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REVIEW AND RECOMMENDATIONS OF USAF SATELLITE RECONNAISSANCE PROJECT SAMOS

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HS/HC-899

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BAKER REPORT ON SAMOS

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I. General Background

SUBJECT: Review and Recommendations of USAF Satellite Reconnaissance Project SAMOS

I. GENERAL - Background Information

A. During the past several months, deliberations and studies concerning the various aspects of the SAMOS Program have been conducted by many groups and individuals. The national nature of this program, and the high importance that the many potential users of the product place on the program, indicates that any review must consider the program as a whole in order to be most effective. Recently, there has been evidence of a revised doctrine of the SAMOS Program, obtained in informal discussions with members of the Office of the Secretary of the Air Force, and as seen in such directives as the General Wilson letter to the BMD. However, in the meantime, national and international affairs have forced a new urgency, coupled with a frantic expectancy, for a project whose technology has been both overstated and underdone. Consequently, this report has attempted to consolidate various reviews made to date.

II. General - Political

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II. GENERAL - Political and Management Considerations

A. The universal applications of satellite reconnaissance have not been fully recognized. World-wide mapping, disaster and rescue surveys, geological search, weather analysis and warning, peace-time inspection and disarmament control, are all possible functions of satellites. Aside from these practical applications, the scientific results are, of course, also of very great importance.

B. International and national approval to conduct operations is, and will continue to be, a serious problem. The situation must be such that the program will be acceptable politically -- initially, on a U. S. National basis, and later, on an international basis. This includes favorable indoctrination of the public, operational and/or executive control by an organization capable of sponsoring both military and civilian peace-time utilization of SAMOS, and of expeditiously and effectively exploiting the end results. Whenever political approval is discussed, it must be remembered that the Soviet Union pioneered in this area by putting into orbit, with no international agreement, satellites of various types (including at least one with photographic capabilities) and with no agreement and uncertain action regarding international sharing of information acquired.

C. The U. S. cannot afford two R & D programs of this type; and the results of this program will be of priority interest not only to the USAF and the DOD but to the entire intelligence community and the nation.

Political approval to undertake satellite reconnaissance will depend ultimately upon the degree that the conditions of universal application are met by the SAMOS system.

D. The military and civilian requirements are compatible -- at least, from the R & D point of view -- and a clearer relation will need to be established between the Department of State, NASA and the DOD as to the exploitation of R & D results.

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E. Effective and expeditious exploitation of the SAMOS material requires that the data reduction be accomplished simultaneously by or in cooperation with all interested agencies utilizing reference material from all available sources and programs. Emphasis by the individual agencies should be consistent with their priority areas of interest and their respective assigned roles and missions. This indicates that existing facilities and agencies should be used, or that immediate action should be taken to prepare an adequate facility to accomplish this task if existing facilities are inadequate.

F. Program reorientation is necessary and so is strengthening of the organization, but one should use care before starting completely new programs or establishing completely new organizations. A solution of existing and current problems, on a technical and management level, is very badly needed, but the emphasis on new R & D organizations, new rocket developments, etc., that are not directly associated with the primary missions of the system, will tend to dilute or degrade timely receipt of usable end products.

Money and effort should be used to clean up, expedite, and improve the existing program; and greater effort should be placed on obtaining improved end results, qualitatively and quantitatively.

G. All of the above indicates that the program should be under the executive control of a national organization that has an international growth potential.

H. Recommendations

(1) It is recommended that the DOD recommend to the NSC that executive responsibility for general guidance operational plans and policies and establishment of operational priority, in both the civilian and military applications of SAMOS, be placed under a new DOD executive officer (ad hoc) or under an existing office, such as, the Assistant Secretary of Defense/Special Operations.

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(2) The USAF be given the task of:

(a) managing the R & D program

(b) operating the military part of the operational program either openly or under cover of a civilian mission

(c) making available both the raw and the analyzed data to all U. S. agencies designated by the Executive Office, whose establishment is recommended under (1) above.

(3) The Executive Officer should examine the possibility of accomplishing data reduction by a "Joint Satellite Processing and Data Reduction Center".

III. General - Requirements

III. GENERAL - Requirements

A. Review

1. The official requirements for reconnaissance satellites have undergone a most important change in the last year. Before analyzing the present (July 1960) situation, it is worth listing here for future discussion some of the interpretations presented by the USAF in official and unofficial briefings.

2. The use of satellites as warning devices was considered basic until just a few months ago. To give effective warning (assuming that this were possible), a large number of satellites (10 to 20) would be required to be in orbit at the same time, with practically instantaneous transmission of pictures required [redacted] and accompanying large scale data handling effort on the ground. (Subsystem "I")(Ref. Annex A). 50X1

3. It is worth noting at this point that the principle of concurrency has been observed too strictly here: the data processors should be built only after the work on the collection system has progressed at least to the point of defining the basic concepts. This was not done in Subsystem "I" and the consequences of the error are serious.

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4. The effect of weather, of orbit geometry, resolution, and economic factors have been forcefully emphasized by a number of technical groups and, as a consequence, the feasibility of the original scheme as a warning device has been shown to be both problematic from a technical point of view, and almost impossible from an economical point of view.

5. The disappearance of the warning function as a fundamental part of the design basis is an event of recent occurrence. The necessary changes in the form of instructions by the BMD to the contractual set-up seems to have lagged the USAF accepted change in doctrine.

6. We should note here, before it is forgotten, that it is this

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erroneous concept that put emphasis on readout rather than recovery, that brought about a large expenditure on data processing devices, video links, digital computers and so on -- all of which may conceivably turn out to be useless.

7. Unless the change in doctrine is recognized by all responsible parties as the correction of a previous error, some of the mistakes of the past will be compounded rather than eliminated.

8. Another error, still present in the Project system, relates to the lack of proper dissemination of Project information. In the early parts of the program, a determined and unwarranted effort was made to reduce the flow of information on SAMOS to the intelligence community with improper use of the need-to-know security rules. The situation has improved, but there is still insufficient appreciation that SAMOS is a national rather than an Air Force project. The USAF owes to all interested intelligence agencies periodic and candid reports on its intentions, plans and achievements. As stated heretofore, the SAMOS capabilities go far beyond merely providing intelligence information; and this fact contributes further to the responsibility of the Air Force towards meeting information needs other than its own intelligence requirements.

B. The USIB July 1960 Document

On July 5, 1960, the USIB re-affirmed the requirements for SAMOS. An analysis of the document brings out the following facts:

(1) The requirement for satellite reconnaissance is important and continuous.

(2) No warning capability is expected, rather repeat coverage with intervals of one to six months; if required, some targets may need to be re-examined at closer intervals.

(3) Optical resolutions (Subsystem "E") at 20, 5, 1 feet are required for different types of intelligence information.

