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DORIAN

June 28, 1965

MEMORANDUM FOR THE SECRETARY OF DEFENSE

SUBJECT: Proposed MOL Program

REFERENCE: Memo for SAFUS fr DDR&E, subj: Manned Orbiting Laboratory, dtd 4 Jun 65

This memorandum presents a summary description of the Manned Orbiting Laboratory program which has evolved from the studies directed in the reference. The memorandum specifically requests authority to enter into Phase IB on this program. Some of the important considerations that led to the specific program we propose are covered in the memorandum. Greater detail is provided by the Attachments.

Briefings in detail on the proposed program have been given to Dr. Brown, and at his request, to the Panel on Reconnaissance of the President's Science Advisory Committee. We are prepared to brief you in any detail you may like, and to assist you with whatever material you may need for possible discussions with the Director of the Budget and the President's Science Advisor.

<u>Proposed Program</u>

A development program of six launches, one unmanned and five manned, is proposed. The first manned launch would take place late in calendar 1968, and the last early in 1970. Total cost for the development program is now estimated at $1653 million.

The recommended payload vehicle for these launches consists of the basic two-man MOL module and Gemini B recovery capsule which has figured in previous Air Force studies. It is proposed from the start to launch into polar orbits from WTR, using the TITAN IIIC booster. Orbital operations of 30 days' duration are proposed. To accomplish these will require increasing the length of the solid boosters on the TITAN IIIC to seven segments; the program provides for this development.

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Primary emphasis in the six-shot program will be placed on the development, demonstration, and use of a manned optical reconnaissance system promising resolutions of [redacted] on the ground. We believe that this order of resolution will be attained using an optical system of relatively conservative design having an aperture of 60"; such a system is considered to be the primary payload for the early flights. Parallel developments will be undertaken along a less conservative approach, leading to the possibility of a system of perhaps [redacted] aperture, capable of a resolution of about [redacted] on the ground.

The optics and optical technology that will be developed are directly applicable to unmanned systems. We shall carry on also the development of those elements, such as image trackers, which are crucial to the performance of large unmanned systems.

During the planning to date of this program, consideration has been given to very large optical systems which might be capable of resolutions as good as [redacted] on the ground. Such systems require new techniques of optical fabrication and radically new techniques for mounting and adjustment on orbit. They could not be accommodated in a payload launched integrally with Gemini and crew, even on TITAN IIIC with seven segment solids. We would however expect to include critical experiments toward their development as part of the six-shot MOL program.

Our studies of reconnaissance, other than photographic, have not progressed to the point that we have specific sensors or flights to recommend. We expect during Phase IB to develop such recommendations. At the present time, it appears that a manned COMINT system, [redacted] may be very productive, but further technical study is required. A manned experiment in ocean surveillance is also being studied further.

Further Details

The Attachments give some of the details of our proposed program as we have developed them in our studies up to this point. Tab H, in particular, analyzes what we have accomplished so far against the specific objectives outlined by the reference. By title, the tabs are:

- A The Potential of Very High Resolution Photography
- B Manned Functions and Simulation Data
- C Optical Systems
- D Program Considerations
- E DOD and NASA Scientific and Technological Experiments
- F Comparison of Apollo/Gemini Configurations
- G Unmanned Flight Program (Pre-MOL)
- H Actions Resulting from 4 January 1965 DDR&E Guidance

High Resolution Photography

We believe that our proposed program, based on the development, demonstration, and use of a manned high resolution photographic system, will stand the test of effectiveness when evaluated against its cost. We believe that there is a valid national need for reconnaissance photography at a resolution of [redacted] As a result of our studies, which have included comparative examination of manned and unmanned systems, we are convinced that development of a manned system can reach a resolution goal of [redacted] sooner and with a higher probability of initial success than a development based on an unmanned configuration. At this level of resolution, with our present cost estimates, we find the manned system about as productive per dollar as an unmanned system, even setting aside the greater development difficulties and risks attaching to the unmanned system. We are presently convinced that to do much better than [redacted] resolution with unmanned systems will be extremely difficult. We regard the manned program as we propose it to be an essential step toward the development of a capability for resolutions in the range [redacted] manned or unmanned. The program will include significant experimental steps toward a system having [redacted] resolution, and we plan actual demonstrations of a manned system of resolution [redacted]

In sum, we expect the six-shot program to give us, first, operational intelligence collection at [redacted] resolution [redacted] second, knowledge of the critical contributions of man to photographic reconnaissance and of the specific differences, in an engineering sense, between manned and unmanned systems of large size and very high resolution, third, the optical technology and designs for systems which, if manned, can give us resolutions [redacted] - we hope, resolutions as good [redacted]

In seeking such objectives, we must of course be confident that the earth's atmosphere will permit satellite photography of the desired quality. We are confident of this. Theoretical analyses, much data on the optical quality of the atmosphere as observed by astronomers from the ground, and an experimental program conducted by the NRO, lead us now to believe that the turbulence of the atmosphere will permit satellite photography [redacted] resolution 99% of the time, and [redacted] resolution perhaps 50% of the time. The NRO is preparing further experiments, using a camera [redacted] resolution on the ground, to establish better statistics on the quality of the atmosphere at resolutions [redacted]

A general need for high resolution reconnaissance photography is implied by the history of improvements to our reconnaissance systems, both airborne and space based. However, despite the intense pressure of need that has stimulated these improvements, we have yet to put into operation any kind of reconnaissance system that regularly produces pictures with resolutions [redacted] The specific needs for photography at this resolution and better, therefore, must be examined without much background of experience to assist the judgment.

Such experience as there is with very high resolution military photography comes from three sources: (1) Tactical reconnaissance aircraft flying at low altitudes. With modern equipment these can be expected regularly to produce photography of [redacted] resolution, and of better resolution under favorable conditions. (2) [redacted] (3) Pictures of representative U. S. military targets which have been produced under carefully controlled conditions at resolutions varying from [redacted] to three feet. A continuing program to produce and evaluate such pictures was instituted by the NRO about two years ago. Samples from the library so far developed, appropriately prepared for convenient viewing, are available for your examination. An account in some detail of what one is able to learn from these pictures is given in Tab A. A summary discussion with some examples is given in the next few paragraphs.

The first and obvious need for high resolution photography is for technical intelligence; this is the application emphasized in Tab A, and discussed in some detail below. There is also a clear need, particularly during times of crisis, for high resolution photography of tactical objectives. During the Cuban crisis, for example, repeated photographic flights were made at very low altitudes to identify details of military equipment, and in particular to determine the country of origin of some of this equipment. Most of this photography was at a resolution of [redacted] or poorer. Many of the intelligence objectives were not met at this resolution. Specifically, the national origin of tents and of some weapons were not determinable.

Closely related to both of these applications is the potential use of high resolution photography, specifically from satellites, to assist in the policing of arms control agreements. In detail, this application imposes much the same requirements, and profits from high resolution in the same way, as the technical and tactical applications.

High resolution is necessary for the penetration of camouflage. In this connection it must be regarded as a measure which would be successful against an unwitting enemy, that could however be defeated by a witting enemy at sufficient cost and effort on his part. As a consequence, inspection by high resolution satellite photography cannot alone be relied upon to prevent cheating on arms control agreements. It can make cheating more difficult and more risky. Both difficulty and risk increase as resolution is improved.

A general caveat applies to all of these applications. High resolution pictures necessarily cover relatively small areas, and are therefore pictures of targets whose existence and location are known in advance from other sources of information. This condition is almost automatic in the usual cases of technical intelligence, since the targets of interest concentrate at known sites for manufacture, test, or operation. In the case of tactical targets, or of inspection for arms control, the targets photographed at high resolution will be at sites which by other means, such as search or surveillance photography, have been identified as harboring suspicious activity. Search at a resolution of [redacted] is not contemplated, except perhaps over areas at most a few miles on a side.

A high resolution photograph reveals more information than one of the same target at lower resolution, and it reveals more unequivocal information. The credibility of findings based on photography is therefore improved by the fact of high resolution. Credibility itself can be critical. Certainly it was essential, in the case of the Cuban crisis, for President Kennedy to have pictures whose credibility was beyond his doubt, before he could make some of his crucial decisions. Much effort was extended to get these credible pictures. On at least two occasions, you have publicly displayed aerial reconnaissance photography to substantiate our Government's claims or to support our actions. I don't know how extensively we have similarly used such pictures in private talks to convince or sway potential critics or doubters. In all cases, however, credibility has been the sine qua non: without it, the pictures do not serve their purpose.

Although no unexceptionable rule can be given, generally speaking, the resolution which a photo interpreter needs to find and identify an object the first time he encounters it in a picture is finer, by a factor of several times, than the resolution he needs to find and identify this object in a picture when he is already familiar with similar pictures of it. Correspondingly, the resolution that is required to make a picture of a military object credible to one not intimately familiar with it or with pictures of it may be several times finer than the resolution needed by an expert in making a routine identification.

The discussions that follow, and those in Tab A, deal with elements of technical intelligence that require high resolution. The resolutions stated are generally those that permit the interpreter to identify a specific feature or form, and to infer purpose or operational characteristics. These are therefore the poorest resolutions at which an inexperienced viewer can be expected to place credence in the identification and inference. Better resolution would contribute further to credibility.

Tab A discusses in some detail what can be learned, respectively, at resolutions of [redacted] and 36", from photographs of missile silos, missiles erected, and a radar installation. The continuing NRO program of study, from which the material in Tab A is drawn, includes naval targets (ships, submarines, and yards), air fields, and air deployments in various states of alert, ground army targets (including field deployments), and various test sites and proving grounds. Production of the basic photographs is difficult, and analysis draws heavily on the time of people already engaged in the preparation of intelligence estimates. What is presented here and in the Tab must be regarded as a sampling from a study which is not yet complete.

Knowledge of the hardness of missile silos and of other hardened installations is of critical military value. Photographs of completed silos show that door spans and door thicknesses can be estimated [redacted] resolution, and thickness of the upper walls [redacted] Greater accuracy with more useful detail results of course at higher resolutions. A picture [redacted] resolution of a silo under construction allows estimates of other wall thicknesses and shows details of construction methods. During construction, [redacted] resolution, the size and amount of steel reinforcing can be estimated, and the arrangement determined. [redacted] resolution the soil structure and type can be fairly well determined. It is our conclusion therefore that a highly credible estimate of the hardness intended by the silo designer can be derived from pictures of construction taken [redacted] resolution, and that coarser resolutions do not serve this purpose. Whether the silo designer's intended hardness is realized in fact cannot be determined from photography at any resolution. Our own silo designs require test before we can be fully confident of their hardness. Short of test, one must study design drawings, seeking errors, and test the quality of the concrete, etc., for a determination. Possible weaknesses of door seals, locks, and opening mechanisms might be observed [redacted] resolution.

We believe that it is fair to conclude by analogy that the hardness of other underground installations can be estimated from photographs of construction taken [redacted] resolution. We expect that photographs of submarines under construction, taken [redacted] resolution, will allow good estimates of their hardness - i.e., their depth capability. We have not yet acquired the photographs necessary to test this expectation. It is significant in this connection that much Soviet submarine construction takes place out of doors.

For a quite different example, we have chosen pictures of a large tracking antenna. Questions of the most immediate military significance are - is it passive - i.e., a receiver only, - or is it active? If active, is it a radar or for communications? At what frequency does it operate? What is its purpose, its range, its threat?

General antenna type and size are of course evident with a resolution of three feet, as well as some indication of power level, estimated from the size of associated buildings and cooling facilities. [redacted] resolution, one sees details of the mount construction which allow estimates of its intended stability. This stability gives an indication of the angular accuracy demanded of the tracking, hence, in association with the size of the dish, some indications as to the highest frequencies of intended operation.

[redacted] resolution, one sees details of the feed system which determine whether the system is passive or transmits as well. [redacted] resolution, details indicative of the power level of the transmitter feed appear. From this, one can be fairly confident of distinguishing a tracking radar from a communication device, and can estimate the power level of either. At frequencies lower than UHF, measurements of the feed system made [redacted] resolution can give a good estimate of the frequency of operation. Higher frequencies, hence smaller feeds, call for better resolution.

In the particular photographs we now have, [redacted] resolution, but not [redacted] resolution, one sees accurately the mesh of the antenna dish, allowing a good estimate of the highest frequency of operation. A higher frequency, and a finer mesh, would demand finer resolution.

In sum, we feel that [redacted] resolution one can fairly well determine the general purpose, power, frequency and range of an electronics installation operating at UHF or lower frequencies. If it is a radar, this determination would establish its threat. With an estimate of frequency, one can target ELINT equipment to determine signal parameters for the design of countermeasures.

In the case of missiles, the items of most pressing military significance are: type (i.e. ballistic, air breathing, SAM, IRBM, ICBM), range, payload, state of readiness, warhead hardness, and special features implying possible vulnerability, such as radio guidance on a SAM. Form and gross sizing can be determined from photographs at a resolution of three feet; inferences as to type can therefore be made, and estimates of gross weight. [redacted] resolution, good sizing of missile, warhead, and of possible aerodynamic fins can usually be done. From this, one determines type and can estimate warhead weight. Accurate estimates however require identifying staging and the junction point between warhead and booster. In some cases these are visible [redacted] resolution. In other cases, junction points can be found only when one sees evidence in the external skin, such as welds, access hatches, explosive separation rings, etc., of critical points of the internal structure. Some of these features can be visible [redacted] resolution, others not. [redacted] have revealed many details of great assistance in forming and corroborating estimates of performance.

We have not yet completed our analyses of photographs of aircraft and of aircraft-related targets. Aircraft type, range, altitude, armament, and electronics are the items of military interest to be identified or determined. Photographs of both aircraft and ground support equipment will be needed for such determinations. We believe, based on our experience with photographs of missiles, that resolutions [redacted] will be required for determinations related to armament and electronics, and that [redacted] may suffice for estimates of flight performance.

We have as yet little photography of ground army targets and tactical deployments to work with. We expect that, viewed in the open, vehicles and artillery will present problems much like missiles and aircraft, yielding fairly well to photography in the range from [redacted] with much information available [redacted] As soon as one tries to deal with people and small arms, however, a new order of resolution becomes important. Many uniforms can probably be identified at [redacted] resolution, but distinctions between officer and enlisted, and many national distinctions, might require [redacted] resolution. Rank and unit insignia - except perhaps some strikingly unique ones - would require resolutions of [redacted] To identify individual people from still pictures generally requires a picture of the face at a resolution [redacted]

Small arms can probably be detected and recognized at [redacted] resolution. Technical details require much better resolution and, generally, also much better contrast than aerial photography can be expected to furnish.

<u>Manned and Unmanned Systems</u>

Tab C outlines some of the important reasons that make us feel we can reach a resolution of [redacted] more quickly and more reliably with a manned system than with an unmanned. For similar reasons, we also feel that a manned experimental program is important in reaching higher resolutions in either manned or unmanned configurations. I would like to review some of the issues here.

In the manned system we are proposing, the man performs or contributes to eight functions or functional areas:

- Detection or selection of targets
- Visual reconnaissance
- Pointing
- Tracking
- Data return
- Film handling and recovery
- Alignment and adjustment
- Maintenance and repair

These items are discussed individually below. In most instances one can think of inventions or of engineering solutions which substitute for the man. Nevertheless, as the discussion goes on, I believe you will see that to get in an unmanned system the kind of performance, in toto, that we expect of a manned system will take some new inventions and will call for a photographic system of much greater complexity than that needed when the man is present. We believe also that the man will contribute directly to the reliability of the manned system. To get comparable reliability in an unmanned system, of much greater complexity, will be very difficult.

The cost of the man is the weight and space of his living quarters, life support, and recovery system, and the weight (and engineering effort) devoted to its reliability. Nevertheless, our analyses up to this point lead us to believe that this cost is repayed by the simplicity, reliability, and better performance of the manned photographic system. A discussion of individual items follows.

Detection or selection of targets. We do not propose to call upon the man to search wide areas or to seek previously undetected targets. In many target areas, however, e.g., Tyura Tam, there are several known alternate targets equally visible but widely enough separated that they cannot all be photographed at high resolution in one pass. We believe that the man can serve an important function in examining these targets, rejecting those obscured by clouds, and selecting among the remainder the one showing the most interesting activity. Only the cloud-sensing function can be directly mechanized. We believe that there is no direct substitute for man's selective judgment. One could imagine a real time TV link to a man on the ground, but this is hardly compatible with the conditions of reconnaissance overflight of remote or denied areas. (There are other cases below in which one could also imagine substituting in this way a man on the ground for a man in orbit, equally impractically.) The substitute for selective judgment is to take pictures of all visible targets. We know today of no way to do this except by using several independent cameras, a costly and in fact impracticable solution.

__Visual Reconnaissance.__ We are designing our manned system in such a way that the man can use the primary optical system for direct viewing at high magnification. This will give him a view, not stereoscopic, but of slowly changing aspect, at a resolution somewhat better than the photo record, to which he can react at once. It is difficult to evaluate the importance of this visual reconnaissance. It is a unique bonus from man's presence. We do not claim it as a reason for including man.

__Pointing.__ For good optical reasons, the area photographed at best resolution is at most perhaps a half-mile in diameter. Off nadir, it is much smaller. Highest resolution is obtained, then, only by pointing the instrument quite accurately at the target of interest. Even assuming that this target is accurately known __a priori__, we cannot today design an unmanned system that will point with the required accuracy. A man can do it easily. Pointing is therefore a function in which man's contribution is, as of today, unique, and can be quantitatively included in comparative estimates. It is so included in Tab C. It is also a function for which alternative mechanizations can be imagined, but remain to be invented.

__Tracking.__ Image motion plagues all photography from moving platforms. Today we know that man can compensate for image motion, by directly tracking the desired target, to an accuracy many times that achievable by our best unmanned schemes. Tracking accuracy is therefore also a contribution of man which is direct, is today unique, and is subject to quantitative estimate. Again also, it is one for which we can imagine a direct substitution by a proper invention. We believe that no substitute will perform fully as well as a man, but we have postulated, in our comparative unmanned systems, a substitute which is half as good as a man - hence about [redacted] better than our best efforts today.

__Data return.__ We are planning in our manned system to provide a data link by which selected images can be transmitted to a ground station. In normal operation, the astronaut would process one frame from each target sequence and select from it an area, up to one third mile by one third mile in size, that he considers to be of most interest. Once each day, upon passing over a specific U. S. ground station, this selected material, from all targets of the day, would be transmitted to the ground where it would be reproduced at a resolution about 5% worse than the original material. Man greatly simplifies the mechanics of this operation, by handling the film, processing only the frames to be used, and preparing them for, and operating, the image transmitter. His unique contribution is that of editing or selecting the particular data to be returned. By this means, an impossibly large data transmission load is reduced to one which can be handled by a single ground station. An alternative to applying judgment on orbit is to transmit at low resolution - e.g., several feet - those pictures which are a priori thought to be desirable, and to select on the ground those small areas which would be requested for later transmission from the satellite at high resolution. Even if we used a separate collimated camera to produce the low resolution pictures, we believe that such an arrangement would be so complex that we would not incorporate it in an unmanned system designed for the highest resolution.

Film handling and recovery. Any system that returns film has the mechanical problem of conveying film from the camera to a take-up spool in a recovery capsule, cutting the film and sealing the capsule before recovery, and, possibly, threading further film into another capsule for later recovery. These operations are not easily done reliably in an unmanned system. As of today, we have never attempted to use more than two successive recovery capsules. While we cannot claim that to go to more recoveries is anything more than difficult, we are impressed by the great simplicity and guaranteed reliability that man provides in this connection. In his presence, the problem goes away.

He also simplifies, similarly, the problem of reloading the camera, to the point that one can think of regularly and reliably substituting special films for special occasions - e.g., color film, or film for twilight photography.

Alignment and adjustment. The optical system we are proposing will be extended, much like a pocket telescope, by about twenty feet in length when it gets into orbit. Man's role in this simple "assembly" operation will be supervisory. We expect thereafter, however, to depend heavily upon his visual and manipulative skills to align and focus the optical system, initially, and to test for and maintain these adjustments during operation. His contribution here is directly and closely to simplicity and reliability, and in our present judgment to performance as well. We do not now see a way, other than by making the optical system larger and heavier, to provide, without attention from a man, the performance that manned alignment and adjustment will permit. Man's visual acuity and judgment contributes here, in addition to his manipulative skill. One could go part way, therefore, by providing a TV link and commandable adjustments, so that on passes over the U. S. a man on the ground could perform an important role. We do this in a rudimentary way - without TV - on GAMBIT. We have seen the Soviets do it on their readout system.

Maintenance and repair. In our studies, we have examined closely the ways to get reliability in the over-all MOL system. One of course designs to get the best intrinsic reliability. Beyond this, he uses redundant parts and redundant circuits. At the other extreme, he provides redundant subsystems, switchable or substitutable upon demand. The astronaut contributes relatively little to reliability obtained in these ways.

Our studies show that in fact, beyond redundancy in the small and at the subsystem level, one has the possibility of carrying a reasonable stock of spare parts having general utility. These then can replace their failed counterparts without replicating one-for-one the counterparts that don't fail. A great improvement in reliability results at relatively little cost in weight.

The astronaut's judgment and manipulative powers are fundamental to this maintenance policy. We believe in fact that a manned system will have a significantly higher reliability from the start than the early phases of any unmanned system of comparable complexity. In the case of a program as developmental in nature as that we are proposing, changes in configuration will take place from launch to launch. We do not believe that an unmanned system would improve in reliability during such a developmental period as rapidly as under a stable configuration. Consequently we feel that the manned program will show a continuing advantage in reliability.

Of course, a manned system <u>must</u> be reliable, for safety. Beyond that, however, any system we consider must operate reliably on orbit long enough to return results commensurate with its cost. We believe that from the start a manned system can do this.

In sum, man's potentially unique contribution appears at this time to be the exercise of judgment in operational situations. We do not know how to assess its value. Practically, in the program we are proposing, man will contribute accuracy to pointing and tracking, and will contribute judgment, skill and simplicity to data return and film handling, to adjustment, and to maintenance. Quantitatively, these practical contributions appear to pay the cost in weight of having the man there, and yield above that a profit in reliability and performance.

