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THE ROLE OF RAND RESEARCH IN THE ORIGINS OF SPACE [Technology] RECONNAISSANCE AND RELATED SPACE APPLICATIONS FOR ARMS CONTROL VERIFICATION, COMMUNICATIONS, METEOROLOGY, MAPPING, LUNAR AND PLANETARY EXPLORATION

by

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TABLE OF CONTENTS

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

Robert Browning, Andrea del Sarto.

INTRODUCTION

This Research Note results from RAND-sponsored research to commemorate the 40th anniversary of Project RAND, a research project of the U.S. Army Air Force that in fact commenced with a study of the utility and feasibility of space satellites, in April 1946. RAND research on space technology continued for the next two decades to emphasize the primacy of photo-reconnaissance and the communication to earth of remotely sensed data. Without the ability to observe and communicate, other applications of space technology appeared infeasible. But as a consequence of the continuing focus on the potential of space for reconnaissance and arms control verification, the writing and security clearance of this Research Note have not been a simple matter for either the authors or for the U.S. government. Hence, a project begun to commemorate the 40th anniversary of Project RAND in 1986, shall now serve to commemorate the 40th anniversary of the spinoff of The RAND Corporation, with a grant from The Ford Foundation, as an independent nonprofit corporation in 1948.

The U.S. Army 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 publication on May 2, 1946 of RAND's first report, Preliminary Design of an Experimental World-Circling Spaceship, Report No. SM-11827.

The initial Project RAND report identified a range of potential applications of space technology. In 1946-47, and following the incorporation of The RAND Corporation as a nonprofit research organization in 1948, members of the RAND staff investigated potential space technologies or impediments to their development, aiding in accomplishment, in the 1960s and later, of space missions for reconnaissance and arms control verification, weather forecasting, mapping and geodesy, communications, planetary and inter-planetary exploration, and other purposes.

This Research Note attempts to capture the breadth of interests, diligence of effort, and synergy of multi-disciplinary applications that contributed to achievements for the United States and for the scientific community worldwide in the exploration of planetary and inter-planetary space.

The authors of this study bring diverse experiences to their review of RAND's early research on space technology and applications. Merton E. Davies, trained as an engineer and mathematician, came to RAND after eight years at the Douglas Aircraft Company in 1940-1947. Since 1947 he has worked at RAND, and in the more 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, Mars, Jupiter, Saturn, and Uranus. He participated in 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, worked with Dr. Katz and others to facilitate the development of space-based reconnaissance systems that many dismissed as impossible. Concurrently, he played a recurring role in identifying potential uses of space reconnaissance to minimize risks of surprise attack, drafting U.S. submissions on verification capabilities for the Geneva Surprise Attack conference of 1958, and working on later initiatives to make arms control initiatives feasible.

William R. Harris, an international lawyer at RAND since 1972, has worked recurringly on treaty verification. He acquired his initial interest in space technology near the end of the period treated in this paper. It was in 1962, at the Woods Hole Summer Study on Verification and Response in Disarmament Agreements, that he learned from RAND's Amrom H. 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, Mr. Harris has reviewed the roles of pioneeers 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 a history of RAND's research on space technology and policy, with access to the remaining archival records and interviews as appropriate. It is but 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, and regrettably, many documents retained in but a single copy are gone, except for the control logs indicating their retention and destruction.

Over the last 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 Research

Note. Much of the RAND work has already been treated in these studies, often with more detail than we provide in this overview of RAND research on space technology. What we hope to contribute is a sense of context, illustrating the impacts of multidisciplinary research within RAND, and suggesting how the RAND staff and their research findings participated in diverse activities leading to early space operations.

The authors wish to express their appreciation to Dr. Amrom H. Katz for his review of a draft of this Research Note, and for his helpful suggestions and observations.

INNOVATIONS IN SPACE TECHNOLOGY AND SPACE POLICY: WHY RAND?

After reviewing the breadth of activities at RAND pertaining to space technology and 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 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 paper, 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, multi-disciplinary 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, General Curtis E. Lemay, saw part of his job as protecting Project RAND staff and RAND as an institution from short-term diversions from the long-term research mission that the U.S. Air Force assigned to the institution. General Lemay committed himself to give RAND at least five years of benign neglect, allowing RAND to structure its staff and research agenda so that it could serve long term needs of the Air Force and the nation. Within RAND this meant there was latitude to innovate, to build research alliances among staffs with diverse training, unlike work habits at the universities from which many RANDites came. At the universities, before the infusion of federal research monies, cross-department research was infrequently encouraged, and often unhelpful to career development. The intellectual ferment at RAND resulted in 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 paper, involved the identification of 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 nonprofit enterprise (within Boston University), which in turn modified the RAND concept in 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 -- was ultimately adopted in the first space photoreconnaissance system. Stimulated by work of Fred Willcox at Fairchild Camera and Instrument Company, Davies' concept was to utilize a panoramic camera with 12-inch 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

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FA-VD/

camera with long focal length, though his concept involved an oscillating rather than a spinning camera lens.

Except 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 traces that historians would prefer. But RAND bridged the worlds of basic research, applied research, and policy innovation, without worrying to excess about its publications record.

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 United States 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 enunciated policies 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.

RAND'S FIRST REPORT

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 4th and Broadway in Santa Monica, before new facilities were built closer to the Pacific ocean in the mid-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, 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.

Despite plans for long term studies, Project RAND commenced with a "crash" effort resulting from perceived needs of the Army Air Force to demonstrate independent competency in the analysis of the feasibility and potential applications of space technology, before an interservice review with representatives of the U.S. Navy in May 1946. General Curtis E. LeMay, Director of Research and Development for the Army Air Force, considered space operations as 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).

A May 1945 report by Werner von Braun reviewed German views on potentials of rocket-launched space satellites. This report echoed interests of a German scientist, Hermann Oberth, whose book, published in 1923, stimulated interest in space exploration and 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 resulted in November 1945.*

This initial Navy report preceded a December 1945 Navy request for a satellite feasibility study, and Air Force interest, expressed in both a report of General H. H. Arnold in November 1945 (design of a space ship "is all but practi-

* O. E. Lancaster, J. R. Moore, Peter N. Olmsted, and M. M. Taylor, Investigation on the Possibility of Establishing a Space Ship in an Orbit Above the Surface of the Earth, U.S. Navy, BuAer, Report ADR R-48, November 1945.

cable today") and a December 1945 Air Force Scientific Advisory Group study, the Von Karman Report, that considered long range rockets feasible and satellites a "definite possibility." (Perry, 1962, p. 9; Augenstein, 1982, p. 3).

Before Project RAND commenced, Dr. Vannevar Bush had ridiculed the recommendations of General "Hap" Arnold in tesimony before the United States Senate, and the Navy had proposed, on March 7, 1946, establishment of an interservice space program. This concept came before the joint Army-Navy Aeronautical Board of Research and Development on April 9th, resulting in a decision to reconsider the matter at a meeting on May 14th, after the Army representatives could consult with Major General Curtis E. LeMay, Army Air Force Director of Research and Development. General LeMay, 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 the Army Air Force could "meet a pressing responsibility." The first Project RAND study was available after Douglas review on May 2, 1946. After minor revisions, it was forwarded to the Pentagon and arrived on May 12th, just two days before the May 14th review with the U.S. Navy. (Perry, 1962, p. 12, citing Memo, Ch, BuAer to JRDB, Subj: "Earth Satellite Vehicles," 24 Jan 1947; H. L. Bowen, MSS; Project 1115 Background, Dec. 1954).

The initial Project RAND report 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. Though the work was preliminary, the reporting of it was both illustrative and detailed. with a total of 321 pages.

[OBTAIN AND REPRODUCE ORIGINAL TITLE PAGE]

PRELIMINARY DESIGN OF AN EXPERIMENTAL WORLD-CIRCLING SPACESHIP

Report No. SM-11827

Contract W33-038 ac-14105

May 2, 1946

Professor Louis Ridenour of the University of Pennsylvania's Nuclear Physics and Electronics Department, served as a consultant on Project RAND's initial study. Ridenouer was one of the nation's foremost experts on radar technology. Later, in the 1950's, he managed research and development at the Lockheed Missiles and Space Company. Considering the specialized focus of his work in World War II, the breadth of his vision in his brief work for RAND in April 1946 is remarkable. Ridenour authored Chapter 2 of Project RAND's first report, "Significance of a Satellite Vehicle." Among the missions identified by Ridenour were: satellites to guide missiles; satellites as the missiles themselves; satellites as an "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 B29s bombing Japan and air transports circling the globe."

It was the combination of the technical feasibility assessments and the Ridenour overview of potential missions that 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."

DECOUPLING IMAGINATION FROM THE WORLD WAR II EXPERIENCE: THE 1947 LIPP REPORT ON SATELLITES FOR OCEAN SURVEILLANCE, RECONNAISSANCE, AND GEOSTATIONARY COMMUNICATIONS

In 1946-1947 Project RAND pursued the feasibility issues identified in the May 1946 report. James E. Lipp, head of the Project RAND Missile Division, managed the continuation of the study on space satellites. A second six-month effort commenced 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, Sep. 1, 1946, p. 3).

RAND's Satellite Study Section staff included, in 1946: James E. Lipp, the Satellite Study Section Chief, and: 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. It was RAND's work in the aftermath of the May 1946 report that 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 1947-1951 that assumed potential for the rapid development of rocketry and reconnaissance technologies should be interpreted against the backdrop of limited wartime technological progress in these areas.

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

In comparison to the development of technology for radar, atomic weapons, and computers, the developments 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 mission during World War II. Photos 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:

> 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 in 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).

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On February 1, 1947 James E. Lipp published Reference Papers relating to a Satellite Study, RA-15032. Collected papers prepared by RAND consultants (Lyman Spitzer, Jr., Luis W. Alvarez, Leonard I. Schiff, and Bruno Rossi) treated 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 treated 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 hundred 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, 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 mammoth Space Telescope, 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 E. 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. Lipp 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.

Lipp 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 for a space communications system, coming from the science fiction writer Clarke, was not in the mainstream of engineering literature, thus less likely to be noted by

Lipp and his staff.* Two years later, another member of the RAND staff, Richard S. Wehner, published RAND Research Memorandum RM-603, further developing the Lipp concept of equatorial orbiting communications satellites, Satellite to Surface Communications - Equatorial Orbit.**

For the first time in a paper on satellites, the 1947 Lipp paper addressed the potential use of satellites to obtain electro-optical images and to transmit them by 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 February 1947 Lipp paper proposed 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

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* See 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 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 Delbert D. Smith, Communications via Satellites: A Vision in Retrospect, 1976.