(4) Very flexible ELINT devices (Subsystem "F") are desired with emphasis on R & D. The only detailed target requirements given at this time are those calling for identification, localization and analysis of key electronic emitters used in anti-ballistic defense, missile telemetry and satellite links.

(5) From a visual or optical satellite two capabilities are needed. Paraphrasing the USIB notes, the following appear necessary:

(a) A quick solution of the surveillance problem is needed before 1962 to find missile bases under construction.

(b) A continuous operational capability aimed at the high priority targets, and both continuous surveillance and a directed reconnaissance (when the weather is suitable) are needed.

(6) COMINT collection is not clearly wanted until better data are available on the capabilities of the system.

C. There will be a continuing requirement for photographic and ELINT coverage. As the state of the art permits and as the accuracy, types and numbers of weapons systems increase, the accuracies and detail required in the end products will become increasingly greater.

IV. General - Readout

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IV. GENERAL - Readout

A. The USIB requirements put a great deal of emphasis on an early capability for the detection of missile bases under construction in the period 1960-1962. They also point out the necessity for a continuing visual surveillance in the years to come with resolutions of 20', 5', and 1 foot.

B. The requirement for an early capability does not specify the resolution necessary, but it is clear that for the detection and identification of missile bases under construction, the USIB considers 100' resolution unacceptable. Detection of construction work rather than recognition of a base may be the only possible result of 100' resolution. The necessity exists, therefore, of carrying on simultaneously an R & D program and a "crash" program with the hope of obtaining initial visual information of important current intelligence value. The usefulness of E_1 package from an intelligence point of view is, therefore, not comparable to its value as an initial R & D test.

C. The following sections of the report will be aimed at obtaining these results. In this introductory paragraph it must be emphasized that the program suffers very seriously from original conceptual errors, but this report is attempting to make maximum use of results already obtained.

D. According to the previous considerations, the early E2 payloads appear the only means for obtaining an interim capability of a type approaching that required by the USIB. There is a chance that additional types of payloads may become available by the end of 1961, but this is not considered as important as the R & D program for recovery which is recommended below.

E. It is fundamental to this program that the recovery problem be solved at all costs, independently of any operational take. If this is properly done, it is felt that a solution can be obtained in time to contribute effectively to meeting the USIB requirement for detection of missile bases in CY 61-62.

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F. The photographic readout aspects of the program appear to have been based on unrealistic assumptions as to warning capabilities, and the claims pertaining to system capabilities were exaggerated. However, readout is undoubtedly satisfactory for all the F applications excepting perhaps some advanced video recording capabilities.

G. Other problem areas in the readout system requiring technical studies to obtain the proper answers are:

(1) The "start-up" problem after computer failure and after down time for normal maintenance, particularly if a number of satellites are used simultaneously.

(2) The accuracy of the tracking information to properly program the camera. Specific problem areas are camera orientation, focusing, exposure control, image motion compensation, and camera on-off times.

(3) The possibility of jamming and the effects of a high density electronic environment (Vandenberg T & A station) on the quality of the transmitted picture.

(4) The possibility of intercept of a continuously orbiting reconnaissance vehicle and the restraining effects of a strong diplomatic protest.

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V. General -
Recovery

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V. GENERAL - Recovery

A. The necessity of achieving resolutions of or better imposes the immediate technical requirement for recovery. The present readout systems limit the possible coverage and the resolution.

B. In contrast to assertions of last year that Discoverer recoveries were either "on hand or on order" it is necessary to conclude that the recovery efforts up to now have failed completely. Accordingly, it is proposed that simplified payloads launchable by abundant and presumably reliable THOR vehicles be promptly devised for prolific studies of object recovery from orbits in space.

X C. These experiments should involve both land and water recoveries. They ought to be characterized by simple but reasonably precise instrumentation to determine the physics and mechanics of the separate stages of recovery. Thus, for instance, deorbiting behavior should be clearly distinguished from pre-entry and re-entry activity. Without extensive technical information like this, orderly and continuous recovery of a useful product cannot seriously be anticipated.

D. We believe that one of the fundamental reasons why recovery has not been successful up to now, and if successful, unlikely to be continuously successful, is the process through which the Air Force has gone in achieving the desired result. We believe that the allotment for the blame cannot be easily made to one contractor or contracting agency. We do believe, however, that over and over, the influence on the research and development recovery program introduced by the necessity for some kind of useable results, has blocked the technical progress of the main contractor.

E. It is felt that the present prime contract responsibility is being well borne technically. However, the R & D demands are so urgent that additional assistance, probably on a test and engineering scale, is necessary. In this way such critical issues as parachute and other re-entry facilities can be developed without unbalanced effects on the development of the payload itself. It is felt that a contract situation must be created where the solution of re-entry problems is reasonably decoupled from modifications in the payload. For instance, the design changes introduced four times in five weeks in parachute improvements appear to be mixed up with other problems of signalling retro-rocket activity, position control, and so forth; while there are inevitable connections among all these, critical stages must be separated. The rather subtle point is that technical development experience shows that components of a system invariably suffer in quality when they are developed in the system. Only after independent recovery components, including parachutes or other slow-down mechanisms, have succeeded should they be coupled into a specific SAMOS function. This situation would, of course, be different if anyone had ever recovered anything. As it is, the present regime resembles efforts to develop Faraday's capacitor for the first time during the construction of a giant computer.

TABS

VI. WEATHER

A. Bad weather and darkness negate the possibility of obtaining photographic coverage, utilizing either readout or recovery systems. As pertains to darkness, the time of year and the latitude will determine when photographic coverage can be obtained. As pertains to weather, the studies that have been conducted were based on statistical averages and can only be used for long-range planning purposes. Based on these studies, any conclusions made, relative to the amount of coverage or the length of time to obtain total or specific area coverage under actual operational conditions, are invalid. Weather is continually changing and there is no assurance that a continuously orbiting satellite will be in the right place at the right time. Large areas free of clouds, haze, and smoke occur infrequently (once or twice a month dependent on the season of the year), and persist for relatively short periods of time (approximately two to three days). The SAMOS readout system is not capable of fully exploiting large cloud-free areas because of its narrow swath and because of its readout limitations. A recoverable panoramic package launched at the proper time and recovered at the end of 48 or 72 hours could fully exploit the good weather area. In addition, studies have indicated that a 70-mm panoramic camera recovered in 24 hours will show a gain of coverage of 6 to 18 times over the E-2 system, operating for the same length of time, because of readout limitations. In terms of information content, the gain is between 260 and 850 times depending on the width of the film used. In the case of areas that are cloud free only one or two days a year, the advantages of one recoverable package launched at the appropriate time as compared to a number of continuously orbiting readout packages are apparent. On the other hand, the loss of coverage during cloud free areas may result in a delay of months before the opportunity would exist again.