As our analyses now stand, an unmanned system flyable on the same booster as the manned system of 60" aperture which we propose, would have an aperture of [redacted] Postulating two inventions - inventions which we do not claim to be impossible - namely, a pointing system twice as good as that we expect to realize on [redacted] and a tracking system five times as good as we expect to achieve on [redacted] unmanned system gives a resolution at nadir essentially equal to that of the 60" manned system, i.e., about [redacted] Resolution is however statistical, varying with target position off axis and off nadir, and with variations in focus and adjustment of the optics. From our knowledge of the man's ability to point and track, and from our estimates of the better level of adjustment that he can maintain, we conclude that the manned system would statistically show a median resolution [redacted] against one [redacted] for the unmanned.

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No new inventions are required for the manned system. Its aperture of 60" is much closer to current optical technology than the [redacted] aperture of the unmanned system. Its reliability I have already spoken to. It is for these reasons that we feel that a manned system will get us an operational resolution of four inches more quickly and more reliably than an unmanned.

Almost all of the arguments I have used above apply as well to the use of man in a development program involving larger optics, or optics of lighter weight which might be scaled prototypes for a later very large system. The arguments for manned alignment and adjustment gets stronger as sizes go up and mirrors, necessarily, get more flimsy. We do not know what the practicable size limit for an unmanned system is. We feel that the limit for a manned system is larger, because of the greater possibilities for adjustment, and we feel that the performance at a given size of a manned system will be better. We believe that the optical technology we will develop in this program will be applicable equally to manned and unmanned systems, and we also believe that a manned system will always show an edge in performance over the best unmanned competitor.

<u>Specific Approval Requested</u>

The major objectives of the Phase I effort are:

1. Generate firm MOL vehicle specifications and firm total program costs and schedules.

2. Make a decision on sensor pointing versus tracking flat for the flight test program and provide MOL vehicle interface data.

3. Study larger aperture systems, manned and unmanned, and determine their possible phasing into the MOL program.

4. Determine requirements for specific flight experiments in the manned program relating to the development of large aperture systems.

5. Continue feasibility studies on SIGINT and Ocean Surveillance and recommend flight test program if appropriate.

To satisfy these objectives and initiate the Manned Orbiting Laboratory program proposed in Tab D, the following specific approvals are requested:

1. Program approach in principle, including the planned expenditures of up to $178.3 million in FY 66 for basic program, exclusive of payload.

2. Use of the Gemini B and Laboratory on the 7 segment TITAN IIIC.

3. Primary emphasis on the development of optical reconnaissance technology and the demonstration and use of a manned system of high resolution.

4. Authorization for the Project Definition Phase.

5. Authorization and release of $39.2 million of MOL RDT&E funds ($16.2 million deferred FY 65 funds, $23.0 million FY 66 funds) to implement Project Definition and continue with Pre-MOL activities.

6. Authorization and release of $10.0 million for special activities during Phase 1 on optics, Ocean Surveillance and SIGINT.

7. Authorization and release of $1.0 million of MCP funds during Phase 1 for Architect-Engineering design of a WTR launch facility.

<u>Conclusion</u>

Simply stated, our case is: that there is a national need for satellite reconnaissance photography at four inches resolution or better, that the manned program that we propose offers the quickest and most assured way of reaching that goal, and that this program is almost essential if we are ever to develop systems, manned or unmanned, having resolutions much [redacted] I urge your approval as requested above. With it, you will initiate a program of great importance to this country's defense.

Signed
Eugene M. Zuckert
Secretary of the Air Force

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1. Tab A (B/TKH) Potential of VHR Photo
2. Tab B (Byeman) Manned Functions & Sim Data
3. Tab C (BYE) Optical Sys
4. Tab C1 (BYE) Optical Sys Flight Test
5. Tab D (BYE) Program Considerations
6. Tab E (BYE) DOD & NASA Sci & Tech Exp
7. Tab F (BYE) Apollo/Gemini Conf
8. Tab G (BYE) Unmanned Flt Prog
9. Tab H (BYE) Actions fm 4Jan65 DDR&E Guidance

TAB A

THE POTENTIAL OF VERY HIGH RESOLUTION PHOTOGRAPHY

Introduction

This paper will summarize significant aspects of present and future high resolution photography bearing on the general utility of such photography and the impact on representative present and future intelligence problems. Current knowledge of atmospheric limitation on achievability of satellite-collected, very high resolution photography will be discussed. Finally, the results of a simulation program initiated to illustrate the usefulness of high resolution photography by specific examples will be described.

Conclusions

Photography is the most credible of all intelligence source material short of official documents or the physical hardware. National policy and decisions must be based on hard data. For example, sufficient proof of the existence of missile sites in Cuba in 1962 necessitated very high resolution photography. The reality of new missiles in being or in test can remain in doubt pending photographic proof. Further, the Soviets have paraded large military hardware items which were entirely unsuspected.

[redacted] Very high resolution photography, in the [redacted] range, is required in order to formulate estimates of military capability and vulnerability with reasonable levels of engineering confidence. In addition, it is needed to ameliorate the increasing danger of technological surprise and to compress the time span necessary to define a new enemy capability after it is identified. Such photography is extremely valuable or mandatory in producing intelligence information for:

- Crisis Management
- Arms Control Inspection
- Specific Tactical Estimates
- Technical Intelligence

Background and Definitions

What is high resolution satellite photography? The definition of high resolution satellite photography has varied depending on the year and the technology existent when the question was asked. In the early days of photographic satellites, 10 to 25 feet was considered to be very high resolution, at least from a capability standpoint. The KH-7 system now produces photography of 2 feet on occasion and the follow-on system, first flight in mid-1966, is expected to produce [redacted] resolution under average conditions.

For the purpose of this paper, and considering the capability of [redacted] with a growth potential to [redacted] envisioned for MOL, "very high resolution" is defined as [redacted] It seems inevitable that in the future, satellite photography [redacted] resolution will be achievable at which time a further re-definition will occur.

Utility and Impact

Intelligence results, value, and confidence levels usually increase significantly as a function of increased photographic resolution.

High resolution is particularly important in the technical intelligence area where primary problems are usually grouped under questions of military capability or vulnerability. For example, the payload weight of missiles and space boosters is one of the first questions asked about any newly discovered vehicle. In the case of a potential weapon system, planners will want an early assessment of the systems' assailable points, i.e., hardness, radar cross section, armor plating, type of guidance, etc.

The usefulness of very high resolution photography for furnishing credible information to the National Policy level and in turn to the public and the world was proven irrevocably during the 1962 Cuban missile crisis. This aspect -- that is, convincing the informed layman and/or outright agnostic -- is often overlooked by the intelligence analyst because he is usually working from a base of a priori knowledge. The Cuban crisis illustrates the role of very high resolution photography in crisis management and tactical reconnaissance cases. Proof of missile-related equipment, launch site construction, and country of origin of military equipment of all types was a necessity. The best of the Cuban crisis photography was at the [redacted] range and was obtained by low altitude reconnaissance aircraft operating at very low altitude. Collection by satellite provides some measure of covertness and surprise and does permit penetration of areas denied to aircraft.

Very high resolution photography may have an even more dramatic influence on the question of technological surprise. Increasingly, advanced and exotic weapons are brought to fruition covertly and in isolation. Any future Arms Control agreement may make such photography almost indispensable.

[redacted]

[redacted]

Atmospheric Limitation

A recent program of analysis and test to determine the limits of resolution caused by the atmosphere has produced evidence that the atmospheric limit in resolution from a moving satellite is almost certainly [redacted] about 50% of the time and that [redacted] photography can be obtained 99% of the time. [redacted] of the atmosphere showed no indication of a turbulence limit in seeing down through the atmosphere. A [redacted] has been started that is expected to demonstrate [redacted] photography through the atmosphere during mid-1966. The extensive follow-on analytical program includes effort to predict seeing conditions which may equal or possibly exceed present weather prediction accuracy.

Simulation Program

A simulation program has been conducted to demonstrate the usefulness and value of very high resolution satellite-collected photography. Photographs were obtained of a number of equivalent U. S. subjects of reconnaissance interest at different, accurately calibrated resolution levels. Contrast ratio and grain were also simulated so that the program would provide photographic samples that faithfully represented present and potential future satellite photography.

Resolution tri-bar targets were placed on the ground beside the subjects of reconnaissance interest. and low altitude aircraft photography was taken. [redacted] resolution photography was thus obtained. This photography was suitably rephotographed so as to simulate contrast attenuation through the atmosphere from a satellite, with grain, scale, and resolution desired. Simulations are now available at [redacted] resolution to match DORIAN, [redacted] resolution to match GAMBIT-CUBED, and 2-1/2-foot resolution to match GAMBIT. [redacted] partial simulations are also available.

Selected examples of portions of these photographs are available in the form of stereo pairs suitable for hand-held viewers. In addition, for comparison purposes, three KH-7 stereo pairs of current Soviet intelligence targets have been mounted and are available. They consist of a completed Soviet SS-7 hard site, a single silo in the excavation stage of construction, and a large parabolic dish antenna.

Simulation Analyses

The photographs resulting from the simulation program were analyzed by a selected group of photographic interpreters and intelligence analyst/engineers. The general results are presented here with detailed discussion of only three areas -- test facilities, hardened missile sites, and large antennas -- for brevity. It is important to recognize that analogous statements and arguments can be advanced for naval vessels; aircraft; armored vehicles; research, development, and test facilities of all types; and other items of interest from a National defense standpoint. The relative importance of most intelligence collection targets fluctuates rapidly, widely, and unpredictably based on the National planning or policy decisions which are critical at any moment.

Among the more permanent, important collection targets requiring very high resolution photography are research and test facilities. For example, the ability to size rocket engines during the development phase would permit estimation of future missile and space booster thrust capabilities. The KH-7 system furnishes excellent engine test facility layout photography, but no rocket engine has even been identified. Present Soviet rocket engine thrust capability estimates are based upon Soviet announcements of payload into orbit, ELINT (telemetry) analysis, [redacted] and extrapolation of U. S. state-of-the-art. Of course, the Soviet engine has completed the development phase and is into the flight test before any of the above data can be acquired. When time for analysis is added, the Soviet systems to date have usually been operational before stage thrust estimates and, therefore, payload capability, have reached a useful confidence level.

Developmental aircraft are often accessible to overhead photography during their test phases. Knowledge of armament types, nuclear weapons sizes, the existence of in-flight refueling mechanisms, and the like, would be available through very high resolution photography during flight line operations. At present, the best we can do is recognize the existence of weapons loading pits, armament firing bunkers, and spot an occasional exercise or operation in progress.

Table I lists some general questions about a hardened ICBM site that intelligence analysts would attempt to answer from available photography at various resolutions. The resolution deemed necessary to provide a reasonably confident engineering answer is noted by each problem area. Obviously, the availability of various other intelligence inputs and a priori information can influence a table of this type, but experience of available photographic interpreters and engineers indicate that these resolutions are needed.

RUFF/DORIAN/GAMBIT

TABLE I

HARDENED ICBM INSTALLATION

	Necessary Resolution
Facility Layout	3 ft
Missile Type	[redacted]
Blast Resistance	
Wall Thickness	
Door Span and Dimensions	
Construction Methods	
Door Seals, Locks, Mechanisms	
Steel Reinforcing Bar Size and Arrangement	
Soil Structure and Type	
Ground Support Equipment	
Handling and Loading Equipment	
Missile Suspension and Support	
Checkout and Calibration	
Launch Control Layout	
Electrical Power Source	
Communications Networks	
Microwave Links	
Telemetry	
Cables and Buried Radio	
Guidance Links	
Physical Security	3 ft
Support Facility	3 ft

Engineers have a difficult time agreeing upon the actual hardness of our own ICBM installations since no full-scale tests have ever been conducted. In the absence of any design criteria for Soviet MRBM/IRBM/ICBM silos, all estimates of their hardness from any standpoint; air blast, radiation, thermal shock, ground shock, electromagnetic pulse, etc.; are somewhat theoretical. At best, the estimates are based upon how we would do it if we were in their shoes, given their construction technology, and with some safety factors thrown in.

The intelligence analyst/design engineer must know silo wall and closure thickness, door span distance, construction methods, and some idea of the percentage of steel within the concrete with reasonable confidence in order to arrive at any useful estimate of completed structure blast and shock resistance. Table I shows that this is achievable with [redacted] photography. For higher confidence estimates, details such as reinforcing bar sizes and arrangements; door mechanisms, locks, and seals; and soil structure information become important. Table I reveals that [redacted] photography is necessary for this level of analysis.

Important questions about any missile in its launch environment are the ruggedness of the missile itself, the duration of time that the missile is essentially soft or vulnerable after the commit to launch decision, the possibility of silo reload, the guidance and control alignment procedures, etc. Inevitably, the problem arises as to whether an existing facility can be modified to handle a later generation missile. A current, extremely important, question revolves around whether the Soviets can retrofit their existing MRBM/IRBM silos with the new apparently solid ICBM [redacted] The implications are self-evident. The best approach to these problems is through analysis of ground support equipment. Inspection of Table I shows that [redacted] photography is necessary to get to the heart of these areas.

One of the most vulnerable aspects of any military operation is its communications links. Tap them successfully and it is possible to learn a great deal about operational procedures, capabilities, control links, etc. Determine their existence, layout, and general characteristics (particularly frequency) and it becomes feasible to attempt negation of the weapon system by command and control interruption. Very high resolution photography would materially contribute to the solution of this problem.

RUFF/DORIAN/GAMBIT

Table II lists information desired apropos of radars and antennas. Current typical examples are probable large Soviet phased arrays under construction and numerous parabolic tracking dishes throughout the USSR. If the capability of these systems is not assessed accurately, the U.S. may find that the USSR can negate its satellite reconnaissance program, or it has a substantial ABM radar capability.

The most important question about a radar is its frequency. Probably next is its range and accuracy capability. While signal modulation characteristics are not amenable to photography, [redacted] photography permits early assessment (long before ELINT becomes available) of eventual antenna functional capability and uses. For example, estimates of eventual power output can be based on feed type and size in conjunction with transmission line lengths, joints, and supports, and transmitter tube locations. Antenna mount and depression angles are very important in connection with the tracking of low altitude aircraft and satellites.

TABLE II

TRACKING ANTENNA AND RADAR INSTALLATIONS

	Necessary Resolution
Antenna	
Type and Size	3 ft
Mount Construction and Stability	[redacted]
Depression Angles	
Electronic Characteristics	
Active or Passive Feeds	
Feed Type and Size	
Polarization and Power Output	
Calibration and Alignment Techniques	
Frequency (if not above UHF)	
Support Facility	
Building and Cooling Pond Size	
Computer Capability	
Electric Power Source	
Electric Power Capacity	

TAB B

MANNED FUNCTIONS AND SIMULATION DATA

Mission Functions and Capabilities

The value of man in the primary mission of high resolution optical reconnaissance and other future military missions basically stems from the ability to provide real time adaptive programming. This capability allows for optimization of operations to the specific conditions at hand and will result in more performance for a given equipment state-of-the-art and more efficient and timely data return. During the past year, an extensive simulation program has been carried out to verify man's capabilities and establish performance levels relative to the critical mission functions. These critical functions in which man can make a direct contribution to improved mission capabilities are:

* Target Acquisition
* Sensor Pointing
* Target Tracking
* Equipment Adjustment
* Vehicle Control
* Information Management
* Assembly Maintenance

In addition to these principal functions, peripheral functions can be performed because of man's presence such as direct visual reconnaissance, film changing, and setting of exposure times.

In target acquisition, the man performs the function of background discrimination and determines if the target material is present, e.g., if the missile of interest is on the launcher, or if the target area is obscured by cloud cover. If the target is not present or if it is obscured, he provides the ability to switch to alternate targets. In unmanned systems target acquisition must be preprogrammed, the picture is taken under any circumstance, thus cutting down the amount of useful data taken. Relative to simulation, the critical aspect is the time it takes the man to make the acquisition. If this is too long, little advantage can be gained from the alternate targeting technique. Simulations were carried out using reconnaissance quality aerial photographs of various targets such as: industrial complexes containing refineries and tank farms and asking the subjects to find a particular tank, airfields with different types of airplanes and asking him to pick a particular airplane, or missile sites such as a MINUTEMAN Complex and asking him to acquire a particular silo. The pictures were presented in a manner simulating space viewing including varying haze conditions. The subjects were pre-briefed, i.e., they had a picture of the general area with the targets marked. The results of the simulation for the severe haze case are shown in Figure 1, and as can be seen, 80% of the targets can be acquired in 10 seconds or less. Under light haze conditions, even better results were achieved, namely 95% of the targets were acquired in 8 seconds or less. Since acquisition can be started by looking some 40 to 50^{0} ahead, on the order of 30 seconds is available. Based on simulation results time is available to acquire alternate targets.

[redacted]

Another acquisition simulation that has been carried out is that of acquiring specific stars. This is only of secondary importance in that it is not directly a military mission function, but would be valuable in providing an autonomous navigation capability. The objective of the simulation was to acquire a specific star for lock-on of star trackers and it was accomplished in a planetarium using a variable field-of-view optical device. The results indicate

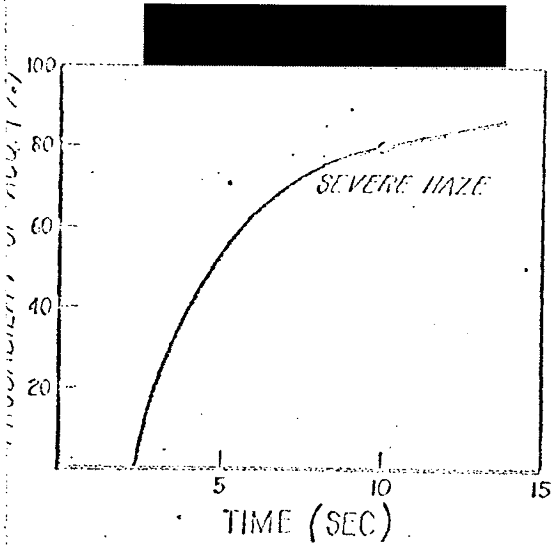

Figure 1

[redacted]

Figure 2

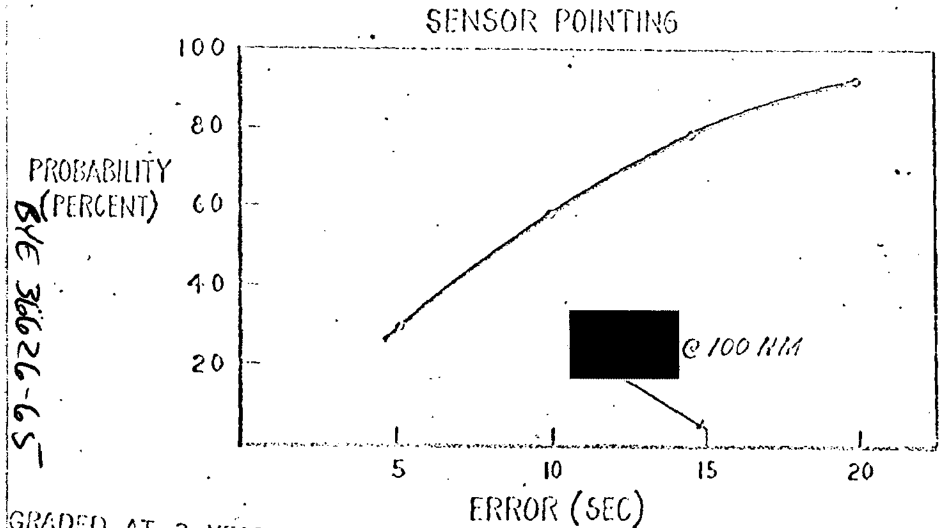

Figure 3

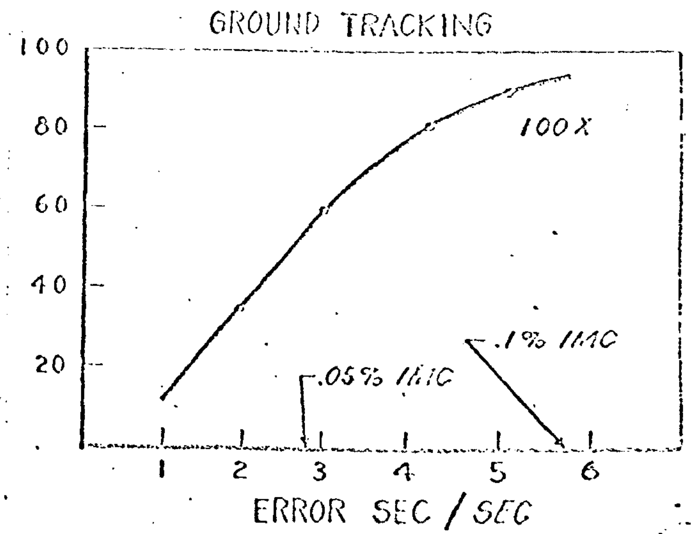

Figure 4

BYE 36626-65

that for fields of view of the order of 20 degrees, acquisition of specific stars can be achieved on the order of 40 seconds, which is a sufficiently short time to make autonomous navigation in this mode quite feasible.

The second critical function area is that of sensor pointing. In the high resolution optical reconnaissance mission, many pictures will be taken off nadir, both looking forward and off to the side. Using a frame camera this results in geometrical smears because of relative image motion at various parts of the field of view. At the periphery of a field of view typical of that suitable for [redacted] unmanned system (2° Fov), these can be on the order of [redacted] smears depending on light conditions. The man plays an important function in assuring the target is in the center of the field where the geometrical smear goes to zero. Also by centering, the optical aberrations are minimized and thus the maximum resolution achieved for a given size system. Simulations were run, using the same type of targets as is the ground acquisition simulations; namely, industrial complexes, airfields and missile sites. The subjects were asked to track the target and position a cross hair on the target; when this had been accomplished, a switch was triggered which would be comparable to actuating the camera for picture taking. The results are shown in Figure 3, which plots the probability of errors equal to or less than a given amount. For the case of a 100 n.m. orbit, the man can maintain the pointing error on the ground 80% of the time to [redacted]. Errors of this magnitude will cause little degradation to the resolution and are to be contrasted to unmanned system pointing errors of the order of 1 n.m.

