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CONTROL SYSTEMS JOINTLY

DEPARTMENT OF THE AIR FORCE
WASHINGTON 20330

OFFICE OF THE SECRETARY

JUN 1 1968

MEMORANDUM FOR DR. FLAX

SUBJECT: ~~(SECRET~~-BYEMAN) Deferral of Development of the Unmanned MOL System

At the $500-520 million level in FY 69, it does not appear possible to avoid slippage of the first all-up manned launch in the present MOL Program from August 1971 until sometime in 1972, plus an increase in Phase II costs to more than $3 billion. In my opinion, this will result in the program position being even more precarious than it is already.

In order to minimize slippage beyond August 1971, keep any future single-year fund requirement below $600 million, and hold Phase II total costs comfortably below $3 billion, I recommend that serious consideration now be given to deferring the development of the unmanned MOL system until a Block II buy. In view of the budget limitations and technical uncertainties in at least two areas essential to successful operation of the unmanned system, such a scope reduction in the present program appears reasonable and justifiable.

More specifically, it is proposed that a six launch MOL Program be established (two unmanned, non-payload qualification launches; plus four manned, all-up 30 day reconnaissance missions). The present baseline manned configuration would be developed without change to permit verification of the feasibility of unmanned "automatic" operations and convertibility to an unmanned system if that should become a necessary or desirable future option. At a $525-530 million level of funding in FY 69, the first all-up manned launch should be possible in November 1971, and with subsequent launches on approximately five-month centers, the total Phase II cost would be at least $100 million less than the present program.

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The following sections deal briefly with what appear to be the pertinent factors associated with a change in scope from a seven launch manned/unmanned MOL Program to a six launch manned-only program.

COST-SCHEDULE CONSIDERATIONS

The present program schedules the first manned launch in August 1971 and the final unmanned launch in Jan/Feb 1973. The cost estimates associated with this program are as follows:

(Millions)

FY68 & Prior	FY69	FY70	FY71	FY72	FY73	Total
$722.3	600	600	485	350	83	$2840

A reduction of $50 million in the present program in FY 69 would result in a 3-4 month slip in the first manned launch date and an increase in total cost of approximately $100 million. A reduction of $100 million in FY 69 would result in a 6-7 month slip in the first manned launch date and an increase in total cost of at least $200 million.

In the present program, the two unmanned launches are estimated to cost somewhere between $300 and $400 million (nonrecurring plus recurring costs -- it is difficult to identify all of the subtle nonrecurring efforts). Of that total, some $25 million in nonrecurring costs will occur in FY 69 and approximately $50 million (both nonrecurring and recurring costs) in FY 70.

To be conservative in estimating the cost of a six launch manned-only program, subtract the lesser figure quoted above for the two unmanned systems in the present program ($300 million) from the total cost. Add $100 million for a fourth manned system. Assuming a $525-530 million funding level in FY 69, the first manned launch would be scheduled in November 1971, and the fourth in March 1973 (one month later than the second unmanned launch in the present program). Additionally, about $75 million more should be added to cover an overall cost increase in the program (resulting mostly from slipping the first manned launch). The total estimated cost for a six launch manned-only program would then be as follows:

(Millions)

FY68 & Prior	FY69	FY70	FY71	FY72	FY73	Total
$722	530	575	450	305	128	$2,710

TECHNICAL CONSIDERATIONS

None of the Gemini, spacecraft or booster subsystems or components for either the manned or unmanned systems appear to be critical technical items. Progress in all of these areas seems to be regulated only by dollar availability.

In the camera subsystem, most components and areas appear to be making satisfactory progress, for example:

1. The early engineering models and brassboards of the Itek camera-back (manned version with secondary platen) have demonstrated the feasibility of all components, and the first engineering model should be delivered to EK on or very near schedule late this year.

2. The engineering models of the test chambers in Rochester have verified that EK will be able to measure flats and aspheres to the required accuracies.

3. The most recent Gambit-Cubed mirrors appear to be about 1/15 wave and are still improving, giving confidence in the future ability of EK to produce 1/20 wave mirrors for MOL.

4. It appears that the latest Gambit-Cubed will have an Optical Quality Factor well above 60 percent, and the

70 percent range in the near future, giving confidence that MOL will meet its 63 percent OQF specification on the first production articles.

5. The ULE flat at EK has passed all tests to date and gives every indication that this mirror material will be available for the first all-up mission, thus greatly reducing potential thermal problems.

6. General Electric has demonstrated the adequacy of the bearings and torque motor drive for control of the tracking mirror (indications are that these will perform better than specification).

7. Simulations and zero-G tests have verified astronaut capabilities to point and track, load and process film, transfer film, etc. The visual-optics bench model at EK is performing better than specifications.

