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FROM CONCEPT TO OPERATIONS: RAND RESEARCH ON SPACE TECHNOLOGY FOR RECONNAISSANCE AND VERIFICATION, COMMUNICATIONS, METEOROLOGY, MAPPING, LUNAR AND PLANETARY EXPLORATION

by

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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 paper is one in a series of Rand Papers written to commemorate the 40th anniversary of Project RAND, a project on Research ANd Development initiated by the U.S. Army Air Force, 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 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 paper 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 paper bring diverse experiences to their review of Rand's early research on space technology and applications. [redacted], 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 experiments teams for missions to Mercury, Mars, Jupiter, Saturn, and Uranus. He participated in Rand's Project FEEDBACK 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 than 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. Other documents, and the topics they treat, may not even at this late date be treated publicly.

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, multidisciplinary research, the application of knowledge to important issues of national security, and the artform of what some have later called "implementation research."

The Deputy Chief of Staff (Development) of the U.S. Air Force, 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. Rand staffers had no qualms about serving as honest brokers for innovations developed elsewhere, if they would accomplish the missions that Rand was asked to support.

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 focal length longer than the 6-inch Baker lens from World War II. It was Amrom Katz who passed Davies' concept along to Walter Levison of the Boston University Physical Research Laboratories. Levison thereafter redesigned a camera -- while lying in a hospital bed with back pain -- that applied the concept of a panoramic camera with long focal length, 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 back-ground 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 by what is now the Santa Monica Municipal Airport (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 aircraft designs, as well as the role of missiles within the 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, 1961, p. 11; Stares, 1985, pp. 24-25).

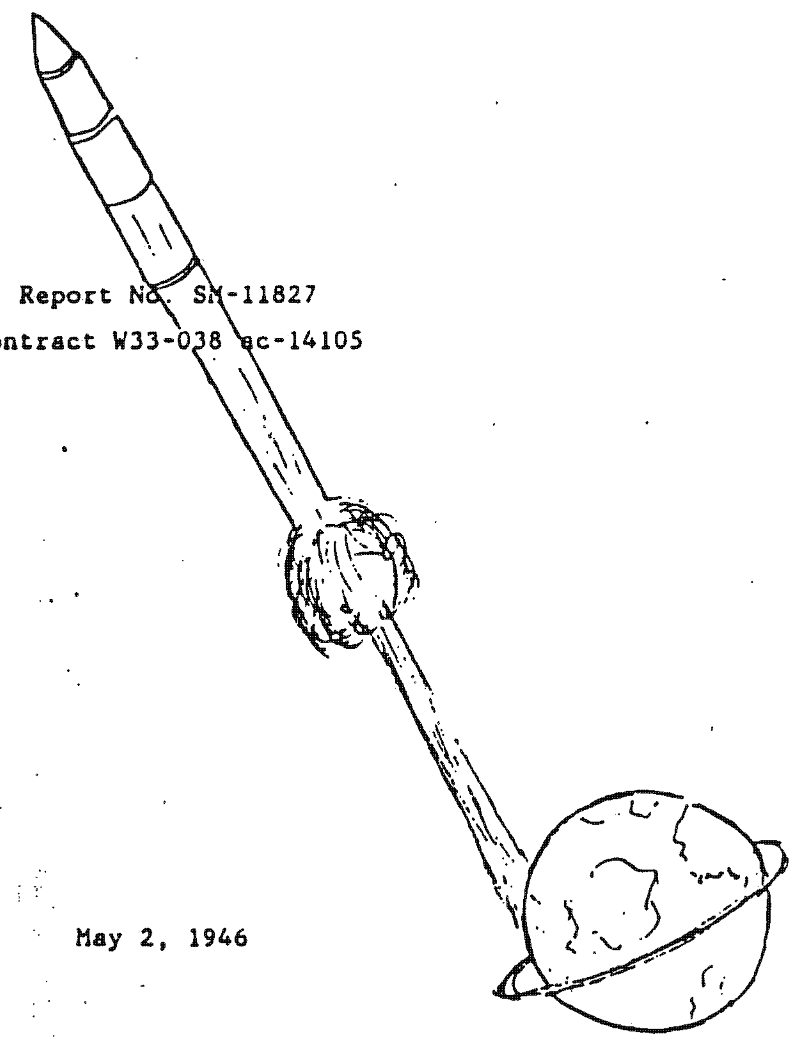
A May 1945 report by Werner von Braun reviewed German views on potentials of rocket-launched space satellites. This stimulated both Navy interest and a December 1945 request for a satellite feasibility study, and Air Force interest, expressed in both a report of General H. H. Arnold in November 1945 (design of a space ship "is all but practicable 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, 1961, p. 9; Augenstein, 1982, p. 3).