Target tracking is an important function in that it provides precision image motion compensation which allows better resolution to be achieved through the use of longer focal length telescopes, minimizing the effects of film graininess. Very extensive simulations of ground tracking were carried out, using an optical simulator with aerial reconnaissance scenes which had the proper aspect viewing and realistic rate input errors. Aiding was provided in that 99% of the total image motion was compensated for (assuming knowledge of the orbit ephemeris) and the operators were asked to track the target and provide the vernier correction by using a rate stick control. The case shown in Figure 4 is that of 100 power magnification in the tracking scope and providing 99% aiding. The results indicate that .1% image motion compensation can be achieved virtually all the time. For 200 power magnifications, .06% image motion compensation was achieved 95% of the time. In comparison present unmanned systems use a pre-programmed image compensation which is poorer than 1%. Image Motion Compensation devices using scene correlation techniques have been built and demonstrated in the laboratory to produce .5% image motion compensation.

[redacted]

In the case of equipment adjustment man can make important contributions to the alignment and focusing of the optical system. Specifically, he can align optical elements such as mirrors and corrector lens in terms of centering and tilt by using auxillary optical elements. The function involves viewing fringe patterns and adjusting the elements, by servomechanism drives, until the proper patterns appear. Similarly using an autocollimating device the focus of the system can be adjusted. The same techniques are used on the ground in the assembly of telescopes and since no direct interaction with the space environment is involved, there is no reason to expect these functions cannot be done equally well in space.

Another type of equipment adjustment is that involved in electromagnetic signal intelligence; the man's function is to take over when signals are intercepted which cannot be handled by the automatic equipment. His function is one of interpreting signal displays and adjusting electronic parameters such as the frequency band pass, pulse width, interpulse timing and dynamic range until the signal is separated from the background emission and optimally displayed for recording. This type of operation is presently used in the USD-7 aircraft system; however, the aircraft intercept is not time limited, whereas the space system has approximately 7 minutes from horizon to horizon. Therefore, a simulation was carried to check man's ability to work within this time constraint using the USD-7 equipment and flying a realistic environment. The results of

88 encounters indicate that the maximum time required was 4-1/2 minutes, average 1-1/2 minutes and the minimum 1/2 minute. Thus, it is concluded that man can do the complex signal analysis job within the short times available from space.

Vehicle control of the spacecraft is a lesser manned function particularly for the high resolution optical mission; however, it does provide for more mission flexibility, particularly in the case of malfunctioning equipments, and to some extent will lessen the ground support requirements. No simulation is necessary since manned vehicle control capability has been demonstrated in both the GEMINI and MERCURY flights as well as the GEMINI rendezvous simulations conducted by NASA.

Information management is an important function in that the man provides a real time decision capability and can effect a large data compression by initially minimizing the acquisition of spurious data and subsequently by selecting only the data of interest for transmission to the ground. As an example only two pictures of an unmanned system could be read per day, assuming one wideband readout station. Instead of reading out the entire 2.8 n.m. unmanned field of view, if the target area of interest is assumed to be .2 n.m. the man can select the target area of interest and readout approximately 400 pictures a day. Since the basic functions involved do not directly interact with the space environment, no specialized simulations were carried out.

Assembly and maintenance may be the most important manned functions of all. Future military requirements may require the use of large structures on orbit where manned control of deployment and erection may be important. More important is the maintenance ability which will allow for cost effective operations and also provide the ability to utilize advanced technologies at an earlier point in their development -- before their reliability has been developed to a level acceptable for unmanned operations. In the area of maintenance and assembly, simulations were carried out for both shirt sleeve and pressure suit conditions using a variety of simulators, consisting of 6-degree air bearing simulations, flying zero "g" profiles in the KC 135 aircraft, and using neutral buoyancy water immersion type techniques. The results of these tests indicate that, with the proper design in the tools and attachments, no problems appear in terms of feasibility of maintenance.

Generally, however, the times required to perform a given maintenance function were several times that required in the normal ground environment. Extravehicular activity has been simulated both for local locomotion, as well as using a propulsion unit. The simulation methods again include the KC 135 and the water immersion techniques as well as the g-visual simulation for the propulsion unit. The results indicate that local locomotion can be done if the proper attachments are provided. In the case of the propulsion unit if it is stabilized the man can do very complex maneuvering operations in space. Also to be considered is the accomplished fact of the Soviet and the GT-4 extravehicular operations.

In addition to the above simulations, direct viewing simulations were carried out using a B-47 aircraft with a modified bombsight which simulated 30 and 60 power magnification from 160 n.m. The targets were airfields, rail junctions, roadways, bridges and shipping docks in port areas. The results indicate that the man can estimate with 90% accuracy the activity in the given area. For an example, in flying over an airport in which 25 airplanes are on the airport the man would estimate maybe 23. Also, he was able, in the case of the 60 power, to classify the different types of aircraft, being able to clearly see airplanes of the 4-engine or jet type versus smaller aircraft of the single-engine type. The significance of this simulation is that the crew while performing their normal high resolution reconnaissance duties may be able to detect anomalies in activity patterns which will lead to early detection of changing strategical situations.

Biological Capability

In addition to the mission simulations demonstrating the critical manned functions, simulations have been carried out to demonstrate man's ability to adapt to the space environment for periods in excess of 30 days.

The first of these is the use of chambers with volumes and arrangement typical of the proposed MOL system. The volumes range from 200 to 600 cu. ft. free volume -- that is volume over and above that occupied by equipment, and the atmospheres used including the 7-1/2 psi oxygen/nitrogen atmosphere, the 7-1/2 psi oxygen/helium atmosphere, as well as the 5 psi oxygen atmosphere. The results of these simulations indicate that there is no problem with the atmosphere nor the confinement for the periods of the simulations which extended from 30 to 45 days except in the case of oxygen/helium which has only been carried to 10 days to date.

Another type of simulation performed was that to test the ability of the man to withstand the re-entry loads after being on orbit. Two groups of subjects were deconditioned by bed rest for extended periods; one group having no conditioning, the other being exposed to exercise and positive pressure breathing during the deconditioning period. They were then placed on a centrifuge and exposed to a "g" profile with a maximum of 8 g's simulating ballistic re-entry conditions from space in a Gemini spacecraft. During the centrifuge runs the subjects were asked to perform a simple tracking function. The results of these runs based on blood pressure, heart rate, and the tracking proficiency indicate no statistically detectable difference from that of the controlled runs using fully conditioned subjects; therefore, it appears that 30 days on orbit will not endanger the astronaut's ability to return from space.

The third area of concern relative to man's ability to adapt to the space environment is that of prolonged existence on orbit in the weightless condition. Here, many simulations have been carried out to evaluate effective countermeasures which would forestall or eliminate the cardiovascular deconditioning effects of the zero "g" environment. The countermeasures of most interest are those of using a short arm centrifuge compatible with the MOL vehicle diameter of 10 feet and that of using exercise of different degrees of vigor for periods of 60 to 80 minutes a day. The countermeasures and results are shown in Table 1. As can be seen the 900 kilocalorie exercise countermeasure is effective in forestalling the cardiovascular effects of zero "g" with the exception of the minor blood plasma reduction. The 700 kilocalorie exercise and centrifuge also are effective; therefore, it is concluded that either of these offers a suitable countermeasure for conditioning of the cardiovascular system.

In summary, then, an extensive simulation program has been carried out during the last year and the results have demonstrated man's ability to perform the critical mission functions and provide a high degree of precision. Secondly, environmental and countermeasure simulations have been carried out which provide reasonable confidence that the man will be capable of greater than 30 days on orbit without difficulties.

TABLE I

WEIGHTLESS COUNTERMEASURE SIMULATION RESULTS

Criterion Measures	Control	Deconditioned	Centrifuge 4-G	Exercise		Centrifuge (4G) +Exercise (700 KCAL)
				700 KCAL	900 KCAL	
o Tilt Table Syncope	0 - 9%	80-90%	12%	50%	None	None
Heart Rate (Beats/Min)	90	160	156	115	90	95
Pulse Press (MM/Hg)	40	--	(18)	(25)	36	30
o Plasma Volume	3.0 L	18% ↓	16% ↓	9% ↓	8% ↓	6% ↓
o Work Capacity	100%	80%	---	100%	105%	100%

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TAB C

OPTICAL SYSTEMS

Background

The military need for optical reconnaissance has been demonstrated by its use in support of many operations -- tactical, strategic, battlefield surveillance, crisis management, technological analysis -- intelligence gathering in general. Our present satellite photo reconnaissance systems (such as GAMBIT) are providing excellent operational material for the National Photo Interpretation Center and ultimately the intelligence community. It is estimated about 95% of our photo take of the Sino-Soviet Bloc comes from this source. Resolution as good as 2 to 3 feet is available from the present GAMBIT system. Development is underway on an improved GAMBIT-CUBED system which is designed to provide photography with best resolution of [redacted] and mission average resolution of [redacted] from 90 n.m.

Optics Technology

Atmospheric turbulence is considered to set a lower limit on ground resolution achievable by space optics. This limit has been investigated both empirically and mathematically and is currently defined as [redacted] with the expectation that, with further measurement programs now planned, it will be [redacted] most of the time. To achieve ground resolutions to the limit permitted by the atmosphere will require systems of very large apertures, [redacted] at 80 n.m. altitude. To achieve nadir ground resolution of [redacted] an aperture of [redacted] is required. The critical technical factors which determine the design parameters for [redacted] resolution are as follows:

1. A fundamental limit to resolution is set by the diffraction pattern of the image; an otherwise perfect system must be about 35 inches in aperture. This dimension implies that reflective optics must be utilized.

2. Optical systems cannot be perfect and if surfaces are accurate to about 1/10 of a wavelength of visible light the resolution will be degraded 20-30%. Practical designs also have obscuration of part of the aperture, transmission and reflection losses. These factors cause the required aperture to be about 45 inches.

3. The above numbers relate to very high contrast targets. A photographic system to resolve low contrast objects must be larger; thus the aperture must be 50 inches or more.

4. Image motion compensation cannot be perfect and, even if accurate to 0.1% (current systems are 1%), the resolution is degraded and the aperture must be increased for a useful range of exposure conditions.

5. The field of view of systems must be large enough to include targets of interest considering pointing errors. To obtain a field of view as large as 1 mile x 1 mile requires that corrector elements be included in the optics. Even with the best correction considered feasible, it is required that the target be centered in the field of view by pointing with an accuracy of a few hundred feet.

These design considerations lead to a set of characteristics which are basic to achieve such high resolution:

1. The optical system must be large, more than 50 inches aperture, and at least the primary element must be a mirror.

2. The optical system must be fabricated and aligned so precisely that it will yield nearly perfect optical performance on orbit.

3. Image motion compensation must be much better than current systems -- at least 0.1%.

4. Pointing control must be precise -- a few hundred feet.

Each of these basic characteristics can be discussed in terms of the technology required and the possible role of man:

1. The technology to design and fabricate these large optical systems is essentially at hand, at least to the point of high confidence in achieving design performance during tests on the ground. New optical materials and new fabrication and design techniques are developing rapidly to offer possibilities of major improvements in the next few years in such factors as weight and thermal sensitivity. Conversely, major improvements in films or other recording techniques which would change the basic characteristics listed do not appear near at hand.

2. The precision required of such a large system on orbit is a more difficult problem. Some aspects of this problem are:

a. Reasonable weight designs cannot be rigid through launch and the optics must be extended, aligned and tested in orbit. Automatic systems tend to be complex, inflexible, and unreliable. One of the clearest advantages of a manned system is the contribution of the astronaut to the initial alignment and test.

b. During the orbital operation several precise functions are necessary to maintain performance. These include continuous refocusing, active thermal control and realignment after thrusting or temperature excursions. While man may not be essential to these functions, his presence permits simplicity, increased reliability and greater precision.

c. For optical systems of this precision there are bound to be unexpected factors which will cause significant optical degradation. To diagnose and correct these problems, there is no substitute for a man observing the image with full optical quality and monitoring the effect of corrections in real time. When a history of orbital experience is available, it may be that these problems can be anticipated but, at least initially, there seems little doubt that the man provides unique confidence in timely progress.

3. The image motion compensation desired is more precise than appears feasible now in unmanned systems. Simulations have shown that a man can provide vernier control and obtain 0.06% precision 95% of the time.

4. Simulation has shown that man can acquire and point to about 40 feet accuracy. Automatic navigation and pointing devices to achieve this precision are not known.

The conclusion is that the basic elements for a photographic system to achieve [redacted] resolution from 80 n.m. can be made available for the 1968-1970 time period, without major invention, if the system is manned.

Optical System Alternatives

For the MOL program several types of optical systems (shown in Figure 1) have been considered. Two are basically Newtonian systems with Ross corrector lenses near the focal plane. The third is a modified Cassegrainian system.

In the first Newtonian system, acquisition and tracking of the target is achieved by motion of a large optical flat in two planes. Pictures are taken at any time during the tracking phase. In this manner, as many as 20 pictures may be taken, from various angles, of a single target. The system is relatively simple in design and alignment and flexible in operation and is a fairly straightforward extrapolation of the GAMBIT system.

The other two systems rely upon pointing the entire sensor, thereby removing the requirement for the large flat mirror. Either version of the Ross corrector could be flown in the 1968-1969 time era. The modified Cassegrainian would take somewhat longer to develop.

Both the Titan IIIC 5-segment and 7-segment boosters were considered; the 5-segment provides about 4,000 lbs. of discretionary payload and the 7-segment provides 10,000 lbs. in a polar orbit. When the weight of payload displays, film, and small recovery vehicles is deducted, and when the orbit sustenance fuel load is optimized, the payload sensor itself is allowed about 1500 lbs. in the 5-segment case and 6500 lbs. for the 7-segment case. The 1500 pound sensor is too small to provide attractive ground resolution. Within the weight allotment of 6500 pounds for payload available on the DORIAN/MOL/Titan IIIC 7-segment combination, a 60-inch aperture f/8.3 Ross sensor with tracking mirror is possible, providing [redacted] nadir best resolution from 70 n.m. or [redacted] from 80 n.m. During a mission, observations are made at various obliquity angles and thus various slant ranges which degrade the resolution. Considering a typical mission with a uniform distribution of obliquity angles up to 45 degrees and a normal distribution of pointing errors and tracking rate errors, a calculation is made of the number of photographs taken at various resolutions. The median resolution is that value where half of the photos over an entire mission are at least that quality, or better. The mission median resolution for the 60-inch aperture from 80 n.m. is [redacted] The other sensor configurations shown in Figure 1 provide even better ground resolution. Ground resolutions versus aperture for a 70 nautical mile altitude are shown in Figure 2.

Manned-Unmanned Comparisons

Two comparable unmanned photographic satellite designs have been analyzed. In one case an equal-sized booster was chosen for a 30-day mission, resulting in an allowance of 14,500 lbs. for sensor payload. Within this larger weight, an [redacted] aperture, f/6.1 optical system provides optimum mission average resolution. At 80 n.m. altitude the nadir best resolution is [redacted] (same as the smaller manned system), and the mission median resolution is [redacted] (compared to [redacted] for the manned system). Figure 3 shows the resolution distribution curves for the 60-inch manned and [redacted] unmanned systems.

The superior performance of the smaller manned system is explained by improved manual image motion compensation, by man's ability to align the optics on orbit and to correct the alignment as often as necessary, and by more precise target centering using the man. These factors of improved manual precision are true even though the unmanned system was given the benefit of a V/h sensor [redacted] better than presently exists, a new attitude stabilization system about [redacted] better than presently designed for GAMBIT-CUBED, and real time orbit position knowledge [redacted] better than GAMBIT is achieving.

Further, the larger [redacted] aperture of the unmanned study is a much more difficult optical manufacturing job; and the associated [redacted] flat tracking mirror that is required for this design is a very major optics problem.

Considering these optics problems, and the probable one to two year longer research and development time, a smaller 60-inch aperture unmanned system was also studied. Such a design is the same optical size as the DORIAN (manned) system. Again giving the unmanned design the benefit of possible improved sensors and subsystems, this smaller unmanned payload will yield about [redacted] nadir best resolution and between [redacted] mission median resolution.

It is concluded that, within the same optical technology and time schedule, a manned system provides significantly better resolution (median value: [redacted]) with higher confidence, due to the several new inventions or new subsystems required in the unmanned case. Even if, for some reason, an unmanned system ultimately proves to be the better operational approach (for example, if man cannot tolerate adequate durations in orbit or if unmanned reconnaissance systems prove more acceptable in international policies than manned ones), the optical technology which can best be developed in manned flights is also a basic requirement for a later unmanned system.

Manned Optical System Development Recommendations

Two basic sensor approaches have been mentioned, differing mainly in the pointing method of acquiring and tracking the target. Choice between these approaches hinges on the following arguments:

1. A 60" aperture sensor is the minimum size of interest to achieve a major step in resolution beyond GAMBIT-CUBED.

2. 60" mirrors have been and are being ground experimentally to the tolerances required. Larger mirrors are not so far advanced.

3. The Ross corrector design is a rather straightforward extrapolation of the GAMBIT design and therefore higher confidence exists now for such an approach.

4. Pointing the mirror or the entire sensor requires larger drive systems than are currently available. Therefore, the drive system design must be based on extrapolation from presently available techniques and equipments. The degree of extrapolation is considerably greater for pointing the whole system than for pointing the mirror alone.

5. In current designs, the tracking mirror is 1.4 times longer in one dimension than the diameter of the aperture. Therefore, as the sensor size is increased for improved performance, the tracking mirror will, at some point, have to be abandoned due to limitations in mirror technology. The aperture size at which this should occur is not well defined but is probably around 90".

6. With sufficient time and effort either pointing approach could most certainly be made to work for a 60" aperture.

7. Careful consideration of interface specifications between the MOL and the two types of sensors indicate that it can be designed to accommodate either.

In view of these considerations, the following approach to sensor development is recommended:

1. For a period of 4 to 6 months from go-ahead, the Ross corrector sensor program will carry a dual approach to pointing and tracking (both mirror and entire sensor) based on a 60-inch aperture for either approach. During this time a vigorous lightweight mirror technology program will be initiated. In particular, zero "g" and temperature tests will be performed.

2. Competitive preliminary design studies will be initiated for follow-on larger aperture optical sensors. In support of these future systems, studies have already been initiated on a modified Cassegrainian pointing sensor involving a scale model (say 20") and design studies of a reimaging optical system.

3. In parallel, engineering work will be initiated to develop a large drive system capable of pointing either the Ross or Cassegrainian sensor.

At the end of the 4 to 6 month period a decision will be made on the sensor configuration to be developed and the time phasing of larger aperture systems into the MOL program. In addition, advanced technology studies will be pursued which may eventually lead (1975/) to very large aperture systems [redacted] in a follow-on Saturn V rendezvous program.

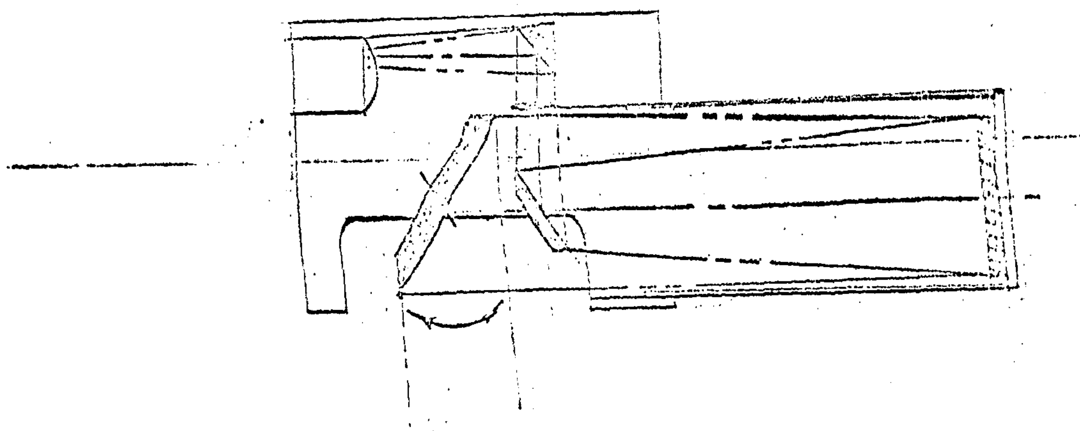
Unmanned Systems Technology Development

In addition to the manned optical system development, continued studies and where feasible technology programs will be initiated for the purpose of improving high performance unmanned systems. Some of the subsystem and technology efforts to be pursued are: (1) improved V/h sensors capable of sensing image motions to 0.1% or better; (2) improved stabilization systems with residual rates less than 10^{-3} deg/sec and pointing errors less than 0.1^{o}; (3) possible optical rectification devices to remove geometric smear off the optical axis in oblique pictures.

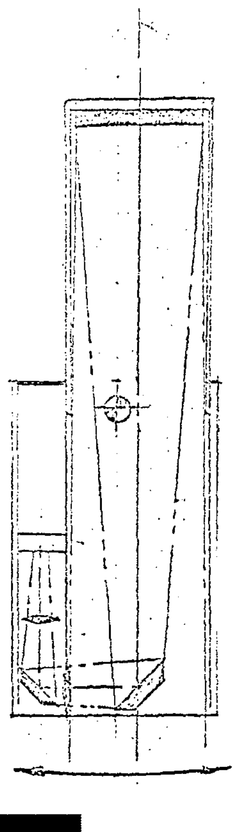
Unmanned systems studies will be pursued in conjunction with this program to provide orientation to the technology program and continue to assess the potential for advanced unmanned sensors. It is important to note that any of the above advancements would also be important to the performance of a manned system, particularly if it is also designed to operate in an unmanned mode.

