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CONVERTIBILITY IN THE MOL PROGRAM

MOL Program Office

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SUMMARY

The purpose of this paper is to examine convertibility in the MOL program; convertibility being defined as the capability to change any given flight from the manned mode to the unmanned configuration, or vice versa. The discussion addresses conversion in both the seven-flight baseline program and in any follow-on "operational" program. The analysis determines the perspective in which conversion is to be treated, and postulates several factors motivating the decision-maker to make a conversion. These factors are categorized as political, vulnerability, technical difficulties and biomedical.

Conversion of the flight mode can be accomplished either by modification or substitution of hardware. The cost, time and technical ramifications of converting through either method relate to each other, and to the reason for converting, in a decision problem that can be quantified and predicted to a fairly high confidence level.

The detailed analysis of conversion options shows that the differences between the manned and unmanned versions of the MOL vehicle are the use of either a Gemini B capsule or the Automatic Support Module, in certain installed equipment in the Laboratory Module, and in certain minor Titan IIIM features. The Mission Module is identical in either case. Four options for conversion are:

- Early Conversion. Accomplished prior to Lab Module Assembly. Must be initiated at least 14 months before

scheduled launch (no launch delay). Requires Lab Module components and both Gemini B and Automatic Support Module availability. The cost of a conversion capability for flight 6 or 7 is $20.5M above baseline. Long decision lead time is the major disadvantage.

- <u>Modification</u>. Could be accomplished on Lab Module up to 5½ months before launch with no launch delay. Requires alternate Gemini B/Automatic Support Module availability. The Lab Module must be fabricated in the manned configuration; modification to the unmanned configuration requires extensive overtime and shortened tests wherever possible. The baseline cost increment for flight 6 or 7 conversion capability is $54.3M. The cost of launching flight 6 or 7 in the unmanned configuration is $35.8M above baseline.
- <u>Substitution</u>. Could be accomplished up to 5½ months before launch with no launch delay if Gemini B/Lab Module combination is substituted. If Gemini B/Lab Module/Mission Module combination is substituted, change can be made as close as 50 days before launch with no launch delay; however, this combination is not feasible for flights 6 and 7 because of mission payload production rate restriction. Cost of first variation for flight 6 or 7 is $68.5M above baseline.
- <u>Dual Countdown</u>. By using second launch pad and counting down two vehicles (one manned, one unmanned), conversion

could be accomplished up to just before liftoff. However, not feasible for flight 6 or 7 because additional mission payloads cannot be produced. Cost for such a capability for follow-on flights is $235.7M.

The early conversion option is not recommended due to the long decision lead time required (minimum 14 months). The dual countdown method is not feasible for flights 6 and 7. For follow-on flights, the high cost makes this option unattractive. The Gemini B/Lab Module substitution option is selected as most advantageous because of less technical impact, less nonrecoverable costs and more decision flexibility.

Recommendations are made to incorporate into the baseline program a conversion capability for flights 6 and 7 (unmanned to manned), using the substitution method. Initial funding of $2.0 million required in FY 69 can be absorbed in the present baseline funding structure. FY 70 funding for conversion can be included in follow-on program funding.

Decisions required are:

1) To provide a conversion capability for baseline flights 6 and 7 by use of the substitution option.

2) To commence funding in FY 70 a follow-on program phased to provide substitute modules.

I. INTRODUCTION

This paper examines the proposition that at some future point in time it may be necessary to convert MOL flights from the manned mode to the unmanned mode, and vice versa. Flight configuration changes in this frame of reference are envisioned as becoming necessary for reasons or circumstances unpredictable at the time the original configurations were established. The ability of the program to make conversions in this sense is termed convertibility.

The dual-mode nature of the MOL program, wherein both manned and unmanned configurations are included in the development effort, not only gives birth to the possibility for conversion, but it also creates a decision problem if conversion options are a real consideration. The purpose of this paper, then, is to derive an appropriate perspective for MOL convertibility as it is influenced by both the decision problem and the substance of the MOL program as it is known today.

The terms of reference for the perspective are developed first in the paper by means of generalized discussion. The substance of the problem introduced by the baseline MOL program is next presented; followed by an examination of several conversion options. Based on the perspective developed and the realities of the feasible alternatives, conclusions and recommendations are then set forth. A glossary of terms and abbreviations is included.

The Genesis of Convertibility

The dual-modality of the MOL Program can be traced to concerns expressed early in the planning and definition of the program, wherein instances were envisioned in which reconnaissance activity by MOL would be either impossible or imprudent if man was present in the satellite. The capability for flying the DORIAN payload in an unmanned mode was therefore desired as a hedge against political obstacles to manned satellite reconnaissance. The unmanned MOL configuration was also viewed, to a lesser degree, as insurance in case man proved incapable of effectively performing the full 30-day MOL mission. A third justification given for the unmanned version of MOL was the belief that, once developed and proven, it could eventually complement the manned system by performing the more routine reconnaissance missions.