Two areas in the camera system, however, have not yet made satisfactory or reassuring progress; these pertain to pointing and tracking with the large flat. A brief discussion of these two areas follow (also attached is a paper which elaborates on them).

A total allowable pointing error of 2,000 feet has been established for the unmanned system. Total pointing error can be considered as including three general error sources (vehicle attitude/alignment error; ephemeris prediction error; and geodetic error). We have just completed a fairly detailed evaluation of the pointing error situation, with conclusions as follows:

1. <u>Attitude/Alignment Error</u>: The allowable pointing error in this general area is 5.9 arc minutes (about 800 feet on the ground from 80 miles). This appears reasonable, achievable, and not worth the cost of attempting to significantly improve it.

2. <u>Ephemeris Prediction Error</u>: Today, the STC can predict ephemeris in-track position two orbits ahead with

4,000 to 8,000 feet accuracy. In-track prediction error is only about 600 feet and not bothersome. Via SGLS, a new atmosphere model, a new math approach to ephemeris prediction, and a low-G accelerometer in the MOL vehicle, it is hoped to improve in-track prediction accuracy to about 1800 feet. However, the ability to do this will not be verified before mid- to late 1970.

3. Geodetic Error: Target geodetic positioning errors today range from a few hundred feet in Western Russia to as much as several thousand feet in Central China. In some target categories, locations are known more accurately. For example, of approximately 2100 SAC missile targets, about 35 percent have geodetic errors estimated at less than 450 feet, about the same percentage have geodetic errors between 450 and 750 feet, with most of the remainder 1000 feet or less. However, great attention has been focused on these targets, and their locations are known more accurately than the majority of the Sino-Soviet Bloc photographic targets. About 500 feet geodetic positioning accuracy (750 feet as an upper limit) is needed for MOL. Progress is being made in this area, but it is slow.

With regard to tracking, the Image Velocity Sensor is absolutely essential to the unmanned MOL (and also highly desirable for the manned system to fully exploit man's capabilities and measure his potential in space). The estimated capability to ground-program the tracking mirror rate is expected to be not better than about [redacted] microradians per second. This, of course, is far above the allowable smear for tracking mirror rate errors. Either the IVS or the crew members must reduce this to [redacted] or less, or else the desired [redacted] resolution can degrade to as much as [redacted] Early tests of the three IVS approaches under development indicate that all sense input velocities correctly only for certain scenes, all have center of power (rather than the specified center of format) tracking characteristics; all are very sensitive to scene detail and light levels; and all apparently will have problems coping with clouds. This is a very high risk area, and it will be another year or more before we really know whether or not one of these devices may be suitable for unmanned use.

On the other hand, simulations have verified the ability of the astronauts to manually point and track well within the desired limits.

A conclusion which could be drawn, then, is that the feasibility of all critical technical areas for the manned MOL has been established, but not for the unmanned system. Answers to the pointing and tracking questions probably will not be available for 1-2½ years.

WHY MANNED RATHER THAN UNMANNED?

The reasons set forth in the past for developing and flying the manned MOL photographic reconnaissance system first (e.g., assurance of meeting resolution goal at the earliest reasonable date; acquisition of a worthwhile intelligence product at the outset; earlier maturing of the unmanned system; increased quantity and value of photography in the manned system through cloud avoidance techniques and/or the selection of targets with a momentary increase in value; the accomplishment of certain tasks such as alternate films, [redacted] visual reconnaissance, selective readout, if desired, etc., not now practical or reasonable for inclusion in the unmanned system; etc.) are all still valid.

However, some of the above-noted advantages of developing the manned system and flying it first can diminish or vanish altogether if the first manned launch is delayed too far into the future. For example, if the known and potential technical risks now associated with the unmanned system were ignored, it would be possible to develop and launch an unmanned system by mid-1971 (either MOL hardware or a spacecraft from another program) for considerably less than $500 million in FY 69. In such a hypothetical program, several launches would be possible before the first launch in the present program if the latter is delayed considerably. I would not recommend such a program, however, believing that if the manned system were canceled, we should enter into a period of analysis and evaluation (proceeding only with the camera) prior to embarking on any unmanned-only program.

The manned MOL system, on the other hand, in addition to offering an operational test bed for other possible manned military space missions or experiments (sea surveillance, radar reconnaissance, etc.), also will provide the necessary means for even better photographic resolutions in the future using the present basic camera system. We have been informally investigating this possibility for the past several weeks, and the results are sufficiently promising to warrant some contractor-funded study efforts in FY 69. Modest future resolution improvements (beyond [redacted] norm) should be expected as a matter of growth through improved Optical Quality Factor, more precise control and drive of the tracking mirror, faster film, etc. The use of an eliptical tracking mirror (for fuller aperture) also appears feasible and would further improve resolution.