FIGURE 1

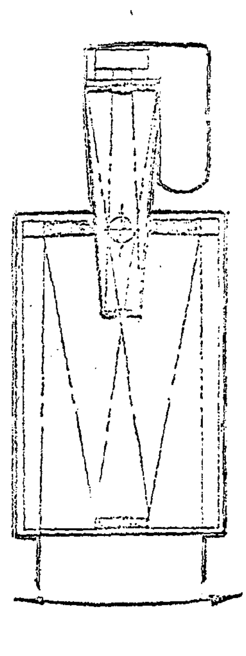
SENSOR CONFIGURATIONS



60 INCH ROSS CORRECTOR SENSOR WITH TRACKING MIRROR



[redacted] POINTING ROSS



[redacted] MODIFIED

FIGURE 2

[redacted]

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[redacted]

TAB C1

OPTICAL SYSTEMS FLIGHT TEST

OBJECTIVES

General

A development program consisting of six flights, one unmanned and five manned, would be capable of demonstrating an operationally useful manned high resolution optical photographic reconnaissance system. Primary emphasis will be placed on achieving resolutions on the ground of [redacted] A conservative optical system design, utilizing a primary mirror of 60-inch aperture can attain resolutions of this order, and will be the primary payload for early flights. Parallel developments along less conservative lines, leading to optical systems of [redacted] aperture offering ground resolutions of about [redacted] will also be undertaken.

Flight Test Objectives

Flight objectives for the first three flights have been defined. Objectives for the last three flights have been deferred, awaiting the outcome of our investigations into optical technology. Hence the option to select more advanced versions of optical sensors or SIGINT sensors for these flights is preserved.

Flight number one is unmanned, and is intended to qualify the integrated Gemini B/Laboratory/modified Titan IIIC vehicle as suitable for manned flight. Test objectives are to:

*Demonstrate Gemini B subsystem.

*Determine structural adequacy of the laboratory vehicle.

*Demonstrate MOL/Titan III and Western Test Range compatibility.

*Demonstrate polar orbit test operations support system.

*Demonstrate recovery and retrieval from polar orbit re-entry.

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Flight number two, the first manned flight, has as a principal objective the demonstration of a useful manned high resolution optical reconnaissance capability. This flight, planned for late CY 1968, will utilize an engineering test model of a high resolution optical sensor, to permit the refinement of equipment, and the development of techniques and procedures leading to the achievement of high resolution photography objectives as early as possible in the flight test program. This flight is also intended to:

*Demonstrate complete functioning of the GEMINI B and laboratory vehicle system in orbit.

*Verify crew transfer.

*Demonstrate control capability for manned missions in polar orbit.

*Conduct biomedical and human performance tests.

*In the event of an unsuccessful flight number one, to back-up that flight, unmanned.

Flight number three is devoted principally to the demonstration of a useful high resolution optical photography capability throughout a thirty-day stay in orbit. This flight will also:

*Demonstrate capability of MOL systems to function for 30 days in orbit.

*Evaluate crew performance.

*Evaluate low altitude orbit capabilities.

A typical mission profile suitable for this flight is discussed in the following paragraphs and is illustrative of specific manned functions to be demonstrated.

Assembly and Alignment

Of particular importance is the assembly and alignment of the optical system on orbit, a procedure which contributes markedly to system performance. This is followed by routine operation of equipment in several modes. The following discussion is based on the activity associated with a tracking optical flat Ross corrector primary optical sensor.

In any high resolution optical system, precise alignment of the optical elements must be maintained if performance goals are to be met. Once the MOL is in orbit, the optical sensor lens barrel must be extended, and secured in place. The internal optical elements must then be freed from their "soft" mounts, which protect them during ground handling and launch, and transferred to their operating mounts. A step by step alignment procedure by the astronauts follows during which each optical element is tilted, translated, or otherwise carefully positioned. This procedure is repeated until the optical system performance converges to its design values. The system is then ready for routine operation.

Basic Equipment

Equipment used during routine operation falls into two categories: on-line, which is used during photographic activity; and off-line, which is used in the intervals between photographic activity. Both categories are essential to the realization of the full capabilities of the optical sensor.

On-Line Equipment

Separate acquisition and tracking telescopes are provided each astronaut to permit simultaneous inspection of two alternate target areas. The telescopes are programmed to track their respective target areas, the astronaut selects the preferred target, and centers it in the optical field.

Each astronaut is also provided with a viewing eyepiece connected by optical relay to the primary optics. Once a target has been selected with either of the acquisition and tracking scopes, the prime optics are slewed, the acquisition and tracking scope freed, and the target is centered, tracked, and inspected thenceforth by direct viewing. Since primary camera shutter travel time consumes only about one-fifth of the camera cycle time, four fifths of the time is available, if needed, for these direct viewing operations. The optical relay has a variable magnification [redacted]

Each astronaut has an operating console displaying, on TV screens, scenes from both acquisition scopes, and primary and secondary target cue data (pre-briefing) displays. All necessary controls for acquiring, tracking and photographing targets are included. An on-board computer and programmer provide preliminary aiming of the acquisition scopes, call up cue data, and control focus, exposure and the operating cycle of the photographic system.

Off-Line Equipment

After each photographic pass, at least one frame from each target sequence may be selected for processing and visual inspection by a pre-editing and processing device. This sequence should take about fifteen minutes.

A viewing table with a traveling microscope and densitometer will permit inspection of processed film to determine correctness of focus and exposure, and to select portions for transmission to ground stations.

Two scanning and readout positions permit transmission of selected data to ground stations.

Recovery capsules will be hand loaded and sealed by the astronauts.

Typical Operational Sequences

Target acquisition is accomplished by programming the acquisition and tracking scope to aim at and track a selected target area. After reviewing the cue data, the astronaut inspects the target area through his scope, evaluates cloud cover and haze, and decides to photograph or to select an alternate, if available. If he elects to photograph, he centers the target in his acquisition scope, and slews the primary optics to the selected target. He then views the target through the primary optics, re-centers if necessary, nulls any residual tracking rate errors, and begins photography.

Meanwhile, the second astronaut is briefed by cue data on the upcoming target and begins acquisition. With targets acquired alternately, about eighteen seconds will be required between targets to permit briefing, acquisition and tracking. A typical sequence of operations for targets of minimum spacing appears in Figure 1.

Typical target swaths were studied to determine the density of targets which could be expected to occur during each 18-second target interval. The width of the possible target area at an 80 n.m. operating altitude is about 140 n.m., and the 18-second interval represents 72 miles along

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OPERATIONAL SEQUENCE
(MINIMUM TARGET SPACING)

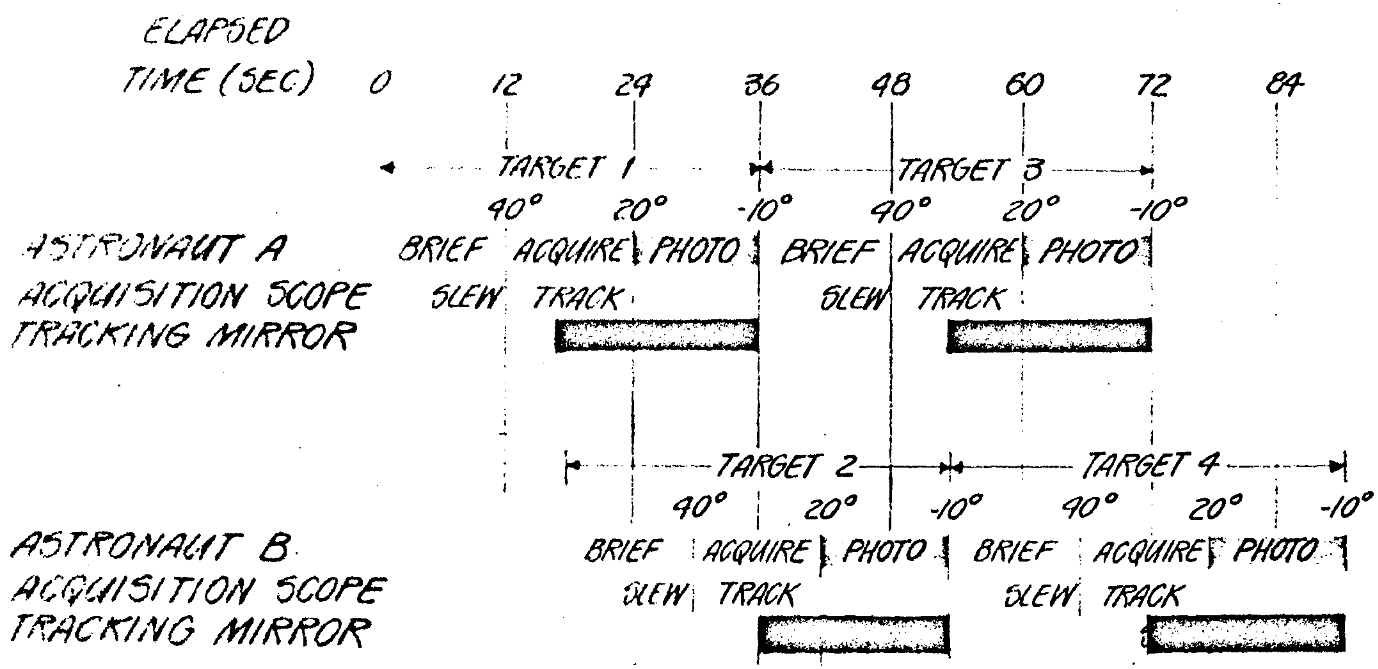

Figure 1

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track on the ground. It was apparent that most targeting intervals contain more than a single target. The ability of man to choose between alternates is a valuable and effective advantage.

Cloud statistics were applied to the target areas which were studied to determine the probability of acquiring a particular target in a single, and in multiple passes. It was found that single pass probability is about 36%, and improves as the number of passes increases. Hence the ability of the astronauts to evaluate obscuration by clouds and to select alternates improves the number of successful targets photographed.

Other Operational Functions

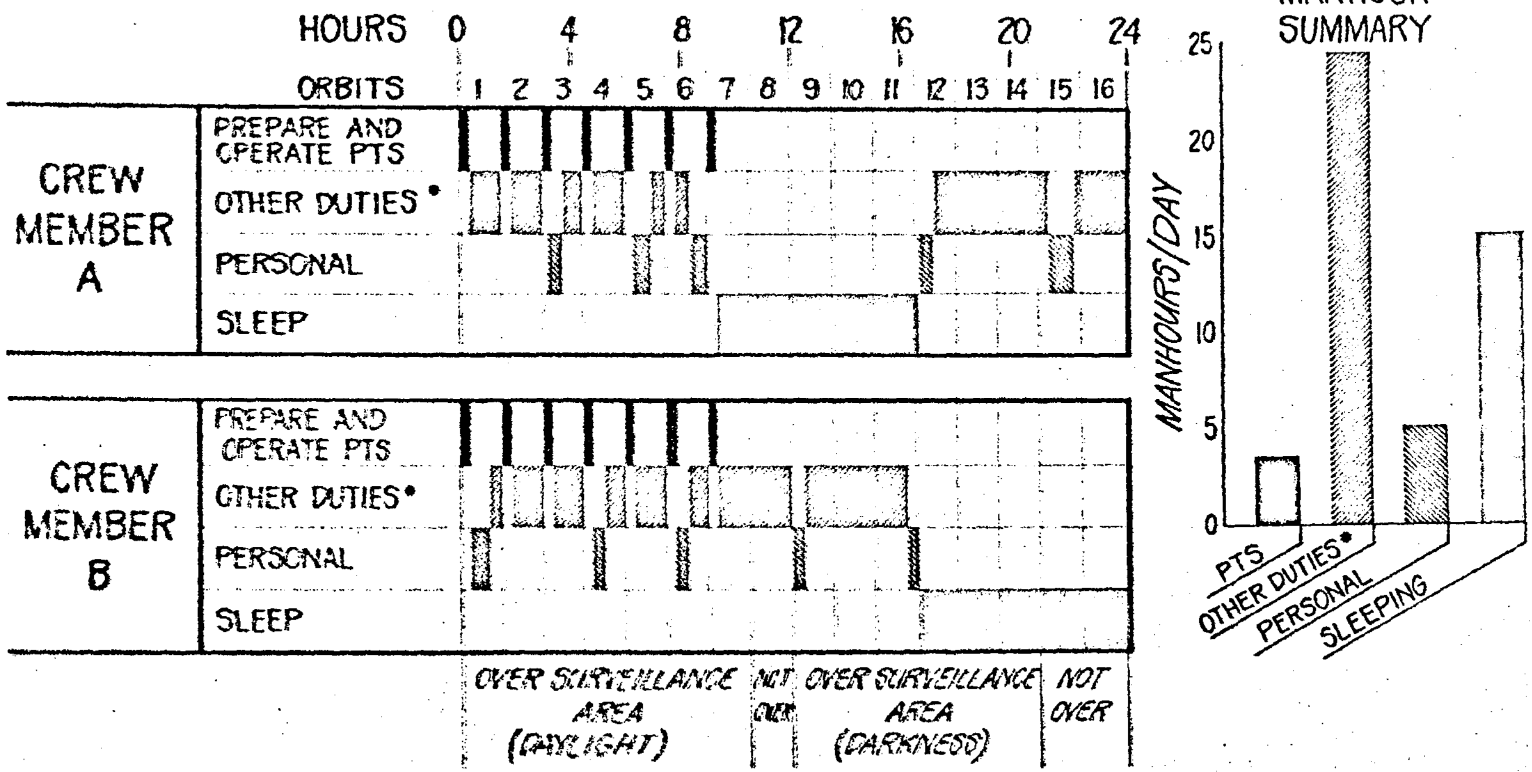
While actively acquiring and photographing targets, the astronauts employ mostly on-line equipment. During other intervals, off-line equipment can be employed to edit and process selected photographic frames. Those which are determined to be of particular interest can be returned to the ground, either as high resolution readout by a wide-band data link, or by capsule. Briefing data can be updated to alert the astronauts to observe particular targets for particular activity. Alternate photographic film, such as color or infra-red emulsions can be selected and programmed by the astronaut for particular targets. Low light level targets can be photographed with high speed (but lower resolution) film. The presence of the astronauts, in sum, provides a unique capability for easy and very flexible selection of alternate operational modes to increase the quality, quantity and credibility of photographic data. A typical crew cycle appears as Figure 2.

Supporting Functions

Operational equipment can be maintained at effective performance levels by utilizing astronaut capability to adjust, calibrate and repair. The principal mission equipment can be utilized for scientific and technological experiment functions when not occupied with reconnaissance functions. The primary optics can be used to collect high quality astronomic data. It can also collect data at infrared wavelengths, supplementing visual light. Figure 3 shows how this, typically, might be done.

REPRESENTATIVE CREW WORK-REST CYCLES

2 MAN CREW



* MAINTENANCE, DATA HANDLING, COMMUNICATIONS, ETC

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Figure 2

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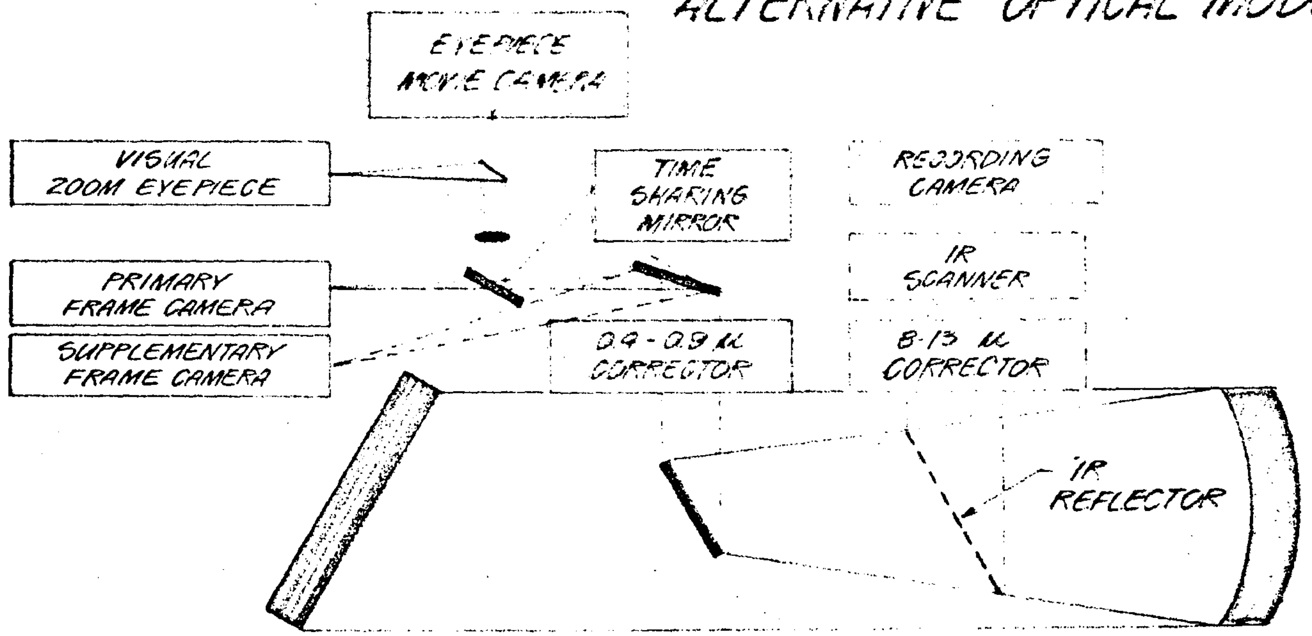
INFORMATION COLLECTION
ALTERNATIVE OPTICAL MODES



PRIMARY PHOTOGRAPHY — 3404 X, 10-20 FRAMES PER TARGET
SUPPLEMENTARY PHOTOGRAPHY — COLOR, IR, MOVIE
VISUAL RECONNAISSANCE — [redacted] RESOLUTION
INFRARED RECONNAISSANCE — [redacted] RESOLUTION
~0.2°F ΔT

Figure 3

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TAB D

PROGRAM CONSIDERATIONS

Purpose

The principal objective of the MOL program is the development of optical technology leading to optical systems capable of improved resolution. The initial objective is to develop and demonstrate, at the earliest time, an operationally useful high resolution manned optical reconnaissance system capable of achieving at least [redacted] ground resolution. Provision will be made in the vehicle design to accommodate larger optical sensors and improvements leading to longer mission times with concomitant increased cost effectiveness.

Other mission applications of the MOL program such as ocean surveillance, COMINT, and ELINT are secondary objectives. Accommodation of DOD and NASA technological and scientific experiments is a tertiary objective.

Approach

In view of these purposes, the MOL program approach provides for the orderly evolution through system definition and development to meet the primary mission with reasonable provisions for follow-on missions.

The configuration selected for the MOL system to accomplish an early manned demonstration of high resolution optics has followed the primary criterion of a minimum cost program. Existing flight and ground system hardware and capabilities from the DoD and NASA inventories are being used to the fullest extent practical. This optimized selection has been made only after exhaustive examination of the many alternatives and trade-offs of subsystems and components developed and tested in other manned and unmanned space systems. The orbiting system is to be initially designed for a 30-day on-orbit stay time with growth potential for on-orbit durations up to 90 days.

MOL Program Alternatives

The MOL program could be conducted at both the Eastern Test Range and the Western Test Range or solely at the

Western Test Range. Three different program options and their costs were examined. These options are:

1. Conduct the development program from the Eastern Test Range using the Titan IIIC 5-segment booster, then transfer the base of operations (with an uprated Titan IIIC, 7-segment vehicle) to the Western Test Range for the collection of useful intelligence.

2. Conduct the development program at the Eastern Test Range using the 7-segment Titan IIIC and transfer to the Western Test Range for the collection of useful intelligence.

3. Conduct the development program from the Western Test Range using the 7-segment Titan IIIC.

The schedules considered and the cost comparisons are shown in Figures 1 and 2.

Although either approach is acceptable from a technical standpoint, certain other factors favor Option 3. These are:

1. The payload required to test the 60-inch optical system proposed for a 30-day period together with the necessary sustenance expendables requires a discretionary payload of around 10,000 pounds. Although the 5-segment Titan IIIC launched from the Eastern Test Range could carry the optical sensor, the lifetime of the vehicle on orbit would be severely curtailed due to limited supplies of expendables. In order to collect useful intelligence data the vehicle must ultimately be used in polar orbits. Hence, transition to the Western Test Range and uprating to 7 segments at some point in time is necessary.

2. The cost to achieve a mission capability using both the Eastern Test Range and the Western Test Range as compared to using the Western Test Range only, is greater by approximately $70 to $90 million.

3. Successes in the early research and development flights could yield useful intelligence data at least a year earlier if the research and development program is conducted from the Western Test Range.