B. A comparison of the effects of weather and the number of days required to obtain coverage using various types of orbits and different swath widths is shown in Annex E.

VII. Optical - Subsystem "E1-E2-E5"

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VII. A. GENERAL PHOTOGRAPHIC

1. The spectacular publicity given to the SAMOS program, and the exaggerated claims as to capabilities have seriously jeopardized the utility of the system.

2. Education of the public, releases concerning program status on a delayed and pre-planned basis as well as releases concerning the current state of the art must be; thoroughly studied, agreed to and understood by appropriate Department of Defense and Department of State officials. The resulting plan must be approved at the Executive level and strictly adhered to by all lower echelons.

3. A problem of long standing and considered appropriate to the SAMOS program, particularly as pertains to the E-5, is to design the configuration of the vehicle to accommodate the primary mission capability or to design the primary mission capability to fit the vehicle, regardless of compromises.

4. It is felt that too much emphasis has been given to the capsule requirement and not enough to the payload requirement. As payloads become more sophisticated in order to meet the USIB requirements, the above problem if not resolved in favor of the primary mission capability, may prevent or delay mission accomplishment.

5. Any follow-on or back-up program to the E-5 should represent significant improvements in coverage, resolution or scale, and be ready for R&D testing in mid CY-1961.

6. A continuous worry in the analysis of SAMOS has been the effect that the clamor for early intelligence take has had on the orderly conduct of the program. A multitude of new techniques required,

the interference with the research and development has had serious effects. In order to illustrate the difference between research and development concepts and operational concepts, the following example is given: - consider the case of an E-1 payload sent in orbit for the first time. From the point of view of research and development this is a major stepping stone and information to be obtained from it is of the utmost importance. From the point of view of intelligence, the 100' resolution is insufficient to make the results of particular significance. For this reason, one could state that 95% of the usefulness of the mission would be acquired if the lens and film of the camera were subjected to a winking light and did not view the terrain. In fact, the first E-1 satellite will carry film exposed and developed, film exposed but not developed, and film to be exposed. Information obtained by the readout system on these films represents more than 90% of the information required from the research and development point of view. The fact that one could also look on the outside and get some incidental intelligence from the terrain below, appears to a research development minded organization an interesting but not overly important by-product of an outstanding R&D achievement.

VII. B. E-1 SYSTEM

1. The E-1 is a strip camera with a 6" focal length lens designed to operate at 260 statute miles. With the 70 mm format and 100 ll/mm AWAR (Av. weighted area resolution) it is reasonable to expect a basic ground resolution of 100'. To realize this

100' the IMC must be within 5% because of the long exposure time of 1/25 second. Since the orbit will be elliptical, this point should be studied carefully.

2. The E-1 system is less complex and much more workable than the E-2 system. Its design makes it a coverage tool (100 mi. wide strip). It is felt that it has limited "seeing" capability since after readout the recognition of objects will optimistically be limited to 300'. Strip cameras are not useful for mapping but approximate measurements of small objects detected are possible. Barring weather considerations, this satellite could cover Russia in about ten days. This is not a very meaningful statement, but weather and darkness play vitally important roles.

3. The quantitative aspects of the readout problem are not as critical in the E-1 as in the E-2 system. The qualitative aspects in terms of degradation due to transmission, reproduction, and system complexity (reliability) are the same as for the E-2.

4. There is an R&D advantage or carry-over value from E-1 onto E-2 in that the image formation, in-flight processing, scanning, transmission, etc., are the same. The degree of success of the E-1 program will define better than any other system study the final destiny of readout programs.

5. The questionable resolution of the end results obtained from this system and the great need for reconnaissance-intelligence information from satellite vehicles for evaluation purposes and future R&D guidance are considered to be the major problem areas.

6. The E-1 package is part of the component test vehicle and will be tested simultaneously with the F-1 package.

7. There is limited power supply available (approximately 15 days depending on the amount of operation planned for each package).

8. The film of the E-1 when launched will be in three different conditions:

   (1) exposed and processed

   (2) exposed and not processed

   (3) not exposed and not processed

   This will allow for the systematic evaluation of the three major functions of the system in flight.

9. Three component test vehicles are scheduled as follows:

   September 1960, January 1961, and March 1961

VII. C. E-2 SYSTEM

1. The E-2 is a strip camera; with a 36" focal length lens designed to operate at an altitude of 260 statute miles; and with a 70 mm format and 100 ll/mm system resolution, it is reasonable to expect a ground resolution of 20 feet. A review of the Lockheed Engineering Analysis Report prompted concern about the distinction between resolution and recognition (Annex B). It is felt that 50-90 feet for recognition is a realistic figure. The width of the ground coverage obtained is 17 miles and the information is transmitted electronically to the ground, after photographic processing and scanning in space.

2. There are two different problems to which the E-2 is directed:

   (a) the problem of covering the entire Eurasian land mass

   (b) the problem of seeing a particular target.

   The coverage obtained by a read-out system is limited by the speed at which film can be scanned, the number of ground stations, the bandwidth of the read-out system, the weather, and the resolution define the overall answer. Total coverage with an E-2 system becomes economically unsound, in terms of the number of satellites required, the elaborate ground system required, and the complexity of both (Annex C and D). For a single satellite to accomplish the job, approximately 500 days would be required. Taking weather and sun angle into consideration, this would be increased to years. In order to obtain coverage of a particular target on the ground with the E-2 camera capable of obtaining coverage, 150 miles on either side of the nadir point, approximately 10 days would be required. (Annex F).

3. Generally the E-2 camera system, viewed from technical advances to date, is obsolete. It imposes such operational limitations (swath-width and read-out) to make satellite type operations economically and politically unacceptable. The extreme sensitivity of the photographic system, the overall complexity, and the extremely close tolerances involved indicate that the possibility of obtaining the technical goals and objectives mentioned in the Engineering Analyses Report is doubtful (Annex E).

VII. D. E-5 SYSTEM

1. The lens of the camera has an F/5 aperture, and a focal length of 66 inches. Minimum operational ground resolution of 5-10 feet with recognition for objects of 15-30 feet are expected, including degradation due to uncompensated image motion and vehicle stabilization residual. (155 ll/mm at 155 na. mi.) Film capacity is 250 pounds (15,000 feet) standard base or 22,000 feet of thin base

film. The design is capable of being modified to accept 500 pounds. The orbit life is 30 days with selected targets on demand. Coverage is 50 nautical miles swath width with the capability of stereo 15 degrees fore and aft.

