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(S) NATIONAL RECONNAISSANCE OFFICE
WASHINGTON, D.C.

OFFICE OF THE DIRECTOR

MAY 06

March 12, 1969

MEMORANDUM FOR CHAIRMAN, UNITED STATES INTELLIGENCE BOARD

SUBJECT: Study of Requirements for Image-Forming Satellite Reconnaissance Responsive to Warning/Indications Needs

The attached NRO Staff study was prepared in response to your letter of February 14, 1968 requesting an assessment of the feasibility and cost of a collection system that would meet the objectives set forth in the study by the Committee on Imagery Requirements and Exploitation (COMIREX), "Requirements for Image-Forming Satellite Reconnaissance Responsive to Warning/Indications Needs" January 5, 1968.

The COMIREX requirements objectives call for an image-forming reconnaissance system with [redacted] near real-time readout capability. Although, as noted in the NRO study, only one type of near real-time readout system has been developed, tested and demonstrated through applied research and advanced development of the system elements to the degree which would warrant a decision for full scale development at this time, there are a number of promising new technological developments which may offer potentially more effective and, in the long term, more economic systems if full-scale development is initiated one or more years from now. These new developments are in various stages of progress ranging from early research on critical elements to engineering model tests. The rapidly advancing technology in fields having potential application to reconnaissance readout systems and the varied status of devices and components currently in research and development, makes it very difficult to make predictions of the technical feasibility, operational effectiveness and costs of systems based on some of the newer developments. The NRO study, as it relates

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to these newer developments, is of necessity based on the limited data presently available and on projections of the performance which may be achieved as a result of on-going or planned research and development.

Particular attention has been given in the NRO study to identifying those factors in the COMIREX requirements objectives which need further refinement or clarification in order to completely define a Warning/Indications system. Also, requirements factors which have significant effects on system costs have been highlighted with a view to providing a basis for further tradeoff studies of requirements versus system capability and cost.

Alexander H. Flax

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Attachment
NRO Staff Study
BYE-12678-69

INTRODUCTION

Over the past several years the Staff of the National Reconnaissance Office (NRO) has consulted periodically with the Committee on Imagery Requirements and Exploitation (COMIREX) of the United States Intelligence Board (USIB) on the requirements for and the feasibility of satellite photographic reconnaissance systems which could provide [redacted] or near real-time return of collected imagery to the United States. The COMIREX, on January 5, 1968, issued a report, "Requirements for Image Forming Satellite Reconnaissance Responsive to Warning/Indications Needs." This report was based on preliminary NRO estimates of readout system characteristics. On February 14, 1968, the Chairman of the USIB requested that the NRO evaluate this report in terms of the feasibility and cost of a satellite system which would meet the requirements objectives set forth in the COMIREX report.

The NRO has, since its inception, carried on a continuing program of applied research and advanced development on readout system techniques and components which may be applicable to the Warning/Indications function although none of these efforts were specifically pointed toward accomplishing that function. The present report summarizes the status of readout system technology, taking into account past and ongoing NRO research and development, as well as other related research and development, and assesses the feasibility, costs and schedule of several candidate [redacted] readout systems which can be projected on the basis of that technology.

The conclusion is reached that only the laser-scan film readout system, previously carried by the NRO to engineering model demonstration of integrated operation of all components on the ground, offers a sufficient degree of confidence to warrant proceeding with development of an operational system at this time. The major development problem with this system would be improving reliability and wear-out limitations on complex mechanical and electromechanical components to increase their orbital lifetime from the 2 to 3 weeks, for which they were originally designed, to the six months to a year required to make the system economically attractive and competitive with newer readout system concepts which might become available for development in the next two or three years. The laser-scan film system is also inherently limited in orbital lifetime growth, once a basic system size and weight is chosen, by the weight of film and processing chemicals which must be expended. Therefore, unless there is considered to be an urgent need to achieve a Warning/Indications capability in the next four years, it does not seem advisable to initiate full-scale development of a laser-scan film readout system at this time.

Other, potentially more attractive, readout system concepts, described in this report, may reach sufficiently advanced phases of component research and development during the next year or two to allow initiation of full-scale development on a readout system with inherently better potential for the high reliability and growth in lifetime in orbit which are among the principal factors determining the long-term economy of satellite reconnaissance systems.

Preliminary estimates of the nonrecurring costs of readout systems range from [redacted] including development and the first six flights, which are assumed to be adequate to test the system and achieve the design lifetime of [redacted] in orbit. The system configuration to meet the Warning/Indications requirements objectives is a [redacted] satellites in a 169 NM orbit spaced so as to provide daily coverage of all targets in the Sino-Soviet land mass plus one or two communications relay satellites in synchronous orbit. Annual recurring costs for these systems, assuming an average of [redacted] lifetime in orbit, range from [redacted] The lowest cost system with respect to both recurring and nonrecurring costs is the laser-scan film system. However, these costs are based on the assumption that a [redacted] average lifetime in orbit is achieved by all systems. This may prove to be more difficult with the laser-scan film system. Also, the weight of film and processing chemicals places a definite limit on the orbital life of a film system of the overall size and weight considered in this study. Purely electronic systems or systems having erasable storage mediums are not so limited and may grow in reliability to lifetimes in excess of the [redacted] design value without a major system redesign.

The schedule for readout system development depends upon the type of transducer chosen. Development of the laser-scan readout system could be initiated immediately and would take from 3 to 4 years from program initiation to first flight depending on the urgency placed on the development, level of funding and the degree of technical risk assumed. The electronic camera/dielectric tape system and the return beam vidicon system may reach a state of satisfactory technical demonstration and confidence by the end of Calendar 1969. If development were initiated then, first flight could be achieved 4 to 5 years later, the exact schedule depending on the factors of urgency, funding levels and technical risk assumption. Solid state array transducers seem unlikely to achieve a sufficient level of technical demonstration and confidence until mid-Calendar 1970. Development time for such systems, once basic transducer technology is established and the image transmission chain is demonstrated, should also be 4 to 5 years.

Attachment 6 is a detailed discussion of factors in the COMIREX requirements objectives which need further refinement or clarification in order to completely define a Warning/Indications system. Particular attention is also given to identifying those requirements factors which have a significant effect on systems cost with a view to providing a basis for requirements/system capability/cost trade offs.

READOUT SYSTEM RESEARCH AND DEVELOPMENT BACKGROUND

A readout system was developed during the earliest satellite reconnaissance activities. The SAMOS program included a version with on-board film processing and readout over a U. S. ground station with a flying spot scanner. The system had very poor performance by today's standards and was dropped. In particular, its data rate was quite low, so that relatively few photographs could be transmitted in any reasonable time. However, the readout subsystem was later used with considerable success in the Lunar Orbiter Program. (See Attachment 4 for a comparison of this readout system with current requirements.)

The directives which formed the NRO incorporated the decision to cancel operational readout systems but directed that exploratory efforts continue. The advent of the laser provided the opportunity to develop a vastly improved film scanning system. An engineering model of such a subsystem was developed as a module which could be used with the GAMBIT system to provide a readout capability for crisis response. This engineering model was successfully tested in end-to-end tests of transducer, wideband transmission link and image reconstruction device. This technique had several disadvantages, the primary being that it led to a short-lived (a few weeks) system and ExCom disapproved operational development in November 1966. The film scanning hardware has found a useful application in the ground elements of the [redacted] (Attachment 1 gives further historical information on the activities and rationale of the NRO in readout system development.) This basic film scan technique remains available for satellite application and is the only proven technique applicable to the COMIREX stated needs. Improvements in the lifetime of film systems can be made; however, the film and processing chemicals cause an inherent limitation in achievable life on orbit.

Applied research is currently being sponsored by the NRO on several devices which may lead to an economic readout system for continuous surveillance. These include an electronic camera with short-term dielectric tape storage, a reusable thermoplastic recording medium and several types of arrays of discrete solid state photo sensors. In addition, an Air Force program is proceeding on development of an advanced television tube called a return beam vidicon. Each of these has its own advantages and limitations and none of the developments has yet progressed to a point sufficient to allow high confidence statements of system performance, development schedule, or costs. A summary of NRO research and development program funding on readout system transducer technology for FY 1968 and FY 1969 is contained in Attachment 7.

The NRO readout research and development program up to this time has been funded at modest levels and has been proceeding on an orderly sequential basis since no urgency has been attached to development of a readout capability, and until the COMIREX report of January 5, 1968, no definition of the requirements to be met by a readout system had been put forward by the intelligence community. The approach has been to conduct applied research on the most critical elements or components of several alternative transducer concepts. No attempt has been made to pursue simultaneously the design of other system elements which would permit system and subsystem integration and reduce the lead time for full scale readout system development.

In view of the increased interest in readout systems, the NRO proposed and the NRP ExCom approved a considerable increase in research and development directed toward readout systems in FY 1970. Also, some increase in readout system research and development effort in FY 1969 will be undertaken subject to budgetary limitations and technical progress and opportunities in ongoing projects.

Since the overall system configuration is most significantly affected by the choice of transducer and its verified performance, the NRO plans to conduct an expanded program during the remainder of FY 69 and at least the first half of FY 70 which emphasizes the exploratory development of candidate transducers. Although this program is by no means as fast paced as would be possible due to FY 69 budget restrictions, it is nevertheless believed that the program is paced as much by technical limitations as by funding. Efforts on transducer development will be significantly increased in FY 1970. In addition, the FY 70 budget contains provisions for an additional effort which will be directed to the design and advanced development of the sensor subsystem and closely related system elements and components if and when an appropriate selection of transducer technology can be made. In parallel with transducer development, there is a continuing program of development under way on critical spacecraft components technology for long-lived photographic satellites which are applicable to readout systems as well as other NRO satellite programs. A summary of the status of spacecraft technology applicable to readout systems is given in Attachment 3.

SENSOR SUBSYSTEM TECHNICAL AND OPERATIONAL CHARACTERISTICS

The critical component in development of readout systems is the transducer element of the sensor subsystem. This is the device which converts light coming through the optical system either directly or via a recording medium into electrical signals for transmission. Some systems either depend upon the use of an intermediate recording medium (film, tape or other memory storage devices) while others presently contemplated would transmit the electrical signals derived from optical images directly via a communications satellite to a ground station. Of course, any set of electrical signals can be recorded on magnetic tape. However, space-qualified magnetic tape units have thus far had a maximum bandwidth of only 5 MHz, and experience in NRO SIGINT systems has shown them to be among the least reliable elements of long-lived systems. Those systems not employing a storage medium would, in general, require provision of two communication relay satellites in order to have access to at least one of them from any point over the Sino-Soviet bloc. At the present time, the only readout system which has been fully demonstrated in ground tests is the one which was proposed in the NRO FY 1967 program but not approved by the ExCom. This system uses conventional film, on-board processing and a laser scanner to convert the photographic image to an electronic signal for readout. The orbital life of a system employing this technique is limited by the amount of film and photo processing expendables which can be carried.

Another [redacted] readout system, for which all component technology has been demonstrated to some degree but which has not been tested end to end on ground is one based on return beam vidicons. However, the largest return beam vidicons being developed at this time are two-inch tubes. A system based on these small tubes would have to incorporate a nine-tube array to provide a three-by-three nautical mile frame size on the ground. The return beam vidicon presently requires 15 seconds between exposures for readout and erasure; potentially, it is believed that this may be cut in half. The 15 seconds corresponds to a travel of 60 nautical miles along the orbital track and reduces the capability of this system to cover closely spaced targets on a single pass.

