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The attached copy of a report was submitted to this office on 2 November 1959. Title of the report is "Review of Visual Satellite Reconnaissance Payloads - Readout and Recovery Types," dated September 19th, 1959. The author is Mr. C. W. Chillson of ARPA/IDA.

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I. OBJECT

1. The purpose of this memorandum is to describe and evaluate present and possible future satellite reconnaissance payloads in the light of national intelligence objectives, with special attention to the relative merits of photographic payloads of the readout and recovery types.

II. SUMMARY OF PROJECT TO DATE

The SAMOS program has as its objective the development of a satellite reconnaissance system to collect and process visual or photographic data and Ferret or electromagnetic data. More specifically, the SAMOS system is intended to acquire a great amount of technical and strategic warning intelligence, resulting in a more precise knowledge and evaluation of enemy military and industrial strength and their deployment. The data obtained should enable us to do a better target analysis job and to detect and identify unknown targets. Observed changes in concentrations of weapons, transportation patterns, communications density, together with the rates of change, will provide evidence of buildup and consequently relatively long lead warning of attack.

There are two approaches being developed for acquisition of intelligence data: (1) The recovery system in which a data capsule is ejected from the satellite upon command and physically recovered, and (2) the electronic data readout system in which all data is transmitted upon command to ground stations. The recovery system is used for photography and the data readout system for both photography and Ferret.

The general characteristics of presently planned visual payloads are as follows:

Designation	E_1	E_2	E_5	E_3
Type	Photo	Photo	Photo	Visual*
	Readout	Readout	Recovery	Readout
Nominal Altitude (SM)	300	300	180	300
Focal length	6 in.	36 in.	54-72 in.	?
Ground Resolution	100 ft.	20 ft.	5 ft.	5 ft.

* The relative merits of photography and of systems using various methods of T.V. image retention prior to readout are being evaluated for this payload on which only preliminary work has been started.

In addition, several developmental payloads (i.e. F-1 and F-2) are included in the SAMOS program, [redacted] Developmental flights will be [redacted] E-1/F-2 payloads in order to develop the techniques involved before incorporating them in the more sophisticated E and F payloads.

Reference (a) instructed AFBMD, ARPA's field agent, to defer development of the E-5 payload and associated recovery technique, "pending ARPA review". At that time, substantially all vendors' quotations had been received for the various elements and vendor selection was in process. The reasons for this "hold" were primarily budgetary and involved the allocations of approximately [redacted] in Fiscal 1960. This memorandum constitutes a portion of the [redacted]

The E-1 and E-2 payloads and associated readout electronics were largely past the prototype stage with final units being in assembly and checkout.

III. COMPARISON OF READOUT VS. RECOVERY PHOTOGRAPHIC PAYLOADS IN GENERAL

This comparison treats of the relative merits of the two types of payload from the standpoint of their potential effectiveness in fulfilling national intelligence objectives, their relative complexity and reliability, their relative status and timewise availability, and their R&D and operational costs. Lacking quantitative data, comparisons in some areas must be qualitative, pending further study and analysis.

Technical intelligence is available to only a very limited extent from the vast interior land masses of Communist Asia, from which an attack on the free world might be launched. The strong need for such intelligence, which it is hoped can be provided to a significant degree by satellite reconnaissance, is the reason for instituting the SAMOS program. It is in view of this circumstance that references (c) and (d), which go into considerable detail regarding technical intelligence requirements and which form the basis for the SAMOS program, were issued. It is apparent from these sources that a considerable premium should be placed on the immediacy or currency of reconnaissance information. While many long range requirements may be filled adequately by delayed information, it is only if technical limitations preclude obtaining the desired detail quickly that delayed receipt of the information should be accepted. Inherent in the recovery system is a delay in obtaining the desired visual data with presently contemplated systems. With a data gathering film capacity of some 30 days, earlier recovery of the film can only be achieved if less than the total capacity is recovered. Unless techniques not now contemplated are employed, the major portion of the film recovered will show only cloud cover and ground areas devoid of targets. If selective techniques are employed to void these areas, the time to recovery of a completely exposed film payload will be increased many fold. In contrast, the photographic readout system can make available information after a delay of only a few hours and inherently provide a basis for selectivity in subsequent passes. Also, by the use of any other techniques developed for avoiding the accumulation of uninteresting information, it can similarly extend its total information gathering capacity before the film payload is expended.