2. The E-5 is programmed to be boosted into orbit by the ATLAS AGENA B. This is dictated by the requirement to keep the vehicle in orbit for 30 days. This in turn dictates an orbital altitude of 180 miles, which in turn establishes a minimum weight basis, the lens parameters of F/5, the focal length of 66 inches and the desirability of a horizontal configuration (in addition, the F/5 aperture is required to maintain depth of focus). The resultant weight of the system, including film, is 1,000 to 1,250 pounds.

3. A design that assumes a 20 day life does not seem to be as well "matched" to weather conditions and intelligence requirements as could be obtained with a 48-inch F/5 package at 140 miles altitude or from a 54-inch F/5 package using 75 feet of film. This would be more consistent with the weather (coverage of large cloud free areas in 24-72 hours), political problems (psychological effect of a continuously orbiting reconnaissance vehicle over long periods of time) and [illegible] requirements mentioned previously.

4. The launch schedule for the E-5 is one per month as follows:

CY 61 - September and December

CY 62 - March, May, June, September, and November

Maximum time to obtain total coverage above 33 degrees (not providing for weather or sun angle) is approximately twenty days and minimum time to fly within range of any target is approximately three days (camera is capable of roll steering and may be rolled up to 30° for specific objective targetting).

5. The development of ground processing and data reduction equipment for recoverable payloads appears to lag behind the development of the vehicle system. Of specific concern in this area are the developments of restitutional printers, adequate mensuration equipment, and the automatic elimination of redundant material, and/or information.

VII. E. RECOMMENDATIONS

E-1 SUBSYSTEM

1. That the existing E-1 program is adequate
2. That the program should remain as presently configured and scheduled (E-1 and F-1). In the event that one of the systems malfunctions, the other system may yield useable R&D results, and, to obtain experience in launching dual payloads for cover purposes.
3. That, if possible, the launch schedule be expedited.
4. That the priority remain on the photo system, but not at the expense of the ferret system.

E-2 SUBSYSTEM

5. It is recommended that the E-2 program be limited to a maximum of four vehicles and be terminated at the end of CY-1961. It is felt that a total of seven readout packages (3 E-1) is sufficient to obtain the R&D objectives and receive sufficient material to evaluate for future R&D guidence in this area. It is felt that this will allow sufficient overlap with the recovery program to insure operational readiness of the latter.

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6. It is recommended that studies and technical development programs be initiated in the readout area that will allow for an adequate readout system in the future if required.

7. It is recommended that the reduced effort in the readout area be reflected in increased emphasis on the early availability of a recoverable system, and in the proper reduction of emphasis in the appropriate ground processing, reproduction, and data reduction systems.

E-5 SUBSYSTEM

8. That efforts be placed on the development of smaller camera packages with higher resolution, and smaller dual payloads (effective stereo for better target recognition, and measurements, as well as for political and weather considerations). Utilization of all government organizations and facilities having primary mission responsibilities in reconnaissance should be utilized.

9. It is recommended that every effort be made to provide the users with adequate ground processing and data reduction equipment in sufficient time to have it operationally ready upon receipt of the recovered film.

10. Since the primary mission of the program is photographic reconnaissance, it is recommended that the vehicle be designed in such a manner that it does not complicate and/or compromise the design and operations of the camera.

VIII. Data Processing Subsystem "I"

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VIII. A. SUBSYSTEM "I"

A general impression has been created by the meager amount of information available on Subsystem "I" that participation and knowledge by the entire intelligence community and by the other contractors in the SAMOS complex has been limited, perhaps because it is not recognized as important by the USAF. This situation has apparently resulted in a lack of coordination which has hampered the system design. In addition, it has been very difficult for cognizant government agencies to examine in detail the procedures, the program, and the hardware of Subsystem "I".

There is no doubt that the principle of concurrency when applied to a ground data handling system of this type is a very difficult principle to follow. Recommendations were made by this and other reports regarding a shift of emphasis between readout and recovery; these recommendations correspond to a radical change in the means of collection and may well make most of the system obsolete after the first few flights.

There are serious worries created by many briefings and discussions as to whether the interface between the collection and the analysis has been properly taken into account.

As a result of premature initiation of hardware work, the state of the art has surpassed certain Subsystem "I" components while at the same time the changes in the overall system concept have made other components of small use. There has been insufficient analysis of the essential requirements of Subsystem "I" during an R & D phase, and confusion has been created between the need of handling R & D intelligence "take" and the need for developing the necessary facilities for an eventual operational SAMOS system.

A substantial number of new problems must be assessed during the R & D phase. These include the type of information collected, the radical difference

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between recovery and readout requirements, the continuously varying information rates, scales and scope of coverage, and the problem of correlating the information with the orbital time. It is evident that a carefully controlled experimental program is necessary to solve these problems and it is very likely that interim solution will be necessary to handle some of the R & D intelligence "take".

On the other hand, it is by no means clear that the program has been handled on this basis; rather, the impression has been created of a large scale effort toward heavily automated consoles. Also, uniquely new digital computers have been developed "per se" rather than in answer to a particular R & D problem. The change in the operational concept between a warning system and an intelligence system should have had early and profound influence on the work of Subsystem "I". The June 1, 1960 letter from General Wilson to BMD is a late recognition of this fact and may not have been properly implemented yet.

Included in the development of Subsystem "I" is an elaborate simulation program that seems not to have involved the use of actual intelligence data. This elaborate simulation program may have led to wrong conclusions regarding the quality of the equipment because of the obvious and very serious differences between simulated and real material. Substantial differences in estimates of the expected signal environment by various contractors is one example of this possibility.

VIII. B. RECOMMENDATIONS

(1). It is recommended that further work on Subsystem "I" components be preceded by immediate test and evaluation work to classify the sub-projects into the following categories:

a. Items which are, or appear likely to be, better than similar devices already available for general use. These should be completed and made available to systems other than SAMOS.

b. Items which are, or appear likely to be, indispensable and available to supply a minimum capability for the interpretation of the interim data that will be furnished by E2, should also be completed.

c. Items which appear indispensable for future handling of recovery payloads should be continued, if already initiated, provided they are general in scope and do not limit the ultimate system performance.

d. Items which do not meet the (a), (b), (c) criteria and those that appear to be limited to the handling of ELINT data should be suspended. ELINT data from more than three payloads are unlikely to become available in the next two years, and the relative importance of analog and digital data is still under question. Items that do not meet the above criteria and the ELINT portions should remain suspended pending discussions between the Air Force, the different contractors, and the ultimate users, aimed at determining to what extent special purpose facilities are actually required.

(2). It is recommended that simulation programs be based on realistic rather than idealistic concepts, and that the purpose of these programs be one of actual evaluation of the equipment, as it will operate in the future, rather than of displaying data and training operators on an unrealistic basis.