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

> 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 February 1947 RAND 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. 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 the February 1947 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.

Following publication in February 1947, the Air Force apparently deferred a formal assessment of the work until on September 25, 1947, one week after the official creation of the U.S. Air Force, HQ USAF 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 the practicality of utilization. AMC proposed, however, establishment of a project to prepare Air Force requirements and specifications for satellites, recognizing however that the development of guided missiles had higher priority. On January 15, 1948 General Hoyt S. Vandenberg stated that USAF "has logical responsibility for satellite..." and on January 16 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 when Project RAND functioned under Douglas Aircraft, but during the transition to independence as a separate nonprofit 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....

Acting upon a commitment of May 1948, in November 1948 Douglas Aircraft Company transferred Project RAND to an independent non-profit corporation, The RAND Corporation, founded with an initial grant from the Ford Foundation. Thereafter, the institution took on a broader mission. With regard to satellite feasibility studies, RAND took the lead in exploring satellite missions and feasibility, but with a mission to support triservice needs, reflecting the assignment of the satellite mission to the Air Force as a tri-service responsibility. RAND had authority to subcontract research studies.

In January 1949 the Bulletin of the American Meteorological Society had published an article by Major D. L. Crowson, "Cloud Observations from Rockets."*

The Crowson article had suggested that even low resolution imagery would assist in weather forecasting.

[*] Vol. 30, pp. 17-22.

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 Report R-217 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, both for peacetime and wartime observation. (Hall, 1963, pp. 430-431; Stares, 1985, p. 29).

In connection with the 1949 reconnaissance study at RAND, Wehner prepared a thorough document entitled "Inquiry into Feasibility of Satellite Television," RAND Document D-563 of July 15, 1949. Wehner also published in July 1949 Research Memorandum RM-603, evaluating an initial plan for equatorial orbiting satellites, 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.

AUTOMATED DATA MANAGEMENT FOR ELECTRO-OPTICAL IMAGING SYSTEMS: THE RIDENOUR MEMORANDUM OF 1950

In August 1950, during the course of this work, Professor Louis N. Ridenour (of M.I.T.) was the first of the RAND researchers to address the necessity to design an information system to manage, retrieve, and display 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 x 10^{10} bits/day...<u>The satellite (if it works) is collecting for us the informational equivalent of 10^{6} books.</u>

TRANSITIONAL RECONNAISSANCE SYSTEMS: 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 Will W. Kellogg and others, 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. But the Japanese ballooons were not optimized for reconnaissance missions but for inciendiary and psychological weapons. The Japanese launched paper balloons with inciendiary payloads. Some of these balloons did reach the U.S. mainland and start forest fires; however, in general they caused little damage because the rangers were prepared for fires caused by lightning. Moreover, press censorship minimized reports of those incendiary balloons that actually reached the U.S., and 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 unpleasantries.

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

This experiment resulted from [redacted] approach (b)(3) to experimentation. [redacted] asked his staff to perform faster, longer, higher, 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 feet, carrying a K-18 camera with 36 inch lens. 9" x 18" pictures resulted, in both black and white and color. This experiment demonstrated that a balloon made a suitably stable platofrm for high altitude photography. Its results encouraged the RAND researchers to consider alternative balloon reconnaissance programs, but also 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 their flights could be tracked.

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. (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 since July 1947. (Bushnell, 1959, xiii). Polyethylene balloons were lighter and became more reliable than rubber balloons, and could both achieve and sustain high altitude flight, appropriate for reconnaissance missions and for development of techniques that were later 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 indicative of preparations for a European War. These measures caused a war scare within the U.S. government, and more specifically forestalled the movement of troop reinforcements to Korea. These events were a reminder of the necessity for improved peacetime reconaissance 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. [~~Possible~~ Regarding means of reconnaissance:] ~~were:~~

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."

Source: Memorandum for the Record, Oct. 3, 1950, RG 341, Entry 214, quoted in Richelson, 1987, pp. 129-130.

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

Air Force review led to establishment of Project GOPHER, to develop polyethylene balloons for high altitude reconnaissance, on October 9, 1950. (See Richelson, 1987, pp. 130-132,and 318 Notes 10-14 citing declassified GOPHER Project records in the National Archives).

At Holloman Air Force Base, New Mexico -

> A significant number of [balloon] flights have been concerned with high-altitude photography, including the development of photo-reconnaissance 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, Will Kellogg produced a Research Memorandum (RM-494) on <u>Balloon Reconnaissance</u> in December 1950. This Research Memorandum encouraged the Air Force initiative the following year to establish at the Air Force Cambridge Research Center a balloon research program, Project MOBY DICK, commencing in 1951. 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.

THE 1951 RAND REPORTS ON SATELLITES FOR METEOROLOGY AND RECONNAISSANCE

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 Kellogg and Stanley Greenfield), and one on the use for reconnaissance (by James Lipp, Robert Salter, and Reinhart Wehner).

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 authors of Report R-217, Utility of a Satellite Vehicle for Reconnaissance, April 1951, 138 pp.*

Stanley M. Greenfield and William W. Kellogg were the authors of a companion report, R-218, Inquiry into the Feasibility of Weather Reconnaissance from a Satellite Vehicle. 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

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

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 as RAND Report R-365, established a visibility for this pioneering study.

The American Meteorological Society presented Messrs. Greenfield and Kellogg a special award for this work, in 1960, and the Department of Commerce honored them for their work at RAND leading to the TIROS weather satellite, during the 25th anniversary of global weather satellites, commencing with TIROS-1, launched on April 1, 1960.

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

> These reports discussed 'pioneer reconnaissance' with extensive earth coverage at resolution (utilizing TV) of between 40 and 200 feet, in a 1,000 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.

COLONEL RICHARD S. LEGHORN AND USAF REQUIREMENTS FOR STRATEGIC RECONNAISSANCE

Merton Davies writes:

> In 1951, Col. Bernard A. Schriever was the director of the Development Planning Office of the Air Force at the Pentagon. His office

> prepared Development Planning Objectives (DPO) on various subjects, such as strategic warfare, tactical warfare, etc. He asked retired Lt. Col. Richard S. Leghorn to return to active duty to head a study of reconnaissance. Leghorn had been a reconnaissance pilot during World War II and among other things had taken pictures in preparation for the Normandy landing.

Colonel Leghorn returned to active duty in April 1951, initially based at Wright Field 's Photo-Reconnaissance Laboratory. There, he took charge of reconnaissance requirements planning. In the midst of the Korean War, the principal emphasis was, as in World War II, 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." Initially he focused upon the British Canberra bomber as a potential high altitude (over 70,000 feet) reconnaissance platform, if appropriately reconfigured. Leghorn worked with Amrom Katz, a civilian at [redacted] lab, and others such as Captain Walter J. Levison, a camera designer recalled to service during the Korean war.

During a Pentagon visit, Colonel Schriever asked Colonel Leghorn to take charge of the Intelligence and Reconnaissance mission of Colonel Schriever's Defense Planning Organization in the Pentagon. (b)(3)

The contribution of Colonel Richard S. Leghorn to RAND's work on aerial and space reconnaissance cannot be overemphasized. And Colonel Leghorn, who together with [redacted] founded the ITEK Corporation in September 1957 [See <u>The Itek News</u>, Special Tenth Anniversary Issue, No. 10, 1967], returns the compliment. The fact is that RAND needed a focal point in the Pentagon to make the research in Santa Monica effective, and for two crucial years -- April 1951 to January

1953 -- Colonel Leghorn was that focal point. Colonel Leghorn had come to know Amrom Katz when both of them worked under [redacted] at the Wright Field reconnaissance lab (b)(3) in World War II. Katz had suggested to Colonel Schriever recalling Colonel Leghorn to active duty during the emergency resulting from the Korean War. Back in uniform at Wright Field, Leghorn soon transferred to the Pentagon where he worked under Colonel Schriever.

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.

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 M.I.T. between July 1951 and the issuance of a final report on June 15, 1952, <u>Problems of Air Force Intelligence and Reconnaissance</u>.

The Air Force contacted Massachusetts Institute of Technology 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 the 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, under consideration at RAND for the past 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.

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 reconaissance as an option of the five year period, 1952-1956. 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 noting the policy concerns regarding overflight by aircraft.

James S. Thompson of the RAND Santa Monica 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 of the RAND Santa Monica staff 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 document called 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 what he called "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 Development Planning Objectives (DPO) review under Colonel Leghorn provided an opportunity for Merton 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.

A KOREAN WARTIME PRIORITY: DEVELOPMENT OF BALLOON RECONNAISSANCE SYSTEMS

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 development of balloon reconaissance systems than satellite reconnaissance systems during the Korean War. This had a fortuitous effect upon the development of satellite reconnaissance programs: balloon platforms encouraged design of lightweight, durable subsystems even though balloons were able to carry heavier payloads than early space satellites. The balloon reconaissance 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 launched Project SINBAD (RAND Memo M-2701, 13 Jul 51, C. G. Habler, RAND Dayton Office to W. W. Kellogg; RAND Memo M-3287, J. E. Lipp to E. W. Paxson, 24 Aug 51). This resulted in a Research Memorandum, RM-692, published in September 1951, and in a Revised Study of Photo Reconnaissance Reconnaissance by Balloon, RM-979, published in November 1950.

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 launch procedures for high altitude balloons. Project GOPHER, underway 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 Labs, 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 the effort to sustain on-schedule launches for Project MOBY DICK. (See USAF Air Development Center, <u>Summary Report on Project MOBY DICK COVERED WAGON Balloon Launcher Development and Test Results, 6 Dec 1951 to 15 Sep 1952</u>, Holloman AFB, NM: Report HDT-21, 12 December 1952; Bushnell, 1959, p. 26 and pp. 37-38, Notes 27-30).