An even more significant improvement in resolution appears feasible through an increase in focal length, a different Ross corrector lens arrangement, and a relocation of the platen. The trade-off here, of course, is the willingness to accept an even smaller field of view (perhaps, only 3-4,000 feet diameter on the ground) than the present system; this would make the pointing problem almost prohibitively difficult in an unmanned system. It appears, that such a system could be incorporated in the present manned MOL system, in addition to the basic camera, with some rearrangement of the pressurized compartment, and with either the normal or reduced field of view selectable in flight.

From all the above, the present MOL camera system (flown no lower than 70 miles) probably could be "grown" by the mid 1970's in the manned system from the present [redacted] to approximately a [redacted] resolution system. Further by adding a 3-4 foot "wafer" to the present forward unpressurized compartment and increasing expendables in the present spacecraft, plus utilizing the large-diameter core TITAN IIIM (or some other booster if available), lifetime of the manned system could be increased to 50-60 days for modest cost.

POLITICAL/PUBLIC CONSIDERATIONS

From the general Congressional and public view of MOL, a change in scope from a manned/unmanned to a manned-only program would not be apparent. The reduction from seven to six launches could be explained in terms of financial austerity, increased technical confidence, etc. If we can preclude slipping the first manned launch into CY 1972, we can also avoid the accusation that MOL has been slipped "another year" and is now "four years" behind the President's 1965 announcement of the first launch in late 1968. Further, it would be refreshing to advise Congress during the FY 70 budget hearings that, despite a modest slip in the first manned launch caused by FY 69 fund limitations, the total estimated cost is now lower than before.

For the Congressional Committees and individual Congressmen and Senators knowledgeable on all aspects of MOL, the full explanation of budget limitations, desire for minimum program slip and minimum total program cost increase, plus technical uncertainties still associated with the unmanned system, should provide an acceptable justification.

In the DoD, Mr. McNamara and Mr. Vance apparently were the primary unmanned system advocates. How the current incumbents feel is an unknown factor to me; however, at least some of the DDR&E Staff would support a change in scope to a manned-only program. Several points should be stressed, however, if a manned-only program is advocated. If a follow-on MOL Program to either the present or a manned-only program is approved, and no great gap in launch capability is desired, follow-on funding must be started in FY 71. Since the unmanned MOL system is already well-defined, it would be possible to start in FY 71 and produce the first Block II vehicle as either a manned or unmanned system. Further, the time interval of two years between now and when the Block II systems would have to be started would permit further analyses and verification of the feasibility and desirability of an unmanned MOL camera system (either in a MOL spacecraft or one from another program).

Outside the DoD, Dr. Hornig and Dr. Land's PSAC Panel appear to be the only reasonably strong advocates of the unmanned system (except Mr. Schultze, in 1965, for purely financial considerations). In advising them of a scope change to a manned-only program, the points should also be emphasized that the spacecraft would retain all of the features of the present configuration to demonstrate the feasibility of unmanned operations, would mature any unmanned system sooner, be relatively easy to convert to an unmanned spacecraft, etc.

DISCUSSION/RECOMMENDATION

Past circumstances and decisions have led to the current situation (e.g., hardware status, sizable contractor team and facility capability, future schedule, etc.) wherein the program apparently cannot be stretched-out further in any reasonably efficient manner. Additionally, another significant launch delay beyond the Fall of 1971 can strengthen the arguments of those who question the advisability of proceeding with the present program and may place it in even greater jeopardy than it is at present -- if that is possible. A change in scope to a six launch manned-only program would appear to decrease considerably the impact of a sizable reduction in the FY 69 appropriation.

A point not made before, and worth noting, pertains to the short time interval between the first possible unmanned launch in a stretched-out version of the present program and that possible in a Block II follow-on buy to a manned-only program. If the present program were funded at the $500 million level in FY 69, the first of the two unmanned launches would take place in about March 1973. In the manned-only program described earlier, if funded at the $525-530 million level in FY 69, the last manned launch would be made in about March 1973. If a Block II follow-on buy to this program were approved, a first unmanned launch, if desired, could be made in June or July 1973. A Block II buy to either a stretched-out version of the present program or a manned-only program would have to be funded starting in FY 71.

In my opinion, the Secretary of Defense could approve a change in scope to a manned-only MOL program, as described earlier herein, without abrogating the commitments Mr. McNamara made to the President in 1965 when he recommended approval of the program. Additionally, it should be noted that work on the unmanned MOL system could be reinitiated at any time in FY 69 or FY 70 with the impact being either additional funds needed in that Fiscal Year or a schedule adjustment to accommodate the unique unmanned efforts within whatever level of funding was available.

Although, it appears that the Secretary could approve such a change without outside coordination, he should so advise the President, National Space Council, Dr. Hornig, and the BoB at an early date thereafter.

I have briefly discussed this proposal with General Ferguson and he concurs in the basic recommendation.

