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3 January 1969

Indications/Warning Coverage: The COMIREX requirement in this area reads, "The capability to accomplish daily sampling of target categories." Satisfaction of the daily sampling requirements in 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.

The costs involved in continuous operation of a [redacted] 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 acquired without interfering with the imaging of the Warning/Indicator targets.

Table 3 describes the Warning/Indicator Deck of 505 targets.

Some of the Warning/Indications targets are located so far north that they are not illuminated by the sun during some portions of the winter. Table 5 identifies these targets by category and indicates the duration of the blackout.

Weather data representing conditions in January and June were used to compute the expected number of cloud free images. The weather data are believed to be pessimistic.

Table 6 summarizes the capability of the System I configuration to perform the Warning/Indications mission. Column 3 shows the average programmed take prior to the application of weather statistics. As can be seen, in the absence of sun angle (illumination) limitations all category requirements are satisfied. Column 4 shows similar information after the effects of cloud data and sun angle for the months of January and June have been included. For System I only about 71% of the category requirements are satisfied. However, since the problem is sun angle and weather rather than target access, adding additional imaging satellites would be a very impractical and expensive way of approaching 100% coverage.

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) targots, 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.

Indications/Warning Coverage: ~~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 [redacted] 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 acquired 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 (para b above) can be met by any of the following:

production of hard copy photographs. In addition, a [redacted]

Sensing satellites would be launched from the Western Test Range, utilizing Titan III B/Agena boosters. The relay satellite would be launched from the Eastern Test Range, utilizing a Titan III C booster.

~~The problem of target coverage was discussed briefly under b. Target Sample Frequency above. The discussion here will be more specific.~~ Table 3 describes the Warning/Indicator Deck of 505 targets. ~~Table 4 describes a merged Warning/Indicator/Surveillance deck of 6078 targets. In performing the study of target coverage using System I, the Warning/Indications targets were given priority so that in the event of conflict, the Warning/Indications target would be imaged.~~

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The component technology question can be broken down into several parts, sensor technology, other critical subsystems and reliability. The sensor technology area is the most critical of these technology areas.

Due to the requirement for rapid delivery of imagery to the ground, the basic sensor satellite must employ an electronic image readout concept. A system which uses photographic film, processes the film on board, and then uses a laser scanner to develop an electrically transmittible analog of the image has been developed and could be integrated into a satellite in a relatively short time. Although the film readout approach is not discussed further here, it is possible to show that such a system must achieve a lifetime capability on the order of [redacted] in order to be competitive with systems based on sensors which are not life limited due to the use of consumables. The following discussion of sensors is limited to those devices which image onto a reusable storage medium and those which convert the image directly into an electrical analog.

The NRO is presently engaged in developmental work on three types of sensors. Two image onto a reusable storage medium, and one converts the scene directly into an electrical analog. None of these efforts has proceeded to the point where a laboratory prototype of the sensor and the associated readout equipment have been demonstrated. The earliest date for such a demonstration is estimated to be mid CY 1969.

Costs: Warning/Indications system performance can vary over a large range, depending on the system configuration which is chosen. At the one extreme is a system which meets or nearly meets all the requirements stated in the COMIREX Report. Such a system might consist o[redacted] satellites using one of the three sensors presently under development, one relay satellite, and a ground station in the vicinity of [redacted] Such a system is estimated to cost [redacted] in non-recurring costs and [redacted] per year in recurring costs for establishing and maintaining [redacted] satellites and one relay satellite. [redacted]

[redacted]

At the other extreme in cost are several minimum capability systems. The one satellite, laser scan system reading out to a [redacted] would cost approximately [redacted] in non-recurring costs and [redacted] per year in recurring costs depending on whether the achievable lifetime for such a system would be 45 or 90 days. This system could be operational in two to three years and would cover approximately 50 per cent of the Warning/Indications targets every three days. The data return time would be as high as 10 hours.

It is obvious that any cost figures quoted at this time must be taken in the context of the rest of this paper, i.e., they are very preliminary estimates based on the results of in-house systems studies and are undoubtedly too low. The cost figures were basically derived by analogy to the development costs and unit costs for existing satellite reconnaissance systems with appropriate adjustments for differing complexities, differences in the state of applicable existing technology and the increased reliability requirement (1 year life) necessary to make a Warning/Indications System economically feasible.

The basic cost elements for System I are estimated to be as follows:

a. Readout Satellite Development [redacted]

b. Readout Satellite Unit Costs (in orbit) [redacted]

c. Data Link Satellite Development [redacted]

d. Data Link Satellite Unit Costs
(in orbit) [redacted]

e. Ground Station Acquisition [redacted]
1. MCP
2. Installed Equipment

f. Ground Station Operation and Maintenance [redacted]

An estimate of the non-recurring and recurring costs for establishing and maintaining an operational version of System I will be calculated using these costs. Assuming that a flight test program of [redacted] and that two relay satellite launches are required during the test and system establishment phases, the non-recurring costs would be [redacted] Following these initial costs, which would be expended over a five-year period, the recurring yearly average costs to maintain the system, based on [redacted] sensor satellite launches per year, a relay satellite launch every three years and the annual ground station O&M would be [redacted] simplify the tracking problem. The final area is image reconstruction. It appears that the ground station equipment developed for the laser scan readout system and currently in operational use as a part of Project [redacted] will, with moderate modifications, perform the reconstruction task for all of the sensors under consideration.