(3). It is recommended that the entire intelligence community participate in all aspects of the Subsystem "I" program, and that evaluation of the system take into consideration all other programs, both special and conventional.

IX. ELINT/COMINT

Subsystem "F1-F2-F3"

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I. It is felt that the following concept of operations can be used today as a guide line of future R&D work (and is therefore subject to future amendments before being acceptable for actual operational use). This plan is drawn according to the rules set by the USIB document either explicitly or implicitly.

1. Surveillance of Sino-Soviet territory will be a primary task of any future operational ferret subsystem.
2. Examination of the Sino-Soviet territory for all appropriate frequencies once or twice a year must be assumed for the cold war period; R&D work will aim at supplying the corresponding capabilities and reliability.
3. Specifically directed reconnaissance flights with special QRC missions will be required at irregular intervals averaging twice or three times a year. (This concept is not explicit in the USIB report but is the necessary consequence of the requirement particularly as related to anti-ballistic missile detection.) R&D work should be conducted to permit the future use of QRC procedures and to develop the techniques required not only for long term surveillance but also for short term reconnaissance.

2. SUBSYSTEM "F" R&D PROBLEMS

A. The orderly development of a satellite ferret capability must take into account the need for early availability of devices capable of meeting the urgent requirements listed above and plan the work toward a more complete, reliable and flexible device capable at a later date of meeting missions of larger scope.

B. A number of problems present themselves and the work should be planned towards their early solution.

(1) Detection and analysis of key emitters in the present environment. The problem of selecting anti-ballistic missile radars from a dense

signal environment is not readily solvable. Present programs have started in the correct direction but insufficient attention was given to the problem until recently.

The detection of satellite-aimed channels and of ground-to-missile guidance channels has not been properly studied and no practical effort has been initiated.

[redacted] 50X1

(3) <u>Inhibit techniques and location accuracy</u>.

A downward looking technique is used for ferreting from a satellite similar in many ways to that used for visual observation. While the idea appears good in principle, no ground or flight test can give a satisfactory evaluation. The use of presently planned F1, F2, and F3 in orbit would give a partial answer regarding the validity of the solution.

(4) <u>Propagation effects on ground-to-space signals</u>.

A number of unconventional phenomena may be discovered of whose existence we now have no information. The antipodal focusing of 40 Mc discovered with Sputnik II in orbit is typical of such phenomena. Use of satellites is indispensable. F1, F2, and F3 will give a partial answer.

(5) <u>Multiple intercept, reflections, spurious signals, polarization errors</u>.

Some problems of this type are anticipated, especially because of the different response of the main and inhibit antennas at different polarizations. The effect of ionospheric sporadic reflections and other similar phenomena cannot be anticipated.

(6) In-flight satellite calibration.

This has never been attempted before. Aircraft tests could be used to test the technique.

(7) Space signal environment.

Wide band exploration of the spectrum has not been made outside the earth and outside the auroral latitudes, however, nothing special is expected. At auroral latitudes, some of the lower F3 bands may reveal unexpected signals. Satellite tests are obviously essential.

(8) High gain antennas stabilized to earth.

This is an essential characteristic of many satellites of the reconnaissance and communication types. We need to prove the technique; there seems to be no reason why difficulties should appear: satellite tests are essential.

(9) Real time payload adjustment to correct errors or to switch in alternate units.

The requirement for reconnaissance rather than surveillance mission will put a premium on payload adjustments that can be made without hours or days delay. In this region, F2 and F3 will give decisive answers. Aircraft rather than satellite tests could be employed to prove the practicality of this technique.

(10) Satellite COMINT.

This collection requirement is not now a part of the present equipment program. A sensible R & D test should be made in a suitable and likely frequency band to determine whether the collection method is effective; whether the take could be used if available on a regular basis; [redacted] 50X1

(11) Overall reliability of satellite take.

A comparison of the received data with the known parameters of signals from U.S. radar, navigation aids and other emitters will be essential as a means of establishing overall reliability of the data. Without this knowledge, no confidence or validity factor can be established.

(12) Feasibility and procedures to be employed by Subsystem "I".

There is little doubt that "subsystem I" will, more than any other, be influenced by the results of the early flights and R&D techniques in collection. The elimination of errors, of redundant data, of inhibit errors; the accuracy of location, the check with calibrations; the feedback to subsystem F; are problems that are not likely to be correctly resolved without intense R&D trials on actual satellite data take. F1 data is essential here, F2 data will be much better, but still insufficient. Analog data handling requirements are very unclear; the ability of SS/I to abstract useful results from partial data; the future extension of ELINT procedures to COMINT; are all open subjects for investigation and development.

C. In addition to these technical problems, a number of operational questions need to be answered before such requirements as those listed by the USIB can be met; this is, of course, always the case with any electromagnetic collection. The enemy's techniques, characteristics and tactics are fundamental in determining the changes necessary in our original plans to achieve operational success. A few of the pertinent questions are listed below:

1) Do the Soviets track our satellites?

2) Do the Soviets have a space surveillance system?

3) What is the power, gain, and character of all the ground-to-satellite links that can be intercepted?

4) What new frequency bands will be revealed as employed by the Sino-Soviets?

It is important to note that the SAMOS equipment, as presently planned, could do only a part — and, a small part at that — of the work that the RB-47's have been carrying on along the periphery of the western world. If the missions accomplished by these reconnaissance airplanes are essential to the country — and if periphery flights were to become politically unacceptable, the present concept of ferret SAMOS subsystem would have to be substantially modified.

IX. 3. SUBSYSTEM "F" RECOMMENDATIONS

A. It is recommended:

1. That since the amount of expenditure allocated to the boosters is out of all proportion with that allocated to the payloads, that greater emphasis be placed on the payloads, the ground support equipment, airplane and ground tests and test data processing.

2. That the number of Atlas Agena boosters be reduced and as many satellites as possible be based on the use of Thor boosters (with or without clustering Sergeant missiles) for R&D tests.

3. That of the three F1 payloads currently available, as many as are necessary, be flown singularly or in combination with an E1 payload, at the earliest possible date, to achieve one successful orbiting ferret collector (for at least 36 hours).

4. That of the four F2 payloads now under construction, as many as are necessary be flown with Thors boosters to achieve successful orbit with two payloads.

5. That in order to meet specific requirements mentioned in the USIB document, a vigorous R&D program be initiated:

a) to develop modifications to the F2 design or of the special test payload package to develop an early capability for the

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X. Management

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X. MANAGEMENT NOTES

A. It is recognized that the management of a program of this type is not an easy task and that the technical difficulties are compounded by the clamor for early intelligence in a variety of forms, by the multiplicity of payloads and by the national importance given to space projects. In addition to these difficulties, serious errors in judgment regarding warning requirements (Annex A) and the controversy regarding the relative importance of an early result vs. an orderly R & D program interfered very seriously with the management of the program.