The system next furthest along in terms of component development is the dielectric tape camera system sponsored by the NRO. This system is based on an electronic camera which records the optical image on dielectric tape. The tape is read out by an electronic scanning gun which provides an electrical signal for readout transmission. In the component development thus far, the most difficult problem has proved to be the attainment of adequate stability and resolution in the electron beam of the scanning gun over the entire image format. This concept should reach a laboratory breadboard demonstration during FY 1969. It is adaptable either to direct transmission via communications satellite or to image-storage for retransmission when over ground stations.

A novel type of transducer which employs a thermoplastic recording medium is STX, a composite plate of several layers which permits impinging light energy to create local electrically induced stress in the thermoplastic material. Application of heat then causes plastic flow in response to the stress pattern; on cooling the shape of the surface represents the image, and this can be read out with a light beam. The plate can be reused by reheating under conditions of no stress. Systems based on STX have not been studied in detail as yet, since the concept is still in the early stages of development.

The potential of systems based on arrays of photosensitive solid state elements as the transducer have recently been highlighted, and some research and development effort in this field has been sponsored by the NRO. There are several fundamental problems with this type of system, although the potentials for ultimate simplicity and reliability are attractive. For a given frame size on the ground and orbital attitude, the focal length of such a system is determined by the minimum spacing of elements which can be manufactured. In present projections of the manufacturing art (16 microns), this type of system would generally require a focal length about twice as large as other systems. The sensitivity of solid state array elements is such that, to provide sufficient illumination intensity to the elements; f numbers must be of the order of eight. Thus, large apertures and correspondingly large optical systems are required for solid state array readout systems. Further, in order to keep the number of elements down to a reasonable figure, it is not contemplated that an array sufficient to scan the entire frame would be provided (for example, such an approach would require two hundred million elements). Typical current designs, therefore, utilize a more limited number of elements [redacted] this linear array of elements is used to successively scan a target frame, as the image of the ground moves by the sensor at orbital rate. The sensitivity of the solid state array transducer on the basis of currently projected technology, however, is not sufficient to allow functioning at the orbital rate. Thus, a slowdown factor must be applied to the time for imaging each frame, to reduce the apparent rate of passage of a given point on the ground by about thirty times. The net effect is that 90 miles of orbital track are used to expose one frame. This type of system therefore calls for the largest optics and spacecraft of any under consideration and is the least productive in terms of photographs per pass. Of course, advances in solid state technology may alter this situation very radically over the next few years. However, at this time it is necessary to assess the overall system implications associated with this type of transducer on the basis of characteristics which can be projected from present state of the art.

The choice of a transducer for a [redacted] or near real-time readout system development program is therefore very strongly dependent upon the planned date for initiation of development. If system development were to be initiated immediately, only the film type system can be regarded as available. A concentrated advanced development effort over the next year should suffice to establish whether the electronic camera system or a two-inch return beam vidicon system would show sufficient promise to initiate development of a system using these a year or two hence. The solid state array system not only would require one or two more years of concentrated effort on the basic array technology but unless array characteristics much more promising than those evidenced today can be evolved, it would not appear to offer an attractive operational configuration on economic grounds unless it can be shown that overall system reliability increases by a factor of about 2 or more with this transducer. (Further details on transducer characteristics and research and development status of various transducer types are given in Attachment 2.)

SYSTEM CONFIGURATION, PERFORMANCE AND COST

The Warning/Indications requirements objectives given in the COMIREX report were used in combination with projections of transducer, optics and other component technology to arrive at system concepts which were assessed with respect to performance, cost and schedule. Study of these system concepts also resulted in identification of those factors in the requirements objectives which had the greatest leverage on system cost.

The potential requirement stated in the COMIREX report called for:

a. consistent production of about $2\frac{1}{2}$ ft resolution;

b. the capability to accomplish daily sampling of target categories; and

c. the capability to deliver results to the ground within [redacted] i.e., in near real-time.

These requirement statements can be considered to have the following system design implications:

a. The imagery should be of the same interpretable quality as the KH-7 in its later missions. Since imagery returned in near real-time may be the basis for quick decisions, it appears to be important to assure that quality is not compromised. However, it is important to distinguish between a normal nadir resolution of 2.5 ft and an average resolution (over all roll angles) of 2.5 ft. Moreover, there is little experience with electronically reconstructed imagery of KH-7 quality and some subtleties of the performance of the sensors and other system elements must be carefully tested before the actual intelligence content of such imagery can be known.

b. Numerous simulations made using the indications target list provided by the COMIREX for study purposes lead to the conclusions that:

(1) Target diameters are often about 2 NM, and for completely satisfactory coverage, the sensor field of view should be 3 to 5 NM; however, 3 NM or better was considered adequate for system design.

(2) Since complete access to targets in the Soviet Union above 40°N is required daily, restricting roll angles to $\pm 45^{\circ}$ results in a requirement for three satellites at 169 NM or two satellites at 254 NM in sun-synchronous orbits.

(3) Each satellite must have the ability to handle 100 targets daily. Considering climatology and sun illumination, it appears that the requirement could be satisfactorily met with these satellite arrangements although, at certain times of the year some categories will be

undersatisfied in the same sense as they are now for "COMIREX Collection Requirements for Planning" satisfaction. Considering a and b together, it is clear that a large optical system is indicated, at least of GAMBIT size, and with some sensors under consideration of DORIAN or larger size. It is clear that the system which best meets the Warning/Indications requirements objective is a spotting system resulting in a relatively small area coverage per pass. This characteristic is a direct result of the requirements statement and technology as it can be foreseen. Therefore, it must be clearly understood that such a system has limited capability in a crisis such as Czechoslovakia or the Israeli-Arab conflict, where area coverage of a limited geographical region in a relatively short time is needed.

c. For data return [redacted] at least one relay satellite is needed. Technology for such a satellite appears feasible; however, it will be a single failure point, and there are privacy questions to be examined. If longer times were permissible, some form of store and forward concept to a CONUS station or stations would be acceptable.

In order to make a preliminary evaluation of feasibility and to estimate costs and schedule, it is necessary to look at some basic system design concepts. The two principal factors affecting overall system design are the sensor (transducer) and the data return method. The data return scheme can vary from the most responsive (multiple imaging satellites which relay data through one or more synchronous equatorial satellites to a [redacted] ground station) to the least responsive (a single imaging satellite which stores imagery data on board and reads the stored data out to a ground station). As a baseline, a sensor will be assumed which can resolve 65 line pairs per millimeter (lp/mm) and which has a storage capability. This corresponds to the performance goals of the CBS all-electronic camera. All system variations based on the 65 lp/mm sensor will be referred to as System I. Since the solid state sensor has significantly different characteristics (performance goal of 30 lp/mm, no inherent storage capability but potential for simplicity and high reliability), system concepts based on such sensors will be discussed as System II. One version of System I (System IA) will be discussed here along with the corresponding version of System II. A more complete listing of System I and System II variations is given in Attachment 5.

System IA would consist of three imaging satellites, one synchronous altitude equatorial relay satellite and a ground station in the vicinity of [redacted] Based on predicted sensor performance, it is anticipated that this configuration will very nearly meet the requirements specified in the COMIREX report. The optics required for System I are a diameter of [redacted] or very nearly GAMBIT-3 size. However, the optical quality requirement is less stringent than for GAMBIT-3.

The projected solid state sensor performance results in a System II configuration including three imaging satellites, two relay satellites in equatorial synchronous orbit, and a ground station in the vicinity of [redacted] which requires optics with a diameter of [redacted] While it appears that there will be some difference in coverage capability per satellite and in the reconstructed format of Systems I and II, the sensor development and ancillary system work have not reached the point where detailed comparisons are possible. It should also be noted if some means of image storage could be provided for the solid state sensor output, the number of relay satellites could be reduced from two to one. However, detailed system reliability and cost trade offs would have to be made to determine whether this would be advantageous.

The costs which are provided in this report have been derived by analogy to corresponding costs for existing reconnaissance systems with an attempt to make adjustments for differences in complexity, increased reliability requirements (system costs are based on [redacted] average lifetime), and differences in the state of the required technology at the time of system start. Although care has been taken in deriving these costs, it should be apparent that estimating system costs, difficult in any circumstances, is especially speculative when the required technology has not been demonstrated. The estimate for System IA development and other nonrecurring costs is [redacted] and for recurring costs is [redacted] per year when the design average lifetime of [redacted] is reached. The corresponding System II costs are [redacted] respectively. These estimates are probably indicative of the relative costs of these two types of systems based on currently projected technology. A more detailed derivation and presentation of estimated system costs is provided in Attachment 5; several variants of System I are covered as well as costs for systems based on other transducers.

Although the candidate systems considered in this study all would nominally satisfy the COMIREX Warning/Indications requirements objectives, they have quite different degrees of technical definition and confidence at this time, as noted in the preceding section "Sensor Subsystem Technical and Operational Characteristics." Also, the candidate systems have quite different capabilities to perform other intelligence collection tasks. Attachment 6 provides a discussion of the general surveillance capability of the various systems considered in this study while the succeeding section, "Overall Effect of Introduction of a Warning/Indications System into the NRP," provides a discussion of the way in which such systems may replace GAMBIT or HEXAGON surveillance coverage when introduced. Also discussed in that section is the possible utility of a Warning/Indications readout system for crisis reconnaissance.

An overall summary of system characteristics, performance, and costs is given in Table I. With respect to the data shown in this Table, it is stressed that, in addition to qualifications already stated with respect to cost estimates, the figures given are based on present projections of transducer and other component performance. Only the laser-scan film system has already been demonstrated to the degree necessary to provide a reasonable level of confidence in the performance predictions. At the same time, it must be recognized that an unanticipated breakthrough in new technologies, such as solid state arrays or return beam vidicons, could result in a radical improvement in performance or reduction in cost for systems based on these transducers.

Subject to the above qualifications on the validity of data and its susceptibility to change with time, Table I shows that the laser-scan film system and the electronic camera system are both superior in overall performance and lower in cost than the systems based on the return beam vidicon and the solid state array transducers. The former systems also have intrinsic to them a film or dielectric tape image storage capability. This feature not only contributes to their lower cost as shown in Table I (because they require one rather than two communications relay satellites), it also provides a degree of redundancy, flexibility, and capability for operation in a lower capability backup mode in the event of relay satellite outage or failure since imagery could be stored until passage over a ground station for readout. Also, systems with intrinsic storage capability are capable of being developed and operated initially without a relay satellite pending determination from operational experience of the need for return times of [redacted] On the other hand, the image storage

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capabilities of the laser-scan film system and the electronic camera system are derived at the expense of some additional electromechanical components which may tend to decrease the reliability potential of these systems.

OVERALL EFFECT OF INTRODUCTION OF A WARNING/INDICATIONS SYSTEM INTO THE NRP

The overall impact of the introduction of a readout system on other NRO photographic collection programs must also be considered. Consideration of this question was put forward in the COMIREX report on the Warning/Indications system which stated "...On the other hand, we envision a multipurpose reconnaissance system that can assist in satisfying current intelligence, search, and special surveillance needs as well as respond to warning/indications requirements. This should afford possible opportunities for savings through reductions in, or elimination of, a wide variety of collection programs."