The recovery method has slightly superior performance (assuming the same altitude, optics, film, image motion compensation) since the degradation associated with readout (scanning, transmission, image reconstitution) is eliminated. This degradation is not, however, expected to exceed 20%, a scarcely significant loss, especially in view of the built-in image enhancement techniques employed in the readout system. Similar techniques can be set up to enhance recovered pictures, but are not an integral part of the recovery scheme. The recovery system is also subject to degradation of a possibly significant amount as the result of latent image growth, a post exposure phenomenon, and from film fogging as the result of temperature cycling which may occur during the recovery sequence, both of which phenomena can occur until the film is developed. The severity of degradation from these sources will depend on the length of the period between exposure and development, as well as on the temperature extremes encountered.

In order to obtain full utility of a reconnaissance system, it is necessary that it have the highest degree of reliability. Based on reference (e) study, it is apparent that this factor deserves major consideration in the relative evaluation of systems, and that it is indeed a serious problem to keep even a simple sytem operating with acceptable performance unattended in space for long periods of time. Of the two systems under consideration, there is little reason to doubt that the recovery camera is less complex than the readout camera with its film processing and readout and communication elements. Furthermore, since it will be operating for lesser periods of time, its overall reliability requirements are not so stringent.. However, in any objective evaluation, it should not be forgotten that considerable complexity exists in the recovery sequence, in the equipment for separation, retro-rocket firing, high temperature re-entry, parachute deployment, and subsequent location and recovery. Nor can the fact be ignored that with respect to a particular mission the degree of operational success can be much more immediately appraised in the case of the readout system. In the event of failure, corrective actions can be more immediately instituted either by launching an additional package or in the event that the failure is in the ground-based portion of the equipment, by repair. A quantitative evaluation of reliability of these photographic systems along the lines of reference (e) is necessary for other than a qualitative assessment of such factors.

IV. SPECIFIC COMPARISON OF E-2 and E-5 PAYLOADS

The E-2 readout camera with 36" focal length will in general have approximately 1/2 of the resolution of an E-5 recovery camera with a 72" focal length, other conditions being equal. In the development plan, the recovery camera was further favored from the standpoint of resolution by placing it in a lower orbit. Here the attitude stabilization problem is somewhat more severe because of the greater aerodynamic drag, and the life in orbit is reduced if additional propulsion is not made available. Hence, the lower operating altitude of the recovery system is consistent with recovery after a relatively short period of time. On the basis of one to two altitude differential, and a two to one ratio of focal length, the E-5 payload has approximately four times the ground resolution of the E-2 readout payload (e.g. 5 ft. vs. 20 ft).

It has been considered that with a 6 mc space to ground transmission link, the E-2 readout camera would be limited in the amount of information it could supply, as compared to a recovery system. The E-1 readout camera with a 6" focal length was not considered to be so limited. The 36" focal length, E-2 camera is limited to transmitting to earth approximately 1/5th to 1/6th as much information per day as it can acquire under ideal conditions. However, a review of Reference (f), study of cloud cover over Asia, and the extent of non-target areas, suggests that the amount of useful information not obscured by cloud cover may be relatively small and that the E-2 readout system may not be in fact, limited in this way under average conditions.

From the standpoint of probable costs, the R&D necessary to bring the E-2 readout system to a reliable operational status may considerably exceed that of the E-5 recovery system. However, once operational, the "cost per bit" of intelligence information could well be considerably less than that of the recovery system which requires the launching of a complete missile for each payload. It should be noted that many of the expensive and complex elements of the readout system are the same ones which are employed in reading out the information obtained by the Ferret payloads and which are, therefore, required in any event.

In summary the following factors are pertinent to a decision on the E-5, recovery payload, at this point in time:

It should be developed:

- since it will provide the earliest means of obtaining 5' ground resolution desired for technical intelligence;
- as a "back-up" to the more complex E_2 system;
- as a possible source of optics for a later E_3 system;
- since the recovery techniques resulting will be a long stride towards meeting man-in-space requirements;

Factors not favorable to its development are:

- It duplicates, to a degree, the E_2 read-out system which could be flown lower for limited periods to obtain a ground resolution of about 10 feet;
- A month or more delay is involved in obtaining both intelligence information and any assurance that any information has been obtained;
- of the pictures obtained, a relatively large proportion will be of cloud cover only;

V. POTENTIAL CAPABILITIES

The previous section dealt with currently conceived configurations. An objective, general comparison of readout and recovery systems must also include considerable of their future potential capabilities.