4. Conducting the program at both the Eastern Test Range and the Western Test Range creates management problems that needlessly detract from efficient program execution. Security measures, personnel build-up and training, procedures

MOL PROGRAM OPTIONS

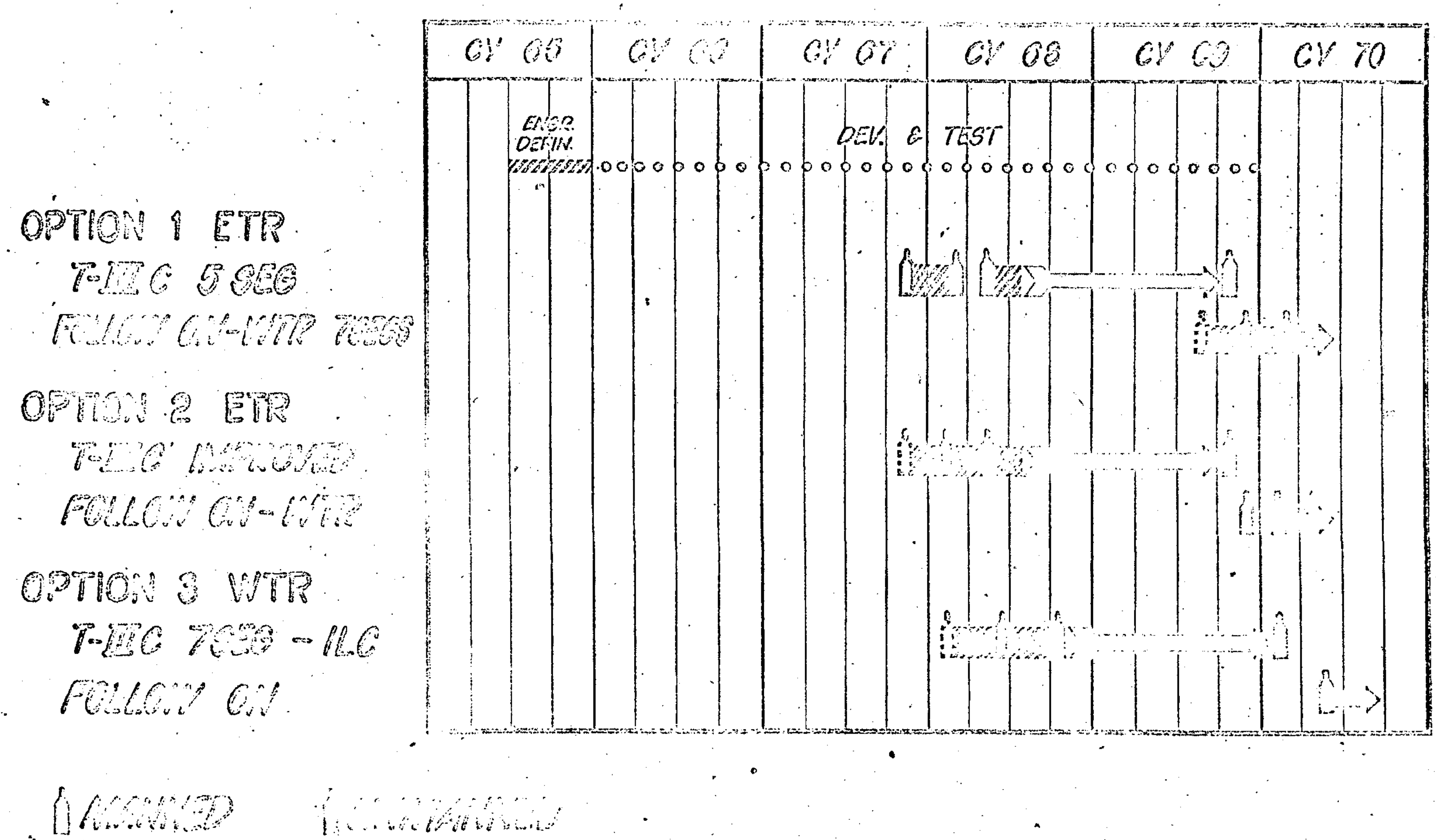

Figure 1

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MOL PROGRAM OPTIONS

COST COMPARISON

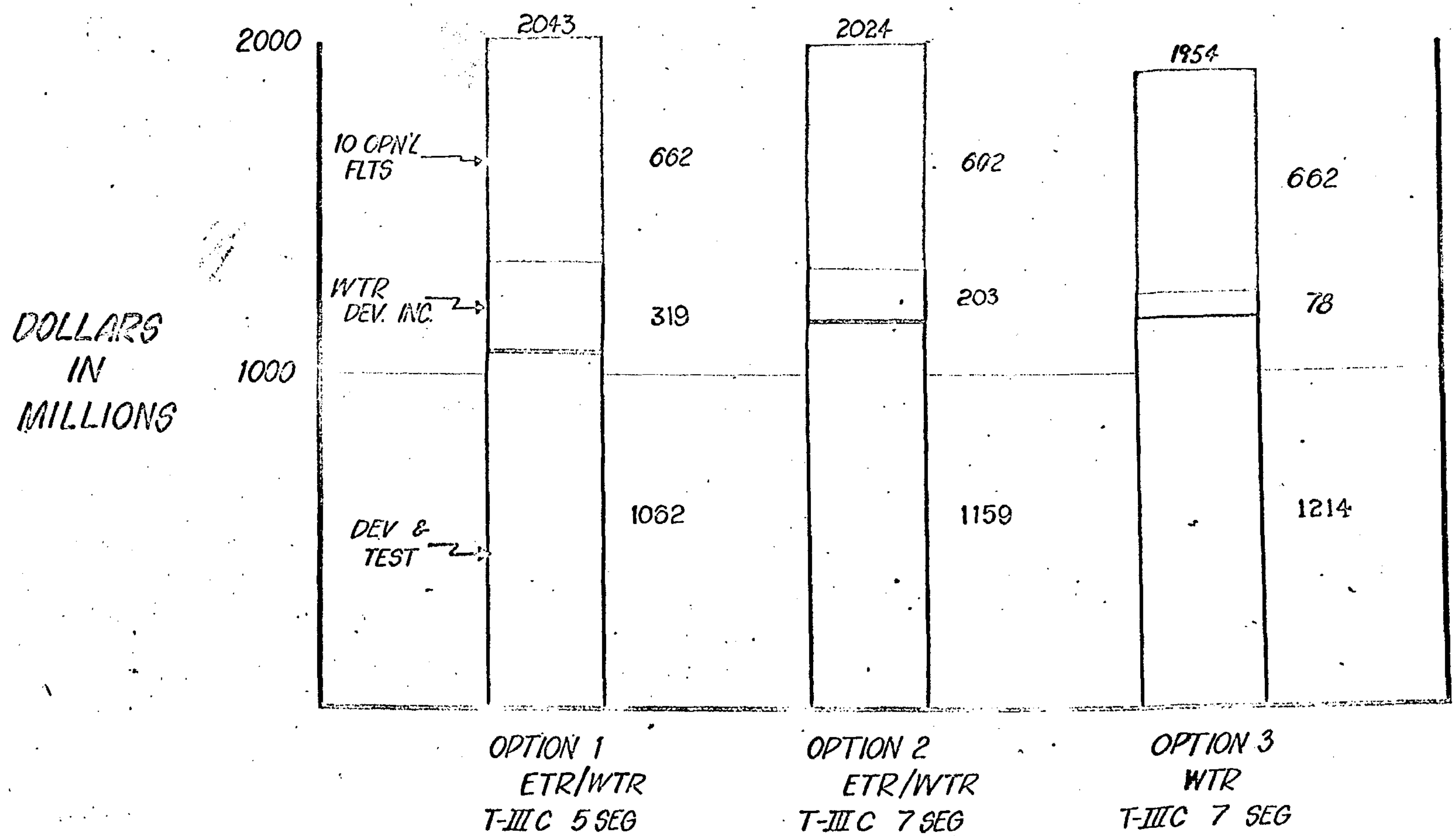

Figure 2

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[redacted]

verification, base support arrangements and other details would create duplication, increase costs, and introduce schedule risks.

There are no known critical schedule items which would preclude achieving the Option 3 first flight date from the Western Test Range.

Program Schedule

The recommended flight test schedule is shown in Figure 3.

Based on a six month Project Definition Phase (PDP), with Phase II development approval following shortly thereafter, the program will be undertaken as follows:

1. Two pre-MOL flights will be conducted from the Eastern Test Range (ETR) using Titan IIIC R&D boosters. The first flight, scheduled for late CY 1966, is a suborbital re-entry test designed principally for qualification of the hatch design in the heat shield of the Gemini B spacecraft. The second flight is designed to obtain experimental data which will contribute to advancing optical component technology. Specific definition of the experiments to be performed will be established during Phase 1B. While not yet firm, this flight is tentatively scheduled for mid to late CY 1967.

2. The basic MOL development program will consist of six integral launches from the Western Test Range, immediately following the Titan IIIC 7-segment booster development flight. The first MOL flight will be unmanned, but otherwise "all-up" to qualify and demonstrate the integrity of the integrated basic vehicle. The second MOL flight, scheduled for late CY 1968, will be manned, and will be the first of the flights essential to the refinement of equipment, development of procedures and techniques, and demonstration of the compatibility and functioning of man as a system element, leading to the achievement of very high resolution photography early in the flight test program. This flight is scheduled to match availability of suitable engineering models of sensor flight hardware to increase probability of early achievement of the desired optical resolution as high quality flight optics become available in 1969.

Operationally useful photographic take, gathered in conjunction with system & sensor development should increase in both quality and quantity as the flight test program matures.

PLANNING SCHEDULE

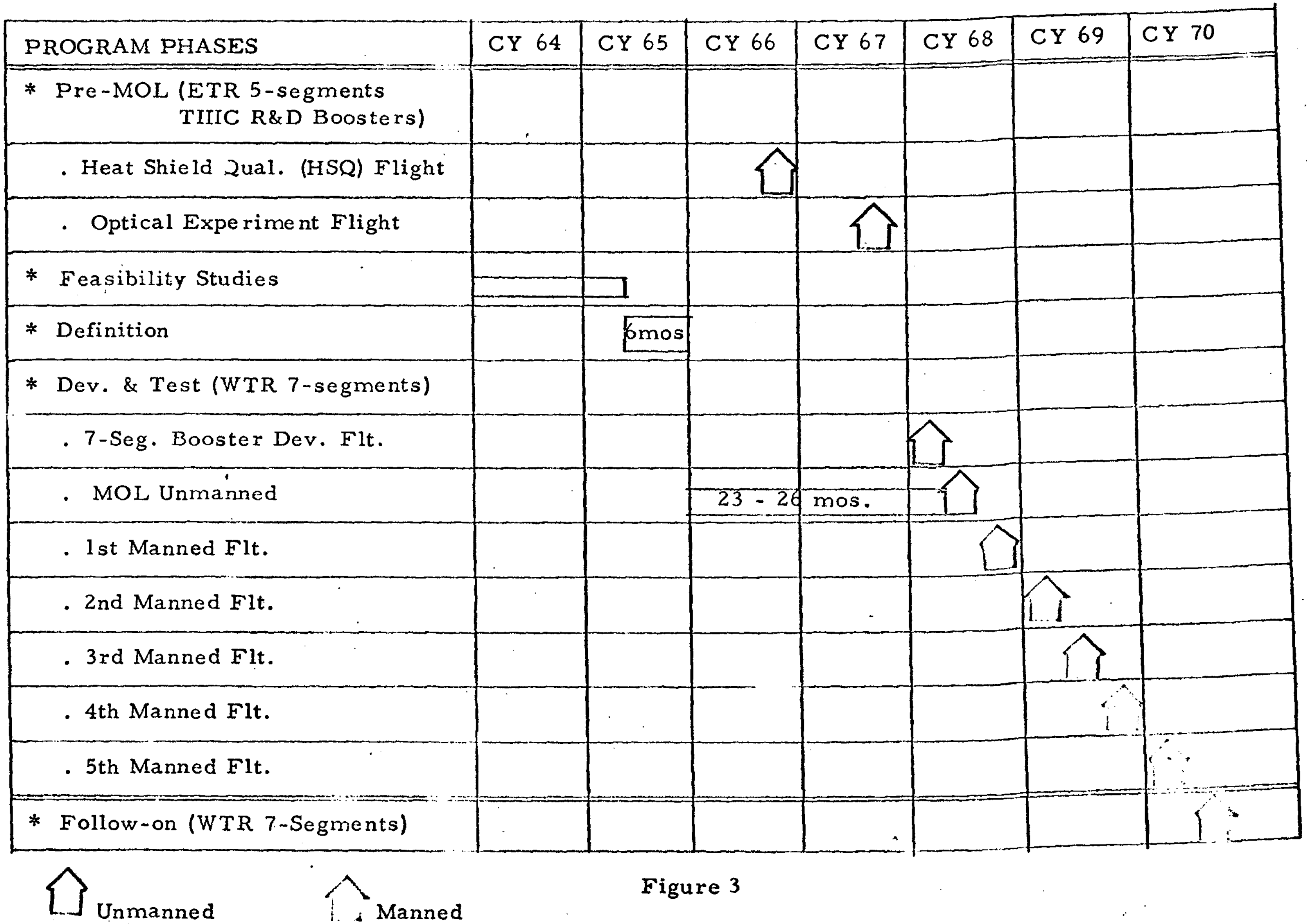

Figure 3

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3. In parallel with the basic MOL program, system design studies involving larger and more refined optical sensors will be undertaken. Other mission applications for the MOL, such as ELINT, COMINT, and ocean surveillance will continue under investigation until specific conclusions can be drawn. When shown to be technically feasible, and worthy of development, suitable recommendations for their addition to the basic program will be proposed.

4. The sensor and system designs demonstrated in the basic program will be suitable for routine operational employment.

5. During the progress of the basic program, other military experiments which directly support very high resolution optical objectives may be added.

System Configuration

The booster recommended for the MOL program is the standard Titan IIIC vehicle modified with 7-segment solid motors and a redesigned 14:1 nozzle expansion ratio and an improved chamber injector for Stage I to improve booster performance. These performance improvements will provide an additional payload capability of approximately 6,500 pounds from the Western Test Range in a 130 n.m. circular, polar orbit. The Stage I engine nozzle improvement also has an added payload performance advantage of approximately 800 pounds for the Titan IIIX program. The original man-rating of Titan III was for the Dynasoar with considerations different than those for Gemini. Gemini considerations require design changes (similar to those made on the Gemini launch vehicle) for an acceptable level of crew safety during launch and to improve mission success probabilities.

Study results show that these modifications and changes to the Titan IIIC/MOL configuration present no major development or schedule risk to the program.

The Gemini spacecraft, which has been designed, tested and successfully flown by NASA, will be the basic building block for the Gemini B segment of the MOL program. In defining the Gemini B segment, minimum necessary changes are being made to the NASA Gemini flight system and ground support equipment. The principal modifications for adaptation to the MOL are the hatch in the heat shield to provide for transfer of the astronauts from the capsule to the laboratory and a modified, shorter and less complex, adapter for attachment to the Titan IIIC. The shorter adapter is possible because of the reduced mission support systems and is alo) desirable to maximize discretionary payload. Equipments contained in the adapter consist primarily of NASA

Gemini systems with some systems eliminated that are not required for the MOL mission. A contract for Gemini B definition yielding specifications, drawings and plans has been negotiated with the McDonnell Aircraft Corporation and will be definitized by 1 July 1965. This six-month effort, previously approved by DDR&E, will provide the definition of those elements necessary and sufficient to initiate acquisition of equipment and services to accomplish the MOL development flights.

The payload sensors and laboratory vehicle as presently envisioned constitute the major developments in the MOL program. Extensive study by the MOL SPO/Aerospace Corporation, by the four industrial laboratory contractors, and by optical sensor contractors warrants the initiation of the Project Definition Phase on these two subsystems. A concurrent approach is needed to closely integrate sensor considerations into the laboratory vehicle so that trade-offs can be made and evaluated and system optimization can be obtained between the laboratory vehicle and sensors.

Unmanned System Considerations

Many of the prime program elements in the manned system, such as the large optics, 7-segment Titan IIIC, and other components could be adapted to unmanned high resolution reconnaissance systems.

Continued studies, and where feasible, component technology programs in critical supporting subsystems will be initiated for the purpose of improving the performance of unmanned systems. Some of the subsystem and technology efforts to be pursued are:

1. Improved V/h sensors capable of sensing image motions to 0.1% or better.

2. Improved stabilization systems with residual rates less than 10^{-3} deg/sec and pointing errors less than $.1^{o}$.

3. Possible optical rectification devices to remove geometric smear off the optical axis in oblique pictures.

4. Image trackers.

Unmanned system studies will be pursued in conjunction with the technology program outlined above, to provide orientation to it.

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CONTROL SYSTEM

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As the technology efforts are defined and initiated and as applicable elements of the manned program are more firmly scheduled, a carefully phased parallel unmanned program will be evolved. Thus, if unmanned reconnaissance systems prove more acceptable in international policies, or if man cannot tolerate adequate durations in orbit, the best attainable resolution by unmanned reconnaissance satellites will be available and at the same time the best use will be made of equipment designed, and facilities established, for manned systems.

MOL Mission Control and Network Support Planning

The Air Force will use existing network and control center facilities to the maximum extent possible, with minimum augmentation to existing networks and control centers. A DoD ground support network adequate to meet MOL requirements consists of elements of the Satellite Control Facility, the National Range Division, and occasional use of selected NASA stations.

For several years, the Satellite Test Center (STC) of the Satellite Control Facility (SCF) has provided an effective control center for multiple satellite control. The STC can provide adequate, competent, and relatively inexpensive support to the MOL program by assignment of programmed displays to the MOL Mission Control Center. Provisions for tight security control are already in effect so that no substantial change to the normal mode of operation of the STC will be needed.

Costs

In late 1963, concurrent with DoD announcement of the MOL program, various task group studies were undertaken to define the possible approaches to a manned military space program and to provide cost and schedule estimates for each. The examinations undertaken at that time indicated that a development program similar in scope to that which is now recommended could be performed for a cost of between \$1.2 billion and \$1.6 billion exclusive of payload and integration costs.

The preliminary definition studies completed to date by MOL industrial contractors and by independent Air Force elements substantiate the original estimates. The development program now being recommended by the Air Force is estimated at \$1.214 billion, exclusive of payload sensor and integration costs. Cost of special activities for high resolution optics and other payload sensors for the basic development program are estimated at an additional $439.0 million. The cost data will be more accurately defined as we proceed with the Project Definition Phase.

Figure 4 shows the deferred FY 65 and approved FY 66 funds required for implementation of the MOL program.

The costs estimated on the attached sheet are based on one laboratory vehicle contractor for the Project Definition Phase. If two contractors participate, the cost will increase by approximately $30.0 million for six months of project definition.

Funds to support the sensor development approach previously outlined in this paper will be requested and funded by separate documentation and procedures. It is estimated that funds totaling $38.6 million will be required for these special activities in FY 66. Of this total, $10.0 million is required for Phase I definition studies and for initial procurement of optical blanks and other long lead time hardware. This sum is further identified to include $7.0 for optics, $1.7 million for SIGINT, and $1.3 million for Ocean Surveillance. The remaining $28.6 million in FY 66 is for Phase II development starting in January 1966.

It is to be noted that the funds being requested for the Project Definition Phase and for continuation of pre-MOL efforts require the release of only $23.0 million of the approved FY 66 MOL funds. The remainder, $16.2 million, of Definition Phase funding can be provided by using FY 65 deferred MOL funds. Based on current cost estimates, the approved MOL program element funds for FY 66 need to be increased by $24.5 million to satisfy total RDT&E MOL funding requirements, exclusive of sensor costs. In addition, $4.0 million of MOL MCP funds currently budgeted for FY 67 will be required in FY 66 to permit the timely initiation of Titan IIIC launch base support facilities at the Western Test Range.

MOL PROGRAM COST ESTIMATES

FY 65/66

WTR - 6 Flights MOL and One 7-Segment Development Flight

(Dollars in Million)

	FY 65	FY 66	
	←—Ph. 1	—→	← Ph. 2 →
T-IIIC (UTC-7 Segment, Booster Improv.)	7.0	---	35.0
Lab Veh	8.0	4.0	48.0
Gemini	1.2	---	26.0
Mission Control Equip.	---	0.5	4.5
Flt Crew Equip.	---	1.0	2.0
Test Support	---	0.3	3.7
Recovery	---	0.2	0.8
System Analysis	---	2.0	2.0
GSE/TD	---	4.5	4.5
Test Stand *	---	---	25.0
Pre-MOL	---	10.5	---
RDT&E TOTAL	16.2	23.0	151.5
MCP	174.5 4.0 178.5		
Special Activities	38.6		

* Proportional Share of ILC

Figure 4

[redacted]

Two Competitive Laboratory Contractors vs. One during PDP

Five factors weigh heavily in examining the question of two competitive laboratory vehicle contractors versus one during the Project Definition Phase. These are:

1. Management complexity
2. Cost
3. Schedules
4. Competitive aspects
5. Security

It is emphasized that the laboratory vehicle, though an important system segment, is only one of the several system segments which will be subjected to the Project Definition Phase. Major system segments are:

1. The Gemini B Spacecraft - McDonnell Aircraft Corporation.

2. The Titan IIIC - Martin Company, Aerojet General, AC Spark Plug, and United Technology Center.

3. Optical sensors - Eastman Kodak.

4. The laboratory vehicle.

In addition, Definition Phase activities will also take place for lesser system segments such as the tracking, telemetry and command network, crew and crew equipment, and also the general systems engineering and technical direction provided by the Air Force/Aerospace management team.

Two laboratory vehicle contractors necessitate a completely dual set of contractor family relationships. McDonnell Aircraft and the Titan IIIC teams would be required to work with both laboratory contractors, presumably in equal amounts if a true competitive environment is maintained. This relationship is further complicated when each of the laboratory contractors is required to integrate his design studies with one or more contractors engaged in large tracking gyro designs as well as with Eastman Kodak on optical payload designs. There would be a major fragmentation of the Air Force/Aerospace Corporation management and general systems engineering effort which, because additional skilled people could not be provided and cleared in any reasonable period, cannot help but dilute and degrade Government supervision during the Project Definition Phase. There would be a major impact on schedules and costs.

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CONTROL SYSTEM

[redacted]

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If the decision is made to compete two laboratory contractors during the Project Definition Phase, there will be a minimum delay of three months in the initiation of Phase II development (Figure 5). Therefore, rather than beginning development in January 1966, as proposed, the earliest Phase II development could commence would be April 1966 with the more likelihood that this date would extend nearer mid-1966 (approximately one year hence). There are several factors which contribute to this delay.

Two of the four laboratory contractors do not presently have any appropriately cleared personnel. The other two have more than 1,000 appropriately cleared personnel working on other contracts in the satellite reconnaissance field. Bringing uncleared contractor personnel to the required clearance level normally takes three to four months. This time could possibly be reduced in some cases depending on the security status of the individual. However, in order to achieve a truly competitive environment, clearances to work on MOL payloads would have to be discretely controlled to assure that each contractor selected to compete had the same number of personnel cleared at the initiation and during the competition. Unless this status is achieved, a true competitive environment would not exist. To structure and maintain the two competing contractors at this equal clearance status will necessarily extend the period required for project definition.