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.

DOUGLAS AIRCRAFT COMPANY
SANTA MONICA PLANT
ENGINEERING DIVISION

presents

PRELIMINARY DESIGN OF AN EXPERIMENTAL WORLD-CIRCLING SPACESHIP



Report No. SM-11827

Contract W33-038 ac-14105

May 2, 1946

Professor Louis Ridenour of the Massachusetts Institute of Technology 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 borthers. 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 Missile Division, and his deputy, Robert W. Krueger, managed the continuation of the Project RAND study on space satellites. 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 lined descendants of cameras available at the beginning of that war. The essentially square or rectangular format, flat film, essentially standard mountings, etc., and especially standard film magazines, prevented novel cameras from being introduced. Furthermore, the fact [is] the film itself imposed a serious limit on image performance and image definition, and precluded making giant steps in lenses. Besides, World War II was, as more recent experience shows, fairly brief, (except of course to participants therein.) The current great popularity, well deserved, of panoramic cameras leads one to inquire how come there were no panoramic cameras developed during World War

> II. The reasons lie in the complex production operations, inventories, standardization of equipment, viewers, processors, etc., that go to make up a standard operational package.
>
> ...It is a curious fact that the panoramic camera, at least 100 years old...was invented specifically because lenses of 100 years ago were resolution limited, and could not cover a wide angle. In the effort to get a wide angle, the lens was scanned across a semicircular piece of film, as in the familiar photographs taken at picnics, class reunions, graduating ceremonies, and the like. Thus, a lens which could inherently cover only a small angle was made to sweep out a large angle giving acceptable definition over the entire field.
>
> ...To a new generation of workers accustomed to this extremely high resolution, it may come as a shock to realize the desperate clawing and fighting that was required to increase resolution from 10 to 20 lines per mm, from 20 to 40. High resolution is an extraordinarily fragile commodity; it can be lost by temperature gradients, vibration, mechanical errors, and even requires special handling once it is brought into the laboratory... (Katz, 1970, pp. 1, 4, 5, 10, 11).

On February 1, 1947 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...

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 $400 million in 1986 dollars) could be reduced by waiting for advances in fuels, materials, and techniques. Nevertheless, 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.

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 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.

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's Air Material Command assessed the work. It reported to the Air Staff in December 1947 AMC concurrence in 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. In January 1948 General Hoyt S. Vandenberg stated that USAF "has logical responsibility for satellite..." (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....

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 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).

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^{11} bits/day...The satellite (if it works) is collecting for us the informational equivalent of 10^5 books per eight-hour day. It will take less than three months to collect the informational equivalent of all the books stored in the Library of Congress; less than a year to gather the informational equivalent of all the books printed since the invention of movable type.
>
> ... It is clear that early and careful attention must be given to the automatic selection of frames of interest, and, if possible, to a more sophisticated type of automatic inspection of the record.
>
> ...something has to be done to avoid the necessity of reading the equivalent of 100,000 books per day. There is not the slightest question that the mechanization of all the steps of record-sorting that can be successfully mechanized is one of the most important parts of the over-all system design. I have not seen this point made in any of the prior

> poop on the satellite, and I urge it on your attention.
>
> (Memorandum for J. E. Lipp, Subj: "Random Remarks on the Communication and Display Problems of a Satellite," 31 Aug 1950, at pp. 2, 3, 4, 6).

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 1950 a formal recommendation went to the Air Force to proceed with advanced research into specific capabilities of a satellite vehicle. In November 1950 the Air Force authorized further research to demonstrate the utility of satellite reconnaissance.
>
> 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 and Robert Salter).

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 and Robert M. Salter, Jr. 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. Publication of the latter report in sanitized form in August 1960 (R-365) established a visibility for this pioneering study of the feasibility of weather satellites.

The American Meteorological Society presented Messrs. Greenfield and Kellogg a special award for this work, in 1960, and the Department of Commerce honored them in 1985, during the 25th anniversary of global weather satellites, commencing with TIROS-1 in 1960. A special award for their experimental work at Rand and in resulting high altitude experiments is well deserved recognition.