In the second half of 1952, personnel and equipment from Holloman AFB, New Mexico, moved to three sites designated for the operational phase of Project MOBY DICK: Edwards AFB, Caliufornia; Vernalis Naval Air Station, California; and Tillamook Naval Air Station, Oregon. (Bushnell, 1959, p. 27). (b)(3)

In conjunction with plans to deploy operational balloon reconnaissance payloads, Will Kellogg at RAND provided Colonel R. S. Leghorn of the Air Staff RAND's estimates for performance of the Project GOPHER balloon systems, in December 1952. In parallel with this technical evaluation, [redacted] a pioneer of content analysis techniques, and J. M. Goldsen, a RAND political scientist, assessed <u>Political</u>

Factors Affecting USAF Pre-Hostilities Reconnaissance, with publication occurring in December 1952. Both RAND and Colonel Leghorn developed an understanding in this period of the uncertain acceptability of high altitude overflight, and 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 proceeded from Paul Kecskemeti's Research Memorandum RM-567 of October 1950, The Satellite Rocket Vehicle: Political and Psychological Problems, to assessments of the high altitude balloon reconnaissance systems that, later in the Korean War, appeared to be technologically mature, and likely to be in operation before space satellite systems. [redacted] and Goldsen (b)(3) focused their attention on balloon overflight, with [redacted] 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 political risk of high altitude overflight had a lasting effect upon, among others, Colonel Richard 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. And subsequently, Colonel Leghorn assisted Richard Bissell of CIA in efforts to anticipate and offset political resistance to aerial and also 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 the 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 AFB, Colorado organized a plotting and control facility. "[I]t 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. It was not until 1956 that the Air Force was prepared to proceed with actual balloon reconnaissance operations, under Project GENETRIX. (Richelson, 1987, pp. 131-135, 318 Note 13, citing Memo, "Future Development Action, GOPHER Project, 17 Jun 53; 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 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," 25 Aug 1953, in Harry S. Truman Library.)

The combination of secrecy respecting 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 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).

Technology

CONTINUING RAND RESEARCH ON SATELLITE [RECONNAISSANCE]

?

RAND assessments of the Project SINDBAD, Project GOPHER, and Project MOBY DICK balloon experiments reinforced the ongoing interest in accelerating satellite [reconnaissance.] technology Space satellites, if feasible, would be relatively immune from the vagaries of weather, and far more predictable regarding their orbits.

Merton 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 missile 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, [redacted]. (b)(3)

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 longer-range options for satellite reconnaissance to improve pre-hostilities intelligence.

In aftermath of the publication of RAND Report R-217 in April 1951, the U.S. Air Force authorized RAND to make specific recommendations for the design of a reconnaissance satellite development program, then called Project FEED BACK. (Perry, 1962, p. 33, citing Memo, [redacted], Asst Ch, War Plans Div, Dir/Plans, to Dir/Plans, DCS/Plans and Prog, USAF, Subj: "USAF Satellite Program," 28 Oct 57).

By November 1951, the U.S. Air Force had arranged for the U.S. Atomic Energy Commission (AEC) to provide RAND a separate research contract for the purpose of exploring the feasibility of small nuclear reactors to provide 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, and the safeguarding of nuclear reactors from diversion of weapons useable materials. nature of the Soviet atomic energy program.

In this round of RAND research on the feasibility of reconnaissance satellites, RAND entered into subcontracts with 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-altitude satellite for reconnaissance, in Report NAA AL-1564. How it compared to the RAND concept of April 1951 is not ascertainable at RAND, which no longer retains the November 1952 North American Aviation Report. This is the first satellite reconnaissance report known to have been produced by a defense manufacturing enterprise.

By June 1952 preliminary results indicated that nuclear reactors could provide the energy source for satellite operations. In that month, RAND subconstracted with 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 (Richelson, 1987, p. 174 and 328 Notes 2 and 5, quoting Memorandum for Deputy Chief of Staff, Development, Subj: (Deleted) Satellite Vehicles," 18 Dec 1952, RG 341, Entry 214, National Archives).

COLONEL LEGHORN'S RATIONALE FOR STRATEGIC RECONNAISSANCE

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, Colonel Leghorn summarized his views in a memorandum for General Vandenberg (thru 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 counter-force 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 counter-force operations. (Leghorn, Draft Memorandum,

27 Jan 1953, Formerly Secret, declassified March 24, 1972).

Colonel Leghorn's proposed counter-force strategy -- articulated nearly a decade before Defense Secretary McNamara's Ann Arbor speech in 1962 -- implied a state of peacetime knowledge of adversary 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 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, 27 Jan 1953, p. 7, declassified Mar. 24, 1972).

Understandably the primary emphasis was upon aerial reconnaissance, long practiced and well understood. Merton Davies convinced Colonel Leghorn to include within the framework for consideration of Air Force requirements the role of the reconnaissance satellite. 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. [redacted] replaced Colonel Leghorn, (b)(3) 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."

RELATED RAND RESEARCH ON BALLISTIC MISSILE DEVELOPMENT AND STRATEGIC FORCE VULNERABILITY

Within the RAND staff there was much other relevant research that aided in concept developments for space technology. Several studies in the period 1952-54 contributed to the mounting realization of the vulnerability of U.S. strategic forces without a combination of 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. vulnerabilities to surprise atomic attack.

A related RAND research activity had a later but profound impact upon the compression of time for the 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, hence exacerbate the problem of pre-hostilities intelligence. But at the same time, the ICBM would, once a commitment to its development had been made, reduce significantly the projected cost of launching space payloads. This in turn would reduce the costs of reconnaissance systems designed for physical recovery of photographic film, instead of nonrecoverable electro-optical reconnaissance systems that RAND had proposed in 1951 and reemphasized in Project FEED BACK during 1951-54.

Augenstein, on his own initiative in about September 1952, began to explore the prospects for 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 Bruno Augenstein to the Strategic Missile Evaluation Committee, known as the TEAPOT Committee and chaired by Professor [redacted] in December 1953, that strengthened that committee's confidence that it was time to recommend full-scale development of the ICBM, in 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 the 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 U.S. Air Force established the Western Development Division (WDD) of the Air Research and Development Command, effective July 1, 1954, under Brigadier General Bernard A. Schriever. WDD, since 1957 a part of the Air Force Ballistic Missile Division, took primary responsibility for ballistic missile and space system devcelopment. (Snyder, et al., 1976, pp.1-2).

(b)(3)

RAND'S RECOMMENDATION FOR FULL SYSTEM DEVELOPMENT OF A RECONNAISSANCE SATELLITE SYSTEM IN 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 IRBM such as the THOR or JUPITER systems, 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, Soviet launch of the first space satellite, Sputnik 1, on October 4th, and the first successful launch of the ATLAS ICBM on December 17th that the means of launching space payloads could be demonstrated to exist.

In May 1953 planners of the Air Research and Development Command (ARDC) 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 Ltr, Maj. Gen. D. N. Yates, Dir R & D, DCS/D, USAF, to CG, ARDC, Subj: "Project FEEDBACK," 22 May 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. (Lt. Col. V. M. Genez, Dir/Intel, Dep/Dev, ARDC, Memo for the Record, Subj: "Conference with RAND Corporation re: FEEDBACK Program," 13 Aug 53, cited in Perry, 1962, p. 39).

On September 8, 1953, James E. 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 FEEDBACK," 8 Sep 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."

By December 1953, the Air Force's Air Research and Development Command 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 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).

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 not from assessments of the Soviet military capabilities but from an assessment of the potential interaction of Soviet and American strategic forces, and the implications for U.S. defense policy. 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 between the spring of 1952 and the spring of 1954. On June 1, 1952 RAND published Report R-235, The Cost of Decreasing Vulnerability of Air Bases by Dispersal - Dispersing a B-36 Wing. On November 1st 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 intercontinental delivery raised concerns regarding the war fighting consequences of a surprise Soviet attack. In particular, Soviet production of TU-4 long range bombers and projection of 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 indirectly 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 and a revised version in July 1953 of a then-top secret document entitled <u>The Military Value of Advanced Warning of Hostilities and its Implications for Intelligence Indicators</u>. 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 effectivness could reach about 90% of its maximum value.

This study attributed to the USSR the possibility of striking without warning, perhaps after deceptive 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 initial 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. This report recommended a 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, on April 15, 1953. Top secret when issued, it was later declassified in May 1967. Fifteen members of the RAND staff contributed to its preparation.*

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

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* H. 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.

penetrating radar warning nets at low altitude; and TU-4 bombers penetrating at high altitudes, with atomic bombs of 40KT and 100KT. 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 bombers and reconnaissance aircraft. But "[t]he 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 <u>provided these could be translated into sufficiently unambiguous states of alert</u>, but from the limited data now available at RAND, the probability of such action appears to be small. (SM-15, p. iii).
>
> 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 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."

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).

RAND Special Memorandum SM-15 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 <u>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.</u>...while improvements in SAC evacuation procedures is certainly desirable, <u>any real improvement in the evacuation picture would have to come through increase of the net warning time...provided to SAC.</u>
>
> 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 <u>all wings on rotation overseas will be caught on the ground.</u> (SM-15, pp. 25-26).

The short-term impacts 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, "[t]here 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 on 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, in 1953-54. It ultimately became one of RAND's best known research studies, The Selection of Strategic Air Bases, R-266, April 2, 1954), by A. J. Wohlstetter, F. S. Hoffman, R. J. Lutz, and H. S. Rowen. RAND Report R-266 drew upon the related studies of vulnerability of the U.S. strategic forces as they existed, and projected alternative strategies to enhance deterrence in the nuclear bomber and missile age. This 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 RM-975, in November 1952. Wohlstetter began briefing preliminary concepts for the selection of a more appropriate basing strategy in January 1953. 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 this Research Note to trace the indirect impacts of these RAND studies, and 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.

RAND'S PROJECT FEED BACK REPORT OF 1954

In parallel with RAND staff studies of strategic force vulnerability, RAND staff and consultants explored technological possibilities for space-based reconnaissance systems that might, if successful, relay data in near-real-time to ground stations. These nonrecoverable reconnaissance 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 officials.

On March 1, 1954 James E. Lipp and Robert M. Salter, Jr., et al., published RAND Report R-262, Project FEED BACK Summary Report. (R. L. Perry, 1962, p. 32; Augenstein, 1982, p. 7). With some deletions, the Appendices comprising Volume II of the FEED BACK Report have been declassified, and key recommendations of Volume I have been summarized in a ~~recently~~ declassified Air Force history (Perry, 1962, declassified 1985).

From the declassified appendices, it is apparent that the FEED BACK team that reported its findings and recommendations in its 2-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 x 1.28 inch photocathode and an f/24, 38 inch 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 that was 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 photointerpreters could obtain from airborne photographic systems. Television and videorecorder technology was not sufficiently advanced, in this era, to provide the Air Force 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 hostilitiies of mounting interest to reduce vulnerabilities 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 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, commenced 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 ~~recently~~ 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, 1 March 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,) ~~declassified 1975)~~.

It was following the publication and favorable reception of the Project FEED BACK report in 1954 that RAND recruited Amrom H. 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 Amrom Katz and Merton Davies gave RAND an institutional memory and diverse contacts in the field of high altitude reconnaissance. And this came to be of importance as the requirements for television-type data storage and retrieval from space systems appeared to be unmeetable in the near term.