Upon completion of the competitive definition phase, it will be necessary to again review, evaluate and select under Source Selection procedures, a single contractor for Phase II development. Past experience has shown this alone to consume 60 to 90 days, and the selection will take place in an environment no less complex nor complicated than the present situation. During this evaluation and selection period, additional funds will be required to sustain not only the two competing contractors but the other associate contractors on the MOL program as well.

Companion to the preceeding schedule consideration is that of funding impact. Figure 6 shows projected definition phase costs by system segments for two competitive laboratory vehicle contractors. Assuming six months for Phase IB and three months for Phase IC, the additional required funds for the definition phase are about $28.0 million. It is emphasized again that these schedules are considered optimistic and the funds required for the definition period will increase proportionally with further extension to Phase I schedules.

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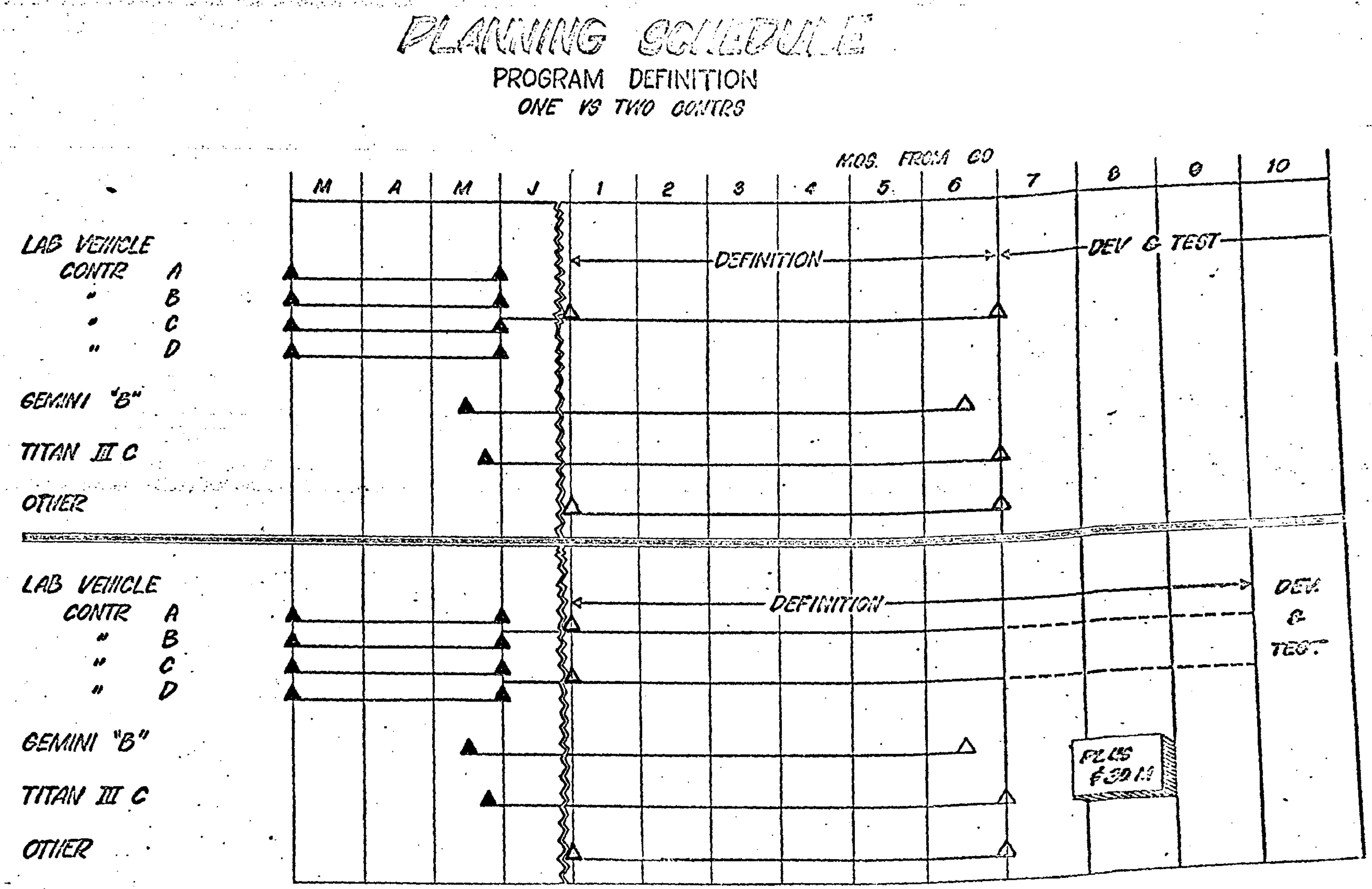
PLANNING SCHEDULE
PROGRAM DEFINITION
ONE VS TWO CONTRS
MOS. FROM GO
M
A
M
J
1
2
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7
8
9
10
LAB VEHICLE CONTR A
" B
" C
" D
GEMINI "B"
TITAN III C
OTHER
DEFINITION
DEV & TEST
LAB VEHICLE CONTR A
" B
" C
" D
GEMINI "B"
TITAN III C
OTHER
DEFINITION
DEV. & TEST
PLUS $30 M

Figure 5

MOL PROGRAM COST ESTIMATES
FY 65/66

WITH TWO LABORATORY CONTRACTORS FOR PDP

(Dollars in Million)

	FY 65	FY 66 1	2	3	4
	← Phase 1B	→ Phase 1C	← Ph. 2 →
T-IIIC	7.0	2.5	15.0
Lab Veh.	8.0	22.0	20.0
Gemini	1.2	2.5	12.0
Mission Control Equip.	----	1.0	2.5
Flight Crew Equip.	----	2.0	1.0
Test Support	----	0.3	1.6
Recovery	----	0.2	0.8
System Analysis	----	2.0	1.0
GSE/TD	----	8.0	2.5
Test Stand	----	----	10.0
Pre-MOL	----	10.5	
RDT&E Total	16.2	51.0	66.4
MCP		117.4 4.0 121.4	
Special Activities		38.6	

Figure 6

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This approach would require less total expenditures in FY 66 due to the delayed start of Phase II development until late in the fiscal year. Total FY 66 funds required of all appropriations in this case would be $160.0 million as compared to $217.0 million under the schedule and costs projected in Figure 4. It would, however, require increased expenditures in subsequent fiscal years if all attempts were to be made to protect the lead times for a manned launch in late CY 1968. Even then, there would be considerable less confidence associated with meeting this launch date than with the schedule and costs associated with a single laboratory vehicle contractor during the definition phase.

TAB E

DOD AND NASA SCIENTIFIC AND TECHNOLOGICAL EXPERIMENTS

Background

In January 1965, DDR&E requested the Air Force to consider, in addition to the primary objectives of the MOL program, other manned military experimentation, and in cooperation with NASA, basic scientific and general technological manned experimentation.

To accomplish these objectives the NASA and the Air Force, with some contractor support, prepared lists of scientific and technological experiment objectives for their respective agencies, exchanged them and analyzed integration feasibility in the Gemini B/MOL and Apollo configurations.

DoD Experiments

As a result of earlier direction to develop an experiment program for MOL, the Air Force had developed a list of experiment objectives which were categorized in two general groupings, primary and secondary experiments. The primary experiments were oriented to quantitatively and qualitatively assess man's utility in performing military tasks in the space environment. The secondary experiments were conceived for the purpose of advancing technology in areas related to military space operations. NASA proceeded to integrate these experiments together with the basic military observational and antenna mission objectives into their proposed Apollo Extension System hardware. As a result of this effort, NASA proposed a nine flight Apollo/Saturn program to carry out all of the DoD experiment and development program objectives. This program provides for two flights of an expandable module and two flights of ocean surveillance experiments, as well as for at least one flight of all other DoD experiments. NASA stated that after a clearer understanding of the DoD experimental requirements and further definition of the NASA continuing program a more efficient application of the resources available from the ongoing Apollo effort could be permitted by elimination of duplication and consideration of priorities.

As the primary reconnaissance mission for MOL took shape and special simulation studies on man's capabilities in such areas as target tracking and acquisition were performed, many of the DoD primary experiments were removed from the experiments category. They became an integral part of the basic system and would be flown as part of the mission demonstration and qualification program. This left a few primary and all of the secondary technological experiments to be accomplished at some time later in the MOL development flight program. Integration analyses of these remaining experiments showed that they could be accommodated on one or two Gemini B/MOL flights.

NASA Experiments

In accordance with the data exchange agreement NASA supplied a list of 80 experiments to the Air Force for integration in the Gemini B/MOL. It was stipulated by NASA that the experiment descriptions were preliminary in nature and have not been selected through the official NASA processes for approval of experiments to be flown aboard Apollo spacecraft.

It is of interest to note that a number of NASA experiments are concerned with earth viewing while employing various high performance optics, infrared, or radar sensors, e.g., operation of high resolution infrared radiometer detectors, multi-spectral target characteristics, synoptic earth mapping, multi-frequency radar imagery, and optical technology.

Because of the tentative nature of the NASA experiment program, the Air Force chose to investigate only the accommodation problems of the NASA experiments to determine the capability of the MOL system to handle the various experiment requirements. Of the 80 proposed experiments, seven could not be accommodated on MOL for various physical and performance reasons, e.g., synchronous orbit requirements or a large diameter centrifuge.

The astronomy experiments proposed by NASA were also eliminated from the accommodation study since it became evident that the primary mission optical sensor could be used with some minor modifications as an astronomical telescope, and in fact be a more effective instrument than those proposed by NASA.

In an effort to further reduce the cost of the experiment program, the remaining primary and secondary DoD experiments were compared to those of NASA and it was found that a large amount of consolidation was possible. A total of 31 NASA experiment objectives could be thus satisfied on the one or two DoD experiment flights mentioned above. The remaining experiment program proposed by NASA can be accomplished with five additional Gemini B/MOL flights.

After the primary MOL mission development objectives are satisfied, the scientific and technological experiment program can be accommodated in 1970. In order to meet the flight schedule, it is necessary to arrive at a firm experiment program decision and hardware configuration two years prior to launch and experiment hardware should be available for integration nine months prior to launch. It is estimated that on a continuing basis the cost of an experiment flight program would be approximately $80 million exclusive of the cost of the experiment payload.

TAB F

COMPARISON OF APOLLO/GEMINI CONFIGURATIONS

Introduction

An evaluation has been made of a number of vehicle configurations proposed as candidates to perform the MOL mission. The configurations were compared on the basis of:

1. Payload weight capability
2. Cost
3. Hardware availability
4. Functional free volume
5. Spacecraft life extension capability

These comparisons were made against the following set of criteria:

1. R&D suitability and cost
2. Operational suitability and cost
3. Minimizing time to move from the R&D to the operational phase.

A NASA/DOD Study Group was formed to exchange data, establish costing ground rules and Apollo/MOL comparison criteria. In accordance with the agreement between DoD and NASA, the evaluations have been carried out by two major efforts. The first effort was comprised of a series of detailed Air Force-SSD/Aerospace studies supported by contractors covering the use of the Titan IIIC launch vehicle with 5 or 7 segment solid rocket motors, the Gemini reentry vehicle, and a range of sizes of laboratory and experiments modules. The second effort was performed by NASA, with contractor support, to determine the applicability of Apollo hardware to support the Air Force program. NASA investigated configurations using the three-man Apollo Command and Service Module (CSM), a lab module derived from the Lunar Excursion Module (LEM), a 250 cubic foot new lab module together with an expandable Special Purpose Module, the

Spacecraft-to-LEM Adapter (SLA), the Saturn IB launch vehicle in its present configuration, and a variety of uprated configurations, as well as the Saturn V launch vehicle in several configurations. The expandable Special Purpose Module is necessary to provide for the accommodation of long focal length optical sensors.

The essential features of the various configurations are presented in the following matrix, and shown in Figures 1, 2, 3 and 4:

LAUNCH VEHICLE/SPACECRAFT CONFIGURATION MATRIX

ETR LAUNCH (LOW INCLINATION ORBITS)	T-III 5 SEGMENT SRM	GEMINI B/LAB
	T-III 7 SEGMENT SRM	GEMINI B/LAB
	S-IB	GEMINI B/LAB
	S-IB	CSM/LEM LAB
	S-IB	CSM/SPECIAL PURPOSE MODULE
WTR LAUNCH (HIGH INCLINATION ORBITS)	T-III 7 SEGMENT SRM	GEMINI B/LAB
	S-IB	GEMINI B/LAB
	S-V*	CSM/LEM LAB S-IVB
	S-IB (UPRATED)	CSM/LEM LAB
	S-IB (UPRATED)	CSM/S.P. MODULE

*Planned for Eastern Test Range launch.

Payload Weight Capability

The payload weight comparison study was performed on the basis of the use of uniform ground rules for analysis of all configurations. These rules are:

1. Launch vehicle capability referenced to 160 n.m. circular orbit altitude at 32.5° inclination for the Eastern Test Range (ETR) program; and 80 n.m. perigee, 160 n.m. apogee altitude, elliptic orbit at 80° inclination for the Western Test Range (WTR) program.

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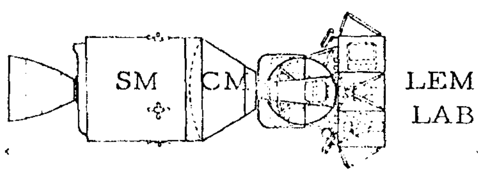
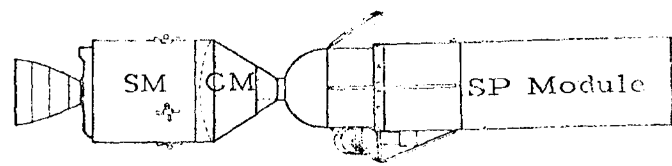
[illegible] MOL [illegible]
NASA APOLLO SYSTEMS [illegible]

○ STANDARD SIV
○ 30 DAY SYSTEMS

LEM LAB CONCEPT	SPECIAL PURPOSE (S.P.) MODULE CONCEPT
	

LEM LAB CONCEPT

○ WEIGHT SUMMARY

CSM	21,000 LB
LEM LAB	6,200
MISSION EQUIP	5,500
TOTAL	32,700 LB

○ VOLUME SUMMARY

PRESSURIZED (GROSS)	613 FT^3
UNPRESSURIZED	~700 FT^3

SPECIAL PURPOSE (S.P.) MODULE CONCEPT

○ WEIGHT SUMMARY

CSM	21,500 LB
S.P. MODULE	4,800
MISSION EQUIP	7,000
TOTAL	33,300 LB

○ VOLUME SUMMARY

PRESSURIZED (GROSS)	616 FT^3
UNPRESSURIZED	~2600 FT^3

STANDARD Sa IB PAYLOAD = 34,000 (i = 32.5, 160 N.MI.)

Figure 1

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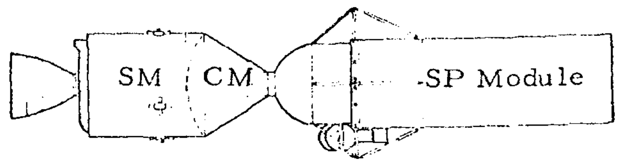
OPERATIONAL MOL PROGRAM
NASA APOLLO SYSTEMS UTILIZATION

○ INTEGRAL LAUNCH



90 DAY

○ WEIGHT ESTIMATE

CSM	32,000 LB
S.P. LAB	6,000
SPACECRAFT	38,000
DISCRETIONARY PAYLOAD	20,000 *
ON ORBIT WEIGHT	58,000

○ PAYLOAD CAPABILITY OF UPRATED Sa IB (4 - 120" SOLIDS) — 58,000 LB

* 11,000 LB S.P.S. PROPELLANT
9000 LB PAYLOAD

45 DAY

○ WEIGHT ESTIMATE

CSM	24,000 LB
S.P. LAB	6,000
SPACECRAFT	30,000
DISCRETIONARY PAYLOAD	17,000 *
ON ORBIT WEIGHT	47,000

○ PAYLOAD CAPABILITY OF UPRATED Sa IB (8-MINUTEMAN) — 47,000 LB

* 8000 LB S.P.S. PROPELLANT
9,000 LB PAYLOAD

Figure 2

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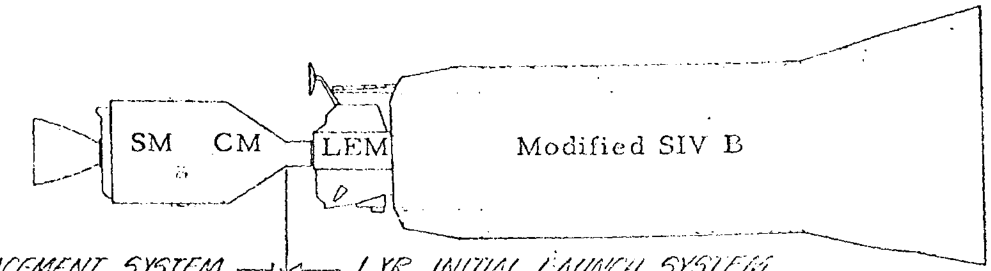
CSAF OPERATIONAL MOL PROGRAM
NASA-APOLLO SYSTEMS UTILIZATION

- ONE YEAR SYSTEM, 90 DAY CREW CYCLE
- ETR LAUNCH Sa V
- ETR LAUNCH Sa IB CREW REPLACEMENT



CREW REPLACEMENT SYSTEM

- WEIGHT ESTIMATES

CSM (EMPTY)	19,500 LB
SPS PROPELLANT	6,000
TOTAL	25,500 LB

- VOLUME SUMMARY

PRESSURIZED (GROSS)	366 FT^3

INITIAL LAUNCH SYSTEM

- WEIGHT ESTIMATES

CSM (EMPTY)	19,500 LB
LEM LAB (EMPTY)	8,000
EQUIP P/L (INCLUDING STRUCTURE)	99,500
DESCRETIONARY P/L	30,000
SPS PROPELLANT	33,000
TOTAL	190,000 LB

- VOLUME SUMMARY

PRESSURIZED (GROSS)	247 FT^3
UNPRESSURIZED	~25,000 FT^3

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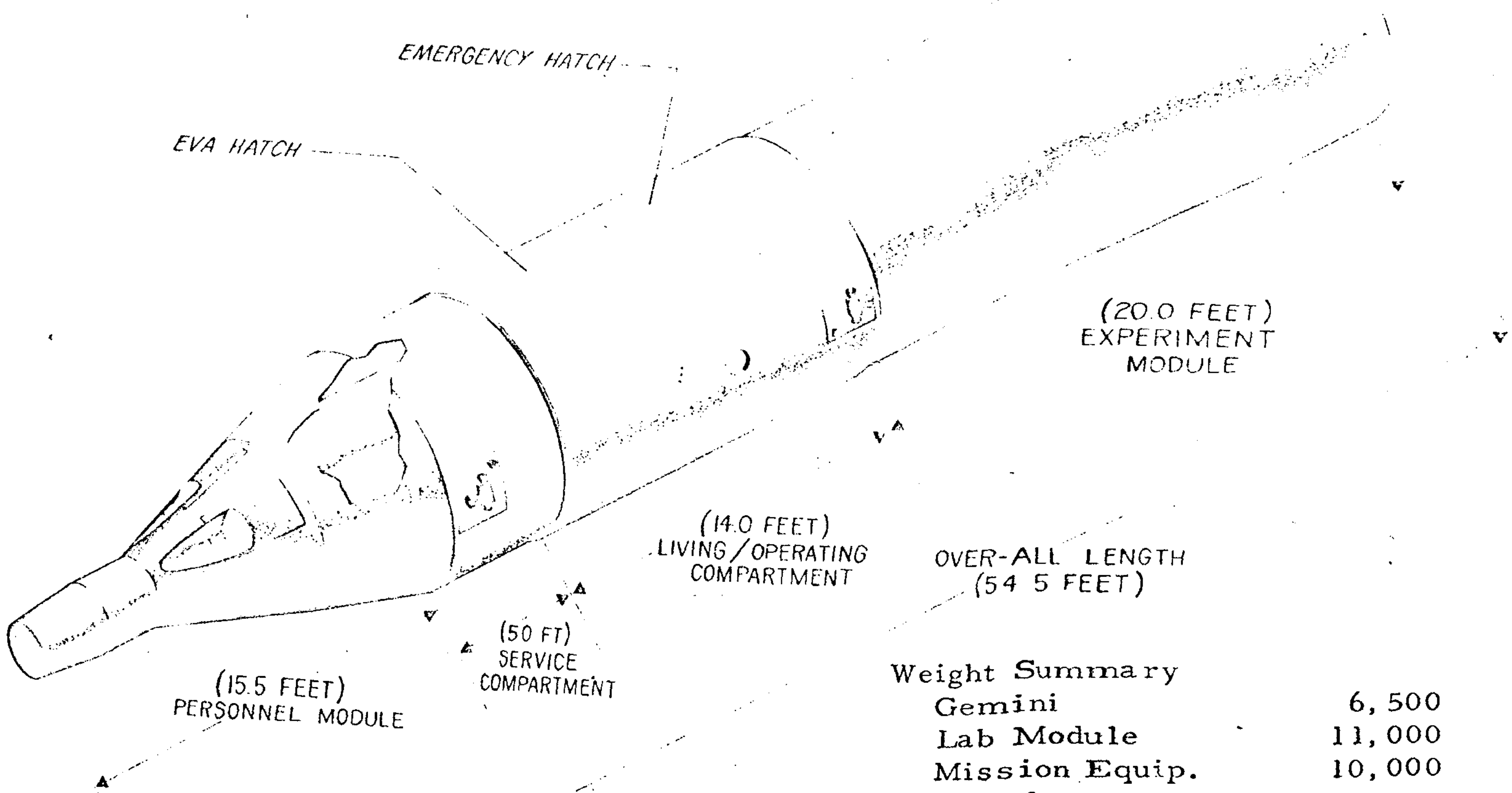
Figure 3

ORBITING VEHICLE
GENERAL ARRANGEMENT



Weight Summary	
Gemini	6,500
Lab Module	11,000
Mission Equip. (Incl. sustenance Propellant)	10,000
Total	27,500

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Figure 4

2. Spacecraft capability referenced to 30 days orbital duration, with orbit keeping propellant included in the follow-on program.