Those at Rand and elsewhere whose work stimulated the development of satellites for reconnaissance and for verification of arms control treaties operated in a different culture. Their satisfaction in accomplishment is no less, but they do not bask in the light of public recognition for their achievements.

Rand Report R-217 is not as yet declassified, but its contents are previously highlighted. (Perry, 1961, 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 Devcelop- ment Board] RDB approval, authorized Rand to recommend development work in reconnaissance satellite programs--now known as Project FEED BACK--in 1951.

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 Feedback. This project was to design an observation satellite with sufficient detail to prepare a development plan. RCA was given a subcontract to design the television system and a video tape recorder (not too different from those we now have in our homes). Robert Salter and James Thompson spent a good deal of time in Camden, N.J., working with RCA on the design. I also went with them on a few trips. James Lipp was in charge of the overall project, and Bob Salter was his deputy. Richard Frick designed the stabilization and control systems. My primary contribution was in the interpretation of simulated TV images working with a consultant, Richard Churchill.

COLONEL RICHARD S. LEGHORN AND USAF REQUIREMENTS FOR STRATEGIC RECONNAISSANCE

Merton Davies writes:

> In 1951 (or perhaps 1952), Col. Bernard 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 Colonel Richard Leghorn (then working at Eastman Kodak) 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. 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 dinnner 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, 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.

The contribution of Colonel Richard S. Leghorn to Rand's work on aerial and space reconnaissance cannot be overemphasized. And Colonel Leghorn, who in 1957 founded the ITEK Corporation, 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 three crucial years -- 1951 to 1954 -- Colonel Leghorn was that focal point. Colonel Leghorn had come to know Amrom Katz when both of them worked under Colonel George Goddard for World War II reconnaissance. Katz had suggested to Colonel Bernard A.

Schriever recalling Colonel Leghorn to active duty during the emergency resulting from the Korean War. Back in uniform at the Pentagon, Colonel Leghorn had the responsibility to draft reconnaissance planning requirements for the Air Force, and he recurringly turned to Rand for help and informal advice. Colonel Leghorn obtained from the Rand staff recurring 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."

It was during the military conflict in Korea that Colonel Leghorn articulated a strategic context for pre-hostilities reocnnaissance. Leghorn summarized his uncoordinated 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 returned to Eastman Kodak in 1954. 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 Eastman Kodak, but in support of the Air Force studies established by Colonel Leghorn and continued by General Schriever's organization.

Within the Rand staff there was much other relevant research that aided in concept developments for space technology. None was more important than the work of Bruno W. Augenstein, who on his own initiative in about September 1952 began to explore the prospects for development of intercontinental ballistic missiles. It was this work, briefed by Frank Collbohm to various audiences in the summer and fall of 1953, and ultimately briefed by Bruno Augenstein to the TEAPOT Committee chaired by [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. Moreover, what the [redacted] Committee recommended was virtually identical to the recommendations that Rand had presented to them. The expectation that development of the ICBM was a practical option gave a new impetus to studies on space missions and space vehicles. (See the declassified version of B. W. Augenstein, Rand Special Memorandum No. 21, 8 Feb 1954). (b)(3)

On March 1, 1954 James E. Lipp and Robert M. Salter, Jr., <u>et al.</u>, published Rand Report R-262, <u>Project FEEDBACK Summary Report</u>. (R. L. Perry, 1961, p. 32; Augenstein, 1982, p. 7).

It was following the publication and favorable reception of the Project FEEDBACK reports in 1954, Rand recruited Amrom H. Katz, who brought nearly fifteen years of photoreconnaissance and camera technology from his work in General Goddard's Reconnaissance Laboratory in Dayton, Ohio. The combination of Amrom Katz and Merton Davies gave Rand an institutional memory 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.

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

It was in 1954 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).

The Air Force issued a formal System Requirement (No. 5) for an Advanced Reconnaissance Systemon March 16, 1955. (Perry, 1961, p. 41; Richelson, 1984, p. 125).

As the Project FEEDBACK concepts were being drafted, 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.

Merton Davies recalls:

> With the publication of the Project FEEDBACK 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 Lockheed as prime contractor to build the satellite, Eastman Kodak to build the camera, and CBS to build the film scan device, the name of the project was changed to WS 117L with the satellite named Samos, and the new program leader was Air Force Colonel Frederick Oder. The satellite was

to be launched by the Atlas ICBM and Lockheed Agena rockets. Over the next few years we stayed in close touch with Colonel Oder and his staff at WDD.