In light of all of the preceding, I recommend that the Air Force advocate to OSD a change in the scope of the MOL Program to a six launch manned-only program, to fund it at a level of $530 million in FY 69, to schedule the first manned all-up launch in November 1971, and request approval by June 15 to proceed accordingly.

J Stewart

JAMES T. STEWART
Major General, USAF
Vice Director, MOL Program

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a/s

EFFECTS OF POINTING AND TARGET TRACKING ON DORIAN PHOTOGRAPHY

If the smear free, or static, resolution of a system is better than the design goal, smear can be tolerated up to the point that the dynamic (with smear) resolution equals the design goal. For the Dorian System the on-axis tolerance in terms of angular rate is [redacted] radians/second (2 sigma). Although many factors are involved, the key item in achieving this specification is the reduction of the residual smear attributable to tracking errors to about [redacted] radians/ second (2 sigma).

While this tracking error and the associated noise are the main contributors to smear, pointing accuracy is also a major concern, since any deviation of the target from the center of format produces smear which degrades the photography. Pointing errors of more than [redacted] of arc will exclude a target entirely from the 9000' diameter field of view. It is evident then that accurate pointing is critical to both acquisition and reduced smear.

There is high confidence that man can point the system well within the specified limits, since by use of the acquisition and tracking scope he can compensate for ephemeris and target location errors. To achieve this same goal automatically with an Image Velocity Sensor will take a great deal of effort and success depends on several current and proposed projects to be successfully completed and demonstrated in the next 2-3 years.

The Smear Budget

The first step in establishing the smear budget is to identify the direct causes of smear and apportion the total smear tolerance among the direct causes on the basis of their 2-sigma variabilities. On-axis smear is caused by steady-state angular velocity errors in tracking the central point of the target (tracking rate error), random perturbations about the steady-state tracking rates (tracking jitter), and vibrations of the camera platen and the optical elements. The current smear rate tolerances allocated to tracking-rate error and vibration and jitter in microradians/second (2 sigma) are:

	Manned/ Automatic	Automatic
Navig/Control	[redacted]	
Vibration		
Image Motion		

Pointing and Tracking are associated directly with Navigation/Control and Image Motion and are the subject of the succeeding paragraphs. While Vehicle Vibration is also very important it will not be considered here.

Pointing

The Dorian System will achieve its goal of collecting [redacted] resolution photography only under specified conditions. One of the prerequisites is that the selected target be acquired in the center of the photographic format. Any deviation from this degrades the resolution from [redacted] The problem of where the selected targets will be in the format (9000' diameter at nadir on the earth from 80N.M.) and therefore what resolutions will be achieved will be in part determined by how well the MOL system is able to point at the target. Pointing accuracy is a function of target position accuracy, orbiting vehicle position accuracy and the MOL system electro-mechanical pointing accuracy.

Each of the three prime contributors to the pointing problem (geodetics, ephemeris, AVE) will be discussed individually, then in a systems context. Results from the latest (1 April '68) Mission Payload System Segment Performance

Analysis Progress Report (CDRL-100) will be used in assessing the total system pointing capability.

Target location (geodetics). The main optical system has a half angle field of view of approximately 0.54° (4500' at nadir from 80NM) which establishes the upper bound for allowable target position error for the automatic MOL system. Although acquisition is the first and paramount requirement, accuracy of positioning the target within the field of view has an important impact on resolution. This is true primarily because all rate nulling systems assume that the target is in the center of the format.

Figure 1a shows the smear that results from target position errors. Noting that the root sum square error budget for the Navigation and Control System is [redacted] radian/second and assuming that the allocation to target error would be comparable, it follows that the target location should be within [redacted] or better if this error source is not to produce excessive smear.

Extensive effort has been devoted to establishing accurate geodetic positions for missile targets. SAC has identified 2077 targets and has designated 1406 as "Hard" sites and 671 as "Soft" sites. Hard sites require horizontal position accuracies of 450 ft (90% CE), while soft sites have a requirement for 1000 ft (90% CE). As of 29 Dec '67, ACIC reported the following status on these targets:

Horizontal Uncertainty (90% CE)	Nr. of Targets
0-450'	732
451' - 750'	792
751' - 1000'	498
1000'	55