Merton Davies recalls:

> Amrom had been working at the Air Force Reconnaissance Laboratory at Wright Field, Dayton, Ohio for many years. He was well versed in the capabilities of reconnaissance by aircraft and when Jim Lipp visited the Laboratory to talk about satellites, he was fascinated with the notion of taking pictures from space. In order to evaluate the use of such data, he had pictures taken with a short focal length lens with a 35 mm camera from a high flying aircraft to simulate the proper photographic scale. The pictures did show considerable detail, and Amrom was excited about the prospect of taking pictures from orbit. I met Amrom when he came to RAND and spent the next five years working with him on a number of projects. These were fun times; although sometimes frustrating, they were always interesting. Later during the sixties our interests overlapped and we again spent considerable time together; that too was a memorable experience.

PRESIDENT EISENHOWER'S COMMITMENT TO STRATEGIC WARNING: THE TECHNOLOGIES CAPABILITIES (KILLIAN) PANEL

In the fourth week after the RAND Project FEED BACK Report was completed, but without any discernibly connected relation to it, President Eisenhower initiated a government review of means to reduce the risks of surprise attack. Specifically, on March 27, 1954, President Eisenhower asked various of his scientific advisers, including [redacted] (b)(3) 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 of 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 Memoranda 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 to address the problem of surprise attack in March 1954.

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

Caltech, 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 recurringly 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 President's Scientific Advisory Committee (PSAC). Gardner reportedly told DuBridge that the PSAC 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 PSAC 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; Fred Kaplan, The Wizards of Armageddon, NY: Simon & Schuster, 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. Purcel of Harvard University; and John W. Tukey of Princeton University. (Burrows, 1987, pp. 70, 358 Note, 358 Note, citing "declassified organizational charts sent to the author by Dr. Killian."

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 Technologies Capabilities Panel (TCP) effort was underway, that the U.S. Air Force authorized a research program to development reconnaissance satellites, WS-117L. (Stares, 1985, p. 22). Bruno Augenstein explained:

> ...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).

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 the applications of the FEED BACK Report. ARDC commenced and documented "Project 1115," for an advanced reconnaissance satellite system. (Perry, 1962, p. 41, declassified 1985). 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 commence work on a satellite reconnaissance system reached the Western Development Division of ARDC. (Perry, 1962, p. 41, declassified 1985).

An Air Force history, <u>Origins of the USAF Space Program, 1945-1956</u>, attempts to summarize impacts of the Project FEED BACK briefings 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 Stafff, 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 Power as research and development command chief, strongly supported the satellite program--as did Power himself. (Perry, 1962, pp. 41-42, declassified 1975).

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 15th, the ICBM Scientific Advisory Committee 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, declassified 1975).

By November of 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, Col. A. J. Goodpaster of Conference with Pres. Eisenhower, 24 Nov 1954, in Richelson, 1987, pp. 140-41 and 320 Note 48; Beschloss, 1986, pp. 81-82).

Three days later, on November 27, 1954 the Air Force's Air Research and Development Command (ARDC) issued System Requirement No. 5, to develop a reconnaissance satellite system. Since the Final Report of the Killian Panel recommended development of a satellite reconnaissance system, it is possible that it was the Killian Panel review of November 24th that, indirectly, stimulated the Air Force to proceed with a formal requirement for a satellite reconnaissance system.

> ...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, declassified 1975).

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. 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, 1955 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.

There were two effects upon RAND research of the transposition from development to operations of overhead reconnaissance programs.

The first was the delimitation of participation by RAND researchers, as reconaissance 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 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 Will W. Kellogg, Stanley M. Greenfield, and D. T. Griggs in November 1951, 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 WS119L and continuing with the follow-on project WS461L.

Merton Davies recollects:

> In 1956, a project called GENETRIX (119L) was implemented in which balloons containing cam-

> eras were launched from three 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 three 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 Col. Paul Worthman's recollections, in Rostow, Open Skies, 1982; USAF Project 119L Final Rpt, declassified in part in 1979, and Richelson, 1987, pp. 132-139 and Notes citing declassified official records.)

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. (Ltr, Levison to [redacted] (b)(3) Curator, National Air and Space Museum, 29 May 87).

Operational launches of GENETRIX balloons commenced on January 10, 1956, under inauspicious circumstances. The photographic subsystem manager, Walter 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.

(Ltr, Levison to [redacted] Curator, National Air and Space Museum, 29 May 87). (b)(3)

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, after Soviet protests and a Washington Post story on February 10th of that year. 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 Col. A. J. Goodpaster, The White House, 8 Feb 56, in Richelson, 1987, pp. 138-139 and 319 Notes 33 through 44; USAF, Final Report, Project 119L, p.8ff; Beschloss, 1986, p. 112).

Walter 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. (Ltr, W. Levison to [redacted] 29 May 87, p. 2). (b)(3)

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; Richelson, 1984, p. 125). This followed by just one month the report of the Killian panel to the President,

According to a recent history, 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. (quoted in Burrows, 1987, pp. 70).

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 stimulation of Air Force requirements for advanced reconnaissance systems. RAND's role was more as a source of technical expertise on the system concepts that might provide improved reconnaissance capabilities.

GOR No. 80 of 16 March 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 electornic intelligence and to provide weather forcecasting 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, declassified 1985).

During this period many of the RAND personnel who had worked on advanced reconnaissance concepts left to work in private industry. And they took with them many of the concepts they had developed or had learned about when at RAND. While Project FEED BACK concepts were under evaluation in 1953, 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 couple years he recruited many of the RAND staff who worked on advanced reconnaissance issues, and from 1956 to 1959 he was both Vice President and General Manager of the Lockheed Missiles and Space Division, and thereafter President of this enterprise as a separate Lockheed subsidiary.

PRESIDENT EISENHOWER'S "OPEN SKIES" INITIATIVE OF JULY 1955

The Killian Panel's evaluation of the requirements to reduce risks of surprise attack preceded a more broadly based review of the 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 in gaining Soviet acceptance. Professor Max Millikan of M.I.T., who had recently served a tour at CIA as Assistant Director for Intelligence, proposed an agreement upon 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; Beschloss, 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 the initial support of Premier Bulganin. Chairman Nikita S. Khrushchev objected to the plan, and denounced it as nothing more than a plan to legalize espionage, though it would have facilitated arms control verification and served as what is now termed a strategic "confidence building measure." (Rostow, 1982; Ambrose, 1984, 257-9, 262-4).

In the aftermath of Soviet rejection of the "Open Skies" concept, self-help measures of reconnaissance appeared all the more necessary. In August 1955 Lieutenant Colonel William G. King, Jr. became the project officer for the advanced

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[reconnaissance] satellite program. (Perry, 1962, p. 43). In October of 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 Western Development Division staff, and 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).

Merton 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 went to Lockheed to work on aircraft, and 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 Missile 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 Anapolis. Amrom 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. After the selection of a prime contractor to build the satellite, a contractor to build the camera, and another contractor to build the film scan device, the project was redesignated WS 117L with the satellite named Samos. The new program leader was Air Force Colonel Frederick ("Fritz") Oder. The satellite was to be launched by the Atlas ICBM and Lochheed Agena rockets. Over the next few years we stayed in close touch with Colonel Oder and his staff at WDD.

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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 would not employ any missile intended for military purposes. (Perry, 1962, pp. 47-48, citing NSC Directive 5520, 26 May 55). This policy decision resulted in the effective elimination of the Atlas-Thor vehicles of the Air Force, and the Redstone-Jupiter vehicles of the Army.

This policy followed more than a decade of intertwined interests in scientific and military missions for space operations. Both the November 1945 Navy and May 1946 RAND reports had identified more scientific than military missions of 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 "Grimminger 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, H. K. Kallmann published RAND Research Memorandum RM-1500, Scientific Uses of an Artifical Satellite.

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 reconaissance satellite systems. (See Perry, 1962, p. 48).

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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 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 studies in which all components were required to be developed to the funded 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.

Robert Buchheim 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 indicated difficulty in stabilizing space objects during flight. The team led by Buchheim undertook a feasibility study for the launching of unmanned scientific satellites and for lunar exploration.

Merton 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.

Robert W. Buchheim published Research Memorandum RM-1720 on May 28, 1956, entitled General Report on the Lunar Instrument Camera, then classified Secret. (RAND, 1959, p. 7). Publicly, also in May 1956, George H. Clement published a paper, The Moon Rocket, RAND Paper P-833. 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.

Merton 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, [redacted], 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... Five Lunar Orbiter spacecraft were flown; all were successful. It was an excellent program.

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PAYOFFS FROM RAND'S INTERDISCIPLINARY RESEARCH: ICBM ECONOMICS, SATELLITE RECOVERY, AND THE BIRTH OF THE VIDEORECORDER INDUSTRY

One of RAND's particular strengths was the easy flow of working relations across departments. 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 large industrial firms.

The transition from RAND's recommendations in Project FEED BACK (1951-1954) to RAND's recommendations of recoverable satellite systems (1956-1957) illustrates the benefits that flowed 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 result.

The underlying cause of interest in television-like remote sensing, data storage, and transmisison 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 the concern that the difficulties in dissipating the heat accumulated during atmospheric entry (called "re-entry") might preclude the recovery of any payload, and heat-sensitive payloads such as film in particular.

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. And the launch facilities for intercontinental missiles could also serve as the launch facilities for space payloads. In RAND Document D-3503, Milton Margolis estimated <u>ICBM Development Cost Estimates, FY1956-1959.</u> Then Carl Gazley joined the RAND staff after working at General Electric Company in Philadelphia, and shared insights regarding 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 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 to film-from-space observation systems.

As the notion of protected entry into the atmosphere gained credence, the potential requirement for space satellites increased concerns regarding diversion of effort within the ICBM program. In June 1955, for example, the ICBM Scientific Advisory Committee reported:

> ...The committee unanimously agreed that any Satellite program, Scientific or Reconnaissance, which is dependent on components being developed under the ICBM program, would interfere with the earliest attainment of an ICBM operational capability and requested the Chairman to write a letter to the Secretary of the Air Force advising the Secretary of the Committee's concern in this matter.
>
> (Perry, 1962, p. 44, citing Lt. [redacted] Minutes of Mtg. 16-17 Jun 1955.) (b)(3)

RAND'S INITIAL RECOMMENDATION OF A RECOVERABLE RECONNAISSANCE SATELLITE IN 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 solid rocket, together with a vertical strip camera. (See A. H. Katz, Memo to L. J. Henderson and R. J. Lew, 3 Jan 1958, pp. 2-3, declassified March 24, 1972).

Merton 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 satel-

> lites and lunar launches; however, our studies at RAND concentrated on the Thor.