B. Further problems were introduced by the assignment of the management of SAMOS to a group that, eminently successful in the administration of ICBM, extended the same techniques to a different project. The fact that the R & D techniques for this project had to be very different was not, and is still not, fully recognized. The knowledge of reconnaissance techniques and systems in BMD was limited to a very small number of people. For this reason in particular, the management group found it difficult to establish a position of leadership and became responsive to a number of outside forces.

C. The fact is that, within the USAF, there are officers and civilians with a very high degree of technical competence whose services were neither sought nor welcome. There is also within USAF a well-developed R & D management capability for projects of this type.

D. For the above reasons, it is viewed with alarm the creation of a new organization, either outside or within the Air Force, that does not use the talents available at WADD, Rome ADC and HQ USAF. It would also be of concern if much confidence were placed upon the ability of an unproven and not yet staffed organization like Aerospace in establishing immediately an effective and efficient engineering supervision over the project. It is felt that several months will be necessary before Aerospace's influence should be reckoned with and that this time will be

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[redacted]

required to staff the organization and to train its personnel into a new field of endeavor.

E. It is felt that Lockheed [illegible] in the main has followed instructions and many of its apparent errors should be traced back to determine the effect of [illegible] directives on contractor's decisions.

F. The present knowledge of satellite launchings, stabilization, deorbiting and recovery does not admit the rigid contract mechanisms imposed by the [illegible]. Also, the intelligence requirements roles that have been played in this program at least since 1957 are unreal and confusing. In the foreseeable future major experimental activity should center on experiments, specifically to expand the knowledge noted above. Properties of payloads and development of optimum photographic and ELINT mechanisms should proceed concurrently but in a relatively independent manner.

G. Recommendations

1. Despite the errors of the present [illegible] management group, it is felt that lessons have been learned and that management has improved and will improve further. It is recommended that every effort be made to make the existing organizations work rather than make radical changes at this time.

2. It is recommended that the [illegible] organization be reinforced with more officers with reconnaissance experience and that the positions occupied on the staff be consistent with the high priority of the project.

3. It is recommended that organizations like [illegible] and [illegible] be brought into the direct management structure, that their advice be given much greater weight than in the past, and that administrative procedures be revised to permit response to special projects on a timely basis. Outside appearances lead one to conclude that [illegible] has sometimes avoided asking for advice from [illegible] and [illegible] and sometimes reversed recommendations in a direction that later events (as in the management of Subsystem I) proved wrong. If the above recommendation is unacceptable, it is recommended that

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the appropriate staff sections of these organizations be reassigned to HD.

4. It is recommended that, in the deliberations concerning Lockheed Corp., the contractor's actions be judged taking into account the policies, guidance and decisions made by USAF authorities that may have been primary or secondary causes of these actions.

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ANNEX A

WARNING

1. The nature of the warning problem is such that it should not be allowed to confuse, justify, or exert technical influence on the reconnaissance satellite system. The various degrees of warning not only imply, but are dependent to a large degree on the known intentions of any potential enemy. Therefore, it cannot be designed for. On the other hand, the importance of early and reliable warning to the national defensive and offensive efforts is recognized. In order to insure the highest quality results, the indicators of the imminence of hostilities should be derived from each and all of the following intelligence categories: (a) scientific and technical, (b) economic, (c) political, (d) military (air, ground, and sea), (e) sociological, (f) geographic, (g) transportation and telecommunications, (h) biographical.

2. This, in turn, becomes a national long-term (days-months-years) problem involving all intelligence agencies. Close coordination of all activities and compatibility of all systems is mandatory in order to provide on a timely basis the contributions that SAMOS may make to the above intelligence categories. The urgency of a threat of any situation is dependent on the degree that it is supported by all of the above factors in addition to the extent that counter actions have been taken during the build-up of the situation.

3. The question of timeliness as pertains to the evaluation of the SAMOS end products should be studied very carefully. As pointed out previously, the advantages of satellite reconnaissance are such that in a very short period of time it can saturate any and all data reduction systems that are now in being. Complete automation of the data reduction process could very easily hinder and slow down the decision process particularly as pertains to the short range - short term problems. Data reduction on a select basis and effective method to eliminate redundant material is required.

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ANNEX B

SUBSYSTEM ("E") PHOTOGRAPHIC SYSTEM PERFORMANCE

System Resolution:

The E-2 system's performance is quoted at 200 lines per mm high contrast and 100 lines per mm low contrast. Conversion to measurement in object space reveals discrepancies in the anticipated 20-foot recognition ground resolution. A high contrast target (100:1) at 200 lines per mm yields a detectable dimension of 8.7 feet or approximately 9 feet on the ground at a scale of 528,000:1 (300 statute miles). However, it is generally accepted that to recognize an object, it must have from 3-5 times the detection resolution. Therefore, this (8.7) 9 foot dimension (detection) will be approximately 25-45 feet in size before recognition level is attained. Operationally one is always dealing with low contrast targets (and accepting the stated figure of 100 lines per mm), the accepted ground object recognition threshold is not less than 50-90 feet. Therefore, it is more realistic to think of this system as a 50-90 foot system than a 20 foot system when it is required to identify and recognise objects. But before considering the E-2 as a 50-90 foot system, it should also be emphasized that the above conditions are based upon a static relationship of camera to ground. The effects of system dynamics during the period of time for exposure further affect these numbers and are discussed in the body of this Annex.

A final consideration of a numerical description of the system deals with photographs taken obliquely and the resulting image degradation.

Camera Orientation Problems:

The E-2 camera is basically a strip camera. The slit is oriented perpendicular to the flightpath. The 70-mm film is then fed in a path parallel to the flight line, and at a velocity equivalent to the relative ground velocity. Object and image planes are thereby synchronized, and exposed by means of a slit in the focal plane. The slit width and film velocity established the exposure time, with the forward motion of the vehicle providing the "scan" motion. The camera is supported in a

3-axis gimbal system so that the optical axis may be directed ± 150 miles of the vehicle nadir for preselected target areas.

This preselection and aiming are considered to be very difficult problems. The transverse dimension of the film represents for this focal length a total angular field of 3.2 degrees. Assuming a safety factor of 50%, a target must, therefore, be angularly determined within a strip of 1.6 degrees from a vertical height of 300 miles. This represents an accuracy of approximately one part in 16.5 in each axis. It should be remembered that this accuracy must be simultaneously maintained in all three axis to hit the target. The 1.6° must, therefore, be considered the 3 sigma limit or at worse the 2 sigma limit remembering at the 2 sigma point 27% (1-. 9 x .9 x .9) of the targets will already be missed. The stabilization system which is usually specified in rms (or the 1 sigma point) will have to be good to .5° rms or .8° rms depending on how many targets one is willing to miss. The stabilization system specified in SAMOS does not meet these requirements.