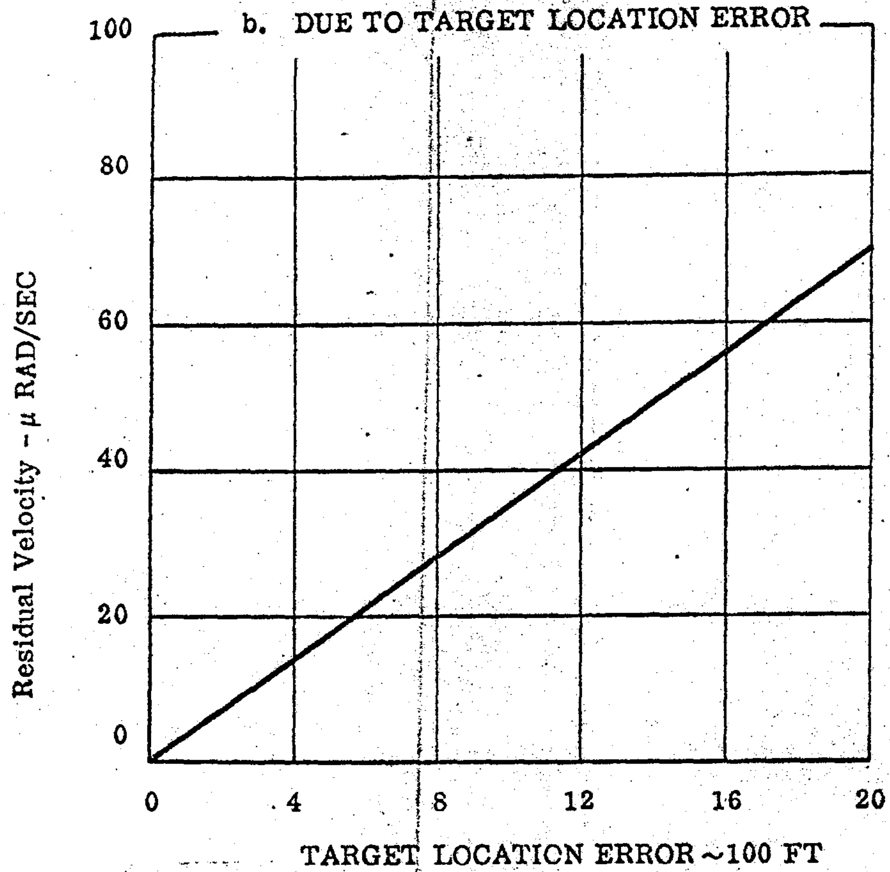

Figure 1a Residual Image Motion After IMC (2 σ)

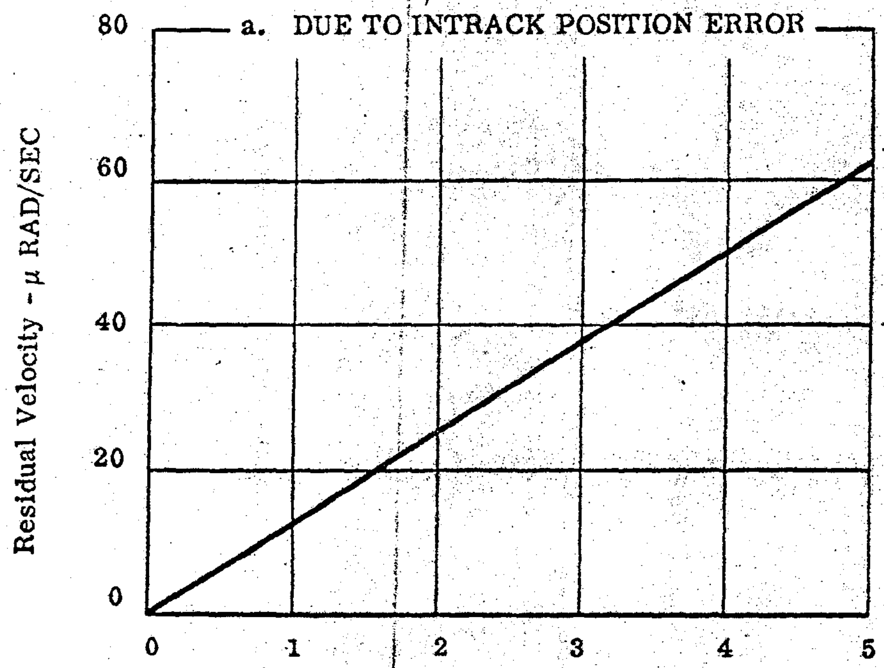

Figure 1b IN-TRACK POSITION ERROR ~1000 FT

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The positioning accuracies discussed above pertain to only the SAC missile targets which have the highest priority. Intelligence targets for satellite photography are located by many agencies, using various methods, and in most instances much less accurately than these missile targets. The large fields-of-view of current photographic satellite systems do not require very accurate target locations to insure that the target is within the frame. Most important to MOL, however, is that even among the highest priority targets there are a large number whose locations are not known within the [redacted] limit necessary to achieve the MOL photographic design goals. In most of the Eastern Eurasian land mass, target location accuracies even approaching those in the SAC missile target deck are not available. ACIC indicates that using DAFF (KH-5) photography accuracies from 1000 to 2000 ft in these areas are achievable but not necessarily programmed.