Based upon the Raymond concept, [redacted] assisted RAND's President, Frank Collbohm, in the write-up of formal RAND recommendation for a recoverable reconnaissance satellite system. The then-top secret memorandum, <u>Recommendations to the Air Staff: Photographic Reconnaissance Satellites</u>, a 20-page document constituted RAND's approach as of March 1956. Within a matter of weeks, the U.S. Air Force issued its plan for full scale development of advanced reconnaissance satellites. (b)(3)

However welcome the recommendation may have been to elements of the Air Staff, RAND soon withdrew the formal recommendation for development of a <u>recoverable</u> satellite system. This was a relatively unusual procedure for RAND, and the specific reasons may not be identified as a result of the prior destruction of RAND correspondence with the Air Staff on the <u>Recommendations to the Air Staff</u> 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. The specific recommendations were judged to be premature, perhaps since their feasibility had not been demonstrated, nor compared systematically with FEED BACK alternatives for television-type transmission ~~without payload recovery~~ 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. But in the spring of 1956 this remained an assumption. In the summer of 1955, the Department of Defense devoted an entire summer study to the problems of atmospheric entry (called "re-entry") under the chairmanship of Professor Robert Bacher of Caltech. The summer study ended without assurance of success. It was not

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Raymond recalls that the ~~impetus~~ basis for his advocacy of a recoverable film payload was an unpublished comparison of the rates of data recovery from electro-optic 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 Penn State University before joining RAND, so he had some confidence in his calculations.

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 the identification of all of 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, published on June 26, 1956 (RAND, 1959, p. 9).

Work proceeded on electronic feedback systems also. But the economics of space systems after the Air Force procured ICBM systems and solved the atmospheric entry problem favored recoverable systems. Even so, RAND helped to spawn an entirely new industry, while encouraging the government to keep its options open. In particular, RAND subcontracted with RCA, and later with the Ampex Corporation, to investigate magnetic tape as a medium for the storage of visual data. Ampex worked on videotape recorders in 1952, and 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 in order to store data for 600-lines of television image. RAND published 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 recorders and related equipment.*

* See 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, Mar-Apr. 1980, pp. 13-15, and Joseph Roizen, "Ampex Home Video Recorder," Electronics World, Vol. 75, May 1966, p. 75.

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 Powers endorsed the plan three weeks later. It was concerned almost exclusively with military reconnaissance activities, and based upon 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," 2 Apr 1956).

Of critical importance, when HQ USAF approved a development directive for WS 117L in July 1956, the Air Research and Development Command of the Air Force authorized funding of only $3 million in FY1957. This was was acknowledged to be "inadequate initial funding." (Perry, 1962, p. 56). The low priority for development of the reconnaissance satellite within ARDC ultimately resulted in the preeminence of civilian managers of U.S. satellite reconnaissance 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).

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

In 1956, the year in which Robert Buchheim commenced a project on lunar exploration and instruments to support it, RAND research staff proposed a de facto merger between research on requirements for high altitude balloon reconnaissance 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, and Richelson, 1987, pp. 132-139). Merton Davies and Amrom Katz were the two members of the RAND research staff who both worked on the balloon and developmental phase of reconnaissance 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 an analyzing tradeoffs between timeliness and system performance.

Davies and Katz formulated the need for both types of systems in a memo of 12 October 1956 proposing a RAND project on "pre-hostilities reconnaissance." As explained in a Katz memo of 19 June 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] with an incoming letter, No. CL1944...
>
> ...We stalled BMD off very neatly with a left jab in the form of a letter, L-21397

> 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, No. L-2166 dated 5 February 1957, from Collbohm to [USAF [redacted] [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." (b)(3)

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

> In its initial form WS/117L included development of recoverable and nonrecoverable . . . photographic techniques as well as electronic reconnaissance subsystems. (Richelson, 1987, pp. 176, 328 Note 12, citing letter, Neil McElroy to Dwight D. Eisenhower, 29 Jan 1959).

RAND prepared in the spring of 1957 to assist the U.S. Air Force in developing specifications for advanced satellite reconnaissance systems, in the Weapon System 117L family. This effort parelleled research on advanced balloon reconnaissance concepts, in the aftermath of operation and termination of the GENETRIX balloon program known as WS-119L. See the USAF Project 119L Final Report, substantially declassified in 1979, and explained through declassified archival documents in Richelson, 1987, pp. 132-139).

In March 1957 Western Development Division commenced "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 organize its reconnaissance-related research to accomplish a broad array of intelligence and operational 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, Amrom H. Katz sought to bring some coherence to analysis of alternative reconnaissance programs and their relationships, by addressing a fundamental question: what were the requirements for reconnaissance?

Katz first addressed types of requirements for reconnaissance in a lecture, published in May 1957, <u>Balloon Reconnaissance-Part I: Intelligence Requirements and Reconnaissance Systems</u>. 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.

Looking back upon a distinguished career, Amrom H. 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 writing on requirements for reconnaissance, in the 1957-1958 period, occurred well after Colonel Leghorn returned to civilian life in 1953, but in support of the Air Force studies of requirements for peacetime reconaissance 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 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, prioriies, 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. This implies that Davies should get out of the basement where he has been working on Riot Squad. We never attempted to deprecate the significance of tactical reconnaissance. However, I now believe we can turn this particular phase of our group's activities over to Cartheuser, who has lately shown more interest in tactical reconnaissance.

BROKERING INNOVATION: PANORAMIC CAMERAS

It was in connection with a balloon reconnaissance project, the previously-noted Project 461L, that Merton Davies and Amrom Katz of RAND encouraged the photographic subsystem manager, Walter Levison, to adopt the concept of the panoramic camera to long focal-length cameras for high altitude photography.

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. Merton Davies tells us about an important role involving himself and Amrom Katz:

> Throughout the 1950s the Boston University Research Laboratory 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, [redacted] (b)(3)
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 70 mm. film, so the image format was about 2.5 by 26 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.

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.

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 a 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 platen 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. They performed beautifully and took very high resolution pictures; 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 they did use the concept of a panoramic camera with a long focal length. Hence, RAND brokered a concept that was applied to operational spacecraft, though 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. Walter 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 cylindrical focal plane and is, so to speak, painted onto the film through the motion of a narrow slit. (Ltr, Levison to D. Dwerkin, 29 May 87, pp. 1, 2.)

In a memorandum of May 11, 1959 (formerly confidential, declassified in 1972), Dr. Amrom 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. 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.

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 fast 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, RAND Memo M-3008, May 11, 1959, p. 2).

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 aerial reconnaissance for arms control, back in 1948. But this was a little recognized concept, with 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 we 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. The following year, several members of the RAND staff participated 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 J. M. 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 Memorandum WM-2297, 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. Davies won the right to include satellite observation within the scope of technical working papers, and 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.

Merton 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 Block countries and five Western Block 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 to Geneva 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 satelite. 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 [redacted], USAF. (b)(3)

ACCELERATING THE ACQUISITION OF RECOVERABLE RECONNAISSANCE SATELLITES: RAND'S RECOMMENDATIONS OF NOVEMBER 1957

Merton 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, 10 Sep 1957, Subj: "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 development of military satellite systems. (Snyder, et al., 1976, p. 42).

On November 7, 1957 -- shortly after the launch of Sputnik 2 -- Davies and Katz completed an important study, with the assistance of various RAND co-authors. Known simply as "RM-2012", this study has been declassified in a highly sanitized form in 1984, with the title A Family of Recoverable Satellites. RAND's formal recommendation to the Air Force, published together with RM-2012 on November 12, 1957 (and declassified without any deletions in 1972) indicates a focus on accelerating the operation of a class of recoverable [reconnaissance] satellites.

consistent with title

RM-2012 and accompanying briefings accomplished in six months what Amrom 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 recce 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 simply 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 the Air Force and CIA represenatives (who attended many Air Force meetings) to accelerate their plans for reconnaissance satellites, but with design differences from the specifics recommended by RAND.

RAND's formal recommendation to the Air Force accompanied RM-2012, and bore the same date, 12 November 1957. It was on this date that Colonel Fritz Oder of the Project 117L Office presented to the Stewart Committee (an Air Force scientific advisory panel meeting at RAND) recommendations of the Project 117L Program Office for a 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 capabilitiey 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 a summary cover letter for the formal Recommendation, declassified fifteen years ago, Project RAND Recommendation to the Air Staff: An Earlier Reconnaissance Satellite System:

> 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 use 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 S.U.) 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, 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 1960's.

?
interpolation to what ground resolution

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 Doc. X-11099, pp. 1-2, 12 Nov 1957, formerly Secret, declassified Mar. 24, 1972).

The breadth, rationale, and technical backup of the RAND recommendations doubtless energized the Air Force to achieve earlier and recoverable reconnaissance systems than those previously adopted by the satellite reconnaissance program office within USAF. 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 1958-1960.

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THE EVOLUTION OF RAND CONCEPTS FOR RECONNAISSANCE SATELLITES

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Amrom Katz prepared a November 1957 document, Some Notes on the Evolution of RAND's Thinking on Reconnaissance Satellites that recapitulates key developments:

> In the early days of RAND's thinking about satellites, it was clearly recognized that a very large first stage booster was going to be needed. There was no such booster. Consequently, RAND's thinking about satellites involved a design of a booster. In principle, if one wanted a satellite, he had to develop a booster and pay for it. There was no ICBM program. Remember, too, that this early period -- the late 1940's -- was a period in which there was absolutely no thought of re-entry. Re-entry was not considered feasible. Therefore, two things followed:

(1) The satellite program had to develop and pay for the booster, and (2) Since there was no thought of re-entry, whatever was going to go up on orbit would have to stay up and work for a long time.

...So here we were a few years ago, thinking of a long life satellite sitting on orbit, no possibility of the satellite coming down physically, or even any piece of it coming down in useable shape. About this time, the notion of long life, meaning at least a year, came into being as a nondisputable axiom of satellite philosophy. Now if the satellite were going to be on orbit for a year, operate successfully, and return its data by the only possible method (electronically through a video link, i.e. a talk back feature), it became fairly clear that the notion of using photographic film in this satellite was not a very productive one...Thoughts turned naturally to television-type techniques. The original RAND FEEDBACK study therefore recommended this type of satellite.

...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 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 camera 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 [Oct. 4 and Nov. 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.

In a comprehensive and now-declassified memorandum prepared in 1959 (Katz, 1959, p. 1) Amrom Katz recapitulated what RAND had done to make recovery of vital payloads happen. He noted, correctly, the importance of the work undertaken in 1957, for it strengthened Air Force commitments to proceed with a near-term system and it 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:

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> 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).

