[redacted]



DEPARTMENT OF THE AIR FORCE
WASHINGTON

OFFICE OF THE SECRETARY

26 Aug 66

BYE-21214/66

MEMORANDUM FOR THE DIRECTOR DEFENSE RESEARCH AND ENGINEERING

SUBJECT: Manned/Unmanned Comparisons in the MOL

Your memorandum of April 6, 1966 requested that a study be made to compare the specified manned performance of the MOL reconnaissance-intelligence mission with the estimated performance of an independently developed unmanned system. The MOL design provides for both modes of operation, but permits taking advantage of the man in the system during orbital testing, and in follow-on operations for as long as this proves necessary or desirable. In order to provide as detailed and valid a basis for comparison as possible, a separate two-contractor study was funded based upon taking the MOL mission module as government-furnished. The results of the contracted and supplementary in-house studies appear in TAB A.

You asked that four particular points be considered in this comparison. The pertinent background and study conclusions on each of these particular points is as follows:

1. (Configure the wholly unmanned system and its method of operation to provide the same quality and quantity of reconnaissance-intelligence information as the MOL.)

There are two significantly different ways in which equivalence of the two systems may be considered: the first would be to design the unmanned system for equal spacecraft weight in orbit; the second would be to design the unmanned system for mission life equal to the manned MOL (30 days). The first of these ways would lead to a vehicle not greatly different from the MOL flown without a man in the automatic mode. The potential mission life of this system would be 60 days. At the present time the longest orbital lifetime attempted and achieved for a complex (pointing) reconnaissance system is 8 days, achieved on the thirtieth flight of the GAMBIT system. GAMBIT-3 in its initial configuration also has an 8-day life but is programmed to achieve 16-day life at about the thirtieth flight, which is scheduled to occur at first about the time of the MOL flight. In general, NRO experience has been that increased lifetime in orbit can be achieved without undue risk by incremental improvements in hardware and software based on flight experience.

It was therefore not deemed realistic to project mission lifetimes much beyond thirty days for the initial operation of a new system in 1969-70, and the contracted studies were focused on the 30-day unmanned system. However, on the basis of these studies and the comprehensive data available on the MOL in the unmanned mode it was possible to derive reasonably valid data on an independently developed unmanned system of 60 days orbital life and this data is included herein. It is estimated that the 60-day orbital life would be attainable about three years after initiation of operations with a new 30-day system, assuming that provision had been made for this growth in booster capacity, inherent subsystem life, qualification testing, and expendables capacity.

2. (Assess the difficulties and risks of obtaining equal intelligence content with the wholly unmanned system and determine the development and operating costs to achieve it.)

Although we have included in the mission module of MOL (which would be used in either the automatic version of MOL or in a completely unmanned configuration) automatic devices which potentially can give the same resolution unmanned as manned, many of these devices have either never before been used in orbital reconnaissance systems or represent large extrapolations in precision, accuracy or other capabilities. While we believe they can ultimately be made to perform reliably within desired tolerances, we are at this time by no means certain as to how long it might take to achieve this result. For this reason, we assess the risk of early achievement of [redacted] resolution to be considerably greater with an unmanned vehicle. To the extent that man's participation in the development proves to be effective, the [redacted] resolution unmanned capability should be achieved earlier in the automatic mode of MOL.

Intelligence content, however, is not restricted to consideration of resolution. A second factor is the need to photograph targets unobscured by clouds since the Soviet weather is on the average only about 50 percent cloud free. Procedures for weather avoidance and weather verification can also contribute to increased intelligence output per mission. We have been examining the ways in which the weather factors may be compensated by sensing the weather ahead and taking corrective action and by verification of successful cloud-free coverage of high priority targets so that other targets may be programmed in successive passes. It is important to recognize that these functions may either be performed by man or by additional automatic devices. However, it is difficult to assess from ground analysis and simulation alone what real benefits may be obtained. Our estimates range between 15 and 30 percent improvement in cloud-free photography from weather avoidance and verification procedures which are discussed in TAB C. In view of the uncertainties connected with the proper implementation of these weather compensation functions and the fact that the unmanned version of MOL is already heavily dependent on numerous new automatic devices, we do not believe it is desirable to plan at this time for automation of this function. However, manual experimentation and execution of this function in the early MOL flights will provide a basis for evaluation and design of suitable automatic devices for one or both of these functions. These devices could be incorporated later if this proves to be desirable.

A third element involved in maximizing the intelligence content of a mission has to do with selectively choosing those targets which are likely to include objects of high intelligence value. If the nature of these targets is such that the presence or absence of intelligence objectives may be transitory (such as missiles on pads or launchers) target selection cannot be made to maximize intelligence content by pre-programming. Ground simulations have indicated that MOL astronauts looking ahead to alternative targets through their acquisition and targeting telescopes may be able to recognize the presence of objectives with high intelligence value at a target location. However, this again is very difficult to establish by ground simulation (although more realistic simulation may be possible from very high altitude aircraft). Our estimates of the opportunities for astronauts to increase these special high value technical intelligence outputs of a mission indicate that factors of between two and three may be attainable. The effect on the total number of photographs taken or total number of targets covered during a mission is negligible. This is possible because the frequency with which these transitory intelligence gathering opportunities occur is relatively low--6 percent of the time for a representative sampling of the targets. This is discussed further in Attachment C.

3. (Compare the wholly unmanned system performance with the expected performance of the unmanned version of the MOL as evolved from the manned development flights.)

4. (A comparison should be drawn between the operational effectiveness of the two approaches. . . .)

As indicated above, our studies of an unmanned DORIAN system considered a 30-day nominal mission and a 60-day nominal mission. The former would be launched by a 5-segment Titan III, while the latter would employ the 7-segment booster similar to the configuration being planned for MOL. The 60-day mission was found to be more economical than the 30-day mission, providing that the component reliability can be developed to acceptable levels. In either case, the absence of man increases the development risk and we have estimated that a 10-launch test program in the operational configuration would be a necessity (see page 5 of TAB A). For comparison, our planning for GAMBIT 3, a considerably simpler system, is for eight development flights.

The new developments needed to automate the system present an added risk during the orbital testing phase. Some functions involving important new components are:

Image motion compensation across-the-format

Highly accurate (.05 percent) image motion sensing and compensation

Focus sensing

Remote optical alignment

Precision automatic navigation

A discussion of the new features appears in TAB C. All of these features are planned for automatic operation during both manned and unmanned flights; the man will, however, be able to override or compensate for most of the failure modes envisioned for this equipment. Out-of-specification performance in any of these functions can defeat the objective of providing [redacted] resolution. The presence of a man during the orbital development period not only will enable us to increase the output and quality of reconnaissance data acquired in this period but will assist in identification and correction of equipment deficiencies.

The development cost of the 60-day unmanned DORIAN is estimated to be $1.50 billion. The 30-day system would cost about $1.13 billion. The estimates are based upon appraisals varying between 95 percent and 105 percent of the quoted figures, depending upon judgments relating to the degree of difficulty in the development. TAB A provides a breakdown of these costs (TAB A, Page 9). A comparison may be drawn with GAMBIT 3, in which the development cost, including the eight development flights, is at present estimated to be [redacted] the weight of the GAMBIT 3 on-orbit vehicle is correspondingly 1/3 that of the 30-day unmanned DORIAN.

The recurring cost of the 60-day system would be about $59 million and the recurring cost of the 30-day system would be about $45 million.

A comparison with cost, on-orbit weight and lifetime of predecessor surveillance systems is of interest.

| SYSTEM | FLIGHT NUMBER | LAUNCHED COST (MILLIONS) | WEIGHT ON ORBIT | DAYS ON ORBIT | $/DAY ON ORBIT (MILLIONS) |
|---|---|---|---|---|---|
| GAMBIT | 1-25 | [redacted] | 4,200# | 4-5 | [redacted] (Avg) |
| GAMBIT | 26-29 | | 4,400# | 6 | |
| GAMBIT | 30 | | 4,500# | 8 | |
| GAMBIT 3 | 1-8 | | 7,200# | 5-8 | (Avg) |
| GAMBIT 3* | 8-23 | | 7,200# | 8-10 | (Avg) |
| GAMBIT 3* | 24 | | 7,700# | 14-16 | (Avg) |
| MOL-Manned* | | $80 | 32,000# | 30 | $2.6 |
| MOL-Unmanned* | | $66 | 32,000# | 30-60 | $2.2-$1.1 |
| Unmanned [redacted] (30 day)* (DORIAN Optics) | | $45 | 21,000# | 30 | $1.5 |
| Unmanned [redacted] (60 day)* (DORIAN Optics) | | $59 | 32,000# | 30-60 | $2.0-$1.0 |

*Estimates

In comparing each system with its predecessor, it should be realized that in addition to longer life on orbit and hence more total photographs, the quality of the intelligence content per target in terms of better resolution is steadily increasing as we go from GAMBIT to GAMBIT 3 to DORIAN. Offsetting this to some degree is the decreasing field of view which reduces the number of targets in one photographic frame; this is important where targets are densely clustered as in test ranges.

The latest estimate of the development cost of the 7-launch MOL Program is $1.818 billion (see TAB B). At the conclusion of the development, the system can be operated manned or unmanned (automatic mode). The automatic mode can have an orbital life of 60 days, subject to the same qualifications on reliability stated above for the independent unmanned system, which would cost $1.50 billion through development. Compared in this manner, the differential development cost for including a manned operating mode and a manned development program is estimated to be $318 million. If the weather compensation potential of the manned system is realized to the extent of 20 percent, this difference would be almost entirely offset by the increased photography collected during the development cycle. The additional benefits of target selection potential in the manned system are not accounted for in any of these figures.

Before summarizing the comparisons, it is pertinent to discuss briefly the effect of the field of view of the DORIAN optical system. Optical systems have a field of view that diminishes with resolution, a very significant factor in mission planning against various target models. The following table presents a comparison:

| System | Width, N.M., of Field of View | Area Covered per Photo, Sq. Mi. |
|---|---|---|
| GAMBIT | 9 | 180 |
| GAMBIT CUBED | 4.5 | 90 |
| DORIAN | 1.5 | 2.0 |

The small field of view puts a premium on pointing accuracy, requiring accurate target location and very precise navigation and attitude control.