Investigations to date indicate the following in regard to target positions:

1. There is no standard method of defining a reference point for the center of a collection requirement target.

2. Target coordinates are not referenced to the same datum.

3. The accuracy of the target coordinates presently used by Imagery Collection Requirements Sub-Panel (ICRS) is not known.

4. The accuracy of target location varies with geographic location. ACIC estimates that by 1970 most targets of interest will be in areas where source material will give them the capability to provide locations within about 750 ft. to 1000 ft.

The seriousness of this problem to the automatic unmanned MOL becomes evident when it is realized that all necessary improvements to the geodetic situation must occur in the next 2 to 3 years. No large scale effort to dramatically improve in this time frame is currently evident, although the capability to do so is said to exist.

Ephemeris Prediction

The solution to this problem is primarily the responsibility of the Satellite Control Facility which will provide the ephemeris to the MOL. The MOL Computer will interpolate the ephemeris table provided and with the aid of inputs from the low G accelerometer will refine its predicted positions against time.

The MOL specification to meet precision acquisition and smear requirements requires the navigational capability of the system to be [redacted] in-track, and [redacted] altitude and cross-track, with desired capabilities about one third of the required values. (For the effects of in-track error on smear see Figure 1b.) The numbers quoted are two sigma, and assume error propagation of 2.5 orbit revolutions. These requirements imply something substantially beyond the capabilities of current ground tracking and orbit prediction. These accuracies require such things as employment of a low G accelerometer (LGA), a much improved atmospheric model, improved tracking capabilities and advanced orbital prediction techniques.

Current estimates of navigation prediction accuracy after $2\frac{1}{2}$ orbits, based on ground tracking and computation alone are given below:

IN-TRACK ERROR (TWO SIGMA, FT)
(No LGA, Radar Data Only)

		Internal To Data Fit (No Predict)	2.5 Revs Predict
	No Drag	1600	2000
Current	Low Activity	1800	3200
	High Activity	3600	8800

It should be noted that the current capability is only marginally adequate to acquire the targets in the 4500 foot radius allocation and that during periods of high solar activity that the targets would not be acquired at all.

The estimated prediction capability for the 1970 - 72 time period not using the low G accelerometer is shown in Figure 2. This estimate is based on the Space Ground Link System (SGLS) and the Advanced Orbit Ephemeris System (AOES) reducing the current conservative in-track prediction estimate of about 8800 ft. to about 6000 ft. The improved atmospheric modeling based on LOGAX data to further reduce the error to 3000 ft. and the combination of these in conjunction with the low G accelerometer to ultimately equal or better the specified [redacted] is shown in Figure 3. Figure 4 is an error budget table for 1970 - 72 based on all the above improvements contributing properly and utilizing the low G accelerometer.

While these accuracies may be achieved there is great dependence on several large improvements occurring in series. In any case the feasibility and practical demonstration of these combined innovations will not occur until 1970 at the earliest.

AVE

The mechanical pointing or AVE pointing requirement of [redacted] of arc appears to be reasonably achievable based on analytical and test data to date. The task is demanding but considered well within the state of art.

System Pointing

An analytical estimate of pointing accuracies achievable in the 1970 - 1972 time period is provided as Figures 5 and 6. These estimates are based on the following assumptions:

a. Target location accuracies less than [redacted].

b. All improvements to the ephemeris prediction system operating properly (AOES, ADS, SGLS, Improved Atmospheric Model).

Estimated Vehicle Position Errors, No LGA, 2σ

Propagation ~ Revs	1.25	2.5	3.5
In-track Error ~ Ft			
1. Drag + Geopotential	[redacted]		
2. Ephemeris Interpolation			
3. Attitude (1%)*			
RSS			
Altitude			
1. Drag + Geopotential	[redacted]		
2. Ephemeris Interpolation			
3. Attitude (1%)*			
RSS			
Cross-Track			
1. Atmospheric Rotation + Geopotential	[redacted]		
2. Ephemeris Interpolation			
RSS			

*Allocations

Figure 2

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MINIMIZATION OF EPHEMERIS UNCERTAINTY