Merton 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 using the Thor booster and film recovery.
>
> Col. Oder made the Air Force presentation to the Stewart Committee meeting at RAND in November 1957. He announced that the Air Force was going ahead with a new program

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> incorporating the Thor booster, spin stabilization, and film recovery. We were excited. Early in 1958 contractors were selected and design decisions made. Lockheed was to develop a spin stabilized version of the Agena; Fairchild was to develop the camera, and General Electric was responsible for recovery. This project was redirected in the spring of 1958.

THE ACQUISITION OF SPACE 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, 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, since 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 exasperbated 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 FY1958 budget of $1.672 billion, but the commitment of the President to achieve a balanced budget, a sentiment reinforced by Treasury Secretary Humphrey, resulted in an initial budget for FY1958 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 Army JUPITER IRBM programs were combined. (Snyder, et al., 1976, p. 40).

Just one day after the Soviets launched Sputnik 1, on October 5, 1957 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 there was simply no available money to augment the WS 117L satellite program in the aftermath of the budget reductions that were effective on October 5th.

On January 22, 1958 the the National Security Council approved NSC Action No. 1846, assigning the highest priority to development of an operational reconnaissance satellite. (Richelson, 1987, p. 177, citing NSC 5814, 10 Jun 58). But finding the funds to accelerate the program was more difficult.

General Schriever implied a lack of funding approvals when he testified before the Senate Committee on Armed Services in late January 1958 (U.S. Senate, 1958, pp. 1634-35):

> 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 reconaissance 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.

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On February 1, 1958 Secretary of the Air Force James H. Douglas urged Secretary of Defense Neil H. McElroy to approve USAF use of THOR missiles to boost test satellites into orbit, starting before the end of the year 1958. (Snyder, et al., 1976, p. 48). On February 3, 1958 President Eisenhower directed the highest and equal materiel priority for the ATLAS, TITAN, THOR, JUPITER, WS 117L satellite, and SW 224A (BMEWS) satellite systems. (Snyder, et al., 1976, p. 48).

According to the biographer Leonard Mosley, in the book Dulles: A Biography of Eleanor, Allen, and John Foster Dulles and Their Family Network (1978, pp. 431-432):

> [The Director of Central Intelligence,] Allen [W. Dulles] suggested that [Deputy Director for Plans Richard M.] Bissell [Jr.] go over and talk to the Air Force, who sent him on to Charles Wilson, the Secretary of Defense. The feeling around was that such things as space programs were 'the kind of foolishness the Democrats indulge in, and we Republicans cut down on." So once again, Allen agreed to fund money for a space satellite out of CIA secret funds, and went to see the President about it. In February 1958, he called in Richard Bissell to see him. Edwin Land was already there. Allen said that the President had approved the development and operation of a reconnaissance satellite, and that Bissell would be

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in charge for the Agency and would have an Air Force officer as his co-director.

In a tribute to Richard Bissell, the Washington columnist Joseph Alsop reports that CIA led the -

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> "all-out secret effort to build a workable reconnaissance satellite....Lt. Gen. Bernard Schriever worked with Bissell. Brig. Gen. Osmond [J.] Ritland [Vice Commander] of the Air Force Ballistic Missile Division] was Bissell's day-to-day partner. 'Din' Land again lent a hand. And others might be mentioned. ("Matter of Fact...A Debt is Owed," The Washington Post, December 24, 1963).

An official Air Force history indicates that Brigadier General Osmond J. Ritland served as Vice Commander of the Western Development Division, ARDC, between April 1956 and May 1957. During this period, General Ritland assisted Richard M. Bissell of CIA in obtaining aircraft engines for the U-2 (AQUATONE) project, and established a working relationship with Bissell. Between June 1957 and April 1959 General Ritland served as Vice Commander of the Air Force Ballistic Missile Division. Both of these positions involved service under the command of Maj. Gen. Bernard A. Schriever. In April 1959 Major General Ritland took command of BMD. When the Space System Division separated from the Ballistic Missile Division in April 1961, General Ritland commanded that organization until May 1962. (Snyder, et al., 1976, pp. 271, 273, 287; Beschloss, 1986, p. 89).

A more recent unofficial account claims -

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> ...in February 1958, President Eisenhower approved Project CORONA, with the expectation that it would result in an operational photographic reconnaissance satellite employing a recoverable capsule system by the spring of 1959. (Richelson, 1984, p. 125; John Prados, The Soviet Estimate, 1982, pp. 195-196).

When President Eisenhower approved the 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 a system, with an eye towards simplicity of design and operation. Others took the view that it would be possible to stabilize the spacecraft so the camera system was oriented towards the earth, then to use an oscillating rather than a fixed camera as an alternative means of obtaining panoramic photographs. 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 one in which the camera performed the scan in a stabilized spacecraft. (Mosely, 1978, p. 432; Stares, 1985, pp. 44-45; Richelson, 1987, p. 177).*

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> ...Within two months [of President Eisenhower's approval of the CORONA project in February 1958] a joint technical review led to a change of conception: rather than a spinning satellite with a fixed camera, the satellite would be stabilized while the camera scanned. (Richelson, 1987, p. 177 and 328 Note 16, citing "Interview with Richard Bisell; Thomas Powers, The Man Who Kept the Secrets: Richard Helms and the CIA, 1979, p. 97).

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In June 1958 the National Security Council approved NSC 5814, "U.S. Policy on Outer Space," establishing as U.S. national policy that the U.S. should -

* Fairchild Camera and Instrument Company continued to advocate employment of a spin-stabilized pamoramic camera system, in Report SME-AB-3 of July 25, 1958, Panoramic Camera System for a Spin-Stabilized Satellite (recently declassified). Fairchild asserted that a spin-stabilized system permitted lower altitude orbits, hence heavier payloads.

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> at the earliest technologically practical date use reconnaissance satellites to enhance to the maximum extent the U.S. intelligence effort. (NSC 5814, 20 Jun 58, quoted in Richelson, 1987, p. 177).

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

The Dulles family biographer, Leonard Mosley, reports that CIA's then-Deputy Director for Plans, Richard M. Bissell described to him a joint venture presided over by Bissell and an unidentified representative of the U.S. Air Force:

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> He and I presided over something that was known as the Corona program...By April 1960 there had been eleven flights, none successful. The first one in which both the satellite and the camera functioned perfectly and from which film was retrieved was No. 14 in August of 1960. (Mosley, 1978, p. 432).

On June 10, 1960 President Eisenhower directed Secretary of Defense Thomas Gates, Jr. to evaluate for the National Security Council U.S. intelligence requirements and the feasibility of meeting them. Gates in turn established a committee consisting of the Under Secretary of the Air Force, Joseph Charyk; 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 U.S. Air Force chronology indicates that the U.S. Air Force activated the 6594th Testing and Satellite Control Facility in a Field Office at the Lockheed Missile and Space Division in Palo Alto, California, in August 1958, and that effective on March 1, 1960, the 6594th Test Wing moved from Palo Alto to the Lockheed Missile and Space Division in Sunnyvale, California. Colonel Charles G. Mathison served as Commander of this Satellite Test Wing. (See USAF, History of 6594th Test Wing (Satellite), 1 Jul-31 Dec. 1960, p. 1, cited in Snyder, et al., 1976, p. 269).

This official Air Force chronology also indicates that on August 10, 1960, a THOR IRBM with AGENA upper stage launched from Vandenberg AFB Discoverer XIII, and that on its 17th 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).

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

AN UNSOLVED PROBLEM: WARNING INTELLIGENCE

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 for which the RAND satellites can not really contribute to in any meaningful way... (Memo, A. H. Katz to L. J. Henderson and R. Lew, 3 Jan 1958, p. 5, declassified March 24, 1972).

In the 1950's the preeminent emphasis in RAND's research on high altitude reconnaissance had been to match requirements with systems, and then to facilitate 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.

Why did RAND concentrate upon imaging satellites, both those involving electro-optical data transmission and those involving film recovery, instead of emphasizing also the importance of other early warning satellites?

Several factors were involved:

First, the RAND studies of strategic force vulnerabilities in the early 1950s had indicated the importance of improving ground based radar coverage, to minimize opportunities for surprise attack by air-delivered atomic weapons. RAND committed substantial research effort to the improvement of the ground-based radar warnings, both for aircraft and for ballistic missiles, the so-called Ballistic Missile Early Warning System (BMEWS).

Second, RAND was less actively involved in initial research on two companion satellite systems, MIDAS and SAMOS, because the Defense Advanced Projects Agency (ARPA), and not the Air Force, initially sponsored these programs. The Western Development Division of the Air Force commenced studies of missile launcher requirements for the Missile Detection Alarm System (MIDAS) in March 1957. But it was not until September 1959 that primary responsibility for both the MIDAS and SAMOS (the Space and Missile Observation System) became 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 ao., 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. On SAMOS performance, see Richelson, 1987, pp. 180-82).

Third, RAND staff did participate, through various advisory committees, in evaluating and assisting in development of various of these other satellite systems. But the primary emphasis in the late 1950s was upon photographic imaging from space, combined with a recognition that other satellites could improve prospects for tactical warning of war.

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 then remaining at RAND, were excluded from the opportunity to participate in the actual developmental phase of concepts that were theirs or adapted from their work. This did not stop innovation at RAND regarding space technology, but it did for a time channel energies in directions other than the primary thrust from 1946 -- reconnaissance.

DIVERSIFICATION OF RAND RESEARCH ON SPACE TECHNOLOGY: MILITARY APPLICATIONS AND COUNTERMEASURES

FA-VD1

A discipline related to space reconnaissance involved reconnaissance mapping. In 1958, RAND published RM-2179, Robert W. Buchheim's collection of materials, 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 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 consideration of countermeasures. In 1958, RAND published a couple studies, both classified secret, S. T. Cohen's Speech S-84, Nuclear Defenses Against Space Weapons, a quarter century before the Strategic Defense Initiative, and Irwin S. Blumenthal published Speech S-76, Problems in Defending Against Satellites. (RAND, 1959, pp. 46, 47).

DIVERSIFICATION OF RAND RESEARCH ON SPACE TECHNOLOGY: FROM MILITARY ORIGINS TO CIVIL SPACE PROGRAMS

Twenty one months before initial operation of the TIROS-1 weather satellite in 1960, Stanley M. Greenfield and William W. 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 1940's and early 1950's had supported development of balloon reconnaissance systems. These, in turn, supported development of earth-sensing payloads that hastened the development of space satellites for remote observation of the earth. Because balloons had the capacity to carry payloads that were heavier than those of space satellites launched in the early 1960s, balloon programs, more than aircraft, provided the testbed 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 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 communications satellites that became a reality later in the 1960s.