When pointing accuracies, equipment alignment and adjustment, image motion compensation and tracking can be done unmanned reliably and within design specifications, the resolution results of all targets covered during a thirty-day mission are expected to be substantially the same manned and unmanned. However, because of man's ability to center images of obliquely located targets and to correct for offset errors introduced by navigation uncertainties, man in the system will be able to maintain peak resolution performance, particularly for predesignated targets of high significance, while the unmanned system is more likely to degrade somewhat, particularly in the earlier phases of the program.

Discussed below are several factors which potentially provide the manned system with a superior intelligence content per day on orbit.

Target Selection

One significant potential function which a man may perform is the selection, by real-time inspection, targets of high value, which occur relatively rarely and at random. The competing unmanned system would acquire them only by chance and fail thereby to take advantage of a majority of the opportunities. The DORIAN optics field of view will cover approximately one-half of a 12,000-foot runway system. In order to insure, for instance, that photographs are obtained of military aircraft parked on the perimeters of such a runway, one must either know their location before the mission or in some manner find them in real time. To illustrate, a single GAMBIT or GAMBIT CUBED target can separate into two or more DORIAN targets because of the smaller field of view. Not only do targets proliferate, but to insure maximum intelligence content, target selection becomes mandatory. A complex such as Tyuratam, measuring 50x100 miles and containing twelve launch complexes, could break into more than sixty individual targets. These targets are so close together that photographs of only a few can be taken on a single pass, but by intelligent inspection, the operator can select those which contain items of high intelligence interest. Our studies show that man can make a major contribution in this role.

To estimate the usefulness of this function, a representative DORIAN mission was analyzed along with operator-reaction tests on a simulator. Results showed that crew participation in target selection could yield almost three times as many photographs of high-intelligence-value targets as could be taken by an unmanned system on the same mission. Details are in TAB C. Representative of the operations performed are:

a. Location of significant military vehicles

b. Inspection of special radar equipment

c. Detection of a silo with an open door

d. Detection of a missile being transported

e. Technically valuable view angle of new radar

This particular application of a trained operator on orbit is representative of the potential advantage of direct viewing, although as noted above further experiments are required to fully define and delineate such manned functions. The Gemini program has shown that man's eye is capable of picking out gross ground patterns. When adapted in MOL through a telescope designed for the function, this capability should translate into a finer and more discriminatory discernment.

Quick Response Intelligence from Readout

Under some circumstances the value of intelligence is considerably enhanced by rapid communication. In those cases in which quick response is important, a satellite-borne readout system is useful. The MOL readout system will be employed to provide the needed timely information by scheduling photography to be performed by the operators using a secondary camera on targets pre-designated or selected by them during the approach. In many cases, the readout function would be combined with target selection. The film will be processed on board and the intelligence-bearing portion of it will be transmitted over the data link. It would be possible to have an alternate unmanned configuration designed to perform readout, but an entire mission would be consumed each time the readout configuration is flown. The loss of a regular mission could be tolerated only in very unusual cases.

Selection of Cloud-Free Targets

In a typical unmanned mission, the photographic loss is 50 percent from cloud cover alone. In the manned system, the operators can employ the spotting scopes, which will have been pre-programmed against targets along the pass, to determine which targets are in the clear and then orient the main optics for photographing the clear targets. An extensive study, performed by the Government Weather Center, of 152,000 frames of KH-4 photography, supplemented by detailed target reporting from KH-7 missions, has provided a weather model which confirms that alternate targets, on the average, will be open for photography in a substantial percentage of those cases in which the primary is obscured.

Additional Manned Functions Which Can Improve Intelligence Information

There are several added benefits provided by an operator and these are particularly valuable during exploratory experiments aimed at evaluating varied or new techniques. One feature, referred to above, is his ability to determine the best viewing angle from which a target should be photographed. For instance, if he is approaching a parked aircraft from the rear and the needed intelligence will come from examining the fore end, he can wait until he has passed over and take a backward-looking picture. He can, on command from the ground, place aerial color film, infra-red film or other special films in the secondary camera so that their special discrimination characteristics can be realized. These special films may be of value in camouflage detection or in acquiring information on the nature and level of industrial plant activity. Man can process photographs in orbit, edit them and transmit the images to the ground. In conjunction with this capability, he can make judgments and render specific decisions as to the relative importance of information to be processed on orbit and transmitted to the ground.

These contributions of the man in the system may provide a substantial increase in the intelligence value of the mission. Each individual function can, without exception, be performed by some automatic system or combination of systems but the possibility in the manned system to experiment with a wide variety of techniques and alternatives is attractive and valuable in time and money, whether or not the function is ultimately performed by man or by automatic devices.

Additional Reconnaissance Capabilities

During times of crisis, the MOL system can be transferred from its nominal 80-mile orbit to an orbit of approximately 200 to 250 miles. In this higher orbit the system will have access to all targets in the Soviet Bloc approximately once every three days, taking photographs at resolutions of about [redacted] The crew can also employ the acquisition and tracking scopes, with a resolution of about nine feet, for intelligence by direct viewing. The absence or presence of aircraft, ships in port, cargo accumulations, parked vehicle build-up and railroad activity are examples of such intelligence. The vehicle can enter orbits of about 200 miles after one to twenty-one days, and still remain in orbit thirty days, permitting daily reports of activity of significant value in determining the posture and state of readiness of Soviet forces.

[redacted]

The foregoing additional reconnaissance capabilities can be accomplished with essentially no change to the baseline MOL system.

Additional Military Missions and Growth

The MOL laboratory module has sufficient flexibility to develop equipment for missions other than high resolution reconnaissance. New military missions, when validated, such as communications intelligence or ocean surveillance, can be added to the MOL Program by the fabrication of new mission modules and some minor modifications to the la boratory module. Other elements of the system can be used without change.

In addition to these military uses, the MOL has the potential of providing a unique laboratory environment for the execution of scientific experiments. The MOL has 1,000 cubic feet of pressurized volume and can provide up to 3,000 cubic feet (8,000 pounds) of unpressurized experiment space.

Finally, the MOL Program, as currently configured, is well suited to allow development beyond the applications outlined in the foregoing paragraphs. Our studies have indicated that growth to sixty days on orbit is feasible, as in rendezvous and resupply. Exploiting either of these two growth areas would ultimately offer potentials for increased cost effectiveness and would permit by incorporating larger sensors, the provision of ground resolutions on the order of approximately [redacted] All of our studies involving applications validate that longer lifetimes on orbit and the use of larger higher resolution optical devices will be greatly augmented by inclusion of manned missions in at least the development phase.

Neither the new military missions, nor the scientific experiments, nor the growth versions, are included in the approved program, and except for study, no work has been done on them. They are included in this report for information only.

Harold Brown

[redacted]

Handle via DORIAN
Control System

TAB A

SUMMARY

STUDIES OF UNMANNED DORIAN SYSTEM

## I. INTRODUCTION

Studies have been conducted of a wholly unmanned satellite reconnaissance system which uses the DORIAN optical subsystem now under development for MOL. This paper summarizes the results of these studies.

The objective of the studies was to define and analyze a wholly unmanned system configured to yield, insofar as possible, the same quality and quantity of intelligence return as that anticipated for MOL. Data on the configuration, performance, schedule and cost were to be developed.

The following paragraphs describe the terms of reference and the approach under which the studies were conducted.

The wholly unmanned system was to involve the lowest possible development risk. Existing and presently projected technology, components and subsystems were to be used to the maximum extent possible. Both the TITAN IIIC five-segment and seven-segment boosters without transtage were studied. Numbers of recovery vehicles were to correspond to mission life; existing vehicles were to be used if possible.

Contractor as well as in-house studies were to be conducted. With the exception of technical information required as inputs, these studies were to be conducted apart from the MOL/DORIAN Program Office; however, close coordination was maintained to assure the greatest possible comparability with current MOL program planning projections. In matters of design, management approach, etc., the wholly unmanned program was to conform to usual practices for similar programs in the NRP.

Study contracts were let to GE and LMSC for a 60-day study. The contractors were told to consider the Mission Module as a GFE item with the first flyable unit to be delivered in October 1969. The contractors were requested to provide nearly complete redundancy in the OCV in order to achieve the highest possible mean mission life. Factors of development risk, reliability, confidence of early success, and costs were identified as key issues and the contractors were urged to emphasize them. Each contractor was able to respond quickly and well by reforming the teams which had performed studies over the past two years of the new search and surveillance system. Since the OCV for the wholly unmanned system appeared to be quite similar to that needed for a new search and surveillance system, the contractors were requested to consider the interrelationship carefully and to draw on their previous efforts in this area.

Concurrently, in-house studies were conducted to provide a basis for careful review of the OCV design by the contractors. Studies of simulated operations against a DORIAN target list were continued and various computer runs made to provide answers to questions regarding weather, target access, anticipated requirements, etc.

## II. BASELINE SYSTEM CONFIGURATION

Figure 1 depicts a 30-day configuration for the orbital vehicle of a wholly unmanned DORIAN system. The placement of the control, recovery, and mission support modules in this configuration is such that it offers the advantage of minimum structural weight and optimum interfaces between the modules. Additionally, this configuration is potentially applicable to other missions.

The Orbital Vehicle is flown in the opposite direction to that planned for the manned system. This may introduce an aerodynamic heating problem on the blunt end of the Mission Module at low perigee altitudes; however, this problem is not expected to be severe and, at worst, may require some additional heat protection.

The performance of the baseline configuration discussed in Section III of this report is based on sufficient weight for orbit keeping propellants for flights with a perigee altitude of not less than 80 n.mi.

Launch would be accomplished from the Western Test Range. On-orbit operations would be conducted through the existing and programmed facilities of the Satellite Control Facility at Sunnyvale, California. On-orbit functions would be controlled in accordance with the following concept:

Target coordinates read up from ground to computer.

Ephemeris computed on ground and read up to vehicle.