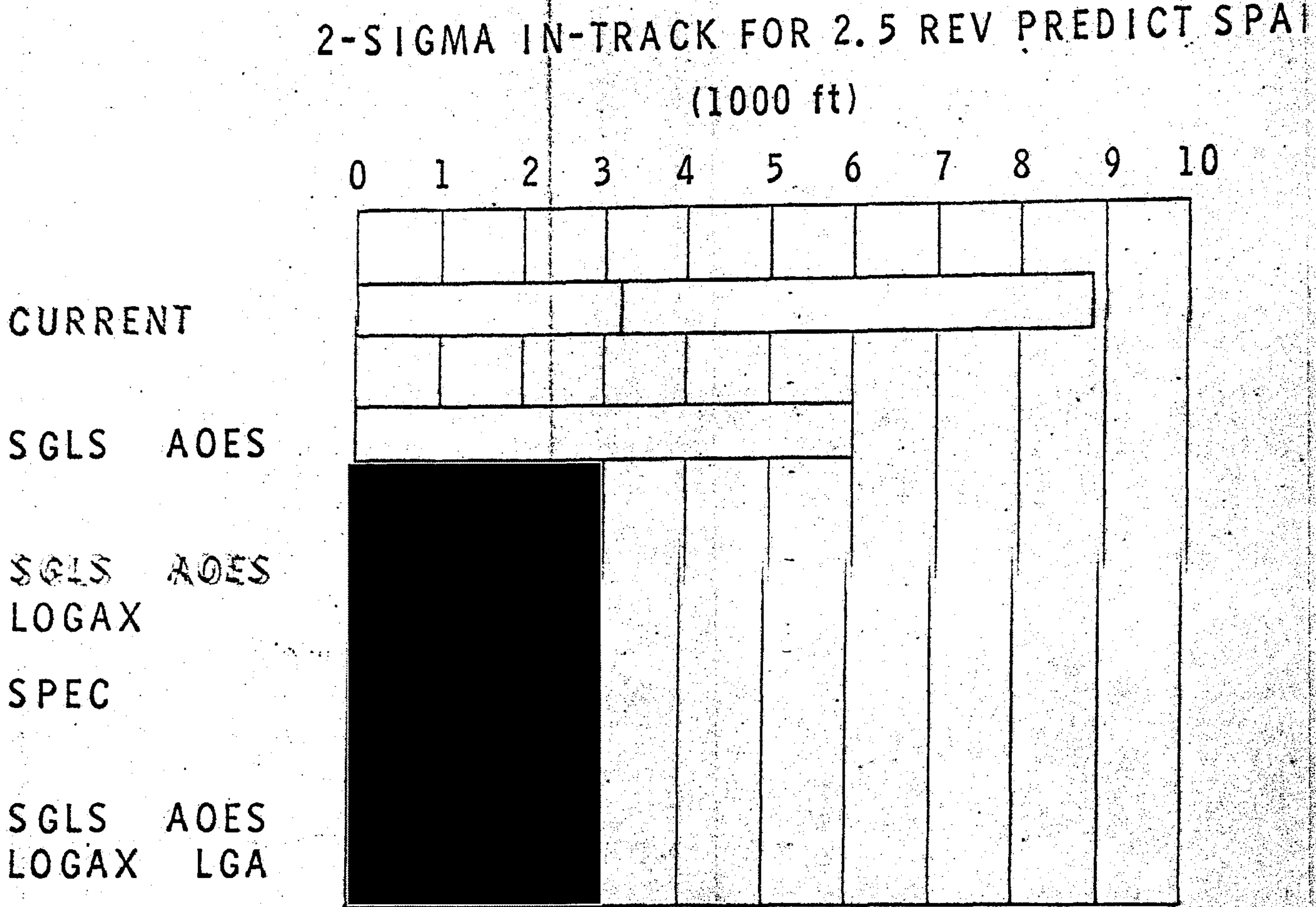

Figure 3

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Estimated Vehicle Position Errors with LGA, 2σ

Propagation ~ Revs 1.25 2.5 3.5

In-Track Error - Ft

1. Geopotential
2. Position Estimation Procedure (1%)*
3. Ephemeris Interpolation
4. Attitude Control Rotations
5. LGA Systematic Errors (1%)*
6. LGA Random Errors (0.1%)*

[redacted]

Altitude

1. Geopotential
2. Ephemeris Interpolation
3. Position Estimation Procedure (1%)*
4. LGA Systematic Errors (1%)*

RSS [redacted]

Cross-Track (Same as Figure 2)

*Allocations

Figure 4

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TWO SIGMA POINTING ERROR (ARC MIN)

[redacted]

2

3

REVS

① AUTOMATIC MODE - INCLUDES EPHEMERIS AND TARGET LOCATION ERRORS WITH NO LEARNING EXCEPT LOW G ACCELEROMETER

② SPEC REQUIREMENT - EXCLUDES EPHEMERIS AND TARGET LOCATION ERRORS

③ POINTING ANGLES DERIVED FROM ATS

④ SAME AS 1 BUT EXCLUDES LOW G ACCELEROMETER

Figure 5

Line-of-Sight Pointing Error

	Pointing Error* (2 Sigma)
Automatic Mode (A Mode)	
Including all errors without LGA Including all errors with LGA	[redacted]
Neglecting vehicle ephemeris and target positions error	[redacted]
Pointing Angles Derived from ATS	
With ATS boresighting on two targets With ATS boresighting on three targets	[redacted]
ATS Pointing Error (Automatic Mode, after boresighting)	
Including all errors without LGA Including all errors with LGA	[redacted]
Neglecting vehicle ephemeris and target positions errors	
(2 Target Boresighting) (3 Target Boresighting)	[redacted]

* Assumes uniform target density on the ground

Primary optics scan field

$$|\Omega| \leq 40^\circ$$

$$-30 < \Sigma \leq 20^\circ$$

ATS scan field

$$|\Omega| \leq 45^\circ$$

$$0 < \Sigma \leq 70^\circ$$

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Figure 6

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c. AVE pointing error of no more than [redacted] minutes of arc.