On September 4, 1958 the Ballistic Missile Division of the Air Force formally initiated a program to launch a Television Infrared Observation Satellite (TIROS). The Air Force transferred this program to NASA in April 1959, so that the world's first weather satellite, TIROS-1, operated since April 1960 under civilian auspices. (Snyder, et al., 1976, pp. 56, 64, 78). The U.S. Air Force had the vision, and Congressional backing, to sponsor RAND's studies and later system development of space satellites with potential for both civil and military applications. RAND researchers supported development of both the civil and military potential of space systems.

As ambitions for space satellite missions expanded, RAND studied concomitant needs for communications with space vehicles. In February 1958 Cullen M. Crain and R. T. Gabler published Communications in Space Operations, Paper P-1394, indicating the feasibility of communicating from ground stations to and from space satellites. But this paper overlooked the potential of space platforms as facilities for redirecting and retransmitting communications, and the particular advantages of geosynchronous orbits for this purpose as suggested by Arthur Clarke and independently in James Lipp's February 1947 report. But in 1960, RAND published Research Memorandum RM- 2709-NASA, for the fledgling space agency, Communications Satellites: An Introductory Survey of Technology and Economic Promise. This study focused NASA's attention on the potential economic benefits of communication satellites.

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, 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?

After reviewing the extant records of the classified and unclassified work performed under Project RAND since 1946, and at The RAND Corporation in all of its programs since 1948, we find that there were more "military" space missions that were transformed into civilian applications than vice versa.

Project RAND's initial task, in the spring of 1946, was to explore the feasibility of reconnaissance satellites for military purposes. Two years before reconnaissance satellites became operational, RAND staffers together with U.S. government officials advocated 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, it is the U.S. Arms Control and Disarmament Agency and not the military services, that bears the legal responsibility for verification of compliance with arms control agreements. Earth observation satellites support military reconnaissance missions, but also arms control and earth resource evaluation missions for civil purposes.

Several of the potential space missions explored by 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, identifying civil applications of space technology.

Development work on 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 requirements 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 interplaneary 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 other programs for both manned and unmanned exploration of our solar system. On February 20, 1962 an Atlas D launched "Friendship 7," placing Lt. Col. John Glenn, USMC, into earth orbit for three orbits 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 a newly-organized Communications Satellite Corporation (see Hughes Aircraft, 1981) and military communications satellites for U.S. and NATO communications. Initial development responsibility within the Defense Advanced Research Projects Agency preceded assignment of primary DOD 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 its cancellation in 1962, the Air Force ~~took~~ regained responsibility for development of an initial defense communications satellite system. Philco-Ford served as the prime contractor for the Initial Defense Communications Satellite (IDCS) under a development contract of the Air Force in October 1964. TRW become 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 development of communications satellites for both civil and defense missions.

Navigation satellites, the subject of some research at RAND in connection with ICBM guidance assessments, were more actively researched under Navy sponsorship of studies at Johns Hopkins University. The Air Force Ballistic Missile Division received the assignment to develop the booster for Transit, in September 1958. 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 serkvices, into broad-ranging civil applications. If one had to choose between the "militarization" or 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.

PUBLIC EDUCATION

Following the launching of the first "sputnik", ~~the growth of~~ 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 years when the public either did not care or could not know, yielded at RAND a core of expertise that was 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 cohesive and comprehensive literature. Many of RAND's staff published professional papers and articles. Several of RAND's activities deserve special mention.

First, in February 1958 RAND issued (and supplemented in 1959) an unclassified bibliography of RAND publications on space flight, containing even 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 McCormick, RAND compiled in a matters of weeks an extraordinary collection of documents and tutorials on space technology, submitted it to the Congress in December 1958, published a commercial edition through Random House in 1960, and a revised edition in 1963. Robert W. Buchheim, together with dozens of the RAND research 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 another "crash" RAND product, and one 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 Publication S-72 in February 1958. Fourth, Amrom Katz wrote publicly and humorously on reconnaissance, finding that if he used the term "space observation" he did not run afoul of security guidelines. A series of six articles in Astronautics (1960) republishes a 128-page RAND paper, P-1707, Observation Satellites: Problems and Prospects, initially published 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.

RETROSPECTIVE

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 the RAND 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 field commands. These officers supported and defended RAND advanced reconnaissance projects that, when viewed in the light of conventional wisdom, were seen as longshots at best. Meanwhile in Santa Monica, RAND staffers found their persistence recommendations remained on the shelf, from 1946 until the mid-1950s. Had they had less enthusiasm and imagination, they might have sought out easier work.

RAND, of course, was not alone in pioneering concepts and applications for space technology. But RAND worked virtually every conceivable mission, with a due regard to security requirements and with a commitment to accomplish RAND's open-ended mission. 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 this era have a contemporary application. In an era 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, ~~without reliance upon formal briefings~~, and persistence. ~~in the research environment~~.

SELECTED BIBLIOGRAPHY OF PUBLICATIONS RELATING TO THE DEVELOPMENT OF U.S. SPACE TECHNOLOGY

[When cited in the preceding text, the works that follow are identified by the last name of the author and year of publication.]

Aerospace Corporation, The Aerospace Corporation: Its Work 1960-1980, Los Angeles, CA.: Aerospace Corporation, 1980.

Ambrose, Stephen E., Eisenhower, Vol. 2, The President, New York: Simon & Schuster, 1984.

Anderson, Frank W., Jr., Orders of Magnitude: A History of NACA and NASA, 1915-1980, Washington, D.C.: National Aeronautics and Space Administration, 2d ed., 1981, ix + 106 pp.

Augenstein, Bruno W., Evolution of U.S. Military Space Program, 1945-1960: Some Key Events in Study, Planning, and Program Development, Paper P-6814, Santa Monica, CA: The RAND Corporation, September 1982.

Augenstein, Bruno W., Policy Analysis in the National Space Program, Paper P-4137, Santa Monica, CA.: The RAND Corporation, July 1969.

Berger, Carl, The Air Force in Space, Fiscal Year 1961, Washington, D.C.: USAF Historical Division Liaison Office, 1966.

Beschloss, Michael R., Mayday: Eisenhower, Khrushchev and the U-2 Affair, New York: Harper & Row, 1986.

Bjerknes, J., Detailed Analysis of Synoptic Weather as Observed from Photographs Taken on Two Rocket Flights Over White Sands, New Mexico, July 26, 1948, Santa Monica, CA: The RAND Corporation, April 1951, Paper P-887.

Boone, W. Fred, NASA Office of Defense Affairs: The First Five Years, NASA HHR-32, multilith, viii + 333 pp., 1970.

Boston University Physical Research Laboratories, Dynamic Decade, Boston, MA: BUPRL, 1956.

Brooks, Courtney G., James M. Grimwood, and Loyd S. Swenson, Jr., Chariots for Apollo: A History of Manned Lunar Spacecraft, Washington, D.C.: National Aeronautics and Space Administration, 1979. xvii + 538 pp.

Buchheim, Robert W., and the Staff of The RAND Corporation, Space Handbook: Astronautics and Its Applications, Washington, D.C.: House Select Committee on Astronautics and Space Exploration, December 1958, and New York: Random House, 1959, xvii + 331 pp.

Burrows, William E. Deep Black: Space Espionage and National Security, New York: Random House, 1987.xxi + 401 pp.

Bushnell, David, et al., Contributions of Balloon Operations to Research and Development at the Air Force Missile Development Center, Holloman Air Force Base, New Mexico, 1947-1958 Holloman AFB, NM: Historical Branch, Air Force Missile Development Center, Holloman AFB, 1959. xii + 140 pp.

Byers, Bruce K., Destination Moon: A History of the Lunar Orbiter Program, National Aeronautics and Space Administration, Technical Memorandum X-3487, for sale by NTIS, April 1977. vi + 411 pp.

Carhart, R. R., Scientific Uses for a Satellite Vehicle, Santa Monica, CA: The RAND Corporation, 12 February 1954, RM-1194, iv + 31 pp.

Chester, Michael, Discoverer: The Story of a Satellite, New York, NY: Putnam, 1960. 48 pp.

Clarke, Arthur C., "A Short Pre-History of Comsats, Or: How I Los a Billion Dollars in My Spare Time," in Arthur C. Clarke, Voices from the Sky: Previews of the Coming Space Age, New York: 1965, pp. 119-128.

Davies, Merton E., A Photographic System for Close-Up Lunar Exploration, Research Memorandum RM-2183, Santa Monica, CA: The RAND Corporation, May 23, 1958.

Davies, Merton E., Lunar Exploration by Photography from a Space Vehicle, Paper P-1671, Santa Monica, CA: The RAND Corporation, March 5, 1959, and Vienna: Springer-Verlag, 1960, Proceedings of Xth International Astronautical Congress, London, 1959.

Davies, Merton E., and Amrom H. Katz, An Early Reconnaissance Satellite System, Recommendation to the Air Staff, 12 Nov 1957, 20 pp. Declassified April 17, 1975, 20 pp. Attachment to Letter, F. R. Collbohm, President, The RAND Corporation, to the Deputy Chief of Staff, Development, USAF, Subj: "An Earlier Reconnaissance Satellite System," 2 pp.

Dordick, H. S., and J. T. Sturak, A Selected Bibliography of RAND Publications on Space Research, 1960-1964, Research Memorandum RM-4508 (Abridged), Santa Monica, CA: The RAND Corporation, April 1965.

Douglas Aircraft Company, Project RAND (AAF Project MX-791): Second Quarterly Report, Santa Monica, CA: Douglas Aircraft Company, September 1, 1946, RA-15004, "The Satellite Study," pp. 28-35; "The Comet Project," pp. 36-40; "Projects under Consideration," pp. 42-43.

Doyle, F. J., "The Next Decade of Satellite Remote Sensing," Photogrammetric Engineering and Remote Sensing, Vol. 44, No. 2, Feb. 1978, pp. 155-164.

Fairchild Camera and Instrument Corporation, Panoramic Camera System for a Spin-Stabilized Satellite, Part I, General Design Factors Syosset, NY: Fairchild Camera and Instrument Corporation, Defense Products Division, July 25, 1958. AD 342599.

Frick, R. H., Preliminary Analysis of Recoverable Satellite Performance, Santa Monica, CA: The RAND Corporation, Sep. 19, 1958, RM-2264.

General Electric Company, Missile and Space Vehicle Department, Summary: U.S. Air Force Discoverer Satellite Recovery Vehicle Program, I thru XIV, Philadelphia, PA: General Electric Co., 1960, ii + 10 pp. GE Publ. PIB-52.

Goldsen, Joseph M., International Political Implications of Activities in Outer Space, RAND Report R-362-RC, New York: Random House, 1959.