In summary, in addition to an existing laser scan technology, there are three different sensor developments underway. None have progressed to the point of breadboard or laboratory model demonstration. The earliest that such a demonstration is likely to take place is mid-1969. While some non-sensor development work will be required in support of a readout system, no formidable problems are seen in this area.

Warning/Indications system performance can vary over a large range, depending on the system configuration which is chosen. At the one extreme is a system which meets or nearly meets all the requirements stated in the COMIREX Report. Such a system might consist of [redacted] satellites using one of the three sensors presently under development, one relay satellite, and a ground station in the vicinity of [redacted] Such a system is estimated to cost [redacted] in non-recurring costs and [redacted] per year in recurring costs for establishing and maintaining the [redacted] sensor satellites and one relay satellite. [redacted] ~~Additional details concerning the basis for these cost figures are given in Appendix F of Attachment 2 under Option 1. In this case, it is expected that the full operational capability would be obtained early in the fifth year following program initiation.~~

At the other extreme in cost are several minimum capability systems. The one satellite, laser scan system reading out to a [redacted] would cost approximately [redacted] in non-recurring costs and [redacted] per year in recurring costs depending on whether the achievable lifetime for such a system would be 45 or 90 days. This system could be operational in two to three years and would cover approximately 50 per cent of the Warning/Indications targets every three days. The data return time would be as high as 10 hours.

In summary, the technical feasibility of a Warning/Indications System which meets the COMIREX requirements depends heavily on efforts currently under way in the area of sensor technology. There are no known fundamental reasons why these devices cannot be developed and we are attacking the problem on a rather broad base, i.e., three parallel development efforts. Even though we are confident of the ultimate success of these development efforts it will be at least a year and perhaps two years before we will have conclusive proof that an electro-optical sensor with the required resolution, frame size, sensitivity and dynamic range can be built for application to the Warning/Indications mission.

~~The final element to be provided in this paper is an estimate of the cost associated with a Warning/ Indications System.~~ It is obvious that any cost figures quoted at this time must be taken in the context of the rest of this paper, i.e., they are very preliminary estimates based on the results of in-house systems studies and are undoubtedly too low. The cost figures were basically derived by analogy to the development costs and unit costs for existing satellite reconnaissance systems with appropriate adjustments for differing complexities, differences in the state of applicable existing technology and the increased reliability requirement (1 year life) necessary to make a Warning/Indications System economically feasible.

The basic cost elements for System I are estimated to be as follows:

a. Readout Satellite Development [redacted]

b. Readout Satellite Unit Costs (in orbit) [redacted]

c. Data Link Satellite Development

d. Data Link Satellite Unit Costs (in orbit)

e. Ground Station Acquisition [redacted]

1. MCP
2. Installed Equipment

f. Ground Station Operation and Maintenance

An estimate of the non-recurring and recurring costs for establishing and maintaining an operational version of System I will be calculated using these costs. Assuming that a flight test program of [redacted] and that two relay satellite launches are required during the test and system establishment phases, the non-recurring costs would be [redacted] Following these initial costs, which would be expended over a five-year period, the recurring yearly average costs to maintain the system, based on [redacted] satellite launches per year, a relay satellite launch every three years and the annual ground station O&M would be [redacted]

As can be inferred from the foregoing, the progress that is being made in the area of sensor technology is encouraging. It is felt that we are presently maintaining a reasonably optimum pace in the Applied Research/Advanced Technology areas which support electro-optical readout technology. In addition it appears that our ultimate attainment of the operational and economic advantages of a long life electro-optical readout system will be best obtained if we continue to conduct a broad attack on the sensor technology without getting prematurely caught up in a full system development program.

Save for future placement:

Because there would be more Eurasian attack warning targets (241) when a [redacted] satellite became operational and because few (17) of these are located in the winter dark zone, many more photographs of these targets could be obtained during the year. Taking account of weather, light conditions, and the [redacted] associated with a NRTPS ~~the real-time photographic satellite~~ systems under consideration, an average of about 33 photographs of such targets a day could be acquired during a typical December and about 50 a day during a typical June. This would permit a fairly high sample rate parameters of ~~of~~ these target~~s~~ categories

10. When these factors are merged with the daily average number of photographs likely to be obtained during a given time of the year (described above), we can assess the confidence in the system acquiring sufficient photography to detect significant changes in the alert status of the various target categories. In the case of the [redacted] the daily average during December would be between 6 and 9 photographs within the 7 to 10 day period. This would mean that we should expect to obtain one- to one-and-a-half times the number of photographs necessary to have a 90 percent assurance of detecting a significant change in the alert status of these bases.