The proposed readout system would in effect provide surveillance data at $2\frac{1}{2}$ ft best resolution comparable to that expected from the HEXAGON in the same period. However, the readout system coverage would be far too small to permit replacement of HEXAGON for search. Further, the resolution of the readout system would be far too poor to permit replacement of GAMBIT for technical intelligence; it could replace GAMBIT utilization for some of the surveillance targets. However, programmed GAMBIT and HEXAGON launch rates have been reduced to low levels for FY 72 and beyond; further reductions in the number of launches of these systems would not lead to proportionate reductions in cost. This is because there is a high annual cost connected with maintaining photographic reconnaissance systems in the inventory even if the number of annual launches is small. The total cost of maintaining a system in the inventory at low launch rates includes the costs of cadres of contractor personnel capable of building, checking out and operating the system and its components; the costs of maintenance of launch facilities and crews to provide launch services and carry out launches; and the cost of high in-plant overhead expenses associated with very small volume production. In view of this situation, it appears that the most likely step that might be taken to provide off-setting cost reductions in other programs, if a readout system were introduced in 1972 or thereafter, would be to reduce either the GAMBIT program or the HEXAGON program by one launch. Conceivably, it might even be found acceptable, after experience with the readout system had been acquired, to reduce both the GAMBIT and the HEXAGON programs by one launch. Because of the low launch rates (4 HEXAGON, 4 GAMBIT) involved in these programs at that time, the corresponding cost reductions would be considerably less than the average unit cost per launch of the present programs. The cost reduction is estimated to be \$15M for a reduction of one GAMBIT and \$23M for a reduction of one HEXAGON in the period 1972 and beyond.

The readout system would also offer certain side benefits such as a capability for crisis reconnaissance; however, the amount of coverage which warning and indications systems could provide in limited geographical areas such as those which were involved in the Pueblo situation, Arab-Israeli War, and Czechoslovakian invasion is very small. For example, even ignoring the effects of weather, the number of photographs of Czechoslovakia per day which a typical warning and indications satellite would provide would be four. An additional four photographs per day could be provided of the southern half of East Germany and Poland. With currently projected performance, the solid state array type satellite system could supply only one photograph per day of Czechoslovakia and one more for the southern half of East Germany and Poland. Clearly, this would be of very limited value in a crisis situation in this region, particularly when weather is taken into account. NRO studies of readout systems more specifically optimized for crisis situations tend to focus on systems having localized search capability with resolutions of the order of 10 ft rather than $2\frac{1}{2}$. There does not seem to be, in the present state of the art, an identifiable economically attractive system for providing search of a localized area such as Czechoslovakia or North Korea at resolution of two to three feet.

The difficulty of providing adequate information in a localized area with surveillance type systems is well illustrated by the situation we faced at the time of the Pueblo incident. At that time, although we had had nine GAMBIT flights in the preceding 12 months, the aggregate surveillance coverage of North Korea provided baseline photography of only 69 of 143 COMIREX targets. On the other hand, adequate search coverage had been provided by CORONA only one month before, but the resolution was insufficient to qualify as baseline photography or to provide the necessary intelligence information. Attachments 8 and 9 summarize the photography collected by the GAMBIT and CORONA systems during the periods of the Arab-Israeli War in 1967 and the Czechoslovakian invasion in 1968. In these instances, also, the small number of GAMBIT surveillance photographs obtained is apparent in relation to the large area coverage of the CORONA search photography. However, in the intelligence readout (OAK reports) on these same missions, the GAMBIT photography generally provided data on the status of ground forces while the CORONA photography provided significant information only on air force, industrial and ship targets.

In some geographical areas, the problem of weather is limiting for surveillance systems which can provide only a few photographs per pass. For example, South China has been an area of great intelligence interest for some time now.

Discounting one mission which was not recovered, ten GAMBIT missions were flown in the period from January 1967 through March 1968; each was programmed for South China photography on every pass with access to that region. For the 15-month period, the GAMBIT coverage of the 63 priority targets in South China was as follows:

Number of Targets	Times Covered
18	0
25	1
14	2
3	3
3	4
63	

Typically, GAMBIT can photograph five priority one targets per pass and there are typically two passes providing access to a given target per mission.

The daily access to every target which would be provided by a three-vehicle Warning/Indications system would, of course, improve the coverage over a long period of time tremendously. However, weather limitations in such areas as South China could severely degrade system capabilities in a given period of time which could be of critical importance in a crisis period.

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Approved for Release: 2021/04/08 C05098490

History

A readout system was developed during the earliest satellite reconnaissance activities. The SAMOS program included a version with on-board film processing and readout over a U. S. ground station with a flying spot scanner. The system had very poor performance by today's standards and was dropped. However, the readout subsystem was later used with considerable success in the Lunar Orbiter Program. The directives which formed the NRO incorporated the decision to cancel operational readout systems but directed that exploratory efforts continue. The advent of the laser provided the opportunity to develop a vastly improved film scanning system. An engineering model of such a subsystem was developed in 1966 as a module which could be used with the GAMBIT system to provide a readout capability for crisis response. This technique had several disadvantages, the primary being that it led to a short-lived (a few weeks) system and ExCom disapproved operational development during FY 1967. The film scanning hardware has found a useful application in the [redacted] This basic film scan technique remains available for satellite application and is the only proven technique applicable to the COMIREX stated needs.

Through 1966, the considerations by the NRO of readout systems were directed mainly to a poorly defined conception of the need for quick return of data during crisis situations. This conception of need led to a number of studies of single or few pass photographic recovery systems and the specific proposal of the film readout system. It became clear after the disapproval of the film readout proposal that the need for a system to obtain photography of a limited area, limited time "hot spot" and to return it quickly was not sufficient to justify major system development. The NRO R&D program was then restructured to work toward technology appropriate to components which could form the basis for systems which would have long life on orbit and [redacted] near real-time return of photography. In February 1968, the USIB requested that the NRO explore the feasibility and general characteristics of systems which could meet a potential requirement for a "Warning/Indications" system. The potential requirements for such a system were described in terms of near real-time [redacted] return of data, surveillance quality (nominal 2.5 ft resolution), and daily sampling of a prescribed target list. Long operational life on orbit is clearly an important economic factor for this type of system and whether or not this particular system requirement actually develops, economy through long orbital life is an attractive long range objective in satellite reconnaissance systems generally.

The NRO has also continued to examine, at a low level of emphasis, low cost means of performing crisis reconnaissance. The need is characterized by a region of the globe, such as Czechoslovakia or the Sinai peninsula, where force deployment is critically important for a limited period of time. If manned aircraft overflight is acceptable and practical, based on political risk, defensive environment and availability of bases, aircraft systems can meet this type of situation more responsively, effectively and economically than any other reconnaissance system currently known. However, recent crisis situations have often been surrounded by circumstances which precluded aircraft overflight. Some of these circumstances may arise under conditions such that drone flight is permissible; in that case drones provide the best means of meeting the requirement. If satellite overflight is the only permissible technique, the need appears to be broad swath coverage at adequate resolution, on call within one day, with data return that same day, and continued daily operation for two weeks. It may be possible to accomplish such a mission with a small photographic satellite and film scan readout at costs which would be low enough to justify consideration. [redacted] period is under study by the NRO. Resolution would probably be of CORONA quality which might prove acceptable for situations where higher quality baseline photography was available. However, much further work needs to be done to establish the trade offs between resolution and area coverage for such systems. Studies and analyses are continuing on this type of readout system.

Some government advisers have recently expressed conviction that [redacted] return of imagery will prove of revolutionary value in the long run due to the opportunity for real-time control of the satellite and its sensor. This belief leads to consideration of designs which offer flexibility in control and adjustment of the sensor during operation. The NRO development efforts, at present, are broad enough that they do not preclude such concepts. When system acquisition is initiated, however, there is strong motivation for conservative approaches which minimize complexity and are based, wherever possible, on space-proven techniques.

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Sensor Technology

I. Introduction:

The element of a readout system not dependent on the use of film which appears to be pacing system acquisition is the sensor or transducer which detects the optical image and converts it into a signal for short-term nonfilm storage or radio transmission. A number of different sensor techniques have been examined over the past years, and several of the most promising are under development. At present, the only system for which all components have been fully demonstrated in end-to-end system tests is film dependent. This is the laser beam film scanning system developed by the NRO, proposed in the NRO FY 67 program but not approved by the ExCom. [redacted] This approach has life limitation for satellite application due to the amount of film and processing chemicals which can be carried aboard and the complications of the processing and film handling equipment. While it is possible in principle to develop film systems for lifetimes of [redacted] other approaches are currently emphasized which do not use film or chemicals and thus, hopefully, will lead more easily to lifetimes of a year or more. The most important of these developments will be described briefly in this paper.

Since each of these sensors has rather different performance characteristics, it will be attempted to describe their performance on a comparable mission basis. The point for comparison is derived from the COMIREX Warning/Indications study and is one system concept for meeting those needs. In a separate paper, variations of this concept with advantages and disadvantages will be described.

II. System Concept for Sensor Description:

Satisfaction of the daily sampling requirement of indicator targets requires complete daily access above 40^{O}N latitude. One configuration of satellites which accomplishes this is a system of three photo satellites at a circular altitude of 169 NM, each with an access swath of $\pm 45^{O}$. Picture return to CONUS in [redacted] requires one relay satellite if the photo satellite has multiple frame, on-board, short-term storage capability or two relay satellites if there is no such storage capability. The target characteristics are described based on a study of 1,000 GAMBIT photographs. The description is an average scene brightness of 570 ft lamberts and a target contrast on the ground of 3:1 which is presented to the satellite

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at 1.45:1. Average roll angle is 22.5°. Resolution described is as specified by COMIREX; 2.5 ft. The photo satellites are in sun synchronous orbits launched from WTR with TIIIB Agena for GAMBIT class optics or TIIID for DORIAN class optics. Details of this system concept and several variants are described in Attachment 5. Also described there are coverage factors and data return times.

III. Laser Film Scan:

A technique has been developed for rapid return of imagery which uses conventional silver halide film as a recording medium, accomplishes on-board film processing, and scans the film using a laser beam and a rotating mirror. The scanned information is transmitted to the ground where it controls another laser beam scanning device which reconstructs the imagery on photographic film. [redacted] The readout system has been demonstrated to produce high quality imagery at 100 lp/mm and 50 MHz information output per channel. A disadvantage of the technique is that the photo satellite would have a definite life limit due to the amount of film and chemicals carried; it would also have long life reliability problems associated with the film handling and processing machinery. Preliminary design studies indicate that it is feasible to obtain [redacted] life based on expendables. (Mean time to failure would be less.) The confidence in the quality of delivered imagery is quite high for this technique.