The weight summaries of the various configurations are shown in Figures 1, 2, 3 and 4. The NASA proposed concept, utilizing the Saturn IB launch vehicle consists of two categories. The first is proposed for an initial development phase with low inclination flights from the Eastern Test Range and is based upon the use of the LEM Lab or the use of a 250 cubic foot Lab module, an expandable self-rigidizing Special Purpose Module and the Saturn IB launch vehicle with its present rated payload capability of 34,000 pounds in orbit. The second category is proposed for operational polar missions launched from the Western Test Range with extended stay in orbit for 45 days, or alternatively 90 days. This requires a major uprating of the Saturn IB launch vehicle capability. The Lab Module with the expandable Special Purpose Module is the only NASA configuration that is applicable to the primary mission objectives of the MOL program, and therefore particular attention has been paid to this configuration in the extended orbital stay candidate evaluation. The LEM Lab configuration cannot accommodate the required minimum length of the payload. Since the LEM occupies a large portion of the Spacecraft-LEM Adapter this leaves insufficient room even for the folded stowage of the optics.

The use of the Saturn V launch vehicle, in a two-stage configuration, has been proposed by NASA as their primary approach to the operational phase of the MOL program. With this proposed system, which would be launched from the Eastern Test Range, the duration on orbit would be one year, while the crew would be replaced every 90 days by an Apollo/Saturn IB ferry also launched from the Eastern Test Range. The Saturn V spacecraft configuration is shown in Figure 3. The Saturn IVB stage propellant tank is modified to carry most of the one year life support and orbit sustenance provisions. The replacement ferry system only carries a new crew and a fresh set of subsystems in the CSM.

Cost

The costs used in this comparison were derived by NASA for the Saturn/Apollo configurations and by the Air Force for the Titan/MOL configuration on the basis of ground rules agreed upon by representatives of the two agencies. The NASA cost figures were used whenever they were available. In isolated instances where NASA figures were not provided, the Air Force attempted to generate them within the same ground rules. The basic Apollo and unmodified Saturn cost figures were generated by NASA after a careful and detailed analysis of the Apollo cost history. The cost estimates for the uprated Saturn boosters, and indeed for the entire NASA proposed operational program, were generated with much less thoroughness and are therefore to be viewed with less confidence. The cost estimates for the DoD elements were based on over a year of extensive study of the particular MOL problem and several competitive contractor studies. The Air Force has as high a confidence in these numbers as can be expected without having proceeded through a project definition phase.

The costs per launch of the Titan IIIC/Gemini/MOL and the two NASA Saturn IBs are shown in Figure 5. Total R&D costs of the NASA integral launch concepts are given in Figure 6 and a comparison of total program costs of the three integral launch systems, predicated on 150 days per year operation for a 10-year period, is shown in Figure 7.

The costs of utilizing Saturn V in a rendezvous mode for the operational MOL program are compared on a cost per launch basis in Figure 8 to another candidate system which utilizes Gemini B and the DoD MOL lab module.

The remaining possibility was to consider the use of a Saturn IB instead of the Titan IIIC for the operational Gemini B/MOL from the Western Test Range. This would allow the use of the Standard Saturn IB instead of uprating the Titan IIIC to a 7-segment configuration. The cost differences associated with such use of the Saturn IB instead of the Titan IIIC launch vehicle from the Western Test Range are shown in Figure 9, where the differential development cost items for the Titan IIIC/Gemini/MOL and Saturn IB/Gemini B/MOL are compared on an individual element basis. It can be seen that the higher cost of the Saturn IB raises the cost of any extensive operational phase considerably above that achievable with Titan IIIC.

Hardware Availability

A significant criterion for use in evaluation is that of availability of major segments of proposed candidates. The availability of NASA Apollo-Saturn hardware is shown in Figure 10. The present NASA position is that because of priority commitments to the lunar landing program, Saturn IB does not become available to DoD until mid-1969, and Saturn V does not become available until 1970; and delivery is predicated upon the specification of a priority to DoD with respect to a NASA

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COST COMPARISON OF INTEGRAL LAUNCH MOL SYSTEMS

COST IN MILLIONS OF DOLLARS

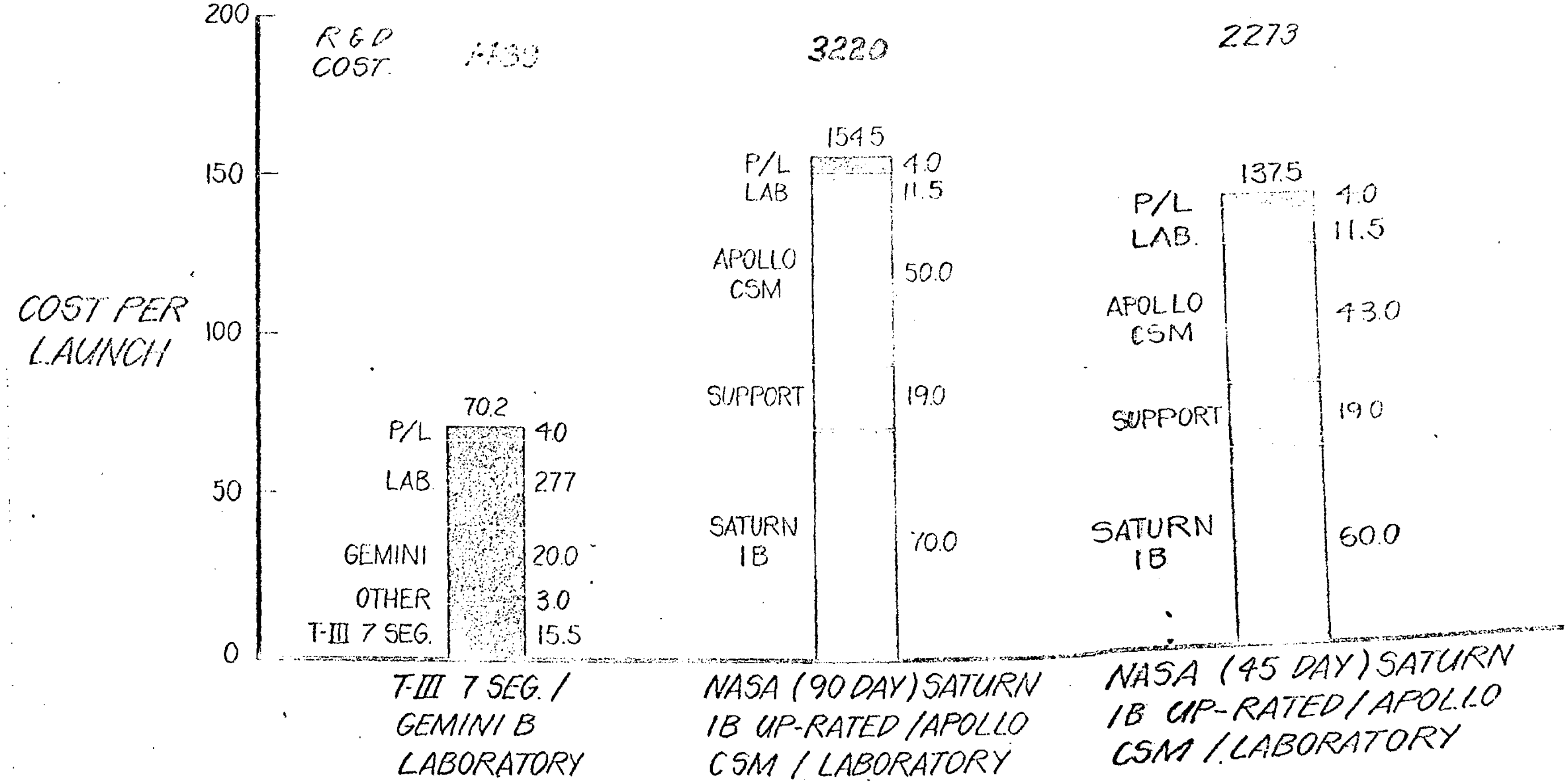

Figure 5

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TOTAL R & D COSTS OF NASA INTEGRAL LAUNCH CONCEPTS

(COSTS IN MILLIONS OF DOLLARS)

	NON-RECURRING		RECURRING	
	90 DAY CONCEPT	45 DAY CONCEPT	90 DAY CONCEPT	45 DAY CONCEPT
SATURN IB UPRATING	1,500	750	70.0	60.0
WTR FACILITIES	300	300	—	—
BLISTER LABORATORY	92	92	11.5	11.5
CSM	200	88	50.0	43.0
PAYLOAD	275	275	4.0	4.0
SUPPORT	—	—	19.0	19.0
EXP INTEGRATION	80	80	—	—
	2,447	1,585	154.5	137.5
5 LAUNCH PROGRAM	772.5	687.5		
TOTAL R & D	3,219.5	2,272.5		

Figure 6

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TOTAL PROGRAM COST COMPARISON OF [illegible] LAUNCH SYSTEMS

TEN YEAR OPERATIONS-150 DAYS PER YEAR COVERAGE

COST IN MILLIONS OF DOLLARS

ITEM	T-III 7 SEG / GEMINI B LABORATORY	APOLLO (90 DAY)	APOLLO (45 DAY)
OPERATIONAL ON-ORBIT DURATION (DAYS)	30	90	45
OPERATIONAL LAUNCHES IN TEN YEARS	50	17	34
COST PER OPERATIONAL LAUNCH	70.2	154.5	137.5
R & D COST	1489	3220	2273
OPERATIONAL COST	3510	2627	4675
TOTAL COST	4999	5837	6948

Figure 7

COST COMPARISON OF MOL SYSTEMS UTILIZING SATURN V

COSTS IN MILLIONS OF DOLLARS

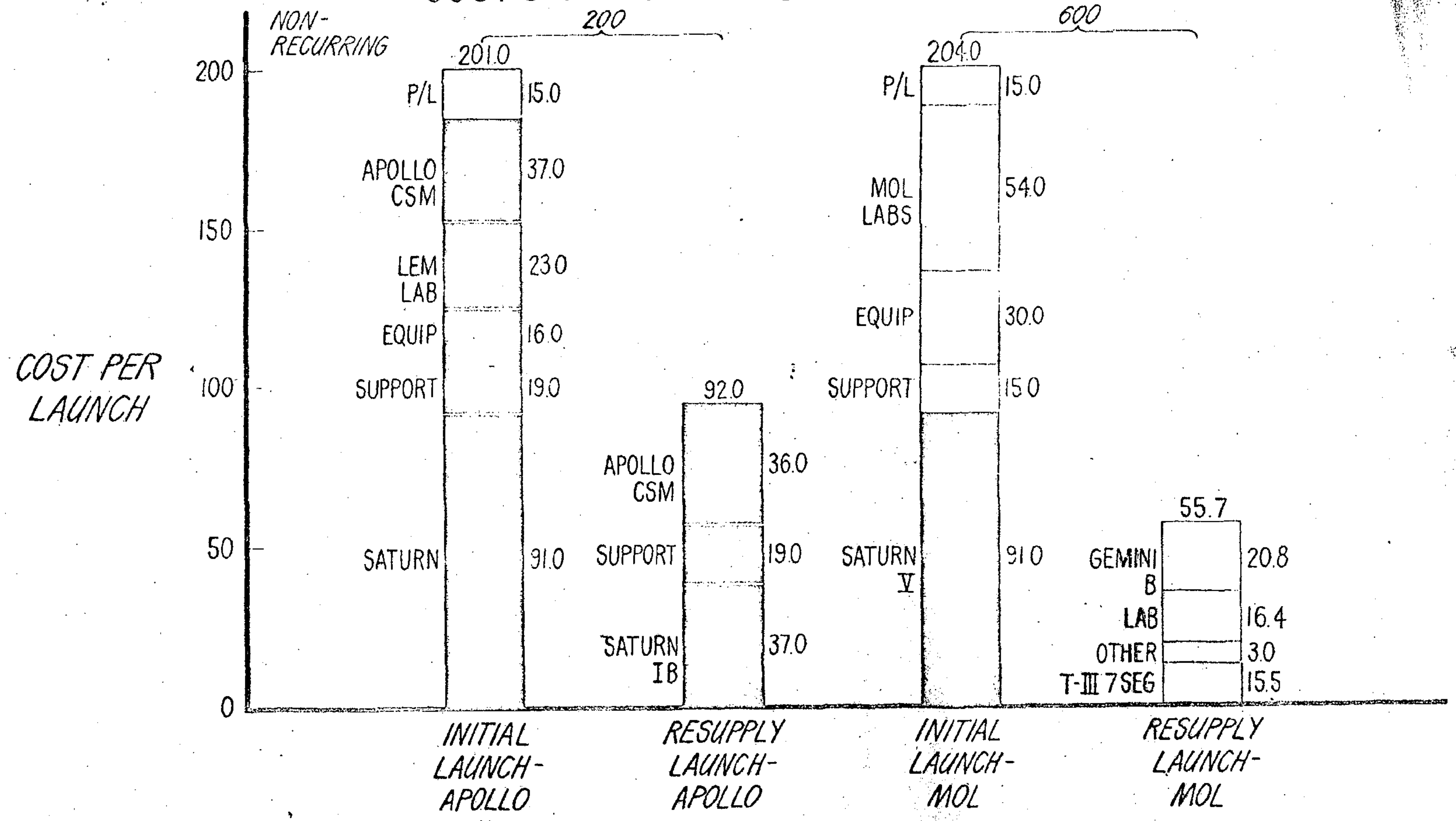

Figure 8

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COMPARISON OF SATURN IB AND TITAN-III

FOR GEMINI B/MOL MISSIONS

	TITAN-III	SATURN IB
- COMMON DEVELOPMENT COST ITEMS (~1000 M$)	Same	Same
- DIFFERENTIAL DEVELOPMENT COST ITEMS		
TITAN-III 7 SEG UP-RATING	82	0
DEVELOPMENT LAUNCHES	53 (2)	37 (1)
WTR FACILITIES	155	200
5 MOL DEVELOPMENT LAUNCHES	86	185
GEMINI B TOWER	-	43
ADAPTER FOR SATURN IB	-	10
DEVELOPMENT SUBTOTAL	376	475
- COMMON OPERATIONAL ITEMS (~2,800 M$)	Same	Same
- DIFFERENTIAL OPERATIONAL COST ITEMS		
LAUNCH VEHICLES (50 LAUNCHES)	775	1,850
GEMINI B TOWER (50 LAUNCHES)	-	15
- TOTAL	1,151	2,340
- COMMON ITEMS	~3,800	~3,800
- GRAND TOTAL	~4,951	~6,140

Figure 9

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MOL VS APOLLO SCHEDULE

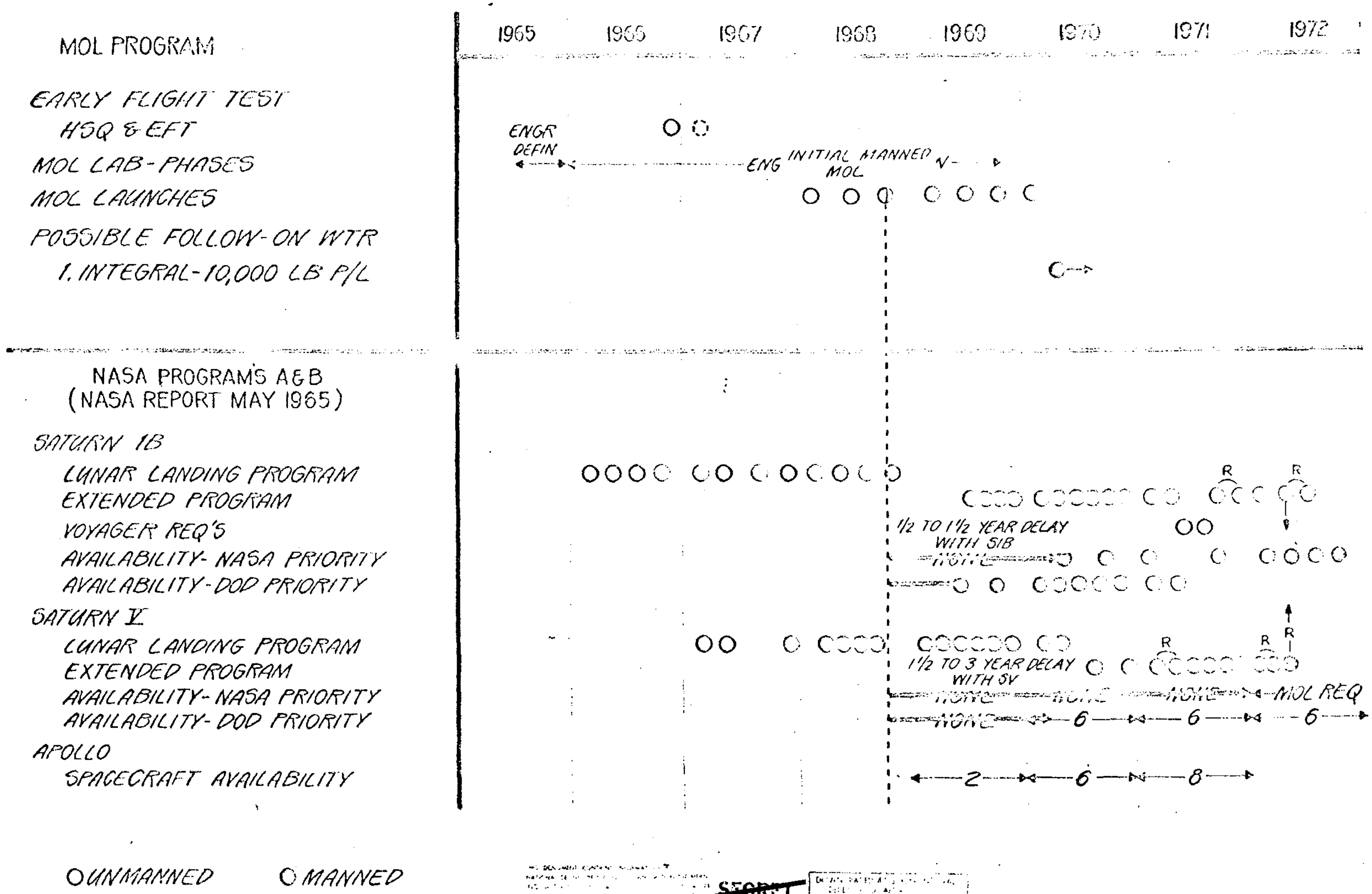

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Figure 10

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earth orbital experiment program. It is evident upon examination of Figure 10 that a 1/2 to 1-1/2 year delay in the MOL program will result from the use of NASA Apollo/Saturn elements.

Functional Free Volume

Detailed studies made by Air Force-SSD/Aerospace, with extensive contractor support, have indicated that a minimum comfortable net free pressurized volume for a two-man crew for 30 days is 400 cubic feet, exclusive of any equipment and furnishings which will be necessary within the cabin. A summary of the various volume constraints of the present and proposed manned space systems is shown in Figure 11. An additional 300 cubic feet of pressurized volume is most desirable to allow the crew to stay in a state of peak performance during operational missions which may later extend to 60 or 90 days. One thousand cubic feet of gross pressurized volume has been established as the MOL program requirement to allow for equipment installation and the above crew comfort requirements. Examination of the NASA candidate configurations, as summarized in Figures 1, 2 and 3, which all use three man crews, shows that the volume is less than the 200 cubic foot per man figure indicated for minimum crew comfort, and that, in addition, it is awkwardly distributed for use.

Spacecraft Life Extension Capability

A most significant increase in cost effectiveness that appears achievable in the near future for MOL is that of increasing the operational stay time on orbit. This increased stay time is primarily dependent upon reliable operation of all subsystems and of the ability of the crew to withstand the zero-g environment for prolonged periods.