# ORBITAL VEHICLE BASELINE CONFIGURATION

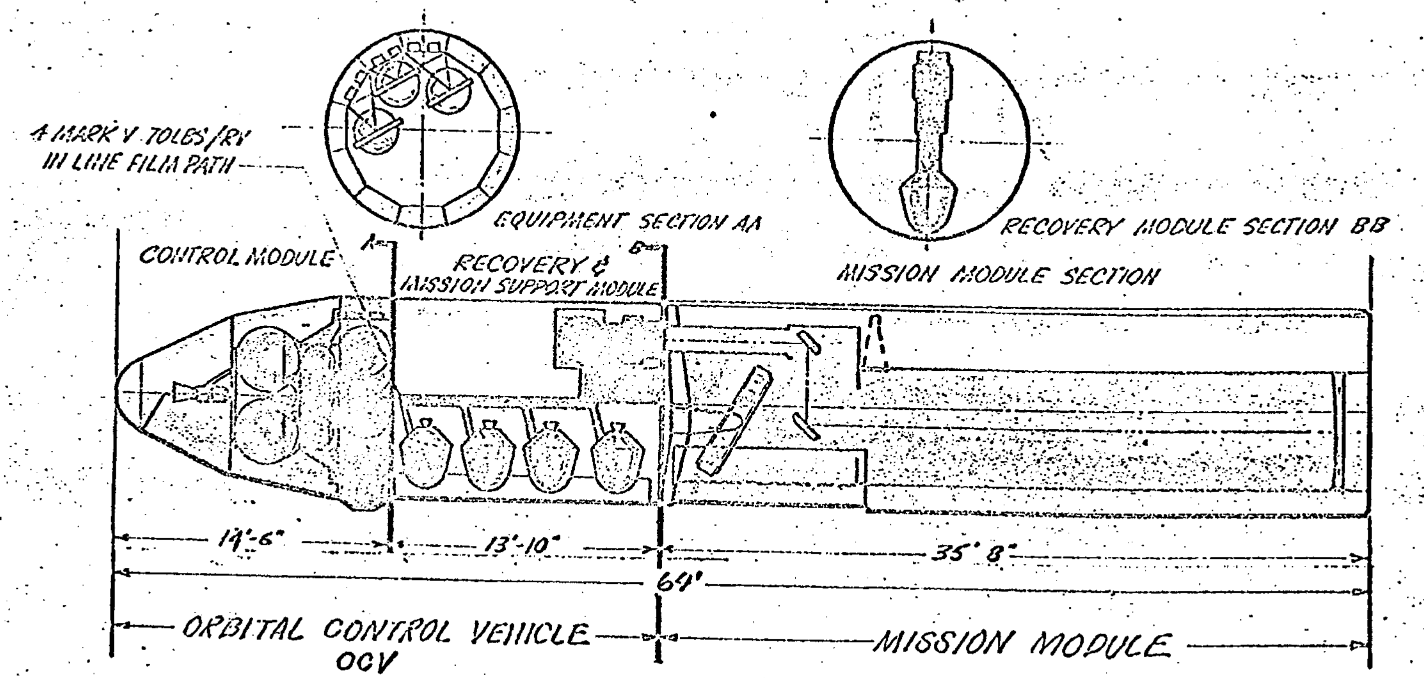



FIGURE 1

Star tracker data and navigation data used to compute sensor pointing commands.

Image motion sensor (V/h) tracking through main optics.

Computer extrapolation of previous V/h data to new target as backup.

Focus and alignment either closed loop or commanded from ground.

Redundant backup subsystems switched in by ground command.

Four recovery vehicles - first vehicle recovered after approximately one week's operation.

Recovery would be accomplished on command in the Hawaiian area by the 6594th Recovery Squadron using existing or projected equipment.

## III. ESTIMATED PERFORMANCE

The configuration described above is based on using a Mission Module configured for automatic mode operation "GFE" from the MOL program. Functions which will be accomplished automatically (i.e., with no assistance from the man) are:

a. Pointing

b. IMC

c. Film handling and recovery

d. Alignment and focus

e. Across format IMC

The manned/unmanned mode was included in the MOL program earlier in the year and was made part of the Contract Definition Phase (CDP). Further progress in the CDP has tended to further support the validity of this technical approach.

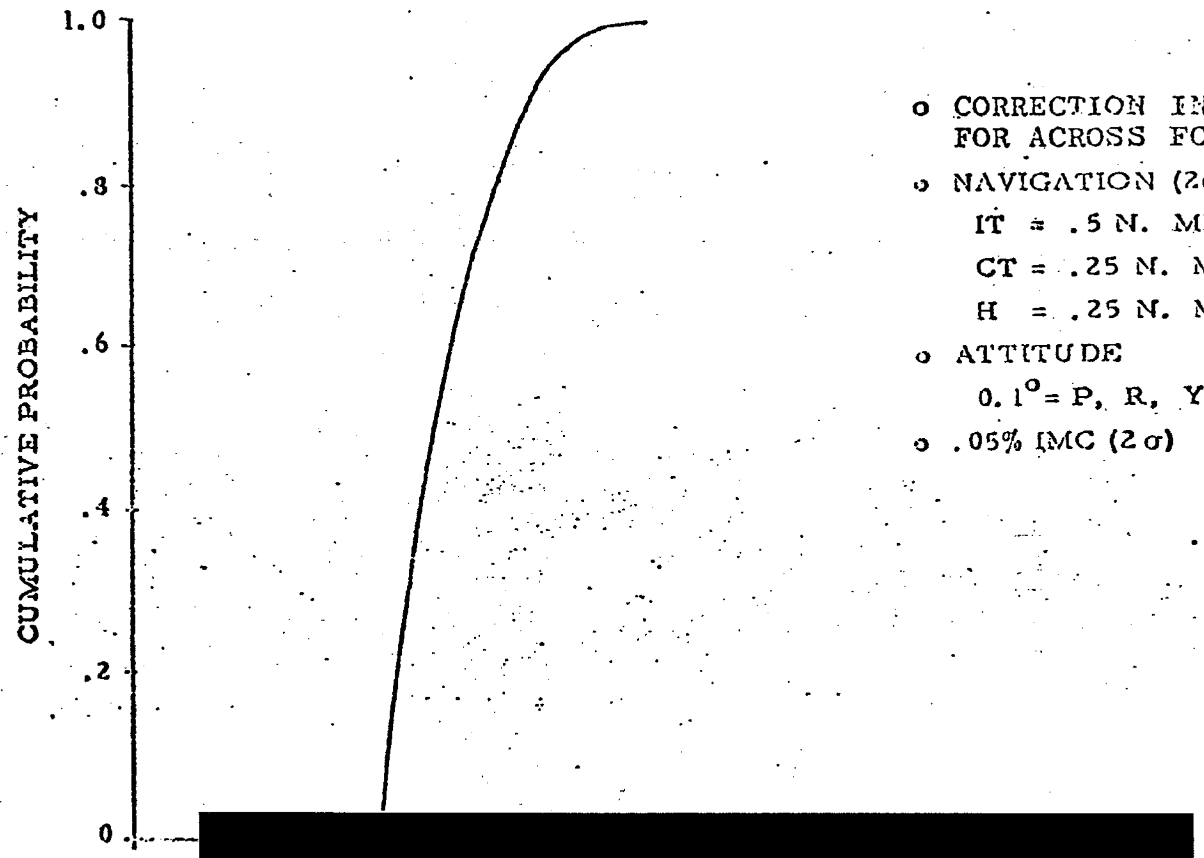
The critical aspects of pointing to acquire the target have been examined further. The precision of the navigation required is attainable for perigee altitudes of 80 n.mi. even in periods of peak solar activity. At 70 n.mi. perigee, some method of accounting for in-track errors due to variations in drag is needed. The precise attitude reference device needed is consistent with several existing star tracking instruments. However, automatic star trackers and advanced high-accuracy horizon sensors have been a constant source of difficulty in NASA programs (the main programs using them) and great care will have to be exercised to balance performance and reliability. A camera to provide compensation for image blur across the full format due to in-track pointing errors has been designed in detail by Itek and submitted to EKC, whose initial reaction is very favorable. Image Motion Sensing is quite critical and exploratory development has continued on three parallel approaches--each of these has given indication of promising to meet unmanned system requirements although none constitutes flyable hardware as yet.

The critical devices needed for automatic operation of the DORIAN sensor have progressed well and offer considerable promise for successful operation in the automatic mode. Thus the quality (resolution) of the wholly unmanned system can ultimately be expected to be the same as that for the manned system in the automatic mode (i.e., with no participation by the man but with the automatic devices operating reliably and within design tolerances). The cumulative probability of achieving a geometric mean ground resolution is shown in Figure 2. As can be seen, at the nominal point of .5 probability, the system should produce [redacted] resolution.

Further improvements in performance may result from technological effort now under way. For example, "zero co-efficient" optical materials are progressing very well and development of mirrors for DORIAN is scheduled. If successful, a significant simplification of the Mission Module will result since the louvres and baffling door movements will not be required. Orbital testing of a drag accelerometer is scheduled and if successful will permit adequate drag accounting and therefore operation as low as 70 n.mi. perigee even in periods of peak solar activity.

The quantity of product to be obtained is determined largely by the expected mission duration. The expected mission duration is a function of the non-random failures (learning factors), inherent reliability and design life. If one considers a mature system in which the inherent reliability is being achieved, the effect of design life on expected mission duration can be seen from the following table. (A "mature" unmanned system is assumed to be achieved after ten flights.) 1A

- $-10^{\circ}$ STEREO
- 3000 FEET ($2\sigma$) TARGETS
- TARGETS DISTRIBUTED OVER $\pm 40^{\circ}$ ROLL
- 30 N. MI. ALTITUDE




- CORRECTION INCLUDED FOR ACROSS FORMAT IMC
- NAVIGATION ($2\sigma$)
  - IT = .5 N. MI.
  - CT = .25 N. MI.
  - H = .25 N. MI.
- ATTITUDE
  - $0.1^{\circ}$ = P, R, Y
- .05% IMC ($2\sigma$)

[redacted]

FIGURE 2

DORIAN GAMBIT

## EXPECTED MISSION DURATION

## WHOLLY UNMANNED SYSTEM

| | | | |
|---|---|---|---|
| Design Life, Days | 30 | 35 | 60 |
| OCV Reliability, $R_o$ | .91 | .90 | .83 |
| MM Reliability, $R_m$ | .81 | .78 | .62 |
| Booster Reliability, $R_b$ | .93 | .93 | .93 |
| Mean Mission Duration, Days | 24 | 27 | 42 |

The increased design life between 30 and 35 days involves an increase in expendables at the expense of reducing the weight contingency from 30 percent to 10 percent.