Characteristics for Specified Application

Optics	GAMBIT Class
Frame Format	6" x 12" corresponding to 4 NM x 8 NM
Frames Per Day	130
Frames Per Year	47,450
Film Capacity	57,000 ft
Film Processing Rate	0.55 in/sec
Film Readout Rate	0.55 in/sec

Characteristics for Specified Application (Cont'd)

Data Return	Film provides storage medium. Single relay satellite required to CONUS, store and dump alternative.
Processing Delay	Minimum delay between exposure and readout - one minute
Data Link	Two channels at 33 MHz information bandwidth each
Resolution Operating Point	65 lp/mm image resolution based on reconstructed hard copy on ground. Laser spot size and line-to-line spacing provide 4 lines per image spatial cycle at 65 lp/mm, thus assuring no banding or distortion.
Reconstruction	

IV. Dielectric Tape Camera:

This camera has been under development for several years. At present, the components have demonstrated performance specifications, and a laboratory model of the complete camera is undergoing development and test with the goal of demonstrating end-to-end performance during FY 69, i.e., an image is supplied to the camera and a photograph from the simulated ground station is obtained. The camera operates in a strip mode. The image is formed on a photo-cathode and converted to an electron image which is stored on dielectric tape. The dielectric tape is scanned by a precisely controlled electron beam, and the modulated return current signal is transmitted to the ground and utilized with a laser beam scanner for generation of hard copy. Specifications call for the reconstructed imagery to be capable of a quality of 100 lp/mm (tribar measurement). Maximum data rate is 50 MHz per scan channel ($2\frac{1}{4}$" wide image channel). The tape provides multiple frame storage and is erasable and reusable so no inherent life limitation exists. Preliminary system designs have been accomplished, and performance can be described as follows:

Characteristics for Specified Application

Optics	GAMBIT class, D = 43.5", f/No. = 5.89, OQF = 5.89, obscuration = 33%
Strip Width	3 channels at 2.25" = 4.5 NM (Provides 0.99 probability that 2.0 NM diameter target entirely within strip.)
Average Frame Length	6.12 inches
Maximum Frames per Revolution	130 (No weather - indicator and surveillance targets)
Maximum Readout Rate	3 channels at 50 MHz info BW; tape velocity 22mm/sec = 0.6 NM/sec
Resolution Operating Point	65 lp/mm for scene specification. Mission average resolution predicted including smear rates, focus errors = 30 inches, i.e., 50% predicted between 22 and 30 inches.
Readout Rate via Relay Satellite	3 channels at 22 MHz
Kell Factor	6 spots or lines per image spatial cycle at 65 lp/mm
Reconstruction	

V. Solid State Arrays:

Exploratory development has been conducted on a class of transducer consisting of an array of discrete solid state photo sensors. Although such devices are in an early stage of development, they offer attractive features of reliability and no moving parts. Several configurations and types of sensors are being developed, but they generally can be described as a linear array of elements, with linear density of about 60 elements per millimeter and sensitivity between 1 and 20 x ~~ft~~ 10^{-4} candle seconds at a signal to noise ratio of 5. The array must be read out during photography as no storage capability exists. It is planned that several versions of such arrays will be fabricated and tested during FY 69, leading to selection of the most promising approaches for further development in FY 70. There is very little data at present on sensitivity, noise, stability, or manufacturing yield. There has also been very little consideration given to ground reconstruction techniques. The sensitivity of these detectors is not sufficient to permit, with reasonable optics, operation at the orbital rate. Therefore, some mechanism of tracking the scene to reduce apparent image velocity is required. Quality in terms of delivered product on the ground is difficult to specify at this stage of development, and for this paper, it is assumed that if each detector cell projects to an area of 1.25 x 1.25 ft on the ground, a resolution of 2.5 ft is possible. This is generally not true if tri-bar targets are the criterion, since for low sampling rates spatial phase effects occur.

Characteristics for Specified Application
(Based on Design Goals)

Optics	DORIAN class, D = 72, F/No. [redacted] OQF = 50%, obscuration = 33%
Strip Width	9 inches - 14,400 detectors, 3 NM (0.86 probability of 2 NM target entirely in strip)
Frame Length	3 NM
Rate Reduction Factor	30 - therefore, 90 NM of orbital track to expose one frame /If parallel arrays are used - [redacted] detectors reduce track required to 18 NM./
Maximum Frames per Revolution	Estimate 15 (if one linear array), 75 if [redacted]
Resolution Operating Point	16 x 16 micron detector = 1.25 x 1.25 ft on ground
Readout Rate	10 MHz per linear array - since no storage, two relay satellites required to CONUS
Kell Factor	2 samples per spatial cycle at 30 lp/mm
Reconstruction	Not established

VI. Vidicons:

RCA, primarily under non-NRO (Air Force) sponsorship, has developed a type of high resolution return beam vidicon (RBV) which has potential applicability to a readout system. Two sizes of RBV have been fabricated, one with a one-inch square image format and one with a two-inch square image format. The one-inch RBV is being developed for space flight application by NASA for earth resources use. The two-inch RBV is under Air Force development for certain improvements pertinent to an aircraft application. Based on the modulation transfer properties of these tubes, as provided by RCA, it appears the two-inch RBV could be operated at about 55 lp/mm for the average scene conditions used here. This tube presently requires about 15 seconds between exposures for readout and erasure, but it is believed that an advanced design could reduce the frame time to about 7 seconds. Exposure requirements for these tubes are typically 0.25 to 0.30 MCS* RCA has proposed development of a three-inch square image format tube with slightly reduced resolution and a frame time of about 13 seconds. A possible disadvantage of vidicons for Warning/Indications application is that the two-inch tube would cover an area of one NM square on the ground at 2.5 ft resolution; therefore, an array of tubes would be required, 3 x 3 for a 3 NM frame size. The lifetime of the tubes is currently limited by cathode life, but improvements appear possible. The RBV can be readout between frames, or a battery of 9 wide-band tape recorders could be used for multi-frame storage, although long life reliability would be a serious question for such recorders, based on experience in NRP SIGINT satellites.

Characteristics for Specified Application

Optics	Larger than GAMBIT, D = 50", f/No. = 6.25
Frame Size	3 x 3 array of 2-inch tubes = 3 x 3 NM
Maximum Frames per Revolution	Minimum time between frames = 10 seconds; estimate 60 frames on peak revolutions
Readout Data Rate	5 MHz per tube
Resolution Operating Point	55 lp/mm
Kell Factor	3 scans per image spatial cycle
Reconstruction	Modulated laser scan

* Meter Candle Seconds

VII. STX (Screened Thermoplastic Transducer):

The transducer (developed by Xerox) consists of 1/8 or 1/16 inch thick glass plate on top of which are deposited several functional coatings. First, a thin metallic layer as an electrical ground, then a metallic screen of about 300 lines per millimeter, next a photoconductive material, and then a surface of thermoplastic material. When the surface layer is charged to a potential of several hundred volts and then the photoconductive layer is exposed to light, a charge pattern is created in accordance with the light intensity pattern. The plate is then heated to the point where the plastic flows due to the electric stress pattern, and when cooled, the surface deformation represents the light image. This pattern can be read out by a reflected light beam. The plate can be reused by heating it again under uniform electrical conditions.

The development is proceeding in encouraging fashion with a goal of producing plates of 8 x 8 inch size which can be reused perhaps 50 times. Resolution and sensitivity characteristics are predicted to be very good. This transducer is predicted to have response characteristics superior to silver halide films, inherent storage capability, and reusability. However, at this stage of development, the mechanical difficulty of handling the glass plate and implementing the heating and readout scheme is insufficiently investigated to permit confidence in describing system characteristics. STX is therefore presently regarded as a less well-defined transducer approach for a long-lived readout system than most of the other approaches described. For this reason no attempt was made to describe a system based on this transducer. However, following further development, an STX system may be of considerable interest in relation to the other alternatives described in this paper.

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Spacecraft Technology

I. Introduction:

The most critical spacecraft subsystem is considered to be the image transducer since feasibility is uncertain for several promising designs. However, there are other subsystems which require development. These subsystems are considered feasible in the sense that there is demonstrated capability to perform as required, although the actual hardware may be so far from optimum as to yield an unreasonable design. The developments which appear most critical and pacing are discussed further below. It must be noted, however, that the most critical development problem is the overall design and test of a spacecraft with at least [redacted] mean time to failure which is as complex, electrically and mechanically, as the W/I systems discussed elsewhere. Very little current experience is directly applicable to a problem of this magnitude.

II. Optics:

Several classes of optical designs have been proposed. Those which are very similar to GAMBIT are not expected to pose difficult design or fabrication problems since similarity is high and optical performance requirements are somewhat less. The question of long life performance of optical surface, mirror mounts, alignment, focus mechanism, etc., is serious but feasible and common to all optical designs proposed. Those designs which are similar to DORIAN are somewhat more difficult but, again, fall within a region where experience and confidence are substantial. Other designs are proposed which are larger than DORIAN for operation at higher altitudes and with lower performance sensors. The DORIAN test facilities are sized to accept optics up to about [redacted] diameter. Modification of these facilities would be required for the long focal lengths desired. Feasibility of such large systems is not a fundamental issue but must be recognized as a problem with substantial technical uncertainty and with highly certain impact on cost. Many of the larger designs are proposed to be of a [redacted] configuration to keep overall length in reasonable bounds. Experience does not exist with such [redacted] but, again, fundamental feasibility is not an issue. More radical designs are also proposed, particularly, off axis designs to reduce obscuration and increase the modulation transfer in the mid-spatial frequency domain. Such designs have never been fabricated in large size and pose basic questions. All-reflective designs are discussed to broaden the spectral transmission and take advantage of the spectral range of response of the solid state sensor. Such designs have also not been fabricated. The NRO has an extensive basic development program of optical technology which is pertinent to these advanced techniques but no major optical fabrication is currently planned since solutions exist within the range of current experience and no choice of advanced designs can be made reasonably until a choice of transducer can be more clearly defined.

III. Attitude Control Subsystem:

Current NRO attitude-control experience is primarily with gas reaction control systems in photographic satellites. NRO SIGINT satellites have employed spin stabilization, gravity-gradient stabilization and [redacted] However, this SIGINT satellite experience is not directly applicable to photographic satellites, particularly pointing systems, because of the much greater disturbing forces and torques which must be dealt with in the photographic vehicles. For a long-lived spacecraft as discussed, it appears desirable to consider a subsystem based on [redacted] Feasibility demonstration is anticipated late in 1969.

IV. Spacecraft Computer:

Substantial on-board computation is required for the attitude control logic of the preferred [redacted] subsystem. The computer should also be able to handle a number of other computational functions for command and control of the satellite. The computational capacity required is moderate in terms of existing technology but the long-life requirement is a substantial advancement over anything in existence. Exploratory development is under way of candidate designs for a satisfactory computer. However, it is not anticipated that the NRO will sponsor development of a basically new vehicle-borne computer. Rather, it is intended to influence the already considerable industrial and government sponsored effort to meet potential NRO requirements.

V. Data Link:

As has been mentioned, the spacecraft technology required for the relay satellite is very similar to that of the [redacted]

The uplink presently identified for readout of the photo satellite to the relay satellite is at [redacted] Several studies and developments are under way for components of a [redacted] link. The Air Force is supporting specific developments as a preliminary to design of control satellites to supplement ground tracking stations for general command and control. The NRO is following this development closely.

If privacy is not a requirement, the choice of uplink relay frequency would be made on the basis of availability of reliable space-qualified components, radio-frequency interference factors, and trade-offs of read-out satellite antenna size, gain, tracking mechanism and power for optimum system design.

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Comparison of Warning/Indications Requirement and Lunar Orbiter Performance

The lunar orbiter was designed to achieve lunar surface resolution of approximately 3.24 feet from a nominal altitude of 46 kilometers or 25 NM. Scaled up to a practical altitude for an earth satellite, the lunar orbiter sensor would provide no better than 22 ft resolution at an altitude of 169 NM.

The lunar orbiter data rate was 100 KHz information bandwidth. A practical Warning/Indications system (System I) would require at a minimum 66 MHz of information bandwidth or in other terms a bandwidth which is greater than that of the lunar orbiter by a factor of 660.