It is important to emphasize that large improvements in target location and emphemeris prediction are mandatory for the unmanned system but are only desirable for the manned system. This is true since man, using the acquisition and tracking scopes to point and track targets, effectively eliminates the navigation and geodetic errors.

Image Motion Compensation

Smear due to image motion which would result in photographic degradation comes from two sources:

1. Changing relationships between the orbiting vehicle and the ground target and

2. Tracking rate errors.

In the first case the scene appears to expand and turn about the nulled axis (the tracked point) as the target is approached and the reverse action takes place as the target is passed.

At extreme look-angles, geometric image motion near the periphery of the format can be as much as 7.5 times the budgeted on-axis smear rate of [redacted] radian/sec (2-sigma). The effect of this off-axis smear at the edge of the format is to degrade the ground resolution to a value three times the on-axis ground resolution (for the nominal exposure time).

With a focal plane shutter, only a narrow strip of the format is exposed at a given instant. If the image motion within this strip can be matched by moving the film, the smear occurring in the area of the slit can be eliminated without effecting smear of points beyond the slit. This technique is called across-the-format IMC (X-format IMC). The nulling of this motion is to be achieved by manipulating the platen and the solution seems quite feasible at this time.

The more serious and currently assessed as more difficult motion compensation is that of nulling in-track rates.

Reduction of the tracking-rate error is accomplished in two control steps: preprogrammed computer control followed by fine control by either a crewman or an Image Velocity Sensor (IVS). The tracking-rate error allowed by specification in programmed rate control is [redacted] radians/second, 2 sigma. The crewman or IVS is required to reduce the tracking-rate error from this level to about [redacted] radians/second or less. [redacted] radians/second smear would yield photography on the order of [redacted] assuming a set of conditions which would yield [redacted] photography with a residual tracking rate error of [redacted] radians/second.

It is therefore evident that without man or the IVS the very high resolution goals for MOL cannot be achieved.

Extensive simulation test runs by the crewmembers provide a high degree of confidence that the specified levels of residual smear can be easily achieved. The same confidence for the IVS accomplishing this job is not enjoyed at this time.

It is too early in the IVS testing program to state that the specified rate nulling job cannot be accomplished automatically in the necessary time frame. It is, however, safe to say that much redesigning, testing, and perhaps re-inventing must be done before a confidence factor approaching the current confidence in man's ability is achieved.

Recent evaluations of the contenders for the IVS production contract were given the following general evaluation by General Electric (direct quotes):

a. All sensors correctly sense input velocities for <u>some</u> scene conditions.

b. All sensors have center of power tracking characteristics.

c. All sensors sensitive to scene detail.

d. All sensors have light level problem.

e. All sensors have "cloud" problem.

On the basis of this test program which was quite comprehensive one vendor was recommended for elimination and the other two were "sent back to the drawing board" to try to eliminate the deficiencies noted in their hardware.

There were two basic deficiencies evident in all contenders. One was that they focused on what G.E. terms "Center of Power" (the area in the format providing the most stimulus to the sensor). This means that the velocity of the "Center of Power" rather than the desired center of format will be measured and compensated for. The other and more serious problem comes from the fact that all sensors centered on clouds when they were present. This characteristic introduces significant errors the magnitude of which depends on the altitude and velocity of the cloud deck and the percent of cloud cover. It is estimated that if the sensor measures on a cloud rather than the target desired [illegible] error of about [redacted] radians [illegible] altitude above the target, [illegible]

Careful study of the [illegible] Vendor evaluation Report [illegible] [illegible] that the TVS is a high risk item in terms of the MOL goal of achieving very high resolution [illegible] automatic mode.

Summary

The ability of the MOL system to provide [redacted] or better resolution of specified targets depends not only on the AVE under development but also on the accomplishments of other agencies such as ACIC and the AFSCF. Without considerable improvement in geodetic and ephemeris prediction accuracy in the next 2-3 years, the photographic resolution desired, and even automatic target acquisition in many cases is in doubt. This fact coupled with the development and testing difficulties and uncertainties associated with the IVS makes the unmanned version of MOL appear as a rather high risk development at this time. There is consolation however in the fact that man can essentially eliminate most of the difficulties associated with tracking and pointing. This fact provides confidence in the manned version as an operational reconnaissance system as well as a test bed available for developing more sophisticated automatic systems.