The reliability figures, $R_o$ and $R_m$ represent the probability of successful operation for the design life. The vehicles which fail to achieve the full design life may achieve some lesser life which on the average will be approximately one-half the design life. Therefore, the mean mission duration, taking account of the booster reliability, is

$$\text{MMD} = \text{Design Life} \quad \frac{1 + R_o}{2} \times \frac{1 + R_m}{2} \times R_b$$

An increase in design life at the same inherent reliability will result in a significant increase in mean mission duration. A mean mission duration of the order of 27 days appears reasonable for an unmanned system with a design life of 35 days as opposed to 24 days for a design life of 30 days. On a straight-line reliability extrapolation, the 60-day mean mission duration would be 42 days.

Experience in flight testing satellites has shown that early failures may be expected in which there are complete mission losses. An estimate for the unmanned DORIAN is that four of the first ten attempts would probably fail in this manner. Taking this factor into consideration and assessing the development difficulty, it was estimated that a 10-launch development test program would be required.

The present configuration of the MOL includes a readout system in each flight vehicle. A readout capability could be developed for the wholly unmanned system and substituted for the recovery equipment in the Mission Support Module. Effort presently under way for possible application to GAMBIT CUBED will develop the technology and

1

basic components for such a readout system and will, within the next few months, demonstrate the capability, film to film, in ground tests. This system will have the capability of reading out and reconstituting photography from the DORIAN with resolution degraded by about 15 percent. Some 80 frames per day could be read out to a single station from a circular orbit of the order of 150 n.mi. altitude.

The readout version would represent an alternate OCV to be used in crisis situations or other circumstances requiring rapid response. In addition to development test flights for this payload, the follow-on program must include flights to exercise the readout capability on a regular basis in order to assure that the capability will be operational when required. However, the costs of developing this alternate OCV for readout have not been included in the costs of the unmanned system.

## IV. ESTIMATED COST AND SCHEDULES

### Schedule

The pacing item in this program (as in the MOL program) is the availability of the DORIAN optical subsystem and the Mission Module. Therefore, a first flight date of December 1969 was assumed. This date is identical to the first flight with optics now planned for the MOL program. Assuming a go-ahead in the near future, the balance of the program elements of a wholly unmanned system could be available to meet this flight date.

### Costs

The costs for the Mission Module were obtained directly from the MOL SPO and the DORIAN sensor office.

Costing ground rules were established to insure maximum interpretability and completeness of the OCV costs submitted by the contractors. Segregation of costs was required and twelve categories were specified for costing breakouts:

1. Program Management
2. System Engineering
3. Module Design
4. Flight Hardware by Subsystems
5. AGE Design, Procurement, Checkout, and Maintenance

6. OV Test and Launch
7. On-Orbit Requirements and Support
8. Flight Evaluation
9. Logistics and Spares
10. Test Models
11. Vehicle Integration
12. Facility Contract Items

Although a detailed system specification was not available, a detailed and precise performance requirement was developed to place specific requirements on each subsystem and the total OCV. These detailed requirements were developed during the first week of the study and were made a part of the contractual documents.

Five full scale models were required with no refurbishment for flight. The total OV system, including prime mission module and necessary spares, were to be qualified.

Four sets of AGE were required: one at the pad, two sets to be used in-house, and one set of engineering AGE for prototype vehicle testing. It was assumed that there would be a single pad at WTR and that the STC at Sunnyvale, California would accomplish on-orbit control. Two sets of major components, including GFP, were assumed as vehicle logistics spares. A flight evaluation report would be required five days after each R/V recovery and a summary report would be required 20 days after termination of flight.

Assumptions were made that GFP subsystems would be functionally tested at the contractor's facility. If problems exist, the contractor will isolate the trouble to component level and defective components will be returned to the supplier with the subsystem made operational be replacement with a good unit.

The estimates for launch vehicle cost were made with the best information from the Martin Company and other contractors and are consistent with the costs submitted for the plan for a new search and surveillance system.

The costs for recovery equipment represent the cost for a contract to supply the recovery system GFE to the OCV contractor. The costs are consistent with current and projected experience on recovery vehicles.

The estimated cost of SGLS equipment and AGE needed by the OCV contractor is based on contractor estimates and actual experience in other NRP programs.

The support item includes funds for Aerospace Corporation support and for mission anticipated optimization based on experience and practice in present NRP programs.

Table I summarizes the estimated costs of a wholly unmanned program for both a 30-day and a 60-day nominal mission. The development costs are the mean of estimates which varied from 95 percent to 105 percent of the listed figure, based upon development uncertainties.

It should be noted that the costs stated are for a ten-launch program; follow-on costs are predicated on a launch rate of four per year.

The costs for development and flight of the alternative readout system discussed in Section III are not included in the cost tables. Cost for development readout hardware for two development flights and an operational ground station is estimated at $94.0 million including savings for recovery vehicle hardware not required. Follow-on costs approximate an additive increment of $2.0 million per flight for the readout equipment only. In order to have this readout capability on call for crisis situations, it would be necessary to exercise it at least once and probably twice a year. This would result in a serious degradation in the normal productivity of these surveillance missions.

TABLE I

PROGRAM SUMMARY
(Cost in Millions)
(Development based upon 10-launch program)

| | Non-Recurring | | Recurring | | Follow-On Per Unit | |
|---|---|---|---|---|---|---|
| | 30-day | 60-day | 30-day | 60-day | 30-day | 60-day |
| Mission Module | 311 | 311 | 221 | 221 | 22.1 | 22.1 |
| OCV | 135 | 220 | 100 | 150 | 7.7 | 10.0 |
| Launch Vehicle | 90 | 155 | 93 | 185 | 9.3 | 16.5 |
| SGLS | 1 | 3 | 9 | 20 | .9 | 1.8 |
| Recovery Equipment | 10 | 20 | 10 | 20 | .9 | 1.8 |
| Support | | | 17 | 30 | .5 | 1.0 |
| Military Construction | 31 | 31 | — | — | — | — |
| Subtotal | 578 | 740 | 450 | 626 | 41.4 | 53.2 |
| Contingency 10% | 58 | 74 | 45 | 63 | 4.1 | 5.3 |
| TOTAL | 636 | 814 | 495 | 689 | 45.5 | 58.5 |

TOTAL FOR 10-LAUNCH PROGRAM

| | 30-day | 60-day |
|---|---|---|
| Non-Recurring | 636 | 814 |
| Recurring | 495 | 689 |
| TOTAL | 1,131 | 1,503 |

[redacted]

TAB B

MOL PROGRAM COST SUMMARY

The planned total RDT&E cost of MOL Phase II development is $1,818.0 million. This figure is based upon the program schedule shown in Figure B-1 and the annual distribution of funds shown, by system segment, in Figure B-2.

The cost figures shown were derived through a methodical and systematic procedure which was formally instituted in January 1966, and which will continue through negotiation of Phase II contracts with all major associates. The cost estimating methodology employed has involved the generation of independent estimates concurrently with preliminary contractor estimates, reiterations of these procedures, detailed evaluation of final contractor proposals where such proposals were available, and detailed reviews of cost estimates by independent groups of highly-qualified individuals. The result is an estimate of MOL system costs which is believed to be realistic.

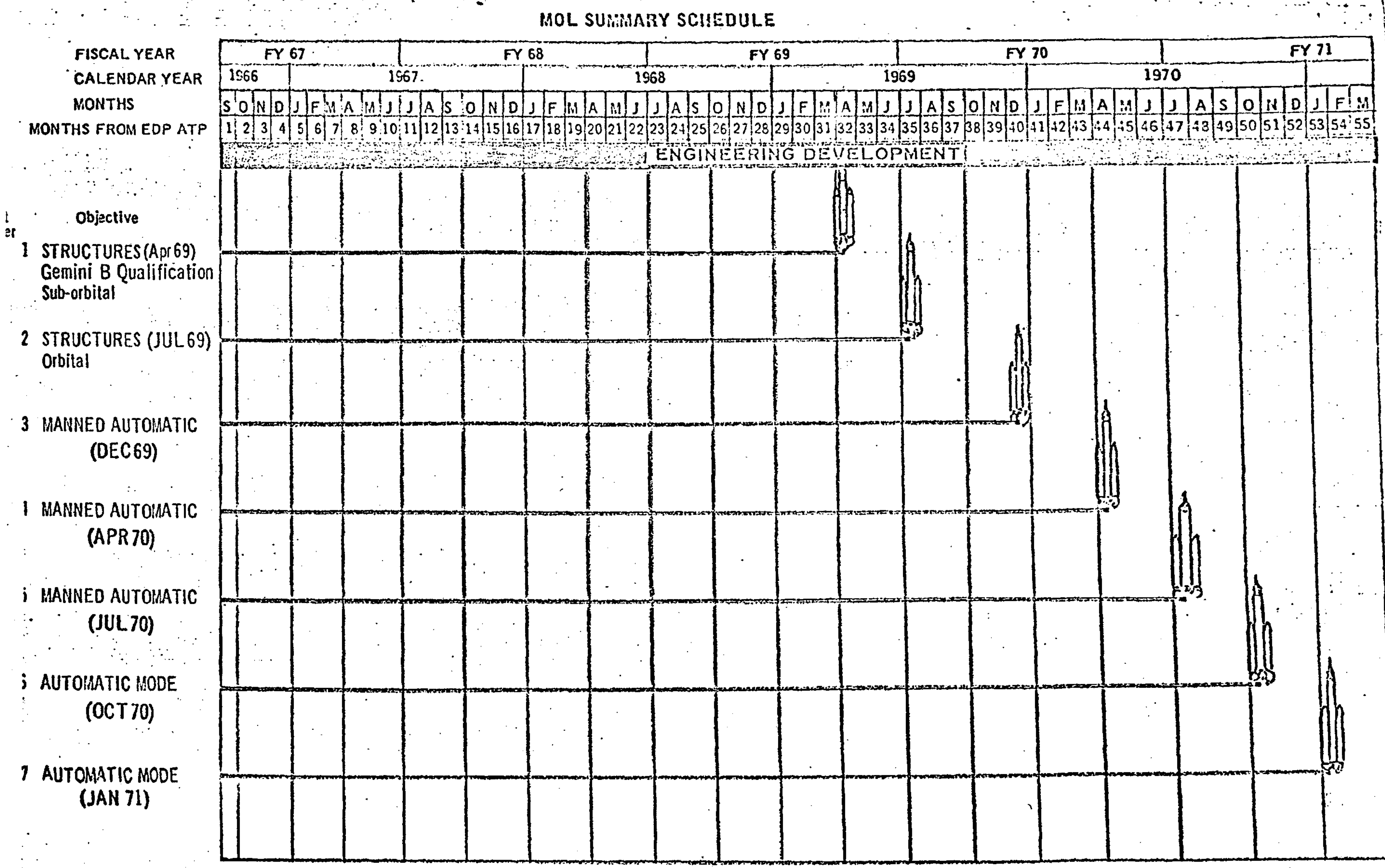
It should be noted that the cost estimates shown in Figure B-2 provide only for the basic program. There is no allowance for system improvements beyond the primary optical reconnaissance mission. While the desirability and potential of other possible military applications of MOL, such as SIGINT and Ocean Surveillance, have been recognized, the costs for such secondary objectives are not included in the estimates shown. Neither are costs included for scientific and technological orbital experimentation effort not related to the primary mission for which MOL may be particularly suited.

