROS program. (See Snyder et al., 1976, p. 324.) RAND research on manned lunar and interplanetary exploration, sponsored by the Air Force, also saw its implementation under NASA auspices. The first of the manned space programs was the Mercury program, followed by Gemini, Apollo, and others for both manned and unmanned exploration of the solar system. On February 20, 1962, an Atlas D launched "Friendship 7," placing Lieutenant Colonel John Glenn, USMC, into Earth orbit for three passes in the first manned orbital flight of the Mercury program. (Swenson, 1966)

Geosynchronous satellites for communications, suggested to the Army Air Force in February 1947 by James Lipp at RAND, resulted in both civil communication satellite systems operated by the newly organized Communications Satellite Corporation (see Hughes Aircraft, 1981) and military communication satellites for U.S. and NATO service. Initial development responsibility within the Advanced Research Projects Agency preceded the assignment of primary Department of Defense responsibility for 24-hour synchronous, equatorial communication satellites to the Department of the Army in February 1960. The implementing Project ADVENT had recurring trouble with the Centaur upper stage. After cancellation of ADVENT in 1962, the Air Force regained responsibility for development of an Initial Defense Communications Satellite System (IDCS). Philco-Ford served as the prime contractor for the Air Force beginning in October 1964. TRW became the prime contractor for the Defense Satellite Communications System (DSCS II) in March 1969. (Snyder et al., 1976, pp. 108, 323) RAND's work in the 1940s and 1950s encouraged the development of communication satellites for both civil and defense missions.

Navigation satellites, the subject of some research at RAND in connection with ICBM guidance assessments, were actively studied under Navy sponsorship at Johns Hopkins University. The Air Force Ballistic Missile Division received an assignment in September 1958 to develop the booster for the TRANSIT satellite. On April 13, 1960, the Navy's TRANSIT IB satellite became the first navigation satellite to be placed into orbit, aboard the Thor/Ablestar. (Snyder et al., 1976, p. 312)

RAND research of the 1940s and 1950s played a role in transferring concepts initially explored for the U.S. Air Force, and implemented in related programs of all three military services and the Office of the Secretary of Defense, into broad-ranging civil applications. If one had to choose between the "militarization" and the "civilianization" of space to capture broad trends in U.S. space policy, the latter would more closely approximate reality. In fact, space technology serves both

civil and military missions, with the latter constrained by the Limited Test Ban Treaty of 1963 and the Outer Space Treaty of 1967. The diversification of RAND research sponsorship in the late 1950s encouraged the pursuit of civil applications of space technology.

Part III

RETROSPECTIVE

III-1. INNOVATION IN THE RAND ENVIRONMENT

One of RAND's particular strengths, then and now, is easy flow of working relations across departments and divisions. By organizing work on a project-by-project basis, RAND brought professionals with diverse backgrounds together. This allowed RAND to bring insights from one discipline to bear on seemingly extraneous tasks more rapidly than generally occurred within universities or at large industrial firms.

The transition from RAND's recommendations in Project FEED BACK (1951-54) to its recommendations of recoverable satellite systems (1956-57) illustrates the benefits that flow from interdisciplinary research. Many an organization, proud of its early work in one direction, would be incapable of reversing course when new insights indicated a need for a different approach to a problem.

The underlying cause for interest in television-like remote sensing, data storage, and transmission to ground stations was economics. The high cost of developing rocket systems, launch and control facilities, and payloads indicated the likely necessity of keeping satellites in orbit for extended periods of time. Also, there was concern that difficulties in dissipating the heat accumulated during atmospheric re-entry might preclude the recovery of heat-sensitive payloads such as film.

Because Bruno Augenstein and others were at the forefront of the ICBM recommendations, they understood that purchases in large quantity could bring down unit costs. The launch facilities for intercontinental missiles could also serve as the launch facilities for space payloads. In an unpublished RAND working document, Milton Margolis estimated ICBM development cost estimates for FY 1956-59. Then Carl Gazley, who joined the RAND staff from the General Electric Company in Philadelphia, shared insights regarding the use of ablative surfaces to dissipate heat and protect payloads during atmospheric entry. In May 1955 the Air Force had awarded General Electric-Philadelphia a contract to develop a prototype nose cone for the Atlas ICBM's atmospheric re-entry. (Snyder et al., 1976, p. 27) Gazley and others came to RAND with fresh ideas that sparked a rethinking of television-in-space observation systems, compared with film-from-space observation systems. This resulted in acceptance of the idea that payloads could be recovered from space vehicles.

The RAND environment encouraged self-initiated research activities, such as studies of high-altitude balloons for peacetime reconnaissance. It also encouraged staff attendance at professional meetings and the open exchange of ideas, such as that which indicated the potential of panoramic cameras for high-altitude reconnaissance cameras.