Lunar orbiter carried a film load of 247 inches. A [redacted] [redacted] film scan Warning/Indications satellite would have to carry 57,000 ft of film.

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Approved for Release: 2021/04/08 C05098490

SYSTEMS AND COSTS

The purpose of this section is to describe several possible basic readout system configurations, variations of these configurations and the associated costs. This is done to illuminate the effect that different sensors and different data return schemes have on a system's cost and on its performance as an intelligence gathering device, measured in terms of the Warning/ Indications requirement.

Table I is a matrix of potential sensor/system configuration combinations. From Table I it can be seen that the system configuration is dependent upon whether or not the sensor has an inherent data storage capability. If it does, imagery can be acquired, stored on-board and read out over a ground station or to a single data relay satellite and then to a ground station. If there is no on-board storage capability, two data relay satellites are required in order to provide a continuous data link from the sensor satellite to the ground station for all of the Warning/Indications targets.

In order for readout systems to be economically feasible, they must be long-lived and this infers that system reliability is important. This favors the simple sensor with few or no moving parts. It also infers that a system which depends on on-board film processing must be able to carry a very long lasting supply of film and chemicals in order to be competitive.

In discussing the various system configurations, it has been necessary to depend heavily on a preliminary design study which was done jointly by the Special Projects Directorate (SAFSP) and the Aerospace Corporation. This study was based on system configurations using the electronic camera as the sensor. Most of the data presented for configurations using other sensors is based on extrapolations from the SAFSP/ Aerospace study using sensor data provided by SAFSP and the CIA Office of Special Projects.

In summary form, the parameters specified for a Warning/ Indications System in USIB-D-46.4/3 are as follows:

"a. Consistent production of about two and one-half ft resolution,

b. The capability to accomplish daily sampling of target categories; and

c. The capability to deliver results to the ground within about an hour, i.e., in near-real time."

The Warning/Indications Target Deck contains a total of 505 individual targets. These targets are divided into 14 categories and a daily requirement is specified for each category.

For example, Category 1, Nuclear Power Ballistic Missile Submarine Bases, contains a total of 14 targets of which five to six are to be imaged each day. Table 2 is a list of the Warning/Indications target categories and the daily requirement for each category.

The first system configuration to be discussed will be referred to as System IA. It is based on the predicted performance of the electronic, dielectric tape camera. This sensor has the advantage of relatively high resolving power (65 line pairs per millimeter), and good sensitivity. It has the disadvantages of some moving parts, principally, the dielectric tape transport, and the requirement for very precise control of an electron beam in the readout gun section.

A study has been accomplished to determine the overall characteristics of a system, based on the electronic camera, which would satisfy the COMIREX Requirement for a Warning/Indications System. In the initial portion of the study, varying orbit orientations, orbit altitudes and numbers of sensor satellites were evaluated. The system selected for discussion here consists of [redacted] sensor satellites, one dedicated relay satellite and one ground station. The [redacted] sensor satellites are in 169 N.M., circular, sun-synchronous orbits spaced one-third of a revolution apart. The sensing system consists of Cassegrain type optics with a [redacted] and the electronic camera. Data readout can be accomplished either by delayed readout to a mission ground station via an [redacted] downlink or by relay satellite via a [redacted] uplink.

The relay satellite is in a synchronous equatorial orbit at approximately 90 degrees west longitude. The relay satellite receives the [redacted] uplink from the sensor satellites and retransmits to the ground station via an [redacted] downlink.

The ground station is located near [redacted], and produces photographic images using existing [redacted]

In terms of performance, System IA very nearly satisfies the COMIREX Requirement. The requirement is not completely satisfied because of inadequate lighting of the high latitude targets during the winter months. The problem is not target access; therefore, adding more sensor satellites does not help. The number of negative sun angle days by target category is provided in Table 3. A comparison of the average number of cloud free photographs in January and June versus the daily requirement is given in Table 4. It should be noted that the weather data used to compute the number of cloud free images in January and June are believed to be pessimistic.

System IA, with a very small increase in workload (17%) could also fulfill the minimum surveillance requirement based on the May 1968 COMIREX deck of approximately 5200 surveillance targets.

Table 1 depicts three variants of System IA. These variants are based on data return schemes which do not require a data relay satellite. System IC employs two CONUS ground stations separated by at least 2000 N.M. This provides sufficient ground station access time per satellite per day to readout the requisite number of Warning/Indications targets. However, there is not sufficient ground station access time to perform both the Warning/Indications and the surveillance tasks. Whereas System IA meets the one hour data return requirement, System IC data return can take as long as 10 hours.

System ID employs one ground station at Thule which, due to its high latitude, provides adequate readout time to perform both the Warning/Indications and the surveillance tasks. Data return time to Thule is one hour. Assuming that the imagery is required in Washington, D.C., a Thule to Washington data link would be required and the data return to Washington would require as much as four hours.

System IE employs only a [redacted] ground station. Due to the limited data return time provided by one station at relatively low latitude, it is only possible to return approximately 50% of the imagery required to fulfill the COMIREX requirement. Therefore, System IA will provide System IE performance in the event of a relay satellite failure.

System IIB is based on the solid state array sensor. A detailed system study is not available. However, based on available estimates of expected solid state sensor performance, an estimate of the optics required to meet the 2.5 foot resolution requirement from 169 N.M. has been made. (Optics of approximately DORIAN size are required.) This allows some performance estimates to be made based on similarity to the System IA orbital geometry. In terms of the Table 1 variations, the solid state sensor lends itself to only one configuration, i.e. [redacted] satellites, two data relay satellites and one [redacted] ground station. The requirement for two data relay satellites is a direct result of the lack of an on-board storage capability since one relay satellite cannot be positioned so as to simultaneously see the ground station and the sensor satellites at all points of the sensor satellite tracks where imagery must be obtained. There are several possible modes of operation when two relay satellites are required. These include two relay satellites in highly elliptical, high inclination orbits, and two synchronous equatorial relay satellites with the data stream going sensor to relay to relay to ground. A comparative evaluation of the possible modes of operation has not been made.

From information available at this time, it appears that it will be necessary for the solid state sensor to scan the ground at some rate less than the rate at which the satellite is passing over the ground. This so called "slow down" factor may be on the order of 10:1. In order to extrapolate the target coverage information from the System 1A study, a slow down factor of 6:1 was assumed. Based on the Warning/Indications requirement only, the slow down factor results in an average coverage reduction of approximately 10%. The penalty is more severe if the surveillance task is added.

Only one more of the available system configurations will be discussed. This is System IIIA, based on the film scan device. System IIIA and its variants are included principally in order to point out the nonrecurring cost advantages associated with this system. Since the sensor module has been designed and since it was designed to be compatible with an existing spacecraft/optics combination, the development costs for this approach would be much less than those for the Systems discussed previously. On the other hand are the uncertainties associated with carrying sufficient film and chemicals and achieving a satisfactory system longevity. Preliminary calculations indicate that such a system must achieve a lifetime approaching one year in order to be competitive.

Since the imaging medium in this system is film, it is assumed that the performance of System IIIA will be at least as good as the performance of System IA. It was also assumed for costing purposes that a [redacted] lifetime can be achieved. However, the average lifetime of System IIIA can never equal the [redacted] figure which was assumed for System IA since it cannot exceed its expendables life limit of one year.

A cost/performance summary for System IA, IIB, IIIA, and their variants is included in Table 5.

In any readout system, the imagery arrives at the ground station in the form of an electrical signal. This makes it very convenient to perform some form of image enhancement by operating on the imagery intelligence while it is still in an electrical form. Indeed, signal processing will be required for some of the sensors under consideration.

Signal processing can range from the most simple techniques, such as boosting the high frequencies, to very complex two dimensional schemes, requiring digital computers, where it may be possible to compensate for such things as focus errors and image motion compensation errors. For some of the solid state array configurations under consideration, ground processing will be required in order to put the image back together in the correct sequence.

[redacted] has provided experience with the more simple forms of image processing and has demonstrated the desirability of some amount of processing. The more sophisticated techniques which require digital processing tend to require relatively large amounts of computer time and, therefore, cannot be performed in an "in-line" fashion. It will most likely prove feasible to use these digital techniques only on a very selective basis.

As image enhancement/ground processing is relatively new, there are many unanswered questions. Will some processing be accomplished "in-line" on the incoming signal or will the original signal be stored for "off-line" processing? Will it be practical to store the incoming data stream? Will the adjustment of in-line processing parameters be a photo interpreter function? Some of these questions and many others are being studied now, but there is an undeniable need for much future work in this area.

It should also be pointed out here that the readout system as described will present the interpretation community with a nearly continuous near real-time stream of imagery. This will undoubtedly require some changes in evaluation and reporting techniques and procedures.

In the absence of detailed system designs and corresponding contractor cost proposals, it has been necessary to estimate costs for the various system concepts by analogy to existing reconnaissance satellite systems. GAMBIT-3 costs were used as a basis for System I costs since the System I and GAMBIT-3 optics are very nearly the same size. Cost increments were then added to the basic GAMBIT-3 costs to account for the more stringent reliability requirements [redacted] average on orbit lifetime required for a readout system contrasted with 10-20 days required life for GAMBIT-3), increased system complexity, and difference in prior experience (GAMBIT-3 had a wealth of prior film return system experience to draw on, whereas we have not yet developed and flown a readout system). This approach was taken for both nonrecurring and recurring costs. Based on the similarity to GAMBIT-3 optics and best estimates for other subsystem weights, it appears that the Titan IIIB Agena booster will be adequate for System I.

System II cost elements are the same as System I in some areas; data link satellite development, data link satellite costs, ground station acquisition and ground station operation; but they are greater in those areas affected by the larger physical size of the System II spacecraft. HEXAGON costs have been used as a basis for the System II sensor satellite costs with the same adjustments being made or were made for System I and with an additional adjustment to account for the DORIAN sized optics. It is assumed that the HEXAGON booster (Titan IIID) will be adequate for the System II sensor satellite since the weight of the larger optics will be offset by the absence of film and re-entry vehicles.

In developing the Data Link Satellite costs, it was assumed that the [redacted] spacecraft can be modified to satisfy the Data Link requirements. Therefore, costs were derived from estimated [redacted] costs.

The following is a list of the basic estimated cost elements associated with System I:

a. Readout Satellite Development

b. Readout Satellite Unit Cost (Launched)

c. Data Link Satellite Development

d. Data Link Satellite Unit Cost (Launched)

e. Ground Station Acquisition

  (1) MCP

  (2) Installed Equipment

f. Ground Station Operation and Maintenance (per year)

[redacted]

The System II cost elements are the same except for:

a. Readout Satellite Development [redacted]

b. Readout Satellite Unit Cost (launched)

The total non-recurring and recurring costs for the various systems described previously are derived from the cost elements listed above and a development schedule. The System IA and IIB costs will be derived here as an example. The other System costs were derived in a similar fashion.

In computing System I non-recurring costs, it was assumed that the ground station is in operation for the last three years of the five year development cycle. Therefore, the non-recurring costs include three years of ground station O&M. In addition, the non-recurring costs are based on a total [redacted] launches, including development launches and the launches required for establishing the system.

The breakdown between non-recurring costs and recurring costs in this paper places all costs through establishment of the full system into the non-recurring category. The recurring costs are then simply those costs required [redacted] plus the ground station O&M and a nominal figure for program overhead to include improvements, etc.