To provide a basis for cost comparisons, the following estimates of recurring costs are shown. These costs assume a 5-year operational program with current baseline configuration at 4 and 6 flights a year.

MOL Recurring Costs ($ Millions)

| | Manned Mode | | Unmanned Mode | |
|---|---|---|---|---|
| | 4/year | 6/year | 4/year | 6/year |
| Lab Vehicle | $25.3 | $23.0 | $22.0 | $19.8 |
| Mission Module | 24.0 | 22.8 | 22.1 | 20.8 |
| Gemini B | 16.5 | 15.5 | - | - |
| Support Module | - | - | 4.0 | 4.0 |
| Titan IIIM | 17.0 | 15.6 | 17.0* | 15.6* |
| Crew & Equipment | 0.5 | 0.4 | - | - |
| Test/Operations | 1.0 | 1.0 | 0.5 | 0.5 |
| GSE/TD | 0.5 | 0.4 | 0.5 | 0.5 |
| TOTAL | $84.8 | $78.7 | $66.1 | $61.2 |

*This cost is for the 7-segment Titan IIIM which provides 41 days mission design life.




~~SECRET~~ - Special access required (SAR)

Figure B-1

TAB C

BASELINE MOL EFFECTIVENESS FACTORS

I. RELIABILITY, DEVELOPMENT RISK AND MISSION SUCCESS

The Laboratory Module segment of the MOL is based on current state-of-the-art subsystems, which in large measure have been adapted from the Gemini and Apollo programs. The Mission Module segment, on the other hand, which contains the DORIAN high resolution optical sensor, represents a major advance in the state-of-the-art, with an attendant high development risk. Additionally, MOL, in its development configuration, is designed to function both in manned and unmanned modes; hence, it is somewhat more complex than would be the case if either mode were flown singly. Many new components and subsystems must be developed, or adapted from existing designs to provide for this dual capability. Important new developments are:

A. Image Motion Compensation (IMC) across the Film Format

B. Image Tracking (V/h) Sensor

C. Tracking Mirror Drive Servo Subsystem

D. Acquisition and Tracking Scopes

E. Thermal Control Door and Louver Assembly

F. Focus Sensor

G. Automatic Optical Alignment System

H. Low Drag Accelerometer

I. DORIAN Optical Assembly

J. Re-Entry Vehicle Launcher

Adaptation from existing designs are required for:

A. On-Board Computers

B. Star Trackers

C. Re-Entry Vehicle

D. Consoles, Displays and Associated Instrumentation

E. Thermal Control System

Because of these new engineering requirements, assurance that the vehicle functions reliably is a major factor in system design. In order to provide a basis for a reasonable projection of reliability values, a failure analysis of the current GAMBIT program was conducted. The types of failures encountered fell into two general categories. The first of these, about 75 percent of the total, consisted of failures attributable to design deficiencies, procedural errors, or faulty quality control, and hence were amenable to corrective action. The remaining 25 percent of failures fell into the second category, failures attributable to statistical or unknown causes. It is also of interest to note that all failures of the first category occurred in the first day on orbit, whereas the failures in the unknown category were distributed throughout mission duration.

GAMBIT failure rates have been reduced in recent flight history through a sophisticated and thorough ground testing program in which incipient failures were detected and corrected before actual flight. This testing is analogous in approach, though neither as extensive nor similar in motivation, to the "man-rating" process which NASA has employed to a high degree of success, and to which MOL will be subjected.

With an intensive approach to ground testing, occurrence of failures of both categories can be reduced, but it is clear that failures of either type cannot be completely eliminated. The Mission Module, representing advanced state-of-the-art, can be expected to experience malfunctions at a higher rate than the Laboratory Module, for which phenomenology and technology are well in hand.

However, the development configuration MOL is being designed to take the maximum advantage of the presence of man in the event of equipment failure. Equipment is being designed and installed wherever practicable to permit astronaut access for trouble shooting, adjustment, maintenance, repair, and replacement. The system is being designed to permit manual switching and override so that man can work around problems, choose alternate modes, or himself perform many of the functions for which the faulty equipment was intended. He can detect malfunctions, both incipient and actual, diagnose, and institute corrective measures. He can also work in coordination with ground based technical support. This team approach, as shown by aircraft experience, is a powerful technique for overcoming in-flight problems. The recent XB-70 experience in which a nose gear failed to lower is an excellent case in point. Repeated consultations between flight crew and ground supported by trouble shooting in flight, permitted the diagnosis of the trouble, and a corrective action to be devised to lower the nose gear. These factors are expected to be major contributions to the early success and maturity of the unmanned and manned configurations of MOL.

Adoption of these design principles also makes it possible to continue a mission in the manned configuration despite cumulative equipment failures beyond man's capacity to repair. The normal mode of MOL operation, either in the unmanned or manned mode, is essentially automatic. When man is present, automaticity is exploited by utilizing the crewmen in tasks such as selection of alternate targets of high intelligence value, selection of cloud-free alternate targets when primary targets are obscured, and rapid return of important photographs by wideband data link. In the event of the failure of automatically functioning devices during a mission, the crew can perform many of the necessary functions manually and hence preserve the capability of the vehicle to continue to collect photographic intelligence. The following equipment can fail cumulatively with little or no degradation in mission performance beyond the basic capability of the manual mode:

A. Image Tracking (V/h) Sensor

B. Image Motion Compensation (IMC) Across the Film Format

C. Star Trackers

D. Data Recovery Vehicle Launcher

E. One SGLS Command and Tracking Data Link

F. Two Fuel Cells

G. One Cryogenic Tank

H. Three Pairs of Attitude Control and Translation System Fuel Tanks

I. Twenty-five percent of Attitude Stabilization System Thrusters

J. Automatic Mode for Orbit Adjust

K. One On-Board Computer

L. One Acquisition and Tracking Scope

M. Laboratory Attitude Reference System

N. Auxiliary Computer Memory Storage

The resulting performance in the manual mode after failure of the above equipment is approximately equivalent to that of the automatic configuration with all of its equipment functioning, except that overall mission photographic resolution still remains somewhat better in the manned mode due to man's target centering capability. A most important outcome of the flexible development and test support functions possible when man is present in the vehicle is that trouble shooting, adjustment, maintenance, repair and replacement, or actual manual performance of automated functions will be done on much of the equipment in the high development risk category.

A numerical reliability analysis of the Mission Module alone in the automatic mode results in a mature reliability figure of .892, although it is somewhat less (.8 to .85) early in the flight program. This analysis is based on a random failure rate of one failure per ten million hours per Active Element Group (AEG), and estimating that the Mission Module contains the equivalent of 10,000 AEG's in serial, and 19,000 in redundancy. For reference purposes, GAMBIT has an equivalent AEG count of 6500, and GAMBIT CUBED is estimated at about 10,000. Clearly the Mission Module is a very complex system element.

Reliability estimates were then computed for the MOL as a system, as presently configured to function in both manned and unmanned modes, and for a comparable wholly unmanned system, both using the same Mission Module. A comparison of the two approaches was then undertaken to determine the number of launches which would be required to complete development programs resulting in vehicle designs of approximately comparable performance and reliability. It was determined that for a wholly unmanned system, about ten development launches completely equipped with the high resolution optical sensor would be necessary as compared with the current MOL Program which provides for seven development launches. Of these seven launches, two are preliminary validation launches not equipped with the optical sensor. The remaining five are equipped with the high resolution sensor, three in the manned automatic configuration and two in the unmanned automatic configuration.

Based on these considerations, the current MOL development approach is considered the most effective in achieving early operationally useful intelligence collection of [redacted] ground resolution both unmanned and manned, earlier, and with significantly decreased development risk than can be expected of a wholly unmanned development program. This is largely due to utilizing crewmen for overcoming equipment malfunctions, for maintaining peak sensor performance, and also as on-orbit development and test engineers during early program phases. The automatic configuration of MOL benefits greatly from this development technique.

## II. QUANTITY, QUALITY AND TIMELINESS OF INTELLIGENCE RETURN

### A. Present Target Programming Operations

In order to provide a baseline for the discussion of the intelligence collection and enhancement techniques realizable with the MOL DORIAN high resolution optical sensor, it would be useful to review the target programming techniques in current use for a typical reconnaissance system such as GAMBIT.

The orbit for each GAMBIT mission is normally chosen to optimize accessibility of high priority targets selected for that mission, within the bounds of booster and orbital vehicle performance, and consistent with recovery requirements. This complex problem is subjected to computer analysis approximately fifteen days prior to flight, and results in a defined orbit and the corresponding required launch parameters. Launch injection errors may result in a slightly different orbit than planned, requiring that adjustments in target programming be made during the mission. Additionally, the spacecraft orbit may also be adjusted to return the vehicle to its planned nominal ground track.