Reliable system operation for relatively short duration missions is primarily provided by the use of redundancy in design. Redundancy is also used for all elements that are critical for crew safety and for equipment located in inaccessible places. Mission reliability for long duration is to be achieved primarily by maintenance and repair. A certain measure of redundancy will still be present in the subsystem design, but will not introduce excessive weight penalty since the ability of man to supply malfunction diagnosis, fault isolation and maintenance and repair, will markedly reduce the degree of redundancy otherwise needed. In this connection, the Apollo CSM vehicles are specifically not designed for in-flight maintenance as reflected in the Apollo System Specification. A significant change in Apollo design philosophy such as making all subsystems accessible and

FUNCTIONAL FREE VOLUME COMPARISON

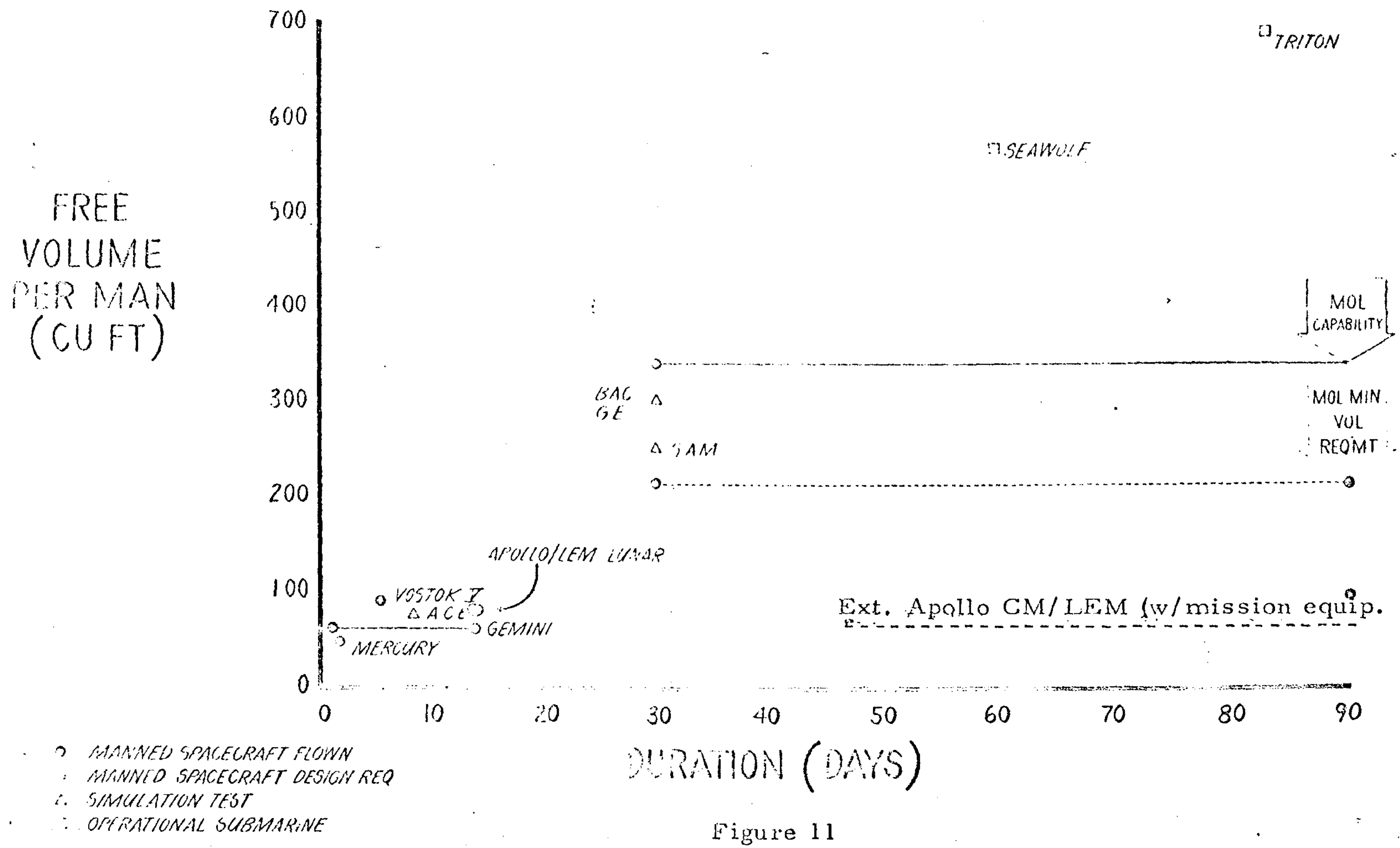

Figure 11

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subassemblies replaceable would be required to allow for in-flight maintenance. This, in turn, would violate the ground rule of minimum change to Apollo and thus increase development costs. The DoD/MOL will be designed from the outset for manned maintenance and repair, and thus will possess the growth capability to achieve long stay time in orbit beyond the initially postulated 30 days.

Conclusions on the Use of NASA Apollo Hardware for MOL

The results of the comparative analyses between Saturn IB and Titan IIIC based systems are shown in Figure 12. The use of Apollo hardware in configurations designed for extended stay in polar orbits requires major uprating of the Saturn IB launch vehicle, development of the new Lab Module and Special Purpose Module, and is subject to the limitation on available pressurized volume discussed above.

The costs of the Saturn IB/Apollo configurations are significantly larger than those of the Titan IIIC/Gemini B/MOL.

The use of Saturn V for the MOL program appears quite attractive when it is considered for operation in a manned orbiting system whose scope is much more advanced than the present plan, since it can only be efficiently utilized if very large optics are used. Therefore, Saturn V is not compatible with an early operational capability. If the large system capability of Saturn V is to be exploited in an optimal manner the requirement is generated for the initiation of development of very large sensors at the maximum rate compatible with acceptable technological risk.

A further undesirable feature of the use of Saturn V for the initial development program is the requirement to use a rendezvous system at the outset of the development program. Thus, there would be no orderly development in the progression from the integral launch to the quite advanced rendezvous system possibilities.

In summary, the applicability of Saturn IB/Apollo hardware to the MOL program is limited by inadequate payload capability and available functional free volume; undesirable restrictions on subsystem life extension; high program costs and conflict of hardware availability and operations. The use of Saturn V is incompatible with early operational capability imposing a delay of several years in the MOL program.

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SUMMARY OF VEHICLE CHARACTERISTICS
INTEGRAL LAUNCH

CONFIGURATION	PAYLOAD CAPABILITY 1000 LBS (WTR)	ON-ORBIT DURATION (DAYS)	FREE PRESSURIZED VOLUME FT^3	FIRST MANNED FLIGHT AVAILABLE	ORBIT LIFE EXTENSION ≈ 90 DAYS	COST M$ DEVEL.	RECURRING COST/ LAUNCH	TOTAL DEVEL. & OPS (10 YR)
T-III 7 SEG/ GEM B/LAB	10.0	30	670	MID 68 [uncertain]	MAIN-TAINABLE	1,189 [uncertain]	70.2 [uncertain]	[illegible]
SATURN IB (UPRATED)/CSM/ S.P. MODULE	20.0	90	90 CM 70 SP 160	½-1½ * YEARS LATER	NOT MAIN-TAINABLE	3,220	154.5	5,837
	17.0	45	90 CM 70 SP 160	½-1½ * YEARS LATER	NOT MAIN-TAINABLE	2,273	137.5	6,948

* NOT CONSIDERING Sa IB UPRATING

Figure 12

There is, further, an indeterminate delay in the program associated with the development of the very large payloads required to utilize Saturn V capability within the constraint of reasonable technical risk. The use of Saturn IB with Gemini B/MOL from the Western Test Range is undesirable because of the very much higher operational costs as compared to the use of Titan IIIC.

On the other hand, the Titan IIIC/Gemini B/MOL is compatible with a program devoted to developing large optical high resolution devices operated by man. The use of 7-segment solid rocket motors with Titan III at the Western Test Range provides adequate operational payload for high inclination orbits. The design of the MOL baseline vehicle, in its provision for manned maintenance and repair, provides growth capability for extended stay on orbit.

It is accordingly recommended that the Titan IIIC/Gemini B/Lab be used to perform the DoD/MOL missions.

TAB G

UNMANNED FLIGHT PROGRAM (PRE-MOL)

Background

Memorandum from the Director, Defense Research and Engineering (DDR&E), dated January 4, 1965, for the Under Secretary of the Air Force requested the Air Force to re-examine the unmanned flights previously proposed by the Air Force. The objectives of the unmanned flight program as stated in the DDR&E memorandum are to:

1. Make effective use of the Titan III R&D flights.

2. Provide for steps toward qualification of components of the MOL system.

3. Contribute to the unmanned operational objectives of the MOL program including the test of experimental payloads toward this end.

In early February 1965, the Air Force in response to the DDR&E memorandum proposed a sub-orbital re-entry test designed principally for qualification of the transfer hatch in the heat shield of the Gemini spacecraft. DDR&E in early March 1965 approved the requirement for a Heat Shield Qualification (HSQ) flight and authorized the release of deferred MOL funds to cover the fiscal year 1965 charges for necessary work with McDonnell and Martin in preparation for this test. The configuration and test objectives for this flight are detailed below.

Heat Shield Qualification Flight (HSQ) - Sub-Orbital

The launch vehicle planned for this flight is Titan IIIC, No. 9 from the Titan III R&D program. The standard 5-segment solid rocket motors configuration incorporating a differential pressure sensor between the solids will be used to provide flight qualification of the solid motor malfunction detection system. The laboratory is to be simulated by use of a Titan II, Stage I, oxidizer tank. External structure will be modified to simulate the anticipated laboratory stiffness. Barrel sections will be provided at either end to extend the tank dimensions to the expected laboratory length. The re-entry module will be a Gemini system with the heat shield modified to incorporate the transfer hatch required of Gemini B. The NASA Gemini spacecraft that flew on GT-2 is being refurbished by McDonnell and will be flown on this flight.

As a result of Air Force/NASA negotiations on the management and conduct of the Gemini B/MOL program, the Air Force has assigned to NASA the responsibility for engineering, contract management, and procurement required for the refurbishment and modifications of Gemini Spacecraft #2 (GT-2).

Integration of the Titan III/Lab/Gemini segments will be accomplished in the Vertical Integration Building (VIB) at CKAFB. The flight vehicle will be launched from the Eastern Test Range on a sub-orbital trajectory with an azimuth of 106°. The trajectory will be lofted but constrained within the Gemini abort ceilings. The flight path angle will be depressed below horizontal at insertion to effect a maximum heat re-entry. After booster engine shut down the separation mechanism will be initiated and spacecraft turn-around will be accomplished. The spacecraft will be recovered after splash down for engineering analysis.

Specific test objectives for this flight are:

1. Verify adequacy of Gemini heat shield to survive re-entry heat and aerodynamic loads when modified with a crew transfer hatch.

2. Qualify new adapter and separation mechanism. A new 15-degree adapter between the Gemini and MOL is required for the MOL system. A change such as this requires flight qualification. Transmissibility of loads across the adapter will be determined and allow for better design definition of the Laboratory/Gemini interface.

3. Obtain environmental test measurements on space vehicle structures and protuberances.

4. Qualify pressure differential sensor added to the launch vehicle. The delta pressure sensor provides early detection of a malfunctioning solid rocket motor. A significant improvement in crew safety is possible with this modification.

5. Exercise selected portions of the MOL ground support system.

The schedule for this flight is shown in Figure 1. GT-2 Gemini spacecraft has recently been shipped to McDonnell Aircraft by NASA to commence refurbishment.

Second Unmanned Flight - Orbital

In addition to the HSQ flight, the Air Force plans a second flight with unmanned experimental payloads aimed primarily at military applications.

The primary objective of the second unmanned Pre-MOL flight is to obtain meaningful data from optical experiments which will contribute to advanced technology. Particular emphasis is to be made to launch and on-orbit environmental effects on large optical surfaces. While the details are currently under examination, areas of interest include early flight test information on suitable mounting provisions of large mirrors and time history data on zero "g" and thermal flux collected on-orbit.

The date for this flight, contingent upon better definition of experimental payloads, could be scheduled for mid to late 1967. The Air Force plans to submit a firm payload and schedule proposal by 1 November 1965. A preliminary planning schedule for this flight is attached as Figure 2.

As in the case of the HSQ flight, it is planned to use a launch vehicle from the Titan IIIC R&D program and a vehicle has been identified for this purpose. Since current planning for this flight does not require spacecraft re-entry from orbit, the Air Force has received from NASA their Gemini Static Test Article No. 4 which, with limited refurbishment as required to correct materiel discrepancies, can be used for this flight. No Gemini subsystems will be installed and a boilerplate Gemini B adapter can be used. The laboratory configuration will be provided by the laboratory contractor and will be structurally similar to the manned flight test laboratory structure.

Costs

Of the initial FY 65 funds released by DDR&E in early February 1965, $7.0 million was approved as the FY 65 charge against the sub-orbital Heat Shield Qualification (HSQ) flight, scheduled for late 1966. Identified within the recommended MOL Development Program is $10.5 million in FY 66 and $6.0 million in FY 67 projected to continue with the two-shot Pre-MOL test program.

SCHEDULE

Heat Shield Qualification Flight (GT-2)

	CY 65									CY 66									
	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Go-Ahead	Δ																		
NASA Gemini Modified for HSQ																			
Drawing Release																			
Structure		Δ																	
Adapter			Δ																
Sequencer				Δ															
Hatch-in-Heat Shld				Δ															
Manufacturing																			
S/C Final Assy						Δ						Δ							
Hatch-in-Heat Shield					Δ						Δ								
Sequencer				Δ				Δ											
Adapter			Δ				Δ												
Systems Test												Δ				Δ			
Simulated Lab																			
Design Release										Δ									
Fabrication										Δ			Δ						
Subsystem Tests													Δ		Δ				
T-HHC Available														Δ					
Integration & Checkout at CKAFB																Δ			Δ
Launch																			Δ

Figure 1

PRELIMINARY PLANNING SCHEDULE

Second Unmanned Flight - Orbital

(Static Article No. 4)

	Months From Go-Ahead																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Contract Go-Ahead:																		
Martin Company	△																	
McDonnell Aircraft Corporation	△																	
Payload Contractor	△																	
Engineering Release:																		
Simulated Lab				△														
Static No. 4			△															
Adapter			△															
Manufacturing:																		
Simulated Lab					△				△									
Adapter				△				△										
Static No. 4				△					△									
Subsystem Test:																		
Simulated Lab									△		△							
Static No. 4									△		△							
Experiments:																		
Design Description					△													
Design Incorporation							△											
Article Delivery									△					△				
Integration:											△			△				
Pre-Launch Checkout:															△			△
Launch:																		△

Figure 2

TAB H

ACTIONS RESULTING FROM 4 JANUARY 1965 DDR&E GUIDANCE

Introduction

The 4 January 1965 Memorandum for the Under Secretary of the Air Force, entitled "Manned Orbiting Laboratory". outlined specific DDR&E guidance leading to a basis for deciding as to the future course of the MOL program. In response to this guidance, specific actions were undertaken in the evolution of the proposed MOL program.

Guidance

"2. Consideration should also be given, in close cooperation with NASA, to the following additional objectives:

a. Basic scientific and general technological manned experimentation.

b. Development and demonstration of manned assembly and service of large non-military structures in orbit such as astronomical telescopes and radio antennae.

c. Biological responses of man in orbit for 30 days or more."

Action

Study teams were formed both by NASA and the Air Force. Together with contractor support, scientific and technological experiment objectives were generated by each agency, and subsequently exchanged. Each agency then performed an analysis for integration of these experiments into their respective orbital configurations, GEMINI B/MOL, and APOLLO.

Study of the consolidation of NASA and DoD experiments indicates that all low orbit objectives can be met in 6 MOL flights scheduled beyond the presently proposed 6-launch program.

NASA has proposed a 9-flight APOLLO/SATURN program to carry out DoD experiment objectives. However, NASA considers that a clearer understanding of DoD requirements, and further definition of the NASA continuing program would permit consolidation and elimination of duplication, and would permit more efficient application of APOLLO resources.

Further details are included in TAB E.

DORIAN/GAMBIT

Cy #6

Guidance

"3. Although it is recognized that the objectives of paragraphs 1 and 2 have been studied in developing the MOL plans, I would like to assure that the primary objectives as stated in paragraph 1 can be implemented effectively by the MOL program and that the results expected are commensurate with the estimated costs."

Action

The approach to satisfying primary MOL objectives has been carefully and continuously examined. A clear understanding of the value of very high resolution photography has been established. A conservative technical program approach has been evolved toward achieving this objective, borrowing heavily from current successful technology. Alternate approaches to the high resolution sensors were examined. In the proposed program, two optical design approaches for early MOL flights would be carried forth at modest cost, without jeopardy to schedule, until the best approach becomes clear. Meanwhile, design studies of improved sensors for later MOL flights would proceed apace, and be integrated into the schedule as they matured.

Close alliance with on-going programs of similar nature was undertaken to insure that desired results could not be otherwise obtained at comparable cost levels. It was found that manned systems have the capability to achieve desired results sooner and with less development risk than with unmanned systems.

Further detail can be found in TABS A, C, D, E and F.

Guidance

"4. Therefore, I request that the Air Force define an experimental military program to meet objectives (a) and (b) of paragraph 1 above, and determine the essential vehicle characteristics to meet these objectives. This study should be conducted in the same rigorous detail that characterized the studies of objectives (c) of paragraph 1 above made by the Air Force during the past year."

Action

Supported by contractor preliminary design studies and by SSD/Aerospace Corporation studies, analyses and evaluation, an experimental military program has evolved. A resumé of the proposed approach, with a brief discussion of principal vehicle and supporting element configurations is contained in TAB D.

Guidance

"5. The Air Force is requested to assess carefully the proposed specifications of the GEMINI B plus laboratory configuration, employing the launch capabilities of the TITAN IIIC, against the needs defined in accordance with paragraph 4."

Action

After careful analysis it has been confirmed that effective use can be made of the NASA GEMINI flight system, suitably modified with a minimum of change into the GEMINI B configuration. As adapted, the GEMINI B is compatible with the laboratory module.

The TITAN IIIC with 5-segment solid booster motors performs acceptably with eastward launches from the Eastern Test Range. However, launches from the Western Test Range into polar orbit require that the standard TITAN IIIC vehicle be modified with 7-segment solid motors and an improved Stage 1 nozzle and injector.

A resumé of these considerations appears in TAB D.

Guidance

"6. In addition, the Air Force is requested to examine approved configurations of the APOLLO system to determine the extent to which any of these could meet the needs defined in accordance with paragraph 4 in a more efficient, less costly or more timely fashion."

Action

Alternative configurations of the APOLLO, furnished by NASA, were analyzed. It was determined that the alternatives examined were not promising in terms of improved efficiency, less cost, or timeliness, as a means of achieving program objectives. A brief of the details of these considerations is included in TAB F.

Guidance

"7. Since the assessment of APOLLO capabilities will require consideration of the interaction of the laboratory vehicle with the proposed experiments, NASA is being requested to provide to the Air Force, as soon as possible, information concerning the configurations of the APOLLO system currently being studied by NASA to meet NASA program objectives. Based on this information and prior Air Force studies, the Air Force is requested to provide to NASA the needs defined in accordance with paragraph 4 to the detail necessary to enable NASA to identify specific configurations of the APOLLO system applicable to DoD objectives. NASA, with DoD cooperation, will then make this identification in at least preliminary form by April 30, 1965. These specific configurations of the APOLLO system will then be further examined by the Air Force."

Action

NASA was furnished needs, as defined by the experimental military program, in sufficient detail to permit identification of specific applicable APOLLO system configurations. Subsequent analysis was undertaken and integrated into the considerations from which the proposed MOL program evolved. Further details are contained in TAB F.

Guidance

"8. The Air Force should also define, in cooperation with NASA, significant experiments directed to the objectives of paragraph 2. The impact of these experiments on the configuration and cost of the vehicle required to meet the objectives of paragraph 1 above, should be defined, and considered in determining the nature of the part of the MOL program whose purpose is as listed in paragraph 2."

Action

An experiments program, embracing basic scientific and technological manned experimentation, development and demonstration of manned assembly of large non-military structures in orbit, and biological responses of man in orbit, has been conducted in coordination with NASA, as explained in foregoing paragraphs. Further detail is contained in TAB E.

Guidance

"9. I would like to review the results of the work described in paragraphs 4 through 8 to assure that the results expected from the MOL program are commensurate with the estimated costs before release of the FY 1966 funds to the Air Force. It is requested that this review be submitted by May 15, 1965."

Action

On 2 June 1965, the proposed program, based on the results of the work described in paragraphs 4 through 8, of your 4 January 1965 memorandum for the Secretary of the Air Force, entitled, "Manned Orbiting Laboratory," was orally presented to DDR&E. Previous to this submittal, on 17-18 May 1965, Dr. A. Hall participated in a detailed preliminary review.

Guidance

"10. I believe a re-examination is desirable of the unmanned flights previously proposed by the Air Force. In particular, the unmanned flight program should:

a. Make effective use of the TITAN III R&D flights.

b. Provide for steps toward qualification of components of the MOL system.

c. Contribute to the unmanned operational objectives of the MOL program including the test of experimental payloads toward this end."

Action

In March 1965, DDR&E approved a Sub-Orbital Heat Shield Qualification test, utilizing the refurbished GT-2 GEMINI Spacecraft modified to the GEMINI B configuration, boosted by a TITAN IIIC R&D vehicle. An additional unmanned flight, which would be orbital, utilizing a TITAN IIIC R&D booster, is under consideration; and steps have been taken to secure long lead hardware to protect the option to proceed with this flight on a timely basis.

Additional detail relative to this aspect of the program is contained in TAB G.

Guidance

"11. To preserve the option for proceeding with the MOL on an orderly basis, the DoD will employ the FY 1965 MOL funds for work on Pre-Phase I and Phase IA studies and for the work on TITAN III and GEMINI B necessary for launches of unmanned payloads using the boosters in the presently approved TITAN III research and development program. Funds for proceeding with Phase IB (narrowing of PDP to two contractors) and Phase II (full-scale development) for the manned flight development program are included in the 1966 estimates and will not be released until a decision is made to proceed as indicated above."

Action

FY 1965 MOL funds have been employed to support Pre-Phase I and Phase IA contractor preliminary design studies, both for laboratory vehicles, and for large in-orbit structures. Necessary work, supported by FY 1965 MOL funds, is underway at Martin Marietta and at McDonnell Aircraft in preparation for unmanned experimental flights, utilizing TITAN IIIC R&D boosters. Further detail will be found in TAB G.

Guidance

"12. It is requested that the Air Force fund with industry three preliminary design studies of MOL configurations employing TITAN IIIC plus GEMINI B to meet the objectives of paragraph 1. The laboratory configuration should include provisions for:

a. Testing concepts of assembly of large optical devices in space.

b. Servicing large optical space systems.

c. Testing concepts of assembly and service of large radio telescopes in space.

d. Testing high resolution surveillance radar concepts.

e. Manned experimentation facilities.

The purpose of these studies is to help to provide the Air Force the cost and technical information required by paragraphs 4 and 5 above."

Action

Preliminary design studies were undertaken with four industrial contractors (per agreements reached subsequent to the 4 January 1965) in which aspects of laboratory design appropriate to utilization of TITAN IIIC as a booster, and GEMINI B as a reentry capsule were considered. The proposed program draws heavily on these studies for preliminary definition of the proposed laboratory vehicle and in the determination of program cost estimates.

Guidance

"13. The Air Force is requested to choose 3 contractors for the studies of paragraph 12 who are qualified to build the laboratory module whether the approach finally selected is:

a. TITAN IIIC plus GEMINI B and lab module,

or

b. SATURN IB plus APOLLO CSM with lab module in place of the LEM adapter section.

The choice of contractors should be based on:

a. Grasp of problem.

b. Management and technical resources.

c. Integration experience.

d. Facility availability."

Action

The 4 contractors chosen (as per agreement subsequent to 4 January 1965) were Lockheed, Boeing, Douglas and General Electric. Each was considered qualified to build the laboratory module.