No distinction has been made between System I and System II inherent reliability in arriving at system costs. Arguments can be made that the solid state sensor is inherently more reliable than the dielectric tape camera. On the other hand, the solid state sensor may require not only larger, but also more radical optics. These factors will affect system costs but are not well enough defined at this point to be included in a cost estimate.

Based on the foregoing assumptions, the System I costs are as follows:

<u>Non-Recurring</u>

Development [redacted]

Initial System Establishment [redacted]

Data Relay Satellite Development

Data Relay Satellite Launch

Ground Station Acquisition

Ground Station O&M (3 yrs @ $12M)

Total Non-Recurring Cost

[redacted]

Recurring

Replacement Sensor Satellite Launches [redacted]

Replacement Data Relay Satellite Launches

Ground Station O&M

Program Overhead

Total Recurring Cost per year

The System II Costs are:

Non-Recurring

Development

Initial System Establishment [redacted]

Data Relay Satellite Development

Data Relay Satellite Launches [redacted]

Ground Station Acquisition

Ground Station O&M [redacted]

Total Non-Recurring Cost

[redacted]

Recurring

Replacement Sensor Satellite Launches [redacted]

Replacement Data Relay Satellite Launches [redacted]

Ground Station O&M

Program Overhead

Total Recurring Cost per year

System Configuration / Sensor	A: [redacted] Sensor Sats, 1 Data Relay Sat, [redacted] ground station	B: [redacted] Sensor Sats, 2 Data Relay Sats, [redacted] ground station	C: [redacted] Sensor Sats, 2 CONUS ground stations separated by 2000NM	D: [redacted] Sensor Sats, Thule ground stations. [redacted] Data Link to [redacted]	E: Sensor Sats, [redacted] ground station	REMARKS
I Electronic Camera	IA	X	IC	ID	IE	--Good sensitivity and resolving power --Requires dielectric tape transport mechanism and precise control of electron beam in readout section --Has inherent data storage capability
II Solid State Array	X	IIB	X	X	X	--Less sensitivity and resolving power than System I sensor --Sensor has no moving parts --No inherent storage capability; therefore, configurations A, C, and E are not feasible
III Film Scan	IIIA	X	IIIC	IIID	IIIE	--Good sensitivity and resolving power --Life limited by film and chemicals --Long term reliability of film transport could be problem
IV Vidicon	IVA	X	IVC	IVD	IVE	--Format size and frame time are main problems --Sensor has no moving parts --Requires additional on-board storage device (tape recorders) in C, D and E configurations
V Thermoplastic	VA	X	VC	VD	VE	--Good sensitivity and resolving power --Requires moving glass plates or flexible belt past the image plane --Has inherent data storage capability

SENSOR/SYSTEM CONFIGURATION MATRIX

TABLE 1

WARNING/INDICATIONS DECK SUMMARY

Category	Description	Number of Targets	Daily Coverage Required
1	Nuclear Power Ballistic Sub Bases	14	5-6*
2	Other Missile Sub Bases	24	6-10*
3	Long Range Heavy Bomber Bases	6	3-4
4	Long Range Staging Slant Recovery Bases	23	6-9
5	Medium Bomber Bases	22	6-9
6	Fighter Deployment Bases	22	6-9
7	Ground Force Bases	43	8-15
8	Ground Force Tank and Motorized Rifle Units	77	9-18
9	Airborne Transport Bases	17	5-8
10	Airborne Regiments	23	6-9
11	Transloading Yards	5	2-3
12	Tactical Missile Support Facilities	8	4-5
13	Soft ICBM Sites	77	8-18
14	Soft IR/MRBM Sites	144	9-20
	TOTALS	505	83-143

*Stereo Required with 35 Degree Obliquity Limit.

TABLE 2

SUMMARY OF INDICATOR TARGETS NOT ILLUMINATED BY THE SUN

Category	Number in Category	Interval of Negative Sun Angle (Days)	
1	6	November 28 - January 14	(47)
2	12	November 24 - January 18	(55)
4	7	December 5 - January 6	(32)
4	7	November 25 - January 17	(53)
4	4	November 16 - January 26	(71)
4	2	October 13 - March 1	(137)
6	5	December 5 - January 6	(33)

TABLE 3

SYSTEM I COVERAGE COMPARISON

Category Number	Daily Requirement	Average Number of Different Indicator Targets Programmed	Average Number of Cloud Free Photographs	
			January	June
1	5-6	10.5 (4.5)	1.40	2.29
2	6-10	15.0 (6.2)	1.60	3.57
3	3-4	5.3	1.83	2.33
4	6-9	22.3 (0)	0	5.77
5	6-9	9.5 (9.0)	2.87	3.18
6	6-9	18.5 (13.5)	4.21	5.43
7	8-15	25.3	6.56	9.70
8	9-18	28.0	7.98	11.84
9	5-8	14.3	3.23	5.71
10	6-9	13.8	3.74	6.19
11	2-3	4.3	2.15	2.15
12	4-5	5.8	1.37	2.11
13	8-18	59.3 (51.7)	13.37	18.09
14	9-20	48.8	11.87	19.01

(Values in parentheses are number of targets programmed in January with positive sun angles.)

HANDLE VIA [illegible] CONTROL SYSTEM / HANDLE VIA TALENT-KEYHOLE CHANNELS

TABLE 4

COST PERFORMANCE SUMMARY

System	Coverage[1/]	Max Data Return time (hrs)	Costs[2/] Non-Recurring	Recurring
IA	100% every day*	1		
IC	100% every day	10		
ID	100% every day*	4		
IE	50% every day	10		
IIB	100% every day*	1		
IIIA	100% every day*	1		
IIIC	100% every day	10		
IIID	100% every day*	4		
IIIE	50% every day*	10		

*Has additional surveillance capability

1/ Coverage in % of Warning/Indications Target Deck

2/ Cost in millions of dollars. Non-Recurring costs include system establishment. Recurring costs are yearly costs required to maintain system including replenishment launches.

TABLE 5

HANDLE VIA BYEMAN HANDLE VIA TALENT-KEYHOLE [illegible] CONTROL SYSTEM

6

Approved for Release: 2021/04/08 C05098490

Comments on USIB Document (USIB-D-46.4/3), "Requirements for Image Forming Satellite Reconnaissance Responsive to Warning/ Indications Needs"

The purpose of this paper is to provide a detailed discussion of the effect of various requirements statements on Warning/ Indications system design.

Those requirements which were stated explicitly in the COMIREX report are listed below.

a. Consistent production of about $2\frac{1}{2}$ foot resolution,

b. The capability to accomplish daily sampling of target categories, and

c. The capability to deliver results to the ground [redacted] i.e., in near real time.

The following additional requirement parameters are necessary to adequately define a Warning/Indications system and should be treated in any further statement of requirement.

d. The image delivery location,

e. The degree of security to be afforded the data return process,

f. The capability for imaging other (non-Warning/ Indications) targets, and

g. The system reliability, i.e., what degree of degradation could be tolerated and for how long.

Each of these fundamental requirement parameters will be discussed below in some detail with emphasis being given to their effect on system design.

a. Resolution. The COMIREX report contains the following statement, "Consistent production of about $2\frac{1}{2}$ foot resolution." This statement could be interpreted in any of several ways. It could be taken to mean a mission average resolution of 2.5 ft at nadir, a mission average resolution of 2.5 ft over the access swath, or that no imagery would be worse than 2.5 ft resolution. These are ordered in increasing severity. Therefore, future requirement statements should specify the resolution parameter as explicitly as possible. Based on electro-optical sensor work to date and preliminary system studies, the achievement of 2.5 ft mission average resolution over the access swath appears quite feasible. It should be noted that 2.5 ft mission average resolution over the access swath means 2.5 ft average resolution at 22.5 degrees off nadir (assuming a swath of 45 degrees either side of nadir) and correspondingly better resolution for targets nearer nadir and poorer resolution for targets at locations farther than 22.5 degrees from nadir. Another interpretation of this requirement is that imagery of later KH-7 quality is desired.

b. Target Sample Frequency. The COMIREX requirement in this area reads, "The capability to accomplish daily sampling of target categories." Satisfaction of the daily sampling requirements in TAB C of the COMIREX study requires photographic access to the entire list daily. Even then, because of the high latitudes of some of the targets and the weather situation, the studies to date indicate that the requirement cannot always be fully met, particularly in the winter. The studies do show that a [redacted] photographic satellites operating at about 169 NM comes quite close to satisfying the requirements as stated. With this concept, if other specifications of the requirement remain fixed, the system design is not particularly sensitive to the size of the target deck provided changes are not in a direction that increases the target density in current high density areas. The design is sensitive to the sampling interval and the sample size required. For example, relaxation of the sampling interval to every three days could allow reduction in the number of photo satellites required at 169 NM [redacted] to one. Paragraph 11 of the COMIREX document is also significant in regard to this question. The costs involved in continuous operation of a multi-satellite imagery system inevitably lead to the serious question of the economic feasibility of a system dedicated solely to the Warning/Indicator mission. Fortunately, if adequate data return capacity is provided, some of the system concepts considered will have collection capacity and access such that a great deal of other imagery can be acquited without interfering with the imaging of the Warning/Indicator targets.

c. Image Delivery Time. In this respect, the COMIREX report reads as follows, "The capability to deliver results to the ground [redacted] i.e., in near real-time." As was mentioned previously, this parameter has a profound effect on system design. Image Delivery Time can be varied from a minimum of [redacted] (essentially the ground film processing time) for a system employing several relay satellites to a maximum of about 12 hours for a system in which the sensor satellite(s) transmits directly to the ground station.

d. Image Delivery Location. As would be expected, this parameter and the previous one are deeply interrelated in that the delivery time is strongly affected by the delivery location requirement. For example, the data quantity requirement (paragraph b above) can be met by any of the following:

(1) A synchronous relay satellite reading down to a ground station anywhere in CONUS. (Two relay satellites are required if the sensor satellite does not have an on-board storage capability.)

(2) A single ground station in the vicinity of Thule.

(3) A ground station in the vicinity of Thule supported by a low data rate satellite link to a [redacted] ground station.

(4) Two CONUS ground stations separated by about 2,000 miles.