The spacecraft orbit parameters, and the complete mission target deck are combined in a computer run which prints out predicted ground traces over the target areas of interest. This printout locates and identifies all targets accessible along the ground track, and specifies the optimum sequential series of photographic operations based upon system limitations, orbital considerations, target priorities, and photographic mode (mono or stereo) requirements. These computer results are modified manually for weather considerations, for conservation of expendables and last minute intelligence requirement changes. Prior to launch, the mission target program is transmitted to the Satellite Test Center at Sunnyvale, California to be translated into vehicle commands for camera pointing data and camera on and off times. Commands sufficient for about one day of on-orbit operation are stored in the vehicle programmer prior to launch. After the launch, and throughout the mission, continuously up-dated target programs are computed, and new commands are transmitted to the vehicle while it is in orbit. In this way, necessary changes in target operations can be accommodated to account for orbit anomalies, last minute intelligence requirements, and forecast weather conditions in the target areas. The time required from the initiation of a desired change in the target program until new commands can be transmitted to the vehicle is at a minimum $3\frac{1}{2}$ hours.

. When the supply of spacecraft expendables (gas for stabilization and control, electrical power, and film) is limited, and when forecasted weather in the target area indicates that the probability of successful photography is low, operations against low priority targets are generally discontinued until conditions improve. If, however, the probability that low priority targets will be cloud covered accumulates to about 70 percent, photographic attempts against these targets are normally suspended altogether. However, high priority targets are normally maintained in the target program without regard to forecasted weather.

B. DORIAN Optical System

The DORIAN high resolution optical system represents a major advance, not only in photographic art, but also in optical science. The size of this sensor, which requires a mission module 35 feet long and 10 feet in diameter to contain it, is difficult to visualize. The prime optical elements themselves stand taller than most men (they are six feet in diameter). Few astronomical telescopes approach this size, and even fewer, including the 200-inch Hale telescope on Mt. Palomar, can match DORIAN optical quality.

An optical system the size of the DORIAN sensor is essential to the achievement of [redacted] ground resolution from an orbit altitude of 80 nautical miles. With this size, and with high resolution, the optical field of view, hence the area on the ground observed by the sensor, becomes very limited.

The GAMBIT and GAMBIT CUBED systems utilize strip cameras, in which film is pulled past a slit in the focal plane in synchronism with the satellite's apparent motion over the terrain. Strips of film are typically exposed for about five seconds, which represents about 21 miles along the satellite path over the earth. The DORIAN camera, on the other hand, is a frame camera, that is the film remains motionless while the scene is tracked and entire frame of film is exposed at the same time. The DORIAN format is round, whereas both GAMBIT and GAMBIT CUBED are rectangular:

| | Camera Field of View | Nadir Frame Width | Frame Width at Maximum Oblique | Included Area per Frame |
|---|---|---|---|---|
| GAMBIT | $6.4^{o}$ | 8.95 n.mi. | 17.94 n.mi. | 188 sq.mi. |
| $GAMBIT^{3}$ | $3.2^{o}$ | 4.45 n.mi. | 8.95 n.mi. | 93.5 sq.mi. |
| DORIAN | $1.1^{o}$ | 1.54 n.mi. | 2.38 n.mi. | 1.88 sq.mi. |

It is immediately obvious that a great premium is placed on the accuracy of target location, and the precision to which the DORIAN optics can be pointed so that the target will fall in the camera field of view. At nadir, a 12,000 foot airfield runway cannot be contained in the DORIAN field of view; hence, we must now specify which end of the runway we wish to photograph. Two major effects arise from these circumstances; one, locations which represent one GAMBIT or GAMBIT CUBED target area (which in itself could contain several specific targets) will not represent several DORIAN sized targets; and two, careful target selection becomes of paramount importance because photographs of all targets which are closely clustered cannot be taken on a single active pass. Every effort must be made under these conditions to insure that each photograph is of the highest intelligence value.

C. Selection of Active and Mobile Targets

A useful operational technique, that of inspecting targets for indications or activities of a transient nature that would yield photography of especially high intelligence value, can be employed with the manned MOL vehicle configuration.

To assess the value of this technique an analysis was conducted which:

a. evaluated the effect of the limited DORIAN field of view when superimposed on actual GAMBIT photography on the size, number, and character of MOL targets;

b. determined whether certain activities or conditions might exist for periods of hours or a few days during which the value of technical intelligence would be particularly high; and,

c. determined whether indicators would be present which the crewmen could detect by examination through the acquisition and tracking scope.

The extremely high resolution of the DORIAN sensor and its limited field of view are of overriding importance in the assessment of its coverage. This becomes evident from a sample of 140 frames of GAMBIT photography in which 700 DORIAN sized targets were found. Some of these targets were larger than the available field of view and hence would actually become two or more targets. This proliferation of targets renders target selection for DORIAN of particular importance. As a first step, indicators of transitory conditions of special intelligence value that crewmen might easily detect were defined. Utilizing the 140 frames of GAMBIT photography with its 700 DORIAN sized targets:

a. The fraction of the targets which had potential for active indicators of conditions of special intelligence value was estimated; and,

b. Of those, the fraction that would have active indicators present at any given time was determined.

Transient Activity Indicator Probabilities

| Target Categories | Possibility of Occurrence | Likelihood of Occurrence |
|---|---|---|
| Missile Development & Test | 99% | 7% |
| Ground Forces | 35 | 11 |
| Airfields | 75 | 18 |
| Radar/Communications Deployment | 35 | 4 |
| Industry | 5 | 2 |
| Missile Production & Logistics | 65 | 1 |
| Nuclear Weapons | 85 | 5 |
| BW/CW | 85 | 5 |
| Nuclear Materials | 5 | 3 |
| Aircraft Production | 75 | 24 |
| Naval Activity | 65 | 9 |
| Radar/Communications Major & R&D | 100 | 25 |
| AVERAGE | 70% | 6% |

I question the validity of this.

The fraction of targets for which active indicators can be defined is relatively large while the incidence of indicators is low.

Because of its importance in yielding early technical intelligence data on the USSR missile and space programs, Tyuratam has been studied in some detail. In addition to its specific importance, Tyuratam is also a typical example of other high target density complexes such as Sary-Shagan and Kapustin Yar which contain large numbers of high priority, active targets. More than 60 targets can be identified currently at Tyuratam and the number is increasing steadily. Five GAMBIT frames laid down with care will cover the entire Tyuratam complex. Forty DORIAN fields of view have been defined, with specific locations, which would generally return the same "target take" as the five GAMBIT frames. With four over-flights per mission and two stereo pairs per over-flight, on the average, one DORIAN system flight will be about equivalent to one GAMBIT system flight in terms of the "target take" at Tyuratam.

An analysis was made of Tyuratam photographs of pads and silos: 159 pad photographs yielded 9 percent with missiles on the pad; 77 silo photographs yielded 21 percent with doors open. These are much higher incidences than would be expected from operational systems, which further emphasizes the importance of obtaining data in the early development phases.

The unmanned MOL configuration would require times from months to years to develop a high probability of catching a particular missile on a pad depending upon the priority structure given to the forty fields of view required to cover the complex.

However, crewmen aboard the manned configuration can examine targets for active indicators through their acquisition and tracking scopes, and can begin to yield a gain in the return of photographs of high intelligence value. An estimate of typical resolutions needed by the crewmen to detect active indicators was carried out with the following result:

| Photo Target | Indicators | Decision Resolution |
|---|---|---|
| Missile Sites (Completed) | Missiles Exposed | 10 Ft. |
| | Erection/Loading Equipment Exposed | 10 |
| | Vehicular Activity | 10 |
| | GSE Exposed | 5 |
| | Silo Door Open | 5 |
| | Special Vehicles | 3 |
| | Snow Removal | 10 |
| Airfields | New Aircraft | 15 |
| | Unusually Configured Aircraft | 5 |
| | Aircraft in Unusual Locations | 15 |
| | Disassembled Aircraft | 5 |
| | Aircraft/Ground Equipment in Weapons Loading Areas | 10 |
| | Aircraft Subsystems Exposed | 3 |
| | Aircraft in Maintenance Docks | 10 |
| | Vehicle/Truck Activity around Aircraft | 5 |
| Ground Forces, Major Installations | Vehicles Present | 5 |
| | Vehicle Types | 3 |
| Motor Pool | Maintenance Activity | 5 |

The question of the practicality of this mode of operation hinges upon two points:

a. with what resolution can the crewman examine the target; and,

b. how long can he examine the target before a decision is required.

It appears that a reasonable design for the tracking scope will permit the following range of operation:

| Ground Resolution | Field of View |
|---|---|
| 3 - 4 feet | $1^{\circ}$ |
| 30 - 40 feet | $10^{\circ}$ |

With the particular time constants of the MOL/DORIAN system, the crewman will have 10 seconds to examine and judge for the presence of indicators (starting the examination with the target at $36^{\circ}$ ahead of the vehicle and ending at $11^{\circ}$ ahead). If the judgment is affirmative, a $15^{\circ}$ stereo pair can be obtained looking aft at $-5^{\circ}$ and $-20^{\circ}$. If a larger aft angle is acceptable the examination time can be correspondingly longer.

The specific concept of the "examination for active indicators mode," is to program the primary optics as though the MOL vehicle were unmanned. In addition, the two acquisition and tracking scopes will be programmed automatically to acquire and track two targets in the immediate vicinity of the target programmed for the primary optics (specifically, the three targets will be chosen to establish to the most efficient roll angle between them, thus optimizing the time to slew the primary mirror from one to the other). At any instant that a crewman makes a judgment that active indicators are present (and the weather is good), he interdicts the automatic program, the primary mirror slews to the position of the acquisition scope mirror, and a stereo pair is obtained. At the end of the sequence, the primary optics returns to the next pre-programmed target.