As was mentioned earlier, both systems are subject to refinement to reduce the amount of relatively useless information acquired. This can be accomplished by programming coverage to avoid areas of no, or relatively little interest, and by incorporation of IR sensors (or equivalent) to shut off the cameras or retrain them when the field of vision is obscured by cloud cover. As was previously noted, in the readout system, information from recent passes can be used to assist in the programming process. With a readout link already in existence, it will also be possible to relatively simply include a low resolution (500 or so TV lines per frame) television-type pickup which can serve a number of purposes. By taking occasional star map pictures, it can be used to more precisely determine satellite location. It can instead or also, in alternate frames, record cloud cover data for use in programming subsequent passes and for meteorological purposes. As TV-type systems with greatly increased capabilities now under study become available, this concept could replace all film-using methods, a possibility being considered for the E-3, high resolution, readout package.

With the advent of communications satellites which can be used for relaying information, these low resolution ground cover pictures can be transmitted in real time. Indeed, the availability of a communications satellite opens up a number of extremely interesting additional possibilities which, it is believed, warrant evaluation. The real time, low resolution picture could be employed to directly aim the camera at unobscured targets within range. The TV camera could, in addition, be refined to incorporate a so-called Zoomar lens which could, despite the relatively limited data acquisition capabilities of current TV systems, be used to view very limited areas at relatively high definition.

The above-described addition of a TV-type camera is just one of a number of combined payload possibilities believed to have merit and considered as ultimately influencing the selection of optimum systems. Following is a discussion of some others, some of which are made possible by the greater load carrying capacity of the now programmed, double-tank capacity, dual burn Agena upper stage.

[redacted]

If a sufficiently compact lightweight recovery system is evolved, it might well prove to be an operationally and economically desirable step to add one of limited capacity to various satellite stages whose basic missions were essentially different and possibly not involved in reconnaissance per se.

VI. RECOMMENDATIONS AND CONCLUSIONS

A. An accelerated study should be undertaken, comparable to that of Reference (e), to assess the relative reliability of readout and recovery of photographic payloads, and to establish a basis for the degree of effort which should be expended to improve reliability and the specific areas where such effort should be concentrated.

B. Despite the fact that readout systems are considered to be ultimately superior for reconnaissance purposes, it is believed that under present conditions the E-5 payload as planned will provide much earlier, high resolution photographic coverage than any new readout system. It is therefore recommended that work on the E-5 recovery system be continued.

C. Steps should be taken to advance the state of the art as rapidly as possible to the end of obtaining an E-3, high resolution, readout system as soon as there is a reasonable chance of success.

D In view of the limitations of present systems and the major improvements considered possible in the future, it is recommended that studies and/or programs be started in several areas such as, but not limited to, the following:

1. A magazine-type recoverable film payload.
2. A "universal" piggy-back recovery system of minimum size and weight with limited capacity for application to a variety of satellite vehicles.
3. A TV-type readout camera of comparatively low resolution with alternate star map and ground cover capabilities, both as a possible "piggy-back" payload on film readout payloads and as a first step towards an E-3 system.
4. The application of Zoomar techniques to such a TV camera and/or to one with improved resolution.
5. The possibility of real time camera aiming using a TV monitor.
6. Various combined payloads to improve intelligence objectives and/or save booster costs.
7. The exploration of new satellite reconnaissance techniques, including new sensors to provide "all condition."

reconnaissance, independent of cloud cover, illumination, camouflage and jamming, and without unacceptable limitations (see Reference (h)).

E. In line with the recommendations of Reference (e), a long-range program should be instituted, on an accelerated basis of basic R&D on new concepts, new materials and new techniques for the fulfillment of complex system functional requirements in a manner providing one or two orders of magnitude greater reliability than present equipment for use in an untended satellite environment.

REFERENCES:

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d. GOR80-3, Reconnaissance Satellite Weapon System, dtd 26 Sep 58

e. Preliminary Study of (MIDAS) System Reliability by Arinc Res. Corp. dtd 31 Jul 59

f. Time Required for a Photo Reconnaissance Satellite to Obtain a Clear Look at the Soviet Union - a supplement to WSEG Report No. 39 (Military Applications of Artificial Earth Satellites) dtd 19 Aug 59.

g. IDA-IM-122 The Use of Color in Aerial Reconnaissance by J. S. Goldhammer, dtd 11 Sept 59

h. IDA-TE-158, All Condition Satellite Reconnaissance, by C. W. Chillson, dtd 22 Sept 59