Goldsen, Joseph M., Leon S. Lipson, and John C. Hogan, Outer Space and International Law, Santa Monica, CA: The RAND Corporation, Feb. 1958, Paper P-1434.

Goldsen, Joseph M., and Leon S. Lipson, Some Political Implications of the Space Age, Santa Monica, CA: The RAND Corporation, February 24, 1958, Paper P-1435.

Green, Constance M., and Milton Lomask, Vanguard: A History Washington, D.C.: National Aeronautics and Space Administration, 1970. xvi + 308 pp. NASA SP-4202.

Greenfield, Stanley M., and William W. Kellogg, "Weather Reconnaissance by Satellites," Astronautics, Vol. 4, No. 1, January 1959, pp. 32-33, 77-78.

Habley, C. G., Memo, Habley (RAND Dayton Office) to J. E. Lipp (RAND Missiles Div.), Subj: "Feed Back History," 28 May 1952, cy in SSD His. Div. File ARS/WS 117L thru 1955.

Hacker, Barton C., and James M. Grimwood, On the Shoulders of Titans: A History of Project Gemini, Washington, D.C.: National Aeronautics and Space Administration, for sale by GPO, 1977. xx + 625 pp.

Hall, R. Cargill, "Early U.S. Satellite Proposals," Technology and Culture, Vol. 4, Autumn 1963, pp. 410-434; in Eugene M. Emme, ed., The History of Rocket Technology, Detroit, MI: 1964, pp. 67-93.

Holbrook, R. D., Outline of a Study of Extraterrestrial Base Design, Santa Monica, CA: The RAND Corporation, April 22, 1958, RM-2161.

Hughes Aircraft Company, Hughes Aircraft Company goesynchronous spacecraft histories, El Segundo, CA: Space and Communications Hroup, Hughest Aircraft Co., 1981. Vols. 1-3.

Hutcheson, J. H., Earth-Period (24-hr.) Satellites, Santa Monica, CA: The RAND Corporation, Aug. 7, 1958, Paper P-1460.

Itek Corporation, "A short history of Itek Corporation," Itek News, Sep. 1977, pp. 2-3.

Itek Corporation, "Itek Marks 25th year; Optical Systems remembers the beginning," Itek News, Sep. 1982, pp. 1-3.

Itek Corporation, "Itek, Space Age Anniversaries Celebrate Decade of Progress," The Itek News, Special Tenth Anniversary Issue, 1957-1967, Lexington, MA: No. 10, 1967, 12 pp.

Itek Corporation, "Political Action and Satellite Reconnaissance," Bedford, MA: ITEK Corporation, April 24, 1959, in Dwight D. Eisenhower Library, Office of the Special Assistant for Science and Technology, Box 15.

Jernigan, Roger A., Air Force Satellite Control Facility: Historical Brief and Chronology, 1954-1981, Sunnyvale, CA: Air Force Satellite Control Facility, Historical Office, 1982.

Kallmann, H. K., and William W. Kellogg, Scientific Use of an Artifical Satellite, Santa Monica, CA: The RAND Corporation, 8 June 1955, RM-1500, iv + 32 pp.

Katz, Amrom H., "A Tribute to George W. Goddard," Airpower Historian, No. 10, October 1963, pp. 101-109.

Katz, Amrom H., memorandum to L. J. Henderson and R. J. Lew, Subj: "Reconnaissance Satlelite and Comments on Your WM-2553," 3 January 1958, 6 pp. RAND Memo M-41, declassified March 24, 1972.

Katz, Amrom H., Memorandum to J. L. Hult, Subj: "Recommendations, Formal and Informal, on Reconnaissance Satellite Matters," RAND Memo M-3008, Santa Monica, CA., 11 May 1959, 7 pp. Declassified September 21, 1976.

Katz, Amrom H., Observation Satellites: Problems and Prospects, Paper P-1707, Santa Monica, CA: The RAND Corporation, 1960, i + 35 pp.; in Astronautics, April, June, July, August, September, and October 1960.

Katz, Amrom H., "Some Notes on the Development of High Resolution in Aerial Photography," Santa Monica, CA: The RAND Corporation, circa 1970, 11 pp. typescript.

Kecskemeti, Paul, The Satellite Rocket Vehicle: Political and Psychological Problems, Santa Monica, CA: The RAND Corporation, 4 October 1950, RM-567, v + 23 pp. Withdrawn, 1955.

Kenden, Anthony, "U.S. Reconnaissance Satellite Programme," Spaceflight, Vol. 20, No. 7, July 1978.

Killian, James R., Sputnik, Scientists, and Eisenhower, Cambridge, MA: MIT Press, 1962.

Kistiakowsky, George B., A Scientist in the White House: The Private Diary of President Eisenhower's Special Assistant for Science and Technology, Cambridge, MA: Harvard University Press, 1976.

Klass, Philip, Secret Sentries in Space, New York, NY: Random House, 1971, ch. 8, "The Genesis of Satellite Reconnaissance," pp. 72-78; ch. 9, "The Promise and Problems," pp. 79-89.

Koppes, Clayton R., JPL and the American Space Program: A History of the Jet Propulsion Laboratory, New Haven, CT: Yale University Press, 1982.

Leghorn, Col. Richard S., "No Need to Bomb Cities to Win War," U.S. News & World Report, Jan. 28, 1955, pp. 78-94.

Leghorn, Col. Richard S., "U.S. Can Photograph Russia From The Air Now," U.S. News & World Report, Aug. 5, 1955, pp. 70-75.

Lipp, James E., et al., Reference Papers Relating to a Satellite Study, Santa Monica, CA: Project RAND, Douglas Aircraft Company, Inc., February 1, 1947, iii + 60 pp.

Lipp. James E., The Time Factor in the Satellite Program Santa Monica, CA: Project RAND, Douglas Aircraft Company, Inc., October 18, 1946, 9 pp. RAD-51.

Lipp, James E., and Robert M. Salter, editors, Project FEED BACK Final Report, Santa Monica, CA: The RAND Corporation, March 1, 1954, Report R-262, Vol. 2, Appendices, declassified, with deletions, per FOIA.

Logsdon, J. M., The Decision to Go to the Moon: Project Apollo and the National Interest, Cambridge, MA: M.I.T. Press, 1970.

McDougall, Walter A., ...The Heavens and the Earth: A Political History of the Space Age, New York: Basic Books, 1986, ch. 4, "While Waiting for Technocracy," pp. 97-111; ch. 5, "The Satellite Decision," pp. 112-134.

Mirabito, Michael M., The Exploration of Outer Space with Cameras: A History of the NASA Unmanned Spacecraft Missions Jefferson, NC: McFarland, 1983. vi + 170 pp.

National Aeronautics and Space Administration, Meteorological Satellites: Past, Present, and Future, NASA Conf. Publ. 2227, 1982, esp. pp. 3-6 (remarks of Stanley M. Greenfield). (b)(3)

National Aeronautics and Space Administration, The Conception, Growth, Accomplishments, and Future of Meteorological Satellites, NASA Conf. Publ. 2257, esp. pp. 1-4 (remarks of Will W. Kellogg).

National Defense Research Committee, Summary Technical Report of Division 16, Vol. 1, Optical Instruments, Washington, D.C.: NRDC, 1946.

Newell, Homer E., Beyond the Atmosphere: Early Years of Space Science, Washington, D.C.: National Aeronautics and Space Administration, for sale by GPO, 1980. xviii + 497 pp.

[redacted] "The Guardians: A History of the 'Big Bird' Reconnaissance Satellites," Spacecraft, Vol. 20, No. 11, November 1978.

Perry, Robert L., Origins of the USAF Space Program, 1945-1956, U.S. Air Force Systems Command, Historical Publication Series 62-24-10, Vol. 5 of History of DCAS, 1961, revised August 1962. Formerly Secret, declassified Mar. 24, 1985. xii + 68 pp.

Perry, Robert L., System Development Strategies: A Comparative Study of Doctrine, Technology and Organization in USAF Ballistic and Cruise Missile Programs, 1950-1960, Research Memorandum RM-458B-PR, Santa Monica, CA: The RAND Corporation, August 1966.

Pierce, J. R., with preface by Arthur C. Clarke, The Beginnings of Satellite Communications, San Francisco, CA: San Francisco Press, 1968. ix + 61 pp.

[redacted], Eye in the Sky, Wright-Patterson Air Force Base, OH: August 1964, 71 pp.

RAND Corporation, The, An Annotated Bibliography of RAND Space Flight Publications, Research Memorandum RM-2113-1, February 10, 1958, revised March 1, 1959. ix + 53 pp.

[This bibliography contains unclassified titles and brief unclassified abstracts of early RAND space technology studies cited in the preceding paper but not fully declassified. It is available in U.S. deposit libraries.]

RAND Corporation, The, Recommendation to the Air Staff: An Earlier Reconnaissance Satellite System, Santa Monica, CA: 12 November 1957, Document X-11099, F. R. Collbohm, Letter to the Deputy Chief of Staff, Development, USAF, 2 pp. + M. E. Davies and A. H. Katz, Enclosure A, 20 pp. Formerly Secret, declassified March 24, 1972.

(b)(3)

RAND Corporation, The, Plans Analysis Section, Vulnerability of U.S. Strategic Air Power to a Surprise Attack in 1956, RAND Special Memorandum No. 15, Santa Monica, CA.: The RAND Corporation, April 15, 1953, Formerly Top Secret, declassified May 1967. 123 pp.

Richelson, Jeffrey T., American Espionage and the Soviet Target, New York: Morrow & Co., 1987, 383 pp., esp. ch. 5, "Overflights," pp. 127-152; ch. 7, "Keyholes and Ferrets," pp. 173-195.

Richelson, Jeffrey T., "The Keyhole Satellite Program," Journal of Strategic Studies, Vol. 7, No. 2, June 1984, pp. 121-153.

Richelson, Jeffrey T., United States Strategic Reconnaissance: Photographic Imaging Satellites, Los Angeles, CA: ACIS Working Paper No. 38, Center for International and Strategic Affairs, May 1983.

Ridenour, Louis N., Further Remarks on the Communications and Telemetering Problem Presented by a Satellite, Santa Monica, CA: Project RAND, Douglas Aircraft Co., April 29, 1946, Document RAD-25, 2 pp.

Ridenour, Louis N., Remarks on the Radio and Radar Problem Presented by a Satellite, Santa Monica, CA: Project RAND, Douglas Aircraft Co., April 23, 1946, RAD-27, 4

Roland, Alex, ed., A Spacefaring People: Perspectives on Early Space Flight, Washington, D.C.: National Aeronautics and Space Administration, for sale by GPO, 1985. viii + 156 pp.