Several key points emerged from the analysis:

a. Because of the low incidence of active indicators and hence infrequent interdiction of the automatic program, acquisition of pre-programmed targets is affected only slightly.

b. The reduction in cloud-free photographs returned in the automatic mode because of crew interdictions is offset by the added number of cloud-free photographs of special intelligence value, even if the enhanced value of the special photographs is not taken into account.

c. The ratio of cloud-free photographs of special intelligence value returned with crew participation is about three times that without crew participation. This ratio is probably conservative since it does not account for: (1) examining more than one target in the 10 second period in high target density areas and with possible slow panning by the crew to cover large targets like airfields and harbors; and, (2) possible increases due to crewman examination and judgment of weather factors.

A digital data readout system in the MOL baseline system is capable of reading out 15 stereo pairs (1" x 1") to the ground per day. Thus the crewmen can select the target area from a frame, and transmit to the ground all cloud-free special photographs which they have acquired. The remaining capability can be used to transmit photographs of high priority targets taken in the pre-programmed, automatic mode. out now!

Turning again to the previous example of Tyuratam, the number of special photographs collected would be expected to increase by a factor exceeding three over an unmanned automatic mode. There are several reasons why the increased ratio should be realized:

a. The targets tend to be clustered so that several may be examined in a single field of view or with a slight amount of panning.

b. Examining launch pads for the presence of missiles might well be done at 10 to 20 foot resolution, thus tripling or quadrupling the field of view examined by the crewmen as compared to the main optics.

c. The targets at Tyuratam have very little background clutter and the crewmen will become extremely familiar with them through repeated training and examination. Thus, it is expected that the time to examine a target will be much less than the allotted 10 seconds.

In general, the MOL system with crew participation can be expected to return two to four times more special photographs from Tyuratam than the current return with the GAMBIT system (with the MOL system flying half as many flights).

A special category of active targets deserves particular attention. These targets are not only transitory, but they are also mobile. Examples are: (a) an experimental aircraft which may operate from a known airfield, but its location on the airfield is not known; (b) a missile or space booster being transported on an access road in the vicinity of a target launch pad; (c) tanks, mobile missile launches or similar materiel in a field or a general research and development area; (d) trains on sidings. The specific location of these targets cannot be predicted with surety, but a search in the vicinity of the main optics field of view can surface these targets. The man can then make a vernier centering adjustment to bring the special target into the primary field of view.

Although this analysis and the results of ground simulations using GAMBIT photography are very promising, they cannot be regarded as totally valid quantitative indicators of orbital manned performance. In particular, the effects of the atmosphere, haze and scintillation in direct viewing by the human eye is quite different than when seen on film. Conversely, color often provides cues not evident in black and white photography. Further exploration of this function from very high-flying aircraft will provide additional data which may validate the efficacy of the unaided human eye or indicate the need to introduce some contrast enhancing transfer medium to give the same effect as film.

Filters

D. Selection of Cloud-Free Targets

A function which is compatible with the selection of active and mobile targets is the observation of weather conditions and the identification of targets which are judged to be in the clear. The Soviet weather averages only about 50 percent cloud-free, so that generally one-half of the target attempts will be unsuccessful unless a selection method is employed.

In the MOL, the spotting scopes are continuously directed automatically toward programmed targets. Employing the scopes, the operators will have a device against which to exercise the weather option along with inspection for indicators of activity.

In order to examine whether the weather patterns will permit such activity, the results of an extensive analysis were obtained, based upon the inspection by the Government Weather Center of 152,000 frames of KH-4 photography. In addition, the photography from more than 3,000 KH-7 camera operations was reviewed for the purpose of correlation. A model of the weather conditions was then drawn which established the probability of finding an alternate target in the clear when the primary was obscured. When applied to a simulated DORIAN mission, these studies showed that a substantial improvement of about 20 percent in the production of clear photographs could be made by cloud-free selection methods.

III. ALTERNATE MISSION POTENTIALS OF HIGH INTELLIGENCE VALUE

[redacted]

[redacted]

B. Crisis Surveillance and Tactical Targets

The MOL can, in times of crisis, be boosted from its 80-mile orbit to orbits of 200 to 250 miles. The advantage of the higher orbits is that they permit access to all targets in the Sino-Soviet land mass once every two to three days or so depending upon the actual altitudes and orbital ellipticity selected. Altitude changes are accomplished by using fuel normally utilized to sustain the MOL in its usual orbit. When the orbit perigee is raised, fuel expenditure for orbit sustenance is sharply decreased, and duration on orbit can remain unchanged at the normal 30 days. The maximum circular orbit altitude which can be attained with available fuel is about 260 nautical miles, although the Gemini B sets a practical limit of about 240 miles. Above this altitude, insufficient thrust is available from the retro-rockets (on the presumption that only five of the six rockets provided function properly) to de-boost the Gemini for re-entry. Eliptical orbits can also be selected, rotating the line of apsides, for example, so that apogee occurs over the area of interest. Orbital limits in this case are set by permissible Gemini re-entry angles, and, at the higher average altitudes, the Gemini de-boost capability. The following shows the circular orbit altitudes to which MOL can be boosted according to when the change is initiated from a typical normal orbit (80 n.mi. perigee, 180 n.mi. apogee, inclination 80°) and the total mission life in days. In all cases, re-entry is initiated after 30 days in the higher orbit.

| *New Circular Orbit Altitude | Orbit Change Initiated on: 1st Day | 7th Day | 14th Day | 21st Day |
|---|---|---|---|---|
| 150 n.mi. | 30 | 30 | 30 | 30 |
| 180 n.mi. | 30 | 30 | 30 | 30 |
| 200 n.mi. | 30 | 30 | 30 | 30 at 190 n.mi. |
| 250 n.mi. | 30** | 30 at 210 n.mi. | 30 at 200 n.mi. | 30 at 190 n.mi. |

*NOTE: 213-6 n.mi. repeats every 2 days, 240.5 n.mi. every 3 days.
**Marginal. Exceeds Gemini de-boost limit.

The field of view of the DORIAN sensor in terms of area of terrain observed is increased, and its resolution decreased at higher altitudes. For crisis purposes, the advantage is the larger area covered per pass rather than the area per frame.

| Orbit Altitude over Area of Interest | Nominal Resolution | Area Observed at Nadir |
|---|---|---|
| 80 | [redacted] | 1.88 sq miles |
| 150 | | 6.56 sq miles |
| 200 | | 11.65 sq miles |
| 250 | | 18.25 sq miles |

In addition to the prime optical sensor, which can be utilized simultaneously in both photographic and visual modes, both of the acquisition and tracking scopes can be programmed to different suspect areas on the ground, multiplying the opportunity for the observation of activities of interest. Although acquisition and tracking scope resolution will fall off to about 9 feet at 250 n.mi., the field of view is large compared with the DORIAN sensor, and some categories of activity can be readily distinguished visually, such as:

a. Gross estimate of large objects, such as aircraft, ships in port, tanks in park.

b. Verification of the absence or presence of aircraft on airfields, ships in port, cargo in port, army vehicles in camp.

c. Estimate of whether railroad yards are empty or full, and if full, general class of rolling stock present.

Hence, operated in this mode, advantage of man's flexibility and adaptability is turned to the return of urgently needed intelligence data on a daily basis.

C. Visual Reconnaissance

Apart from the support which visual observation affords the primary photographic mission in terms of weather avoidance, active and mobile target selection, and to the crisis surveillance mode in terms of verifying order of battle, and confirming presence or absence of major activity, visual reconnaissance remains a latent potential. It is possible that a critical examination of important targets, during the high resolution photography sequence, can provide supplementary information of major value. Targets can be inspected by the crewmen from a continuously changing aspect. They can do simple counting by class of object, discriminate detail by color, classify activity, and detect and classify movement. The value of visual reconnaissance from space is difficult to assess at this point in time, but an assessment will result as a byproduct of other MOL program activities.

D. Observation and Mapping of Mars

It is expected that interest in the planet Mars will be heightened in the 1970 time period as the national space program looks beyond Apollo. In support of this interest, the DORIAN sensor, with no change in its configuration, offers a capability to examine and map the entire surface of Mars at about 50 n.mi. resolution. This is considerably better than present ground based systems (300 n.mi.) which are handicapped by the turbidity of the earth's atmosphere. At present, the DORIAN sensor appears to be the largest instrument capable of astronomical observation which will be in orbit during the time of interest.

Astronomical and planetary observations in addition to Mars can also be conducted. However, the current DORIAN pointing and tracking system is not configured to support the long exposure times needed for photography of distant objects. This aspect is treated in more detail in TAB D.

TAB D

## ADDITIONAL CAPABILITIES OF THE MOL SYSTEM

## I. INTRODUCTION

MOL system capabilities can be treated in four different categories:

1. Basic MOL/DORIAN system capabilities for additional missions without changing or adding to basic equipment.

2. Basic MOL/DORIAN system capabilities for mission enhancement with minor equipment additions or changes.

3. Basic MOL vehicle capabilities for other than high resolution optical reconnaissance missions.

4. Growth potential capabilities toward higher optical resolution, and increased effectiveness.

The category stage of the use of MOL has been treated in TAB C. This tab summarizes the latter categories stages of MOL capabilities which can be achieved with varying degrees of modification of the present MOL baseline system.

## II. BASELINE SYSTEM WITH DORIAN PAYLOAD AND MINOR EQUIPMENT ADDITIONS

### A. Improving the Current System

Improvements to the MOL/DORIAN system as now configured will continue as a normal consequence of the growth of technology. Effort both in the application of technology, and in studies is now being expended to this end.

However, there is also existing technology which has developed to the point that serious consideration must be given to is application to MOL. Of major current interest is the proprietary ceramic-vitreous material CER-VIT manufactured by the Owens-Illinois Glass Company. This material has a very low thermal coefficient of expansion ($0.05 \times 10^{-6}$ in/in/°F). Used in place of fused silica for the primary asphere and tracking mirrors in the DORIAN optical system, it would permit a reduction of about 700 pounds in basic vehicle weight, as much sensor thermal control equipment could be dispensed with CER-VIT polishes as well or better than fused silica and, unlike fused silica, can be cast into desired configurations. Hence its manufacture is considerably cheaper than fused silica.

B. Electromagnetic Pointing System

Activities are presently underway to define and evaluate a small, lightweight auxiliary electronic sensor system to enhance the system effectiveness of the primary optical sensor. The Electromagnetic Pointing System will be capable of identifying and locating emitters, and pointing the primary optics with sufficient accuracy to assure that the target emitters will be contained within the optical field of view. [redacted] Overall system weight including antennas will be less than 300 pounds, peak power less than 250 watts, and total volume less than 5 cubic feet.