III-2. PUBLIC EDUCATION

Following the launch of the first Sputnik in October 1957, public interest in prospects for space technology exploded. The commitment of the U.S. Air Force to sustained support of RAND research on space technology, over earlier years when the public either did not care or could not know, yielded at RAND a core of expertise that constituted a national asset. It was not until after passage of the National Space Act of 1958 that the California Institute of Technology shifted its Jet Propulsion Laboratory from U.S. Army to NASA research sponsorship. In this formative period of national space policy, RAND made available to the public a cohesive and comprehensive body of literature. Many of RAND's staff members published professional papers and articles. Several of RAND's activities deserve special mention here.

First, in February 1958, RAND issued (and supplemented in 1959) an unclassified bibliography of RAND publications on space flight, RM-2113-1, containing summaries of otherwise classified RAND studies. Second, F. J. Krieger published a documentary collection on the Soviet space program, *Behind the Sputniks: A Survey of Soviet Space Science*. Third, at the request of the Speaker of the House of Representatives, John McCormack, RAND compiled in a matter of weeks an extraordinary collection of documents and tutorials on space technology and submitted it as a "handbook" to the Congress in December 1958. A commercial edition was published through Random House in 1959, and a revised edition in 1963. Robert Buchheim, together with dozens of the RAND research and support staff, provided in a single reference work a collection of information on space that remains useful today. RAND's *Space Handbook: Astronautics and Its Applications* was a "crash" RAND product, and one that was met with effusive thanks. It drew upon a two-volume compendium of then-Secret lectures prepared as a course for senior Air Force officers, and published as RAND Classified Paper S-72 in February 1958. Fourth, Amrom Katz wrote publicly and humorously on reconnaissance in a series of six articles in *Astronautics* (1960), which were taken from a 128-page RAND Paper, P-1707, *Observation Satellites: Problems, Possibilities, and Prospects*, initially issued by RAND in May 1959. Four years later, Katz published a collection of readings on principles of remote sensing, Paper P-2762, *Selected Readings in Aerial Reconnaissance*, August 1963.

Finally, with a grant from The Ford Foundation, RAND commissioned a series of papers by distinguished scholars and hosted a conference on "International Political Implications of Activities in Outer

Space" in October 1959 (Goldsen et al., 1959). The conference proceedings, published as RAND Report R-362-RC and as a book by Random House, encouraged consideration of space launching systems, bombardment systems, and arms control; relationships between political strategy and space activities; forms and methods of international organization for space activity; the impact of space systems upon the balance of power; public opinion and incentives to develop space technology; radioactive contamination from nuclear-powered satellites; communications through space; space reconnaissance; the passage of missiles through space; and the occupation of space, the moon, or some planet through space stations. In the RAND tradition, this conference raised more questions than it answered.

III-3. FREEDOM TO INITIATE, PATIENCE TO PERSIST

RAND's early work on space technology and its applications reflected both imagination and endurance. The one without the other was not enough. One of the RAND traditions that contributed to the success of its research on space technology was the practice of self-initiated research. Work on electro-optical sensing systems, on the potential of intercontinental ballistic missiles, on the feasibility of recovering satellite payloads, and on spinning panoramic cameras was self-initiated by members of the RAND research staff. Entire projects were self-initiated, with the Air Force endorsing this concept, in part because of the demonstrated record of achievement from a research process that allowed for researcher-sponsored innovation. It is true that there were internal reviews of the wisdom and priority of research projects. A RAND Steering Committee reviewed projects that were proposed within RAND, before their formal adoption. And the Air Force had certain of its own research priorities, which the RAND staff either implemented or adapted, with occasional impertinence, by asking and answering more fundamental questions.

It took both perseverance at RAND and patience on the part of U.S. Air Force officers in the Pentagon and at the field commands. These officers supported and defended RAND space satellite projects that, when viewed in the light of conventional wisdom, were seen as longshots at best. Meanwhile, in Santa Monica, RAND staffers found that their persistent recommendations often remained on the shelf from 1946 until the mid-1950s. Had they had less enthusiasm and imagination, they might have sought easier work.

RAND, of course, was not alone in pioneering concepts and applications for space technology. But its staff worked virtually every conceivable mission, with due regard to security requirements and with a commitment to accomplish RAND's open-ended charter. RAND served not only as a repository of multidisciplinary knowledge but as a key training facility. Groups of RAND project managers and colleagues moved into leading positions in the aerospace industry and continued their innovative activities there. Project RAND's diversity of activity and accomplishments in space technology are a reminder of what a few people can accomplish in the right environment.

Some of the principles associated with RAND's achievements in that era have a contemporary application. In a period of micromanagement and computerized budgets, it is worth reflecting upon the rewards flowing from the encouragement of research staff initiation of research projects, the inclusion of a diverse group of consultants, informal contact between research and government staffs, and persistence.

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