One must further keep in mind that all of the above pre-supposes <u>no</u> error in position along the orbital track. Such assumptions should not be allowed to stand in an active program.

It should be mentioned that both of the above difficulties (strict stabilization and position along the track) are overcome by scanning across the track rather than along it, as is the case in other panoramic type cameras. In panoramic type cameras, the entire section is scanned and errors in position along the track can be minimized by starting the cameras early. This insures target coverage with a penalty in film weight proportional to the stabilization and track position accuracies. The trade offs when viewed from a panoramic configuration are clear. Since the panoramic method is superior to the present E-2 method, the E-2 method should be changed. In addition to accuracy, it is also interesting to examine stabilization system rates, they are:

Roll: 2.1°/min.

Pitch: 2.4°/min.

Yaw: 4.4°/min.

A roll rate of 2.1°/minute corresponds to a motion of 126 arc seconds/second, or 1.26 arc seconds in an exposure of 0.01 second. The 1.26 arc seconds represents a ground motion of approximately 9.6 feet which already borders on deterioration of supposed 20-foot resolution, for this represents the blur component along the photographic slit axis. Notice the motion is not corrected by IMC; it is strictly stabilization motion. By the same token, the pitch axis component contributes to motions not corrected by IMC, which in turn contributes about 10 feet of image blur in the film feed direction.

Viewed another way, a twenty (20) foot objecton the nadir at an altitude of 300 miles represents an image on the film of 0.0004 inches, or microns. Accepting for the moment the criterion of 60% image motion compensation, the residual acceptable blur is but 4 microns. This means that in 0.01 seconds the stabilization equipment must not contribute as much as 4 microns of motion.

This degree of accuracy is not presently available in the E-2 system. Vehicular stabilization required is approximately 0.5°/minute.

Weather Problems:

Despite the fact that much data exists regarding cloud cover, no true operational level of performance is stated for the E-2 system. The operational performance section does not mention the effect of haze (industrial or natural) which affect end performance.

From available weather data, it has been determined that approximately 50% of the area of the USSR is cloud covered most of the time. At least 40% of the remaining areas are determined to be partially cloud covered. Only 20% of the entire area is considered open and clear, and this on a rather sporadic basis as related to moving cloud pattern.

The E-2 system operates on a basis of preselected target areas. There are no sensors aboard which provide remote ground indication for the presence of cloud cover. This is a problem of special importance in the E-2 photographic system, because the angular field of its film record is just 3.2 degrees square. It is, therefore, not at all inconceivable that cloud cover can completely obscure the full field angle of 3.2 degrees.

Moreover, this may occur even when a normally usable condition for coverage of 0.2 to 0.3 cloud cover exists. There also exists the problem of narrow angle lenses obliquely related to the cloud cover. Solar position under these conditions is important too, for the sun at the incorrect angle to the cloud openings will provide undesirable shadow on the ground scene below the opening. Such a condition makes it difficult to get overlapping photography. The probability is quite low that one can accurately locate a single exposure through the cloud openings.

Exposure Criteria:

High resolution photographic systems are particularly subject to deterioration as a result of motion. The greater the resolution, the more rapid the deterioration in the environment of motion. As the photographic scale decreases (smaller image size) the reduced contrast also contributes to a lowered performance of recognition. The slit camera does have one unique characteristic which sets it apart from all other cameras--a non-dynamic shutter capable of very short exposures. There is no cheaper or more reliable means for minimizing the effects of motion than fast shutter speeds. This important and useful characteristic of the slit shutter has been compromised by choosing a very slow emulsion, which has high resolution capability to be sure, but forcing complex and exacting compensations (effects described earlier) to make a strip camera useful at exposures of 0.01 second.

Next examine the problem of camera exposure control. The camera is provided with a glass plate in the focal plane on which metallized slits are plated.

This method was employed to minimize the problem of slits which are difficult to maintain in parallelism at narrow separation. The slit plate is capable of indexing a variety of slit widths to provide exposure control (lens aperture at maximum opening), and is subject to pre-programmed command dictated by course and ground cover. This system cannot, however, provide the necessary control in the presence of cloud cover. Here it is necessary to deliberately overexpose in order to render the lower reflectivity ground scene usable. The present system does not accommodate this condition nor does it supply the necessary sensory devices to make this possible.

Film:

The film, SO 243, is a modified version of microfile, and emulsion know for its inherently high resolution and low speed. Choosing an emulsion of more reasonable resolution coupled with high emulsion sensitivity would have substantially lessened the design and control burden and affected a realistic compromise resulting in a higher resolution output.

Optical System Window:

No sufficiently detailed optical description is provided so that one may determine if the lens system window has been considered as a part of the basic optics. The matters of concern relate to the fact that in operation the optical system window is both pressurized and heated to maintain the desired environment. With no detailed knowledge given it is felt some mention should be made of the affect of window quality, heating and pressure loading.

The pressurization level is stated at one atmosphere of nitrogen. Assuming a 10-inch diameter window, the total load upon the window is 1100 pounds approximately. A lower pressure (1.5 psi) would surely suffice. Unless the window thickness is sufficiently thick to withstand this load, the window will become bowed and its zero lens power characteristic changed. If lens power is so introduced, it may be of such magnitude as to shift the focal plane position.

This is important in view of the extremely narrow range of critical focus.

The lens system window is critical, under load, for internal stresses (from temperature gradients and/or pressure) can approach such magnitudes where its resultant quality sets the resolution limit of the entire optical system. It is essential that the window be kept in a stable condition, for the existence of thermal gradients will vary the quality until such time as the window resumes thermal stability. This means different characteristics for different photographs until stability has again been reached.

The present LMSD procedure for ground collimeter tests of the E-2 camera does not provide that the camera be pressurized to match the expected spaceborne situation. This should be remedied.

Ground Control of Resolution:

The E-2 photographic system provides for command control of resolution. This is impractical since there are too many parameters which enter into this end effect. For example, a focus control and image motion compensation control are provided and this directly raises the question as to whether an operator at a remote console on the ground is able to determine which of these two are in error. How is the operator to know if the difficulty is thermal stability, window effects, mis-alignment due to launch forces, etc.? In the absence of resolution targets somewhere on the ground, it is virtually impossible to make an adjustment in resolution remotely. This operational mode required redefinition and evaluation.