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 proposals were not considered because they would interfere with the Atlas ICBM development. The Department of Defense established the Committee of 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 Vanguard project for the IGY. The Army continued support of the Orbiter project and eventually 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.

PAYOFFS FROM RAND'S INTERDISCIPLINARY RESEARCH: THE ECONOMICS OF THE ICBM AND SATELLITE RECOVERY

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.

The transition from Rand's recommendations in Project FEEDBACK (1951-1954) to Rand's recommendations for recoverable satellite systems (1956-1960) 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 diferent 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 ICBM Development Cost Estimates, FY1956-1959. 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. It was the rapid sharing of fresh ideas that sparked a rethinking of television-in-space observation systems, compared to film-from-space observation systems.

Richard C. Raymond 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 sat-

> ellite orbit or 85 pounds on a trajectory to the Moon. Launch vehicles of this class were available sooner and were less expensive than the Atlas or Titan. Like the Thor, the Army's Jupiter missile was used for satellites and lunar launches; however, our studies at Rand concentrated on the Thor.

Based upon the Raymond concept, Brownlee W. Haydon 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, Recommendations to the Air Staff: Photographic Reconnaissance Satellites, a 20-page document constituted Rand's approach as of March 1956. But the specific recommendations were premature, and Rand soon withdrew the recommendation. Meanwhile, work proceeded to identify all the requirements for payload recovery.

John H. Huntzicker and Hans A. Lieske investigated the recovery of "such heat-sensitive items as photographic film" in Rand Research Memorandum RM-1811, Physical Recovery of Satellite Payloads: A Preliminary Investigation, 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 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 the Ampex Corporation to investigate magnetic tape as a medium for the storage of visual data. Ampex 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 helped in the development of what is today a multibillion dollar videotape market for electronic products.

REQUIREMENTS FOR HIGH ALTITUDE RECONNAISSANCE

As Rand prepared, in the spring of 1957, to assist the Air Force in developing specifications for advanced balloon reconnaissance systems --- in the aftermath of the (now publicly reported) 119L balloon experience of 1956 -- Amrom Katz turned to a fundamental question: what were the requirements for reconnaissance?

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

THE MERGER OF RAND RESEARCH ON BALLOON AND SATELLITE RECONNAISSANCE SYSTEMS

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. Due to compartmentation of ongoing balloon reconnaissance programs (now declassified in a 32-page summary of balloon reconnaissance in 1955-56: U.S. Air Force Final Report on Project 119L, substantially declassified in 1979), Merton Davies and

Amrom Katz were the two members of the Rand research staff who first articulated the logic of merging Rand's work on balloon and satellite reconnaissance systems.

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 Colonel] Terhune...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."
>
> [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 Steering Committee knows we have been very active on Air Force Project 461L 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 461L and 117L. 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 depreciate the significance of tactical reconnaissance. However, I now believe we can turn this particular phase of our group's activities over to [redacted] (b)(3) who has lately shown more interest in tactical reconnaissance.

BROKERING INNOVATION: PANORAMIC CAMERAS

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. [redacted] 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 [redacted] 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. The story of balloons started many years ago, in the 1940s, when Rand meteorologists William W. Kellogg and Stanley Greenfield became interested in the flights of paper balloons launched by the Japanese during World War II. 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. Kellogg and Greenfield became interested in predicting the paths of the high altitude jet streams and participated in instrumenting polyethylene balloons so their flights could be tracked. The balloons would drift for many days and at the proper altitude rapidly cover many thousands of miles. In 1956, a project called MOBY DICK was implemented in which balloons containing cameras were launched from three locations in Europe. They drifted across Europe and Asia, taking

(b)(3)

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 (Rostow, 1982), and the declassified MOBY DICK summary history (U.S. Air Force, 1956; declassified 1979, pp. 1-30).

Levison described a new 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. Levinson 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 Levinson 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. After a brief illness involving a stay in the hospital, 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 struc- ture 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. (See Katz, 1959, p. 2).