If the ground station is also the Image Delivery Location, (1) and (2) will satisfy the Delivery Time requirement. Delivery Time for (4) can be as much as [redacted] If the Delivery Location is in [redacted] only (1) with the ground station very near [redacted] will satisfy the Delivery Time requirement. The data return concept indicated by (3) above assumes a limited analysis capability at Thule, e.g., sufficient to select the photographs of immediate interest. After a preliminary screening, these photos (which will probably constitute less than 30% of the total take) could be retransmitted to [redacted] via a communications satellite at a lower data rate. This concept could provide data return times on the order of [redacted] for the case where [redacted] is specified as the delivery location. Another concept, not listed above, involves a ground station in the vicinity of [redacted] and no relay satellites. This concept would provide a marginal data capability for the current Warning/Indicator deck and an overall capacity far less than the collection capability of the system. Further, the Delivery Time can be as great as [redacted]

e. Image Return Security. This subject is not addressed in the COMIREX report. Any future statement of requirements for a Warning/Indications system should provide guidance in this area. There are techniques for providing a number of different levels of protection against intercept. They all consist of various combinations of physical denial and encryption. Physical denial, in general, imposes fewer system design penalties; but once the transmission is intercepted, the interceptor will almost certainly be able to determine that photographic information is being transmitted. Depending upon the quality and duration of the intercept, he may be able to determine the approximate upper bound of system performance, he may be able to reconstruct a few lines of degraded imagery, he may be able to identify the areas being imaged, and he may be able to make a reasonable assessment of the mission of the intercepted system. Encryption would impose some system penalties. However, if an encrypted transmission were intercepted, the interceptor could infer nothing more than the fact that a very large quantity of data is being transmitted to the ground station.

f. Capability Against Other (non-Warning/Indications) Targets. The COMIREX report treated this item in a general way in paragraph 11 which states in part, "Requirements should be interpreted as calling for a flexible system that can carry out the Warning/Indicator role and at the same time possess a capability to assist in satisfying routine current intelligence and special reconnaissance tasks." Paragraph 21 is also pertinent and it states, "We believe that except for crisis periods, once familiarity with individual installations is obtained and norms have been recorded, sampling rates can be reduced, thereby permitting a greater percentage of system capability to be used in satisfaction of routine or special surveillance needs." Paragraph b above contains a general statement concerning non-Warning/Indications targets. It is pointed out that if adequate data return capacity is provided for the Warning/Indications mission, any of the system concepts considered will be able to acquire a great deal of other imagery in addition to that imagery required to satisfy the Warning/Indications role. For example, the May 1968 COMIREX requirement for the deck of approximately 5200 surveillance targets stated that a minimum of 3757 targets, including duplicates, need to be photographed each year. This was subject to the further restriction of:

893 unique targets	once/3 months
1187 unique targets	once/6 months
2431 unique targets	once/12 months

To satisfy the total yearly requirement stated above, a system would need to photograph an average of approximately 11 cloud-free targets per day. Multiplying by a factor of three for weather and a factor of 1.6 to account for the fact that 60 percent of the targets are required in stereo, it is seen that the average number of exposures required per day to satisfy the minimum requirement is approximately 53. With [redacted] satellite system, this implies an average [redacted] exposures per satellite per day, which is only a [redacted] percent increase in work load over the average of 100 exposures per day required for the Warning/Indicator mission alone. From the foregoing, it can be concluded that the typical Warning/Indications system will have some degree of capability against other (non-Warning/Indications) targets or that the addition of such a capability would not be a major undertaking.

The most appropriate statement of requirement in this area would be one that establishes the relative importance between the primary Warning/Indications mission and the "other targets" capability which might be included in the design considerations.

g. System Reliability. This requirement should be stated in terms of the maximum degradation in Warning/Indications target coverage which is acceptable and for what period of time. Such a statement would, in turn, allow the system designer to provide the necessary alternate (degraded) modes of operation, and it would also help to specify the required reaction time of replacement satellites.

In summary, the COMIREX report provided adequate guidance for an initial feasibility study. However, any future statement of a Warning/Indications requirement should treat all of the parameters a through g above.

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NRO Electro-Optical Sensor Program

CIA/OSP (Thousands)

	FY 68 (Obligated)	FY 69 (Approved)	On Contract Nov 30
a. [redacted] (STX)	[redacted]	[redacted]	[redacted]
b. Tech Ops (Fiber Optics)	[redacted]	[redacted]	[redacted]
c. [redacted] (quasi-linear array)	[redacted]	[redacted]	[redacted]
d. [redacted] (linear array)	[redacted]	[redacted]	[redacted]
e. [redacted] (photo-diodes)	[redacted]	[redacted]	[redacted]
f. [redacted] (Optical System Design)	[redacted]	[redacted]	[redacted]
g. [redacted] (Data Processing	[redacted]	[redacted]	[redacted]
h. [redacted] (Data Processing)	[redacted]	[redacted]	[redacted]
i. RCA Vidicon	-	-	-

SAFSP (Thousands)

	FY 68 (expend)	FY 69 Approval	FY 69 Obligated
a. [redacted] Electron Camera	[redacted]	[redacted]	[redacted]
b. [redacted] Data Link	[redacted]	[redacted]	[redacted]
c. [redacted] Solid State Gun	[redacted]	[redacted]	[redacted]

Handle via BYEMAN Control System

HANDLE VIA TALENT-KEYHOLE CHANNELS

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8

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CZECHOSLOVAKIA INVASION RECONNAISSANCE

The actual invasion of Czechoslovakia took place on August 20, 1968, at approximately 2100Z. The airlift/airborne portion of the invasion occurred the following day at about 0400Z.

Two NRP satellite missions are of prime interest to this crisis; GAMBIT 4315 (6 - 16 August) and CORONA 1104 (8 - 21 August). Other missions in this general period are shown in Table I. The collection effort in the Central European area during the crisis is reflected in Table II and Maps I and II.

Coverage of air, naval and missile targets followed a consistent pattern throughout the period, and redirection of priority of coverage was not requested inasmuch as those targets normally get a high level of attention. Redirection of collection effort for ground force targets was requested on July 27 when 49 targets in areas contiguous to Czechoslovakia were nominated for high priority collection effort. These nominations contributed to the increased emphasis given to the Central European area on missions 4315 and 1104.

In regard to the coverage of the crisis area, GAMBIT 4315 probably obtained about as much coverage as one would hope to get from a high resolution satellite whose orbit is tailored for coverage of the entire Soviet land area. Both ascending and descending coverage was obtained of the crisis area and the weather in the area was generally good.

CORONA 1104 was in orbit from August 7 - 22, 1968, and had obtained continuous coverage from the Baltic down through Czechoslovakia prior to the invasion on August 20. Two passes over the crisis area were made following the invasion. These covered most of Czechoslovakia, E. Germany and Hungary plus the eastern 1/3 of Poland.

As regards the information content of the coverage, the following highlights are noted:

4315 - Photography of August 7 revealed that the 97th GMRD at Slavuta in the Carpathian MD had increased its major items of equipment from 1300 to over 2400. This indicates the division to be at near full combat strength.

GAMBIT/CORONA

TABLE I

Mission	Date
4314	6 - 15 June
1047	20 June - 5 July
4315	6 - 16 August
1104	8 - 21 August
4316	10 - 20 September

TABLE II

Country		Coverage Programmed			
	Mission #4314	1047	4315	1104	4316
Czechoslovakia	45	64	40	763	12
East Germany	190	0	174	1401	39
Hungary	33	171	91	123	19
Poland	36	243	81	399	28
Rumania	21	199	22	183	23
	325	677	408	2869	121

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4315 - On August 12 military deployment in the Kornevo area of the USSR, within one mile of the Polish border indicated significant military activity in that area. Other sightings in the Chernyakhovsk area revealed large amounts of military equipment on rail cars.

4315 - Out of garrison deployment was noted by two divisions of the 28th Army in the Belorussian MD and in the Odessa MD there were noted large amounts of civilian trucks alongside the Tiraspol training area and high military activity in the Tiraspol Army barracks. This indicated mobilization was in progress.

4315 - Significant activity in the Muckachevo area revealed an increase in AOB; activity in the army training area; tents in POL storage area; and many civilian trucks alongside. This indicated mobilization or increases in military posture.

1104-1- The Czechoslovak borders with East Germany and Poland are partially covered by one photographic pass, the analysis of which was hampered by scattered to heavy clouds and poor to fair interpretability. No significant ground force activity is observed. A significant change in air order of battle was noted at Szprotawa Airfield, Poland, where 65 probable Fishbed and two probable FAGOT/FRESCO are observed. This represents an approximately 75 percent increase in aircraft since May, 1968. At Welzow Airfield, East Germany, 34 light straight-wing, five small swept-wing, and 23 small aircraft are observed. This represents an increase of approximately 50 percent in air order of battle normally observed at this field. In Northern Poland, a permanent-type occupied SA-3 SAM site is identified adjacent to Kolobrzeg Airfield. Previously, SA-3 equipment was identified at this airfield on mission 4312, April 1968.

1104-2- Soviet deployment to the border areas is evidenced at Zendek Airfield, Poland, approximately 40 NM from the Czechoslovakian border, where 22 probable cub are present, 20 of which are parked nose to tail along the parallel taxiway. Other aircraft at the airfield include seven probable Fitter, 20 Fishbed, and 27 FAGOT/FRESCO. Eight rows of vehicles/pieces of equipment are parked on grass in the vicinity of the probable cub aircraft. Also, at Olawa Airfield, Poland, approximately 35 NM north of the Czechoslovakian border, 19 Firebar-type aircraft are observed. This is the first identification of fighter aircraft at this airfield. No significant ground force activity is observed.

HANDLE VIA BYEMAN CONTROL SYSTEM /TALENT KEYHOLE

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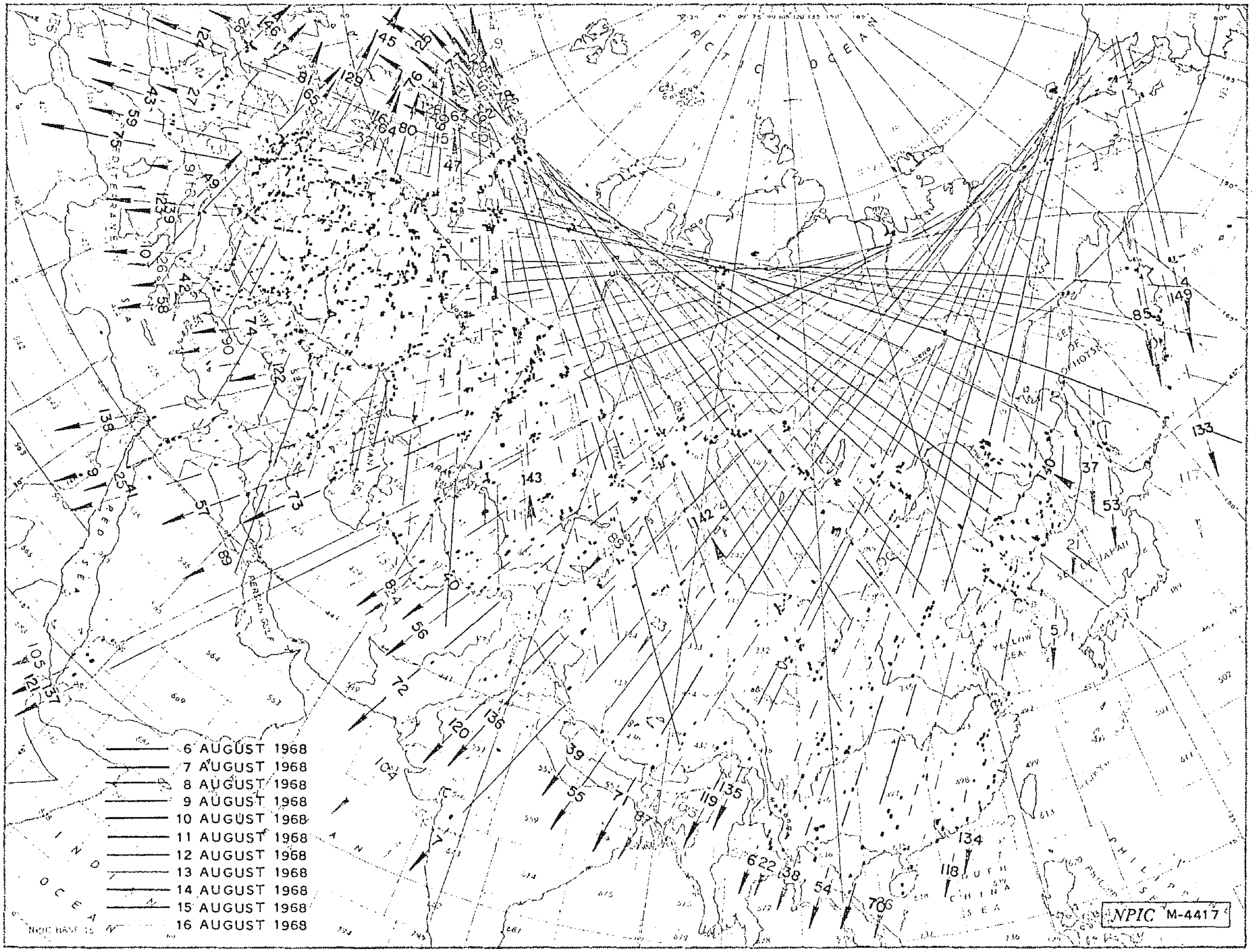
KH-8 MISSION 4315, 6-16 AUGUST 1968

MAP 1



APPROXIMATE TRACK AND COVERAGE OF MISSION 4315, 6-16 AUGUST OVER EURASIA.