Stereo Photography:

Brief comments are also included in the E-2 report regarding the availability of stereo photographic coverage at angles up to ± 17 degrees. It is not at all clear just how camera orientation is programmed for this purpose. Intuitively, the value of such stereo is questionable in view of the involved geometry. It is considered doubtful that such height data could be of value unless points of known elevation are located in the overlap area. On this basis realtive measurements might be of some value, but at best, questionable. A convergence angle of 3½ degrees at a scale of 525,000:1 (nadir only) cannot begin to provide elevation detail much less than 500 feet. This is not considered worthwhile in the light of the equipment complexity required to provide this motion, since in the light of the complex aiming problem previously discussed above, it is doubtful that the two photographs required could actually be obtained.

Processing Limitations:

The chemical processing in flight involves the use of monobath solutions. There is no doubt that if a data link is to be used that this be the process used. The monobath process does affect the latent image resolution; for unlike conventional processing, it cannot provide the compensation for continuous gamma and density control. On a film recovery basis there is no doubt but that conventional processing with the close control available, will yield desirably higher results than a monobath process. The ground process would even compensate for the unexpected variations of airborne exposure.

Film Scan Method:

Subsequent to monobath processing and drying, the film is then presented in a gate to be scanned by a flying spot scanner and related optics. Here image resection occurs. The 2x2-inch frame is then scanned in 0.1 inch x 2 inch strips for the data link transmission. This means that in a 2-inch fram length, the system deliberately introduces 19 breaks in image continuity. Assuming a 1% linearity (sweep) the abritted (missing) areas can vary by ± .001 inch, or ± 44 feet at each scan section interface. This appears most undesirable.

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Annex C

I. Read-out Limitation Due to Scan Rate = 6" film per minute

No Read-out Stations	3	2	1
Read-out Time/Station (Min/Day)	[illegible]	50	25
Film Read-out/Day Inches	396	300	150
Feet	33	25	12.5
Linear Miles/Day	2,790	1,860	930
Sq. Mi./Day	47,430	31,620	15,810
Average Length of Flight Line (Miles)	2,000	2,000	2,000
Average Number of Times Over Each Flight Line to Obtain Coverage		1.07	2.15
(Russian Block=160°) 19.2 M Sq. Mi. No. of Satellite Days Required for Coverage	444	666	1,333
Weather Degradation 50%	888	1,332	2,666
Period Degradation			
Control Degradation			
Reliability Degradation			

Film Size = 2.75" x 12.5' (150")
150" ÷ 2.75 = 54.54 (the number 17-mile units in 150")
54.54 x 17 = 930 (linear miles forward direction)
Single frame = 17 mi x 930 mi or 15,810 sq. mi.

II. The effectiveness of VAFB as an operational T&A station is questionable. The amount of read-out will depend upon the type and amount of activity at the Pacific Missile Range, and the degree that the electronic radiations of these activities interfere with subsystem H reception.

III. In comparison a 70mm recovery system will cover 278,000 sq.mi./day and 16,000 linear mi./day. The number of satellite days required to obtain total coverage would be 72. Degraded 50% for weather, the total would be 144. Degradation due to period, control and reliability is not as great or as critical because of the fewer number of days required. If the satellite is recovered in a 24-hour period, it will show a gain of 6 to 18 because of the read-out limitations.

IV. Using a panoramic recoverable system with the capability of a 150-mile swath, the comparison would be:

16,000 linear miles/day

2.4 M square miles/day

8½ satellite days would be required to obtain coverage

17 satellite days would be required if weather were considered

The degradation due to period, lack of control, and reliability would be substantially less because of the wider area of coverage obtained resulting in a fewer number of vehicles requiring a fewer number of days to obtain coverage.

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Annex D

SYSTEM COMPARISON SUBSYSTEM "E"

	E-1	E-2	E-5	24" Pan	36" Pan
Performance focal length	6"	36"	66"	24"	36"
Altitude	260 mi.	260 mi.	180 mi.	127 mi.	142 mi.
* Ground Resolution	100'	20'	5'	25'	6'
System Resolution	100 ll/mm	100 ll/mm	100 ll/mm	80-100 ll/mm	140 ll/mm
Strip width miles	100	17	60	150	300
Aperture	4.0	4.0	5.0	5.6	3.5
Shutter Speed	1/50	1/100	1/70-1/7[illegible]	1/300-1/2000	1/4000
Center Scale	3×10^6	5×10^5	7.5×10^4	$3.[illegible] \times 10^3$	2.5×10^4
Life Min. Expected R&D (days)	15-30	30-60	30	1-4	1-4
Coverage/Vehicle Life (independent of weather)	42×10^6 Sq Mi	6.7×10^6 Sq Mi	$15\text{-}20 \times 10^6$ Sq Mi	Can carry only 1 day of film 7.3×10^6 Sq Mi	4 M/Day 14.6×10^6 Sq Mi Total
Film Size	70 mm x 1200'	70 mm x 4520'	5" x 15-2200'	70 mm x 2500'	5" x 1500'
Effective Stereo	No	No	Yes	No	Yes

* Distance on ground subtended by one photographic resolution line. Recognizability usually requires 2½ lines.

At the present time, the 24" system listed above has the following growth potential and could possibly result from minor changes:

(1) The addition of a 36" F.L. lens with a system resolution of approximately 140 ll/mm.

(2) A 100% increase in ground coverage due to increased film width and capacity (70 mm to 5").

([illegible]) A higher reliability factor by cutting the number of frames or exposure [illegible] for every pass.

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Mean number of E-2 Satellite days required for photographic coverage with a probability of 0.95 for fixed (17-mile wide) and trainable (75, 100, 200, and 300-mile wide swath) cameras for specific locations, for a winter month (Jan) and a summer month (July) for orbital inclinations of 83° & 70° (without illumination degradation effects) and given $15\frac{1}{4}$ revolutions per day.

Photo Width	Orbit	Month	Moscow	Sverdlovsk	Irkutsk	Novosibirsk	Astrakhan	Pekin
17	70°	Jan.	175	125	80	115	195	70
		Jul.	225	95	130	105	90	160
	83°	Jan.	210	140	105	125	235	95
		Jul.	140	115	125	115	95	165
75	70	Jan.	40	28	18	26	44	16
		Jul.	[illegible]	22	30	24	20	36
	83	Jan.	48	32	24	[illegible]	54	22
		Jul.	32	26	28	26	22	38
100	70	Jan.	30	21	14	19	33	12
		Jul.	21	16	22	18	15	27
	83	Jan.	36	24	16	21	40	16
		Jul.	24	20	21	19	16	28
200	70	Jan.	15	10	7	10	16	6
		Jul.	10	8	11	9	8	14
	83	Jan.	18	12	9	10	20	8
		Jul.	12	10	10	10	8	14
300	70	Jan.	10	7	4.5	6.5	11	4
		Jul.	7	5.5	7.5	6	5	9
	83	Jan.	12	8	6	7	13.5	5.5
		Jul.	8	6.5	7	6.5	5.5	9.5