SCIENTIFIC SATELLITES AND LUNAR EXPLORATION

Merton Davies explains the development of Rand staff interest in space exploration, and the selection of space launchers for scientific missions that were later recommended for reconnaissance missions because of their simplicity and feasibility:

> 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 proposals were not considered because they would interfere with the Atlas ICBM development. The Department of Defense established the Committee of 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 Vanguard project for the IGY. The Army continued support of the Orbiter project and eventually launched the first successful U.S. satellite called Explorer, which was an improved version of the Orbiter proposal.
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> 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, Robert Buchheim was at the center of a group that developed a philosophy of simplicity in design to establish early, reliable space operations. 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 unspun 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 servivable, 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 <u>General Report on the Lunar Instrument Camera</u>, then classified Secret. (Rand, 1959, p. 7). Publicly, also in May 1956, George H. Clement published a paper, <u>The Moon Rocket</u>, Rand Paper P-833. In September 1957, Buchheim published a second Research Memorandum, RM-2005, <u>Outline of a Study of Manned Space Flight</u>, 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 (b)(3) 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 (the same companies responsible for the Samos photographic system). Five Lunar Orbiter spacecraft were flown; all were successful. It was an excellent program.

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] (b)(3)
[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).

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 <u>A Family of Recoverable Satellites</u>. 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.

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 repre-senatives (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.

Rand's President, Frank Collbohm, provided a summary cover letter for the now-declassified document, <u>Project RAND Recommendation to the Air Staff: An Earlier Reconnaissance Satellite System</u>:

> 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 is this recommendation differ substantially from the current 117L system concept.

- o The proposed systems use a spin-stabilized payload stage.
- o They use a transverse panoramic camera of essentially conventional design, fixed to spin with the final stage, which scans across the line of flight.
- o 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 + 35 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.

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.

Amrom Katz prepared a November 1957 document, <u>Some Notes on the Evolution of Rand's Thinking on Reconnaissance Satellites</u> 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 prin-

ciple, 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 of 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:

> 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 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.

Major General Bernard A. Schriever of the Air Force Development Command (ARDC) 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 sputnikin October 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 significangtly accelerated satellite program. General Schriever implied a lack of funding approvals, when he testified before the Senate Committee on Armed Services in 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.

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 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 -

> "all-out secret effort to build a workable reconnaissance satellite....Lt. Gen. Bernard Schriever worked with Bissell. Brig. Gen. Oswald Ritland 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).

A more recent unofficial account claims -

> ...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).

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:

> 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).

AN UNSOLVED PROBLEM: WARNING INTELLIGENCE

In the period 1946 to 1958, the Air Force sponsorship of Rand projects facilitated the development of space reconaissance systems. When the Soviets were finally able to shoot down a U-2 reconnaissance plane in May 1960, the nation was not without alternative means of acquiring information needed for survival in the nuclear age. But Rand staff did not consider they had significantly ameliorated the problem 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).

Moreover, between 1958 and the Soviet shootdown of the U-2 reconnaissance aircraft in May 1960, virtually all of the pioneers of space reconaissance 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

Somewhat more than a year 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 Air Force had supported meteorological satellite development when no other sponsor was available, but as of October 1, 1958 NASA became an operating agency, and in April 1959 NASA took charge of the TIROS meteorological satellite program. NASA launched the TIROS-1 weather satellite on April 1, 1960.

In 1959 John Huntzicker wrote a Rand document, An Air Force Weather Satellite Utilizing TV, which accompanied another Rand document, An Air Force Weather Satellite - Why and How. (Katz, 1959, p. 7). During the transition to civilian management of the TIROS satellite program, it was important to plan for weather reconnaissance essential for defense programs.

A related discipline involved reconaissance mapping. In 1958, Rand published RM-2179, Robert W. Buchheim's study of a space reconnaissance mapping satellite for General Ferguson's office in the Air Force, which led to modification of the USAF reconnaissance requirements document (GOR 80-4) so as to include mapping reconnaissance missions. (Katz, 1959, p. 6).

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 commujnicating to and from space satellites. But this paper overlooked the potential of space platforms as facilities for redirecting and retransmitting communications. By 1960, Rand published Research Memorandum RM-2709-NASA, for the fledgling space agency, Communications Satellites: an introductory survey of technology and economic promise.

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).

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. And the endurance was double-edged. On one edge were the Air Force officers who defended budgets for studies of advanced reconnaissance systems seen as longshots at best. On the other edge were the Rand staffers whose recommendations remained on the shelf and who, had they had less enthusiasm and imagination 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 vision, initiative, and persistence in the research environment.

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