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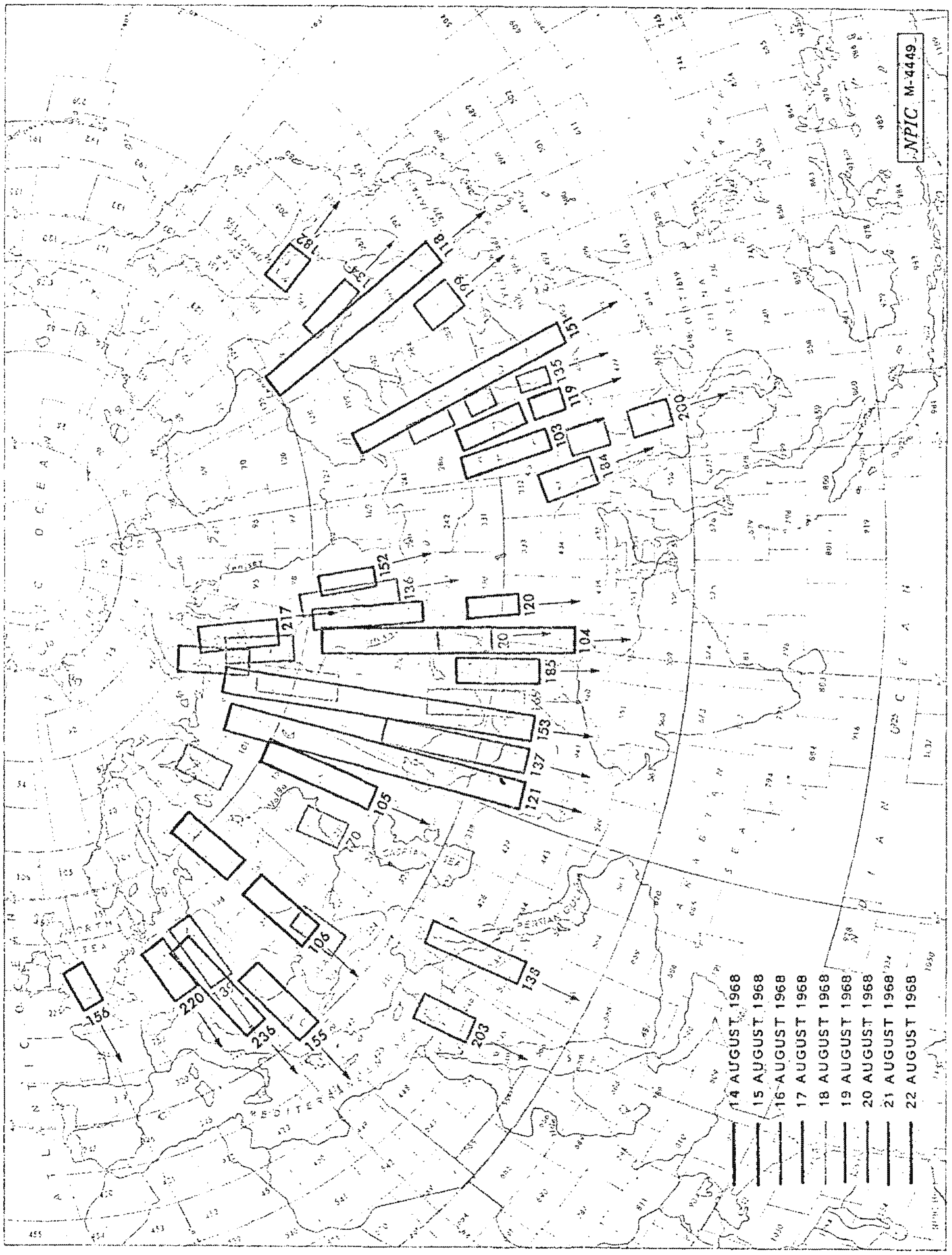
TALENT-KEYHOLE
Control System Only

TCS-20312/68

KH-4 MISSION 1104-2, 14-22 AUGUST 1968



APPROXIMATE COVERAGE OF KH-4 MISSION 1104-2, 14-22 AUGUST OVER EURASIA

MAP 2

ARAB - ISRAELI WAR RECONNAISSANCE

On June 6, 1967, when the Israeli-Arab war commenced, GAMBIT 4038 had just been launched. This was the GMAIC mission aimed primarily at Sary Shagan. Pass #9 went through the Arab-Israeli area, and 12 targets were read out from the 9 frames of coverage. Following Pass #9 an orbit adjust occurred, and 4038 did not pass through the area again. All photography was of good GAMBIT quality. (Map 3)

Following the war, on June 22, 1967, CORONA 1042 was launched; and good CORONA quality photography was obtained of the entire crisis area. Examples of the intelligence content of the mission are given in the following quote from OAK #1:

"1. All high priority targets in Egypt, Israel, Jordan, and Southwest Syria are covered on four passes imaged on 17 - 20 June. Iraq is not covered.

"2. The Suez Canal is blocked 3 NM south of Port Said by a sunken passenger vessel. Approximately 30 vessels are located along the Canal awaiting reopening. No traffic is observed in the Port Said area.

"3. Sixteen Cat/Cub aircraft are observed at Cairo International on 19 June. This represents twice the normal number of Cat/Cub usually seen at this airfield.

"4. Extensive bomb damage is noted at several of the significant Egyptian airfields. Although the count of aircraft observed is relatively low, a total of over 200 charred areas (probably destroyed aircraft) are observed at the aircraft parking aprons, hardstands, and dispersal areas of these airfields.

"5. The Egyptian SAM facilities are covered on 3 passes. Of the 24 sites, 9 have been analyzed, and it is determined that 6 are occupied, 1 possible occupied, 1 unoccupied, and 1 undetermined. One SAM support facility is observed; however, no activity is noted.

"6. Photography of the Dimona Nuclear Reactor Center, Israel, shows no apparent change since October 1966, Mission 4302. The 2-fan, forced-draft cooling tower is not emitting vapor.

"7. Many industrial targets in the UAR are covered on photography of relatively poor interpretability. No significant changes are observed.

Industrial targets in Israel and Jordan are visible on photography of good interpretability. No significant changes are observed."

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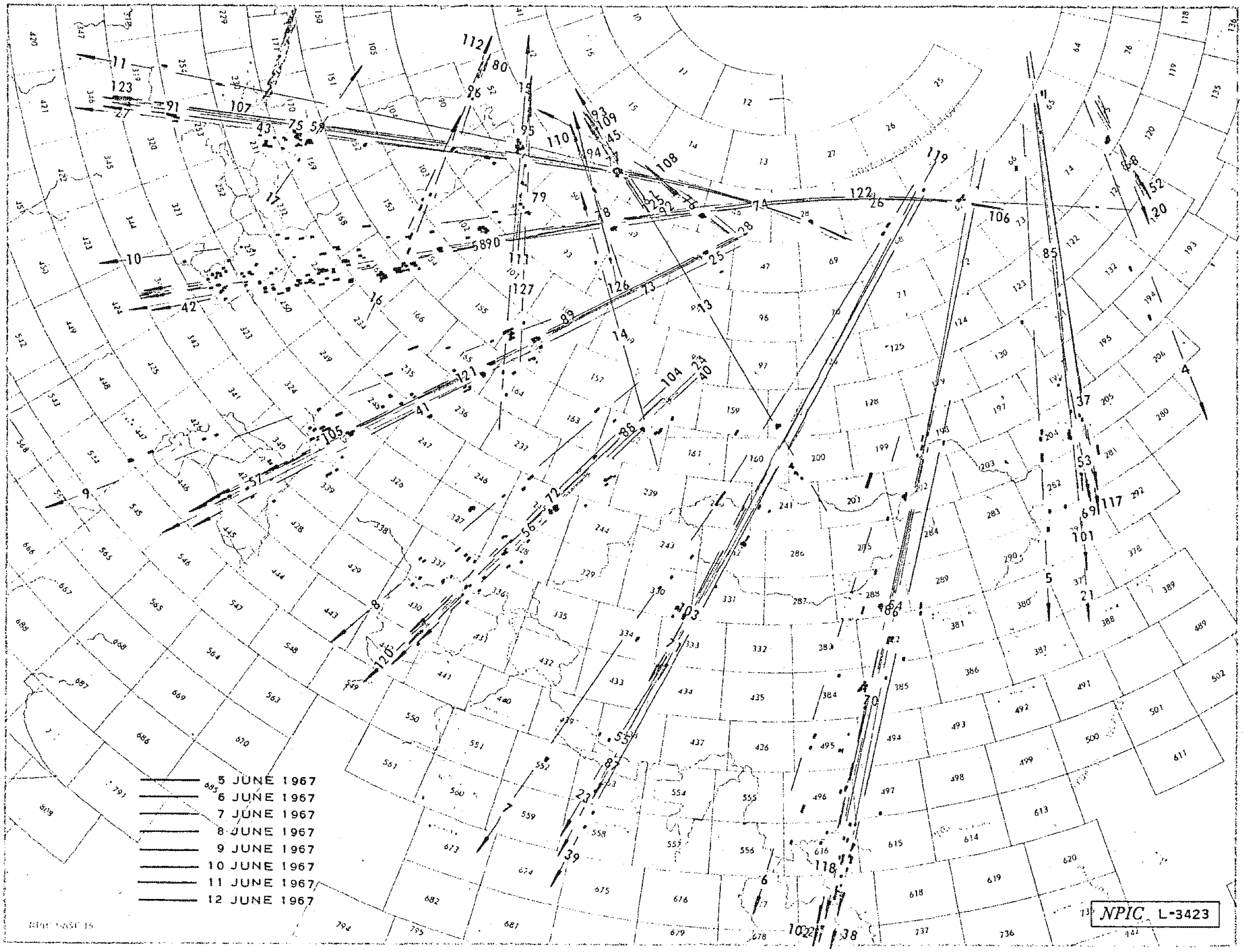
KH-7 MISSION 4038, 5-12 JUNE 1967



APPROXIMATE TRACK AND COVERAGE OF MISSION 4038, 5-12 JUNE OVER USSR, FAR AND MIDDLE EAST

TCS-80380/67

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