The primary employment of the Electromagnetic Pointing System (EPS) will be to furnish information to the operator which will increase mission effectiveness by giving him options of:

1. Observing that pre-programmed photography is possible and appropriate in terms of the electromagnetic environment when this is an element of the target characteristics.

2. Determining that a pre-programmed alternate target is more appropriate.

3. Determining that a non-preprogrammed "possible" target is more appropriate.

In the latter two cases this action will be "appropriate" either because of the transitory nature of the target or the necessity for real-time photo and electromagnetic intercept of a target emitter. [redacted] The technical analysis capability will permit the operator to obtain detailed wide-band photographic recordings of complex signals on a pre-programmed basis.

The design of the EPS will be such that its inclusion with the primary photo sensor will neither degrade its operation nor result in a lower reliability for the system. There will be no direct automatically controlled connections between the photo sensor and the EPS. Coordination of the pointing functions of the two sensors, if any, would only be initiated upon manual command of the operator.

C. Ship Detection

In-house studies have defined a radar system with modest capabilities, power and orbit sustenance requirements which would be suitable used for detection of ships on the high seas. The system would cover a swath 100 miles wide and detect ships of the size of trawlers. Its weight is estimated at 400 pounds. It can enhance the intelligence value of the MOL mission by detecting moving targets, such as ships, which cannot be accurately programmed into the MOL target deck. It would be used in specified limited areas to alert the MOL crew to obtain high resolution photographs of ships.

D. Astronomy

The DORIAN optical sensor is capable of being used as a precise astronomical instrument. It can be employed for some planetary and near stellar photography without change. However, as the baseline configuration is designed with attitude stabilization tolerances and refractive optical system components best suited to high resolution photography of the earth's surface, its baseline capability is confined to the visual spectrum, and to those objects sufficiently bright to permit use of short exposure times.

Application of current state-of-the-art stabilization and pointing techniques would permit the sensor to resolve distant stellar objects to 0.1 seconds of arc, an order of magnitude improvement over current observations from the earth's surface which suffer from atmospheric limitations. The limiting visual magnitude of the DORIAN sensor is about 26, with a 20 minute exposure on high resolution film.

The refractive optical elements in the baseline Ross corrector can be replaced by fused silica to permit access to a wider spectral range. The basic sensor design could also be slightly altered by replacing the Ross corrector with first surface reflecting elements to permit access to an even wider spectral range. These altered configurations would permit observation of ultra-violet sources which are denied to sensors on the earth's surface due to the filtering action of components of the earth's atmosphere. This latter configuration of the basic sensor is also capable of high quality spectrophotography.

III. BASELINE MOL WITH OTHER PAYLOADS

MOL, in addition to performing optical reconnaissance has a potential for fulfilling other mission capabilities. At present Ocean Surveillance and SIGINT missions are being studied by the Navy.

A. Ocean Surveillance

The objective of the MOL Ocean Surveillance studies under way is to define an experimental program for testing satellite sensors and sensor usage concepts, needed to obtain information for the design of an operational ocean surveillance satellite system.

The following types of sensors are being considered:

1. High-Resolution Synthetic Aperture Side Looking Radar
2. Conventional Search and Detection Radar
3. Photo-Optical Equipment
4. Passive Electronic Signal Intercept Equipment

The necessary level of detail which ocean surveillance satellites must collect relative to detected targets has not as yet been established. It is possible that with improved and properly integrated ground systems, satellites need only supply accurate location information for detected targets. On the other hand, it may be necessary for the satellite to classify every target as to type and identify specifically some percentage of targets in the open ocean. In addition it may be necessary to frequently observe conditions in selected ports and harbors throughout the world.

The Ocean Surveillance configurations under consideration are designed to operate in at least four modes, according to the amount of information to be obtained on various test runs. The role of man in the various modes will range from no participation to complete integration in a man-machine combination. The four modes in order of increasing data transmission requirements are:

1. Target detection and location only. Fully automatic operation, with all data transmitted to ground.

2. Fully integrated man-machine operation, with the astronauts performing image interpretation and data analysis aboard the satellite.

3. Semi-automatic operation of full array of sensors, with man intervening for functions such as selection of targets for high resolution sensors, and selection and cropping of imagery for transmission to the ground. Image interpretation to be performed on the ground.

4. Target detection and location, plus heading and speed determination (if feasible) and collection of high resolution imagery. Fully automatic operation, with all data to be transmitted to ground.

B. SIGINT

SIGINT Studies are currently underway aimed at determining the feasibility of obtaining intelligible data from side-lobe and re-radiated energy of sophisticated communication systems. On completion of these studies, it is hoped that the technical parameters of a configuration can be developed which would permit the interception of this category of intelligence. It has been estimated that the information transmitted via soviet microwave radio relay links, presently not available to our intercept systems, spans both military and civil activities in the Soviet Union and that this condition will become more pronounced as these types of systems come into more and more general use.

Other types of sophisticated Soviet electronic systems under development could yield valuable technical intelligence if intercepted.

At the conclusion of these studies it is proposed to configure a SIGINT system which would incorporate the SIGINT missions considered most urgent and which can be done effectively by a manned system. The majority of the manned tasks which have been identified by current studies [redacted]

C. Multi-Purpose Laboratory

In addition to its other capabilities, MOL has the potential for providing a unique laboratory environment for the execution of specific experiments. These experiments can support the objectives of both NASA and the DOD. The MOL has 1,000 feet of pressurized volume, and can provide up to 3,000 feet of unpressurized experimental equipment into polar orbit on 30-day missions with a crew of two.

The experiments considered of interest to the Department of Defense can be grouped into the following three categories:

1. Those having potential for improving the ground resolution capability of the primary mission sensor.

2. Those which demonstrate and test concepts and components necessary for advancement and growth of the primary mission capability.

3. Those which explore future potentials or contribute to development of equipment for other military space systems, either manned or unmanned.

Examples of these various categories of experiments which might be conducted with the MOL for the Department of Defense are listed below:

Knowledge is needed on the performance of large mirrors on orbit. The alignment, erection, pointing and tracking, focusing, figure control and the behavior of materials such as beryllium, CER-VIT, fused silica, pyroceram are all essential to improving ground resolution capability of the primary sensor.

To establish our potential for new manned military missions, experiments must be conducted in the area of communications (low frequency, millimeter wave, laser propagation and high frequency inospheric ducting) and the erection and maintenance of associated antennas. Experiments to establish countermeasures against hostile attack of the MOL are needed. Experiments to improve techniques for nuclear detection and arms control are also essential.

## IV. MOL GROWTH POTENTIAL

The MOL system is well suited to grow beyond its present development program status toward greater operational utility. It can grow in two ways which are mutually supporting. The optical sensor can be increased in size to approach the ultimate capability which is limited only by atmospheric phenomena. Because of the necessary weight growth of such a large optical system and the natural conclusion that orbital life longer than 30 days is more cost effective, the system will grow in size. The consequence of this size, weight and life growth is that a bigger booster is required or the rendezvous approach be employed. The large optical sensor and rendezvous are discussed in greater detail below:

### A. Large Optical Sensors

Studies indicate that primary and tracking mirrors up to about [redacted] in diameter are feasible under existing technology. Larger size optics will probably require new construction methods primarily due to problems of structural rigidity, test and handling problems in the earth's gravitation environment. Ground resolution improves with increasing mirror diameters of up to about [redacted] where vehicle vibration, atmospheric turbulence, reduced field of view, weight and other such system factors assume much greater significance. The present state of technology should permit the acquisition of optical systems capable of [redacted] photographic ground resolution.

The capability to achieve [redacted] ground resolution can develop readily from the MOL baseline program. The development risk will be inherently high but minimized by the presence of man. The need for the man in system operation will be definitely higher than for the present DORIAN system. The fabrication difficulties, complexity and costs may well dictate a rendezvous approach to minimize the number of sensors required. It is estimated conservatively that a sensor with [redacted] ground resolution will weigh a minimum of 20,000 pounds.

B. Long Duration and Rendezvous

For satellite missions involving complex, heavy, or costly payloads, cost effectiveness is generally improved by increasing the orbital lifetime. The lifetime of a satellite is limited primarily by the quantity of expendable supplies such as fuel for power and propulsion, film, gas, etc., that can be injected into orbit with the selected booster. For a manned satellite, expendables such as food, water, and atmosphere and adverse physiological effects such as yet unknown effects of zero gravity and accumulated radiation dosage further limit the lifetime. In either the manned or unmanned case, equipment reliability is also a limiting factor, although in the manned case the test, maintenance and repair capability reduces the probability of mission failure. Essentially then, longer life missions are obtained by larger boosters, increased equipment mean-time-to-failure, and rendezvous.

At present rendezvous is conceived of as applicable only in the manned case. The operations of docking, transferring expendables, etc., appear too complex to be accomplished completely automatically. Orbital rendezvous is advantageous for long life missions requiring resupply of expendables, crew replacement or rescue, and assembly of large, heavy objects. The cost effectiveness trade-off of increasing booster size versus resupply for satellite missions varies with the value of the payload remaining in orbit and the mission lifetime.

It has been determined that the expendables section of the automatic mode configuration of the baseline MOL can be sized so as to evolve into a follow-on configuration with minimum modifications. The automatic mode vehicle would be launched as the first vehicle in a rendezvous program. The resupply vehicle would consist of the same expendables section mounted as a trailer to the Gemini B. Early in the program, a vehicle could be maintained on orbit continuously with 3 and 5 launches of the mission and resupply vehicles, respectively.

The payload capability of the rendezvous and resupply vehicle on the T-III 7-segment booster would permit launch of the [redacted] resolution sensor. In addition to providing improved performance and economics, the rendezvous system has the following attributes:

1. Simple evolution from baseline program.

2. Minimum development risk for [redacted] resolution sensor.

3. Continuous, on-call, operational capability.

4. Maximum acquisition rate and readout of special intelligence photographs.

5. Minimum recycle time (as low as one day) to photograph specific targets.

6. Continuous, on-call, multi-mission sensor capabilities.