Thus, the MOL program was proposed and approved on the basis that there would be developed in parallel, with equal emphasis, both manned and unmanned configurations. The objective was, of course, to develop one system which could be used in either mode with a minimum of conversion effort.

A Fundamental Definition

Based on the original rationale for development of both manned and unmanned versions of MOL, and with due regard for the existing technical characteristics of the program, a fundamental definition of convertibility can and should be stated.

Convertibility, in terms of the MOL program, is defined as being the ability to change (at some time prior to launch) the mode of a flight from manned to unmanned, or vice versa. Program planning shifts resulting in particular flights being switched from one mode to the other are excluded from this definition as long as such planning exercises do not involve hardware already in production. The focus of meaning in this definition is on "change...a flight ...," which, as described further below, basically involves either modification, substitution, or some combination thereof.

Why Convert?

The fundamental reasons for having two flight modes in the MOL program (i.e., manned and unmanned) are equally applicable as reasons for converting a flight after one particular mode has been established in the program planning.

At the same time the different reasons for conversion are an essential part of the total decision problem. The inseparability of the conversion motivation from other considerations is due to the fact that there are varying degrees of concern associated with the different arguments for conversion, and each reason has a time scale in which the concern may range from mild interest to urgent demand. Thus, the degree of necessity and the time element are two major factors influencing planning for conversion capabilities and any subsequent exercise of the option.

Political

The most probable reason for wanting to convert a flight from manned to unmanned is fear of domestic or international reaction to overflight of a foreign country by one of our manned military satellites. While it is true that reconnaissance satellites are routinely employed by both sides today, the tacit international accommodation of unmanned reconnaissance vehicles may not be extended to manned activities of this sort. On this basis, and particularly in times of greater international instability, one can imagine circumstances wherein the interests of the United States would best be served by removing man from a particular MOL flight.

Vulnerability

An extension of the political motivation described above, but which involves more extreme reaction by a foreign country, is the case in which active countermeasures might be employed against an MOL flight. A hostile nation, knowing or strongly suspecting that MOL is designed to accomplish reconnaissance activities, might be provoked into taking some overt action to negate MOL's capability. At any such time that we, in turn, believe that countermeasures against an MOL flight are a potential threat, there would undoubtedly be extreme pressure to remove the crew.

Technical Difficulties

This category is predicated on the historical pattern of unforeseen development difficulties inherent in any complex technical development program -- possibly even more prevelant in space systems where man is an integral link in the total system. The recent Apollo disaster, as unfortunate as the case may be, represents a vivid example of what can happen. In the context of this discussion of convertibility, any reasonable doubt as to the safety of the crew would undoubtedly produce a decision to hold in abeyance any manned flights. If in the same instance there existed an extreme need for intelligence information obtainable only with the DORIAN payload, there would certainly be motivation for conversion.

Motivation of this kind is not limited to conversion in the manned-to-unmanned direction. Success of the unmanned configuration is based to a large extent on adequate performance of certain automatic devices. Any development difficulties with these devices, all other system elements being qualified for flight, could produce a desire to fly the system manned with man functioning as a trouble-shooter, repairman and even as a manual override capability (if necessary). The specific examples of equipment troubles that could spell failure for an unmanned flight are numerous and somewhat obvious, and need not be detailed. But the rationale for considering conversion from unmanned to manned is supported by the possibilities of equipment problems, and in fact, such thinking contributed to the approval of a manned satellite reconnaissance program in the first place.

<u>Biomedical</u>

A final case for conversion motivation concerns the possibility that man may prove to be unable to perform in the MOL environment for the mission durations desired. Although this possibility is for the most part discounted, there will not be proof until manned missions achieve the 3-4 week times on orbit. Again, with sufficient urgency attached to the need for the DORIAN photographs, there would arise considerable pressure for proceeding with unmanned versions of MOL.

How to Convert

The generalized definition of convertibility set forth earlier provides a basis for describing the several ways in which a particular MOL flight might be converted to the opposite mode -- manned or unmanned, whichever the case might be. In the following delineation of methods no attempt has been made to reduce the number of possibilities to one or two optimum alternatives. The objective at this point is to identify rational courses of action, with subsequent discussion serving to point out the merits and disadvantages of each.

1) In the first case a particular vehicle is assigned to a specific flight, and a decision is made to change the flight mode. If the decision is made early enough, the configuration of the vehicle allocated to that flight could be changed by re-arranging delivery dates for components that are peculiar to the newly assigned flight mode. This conversion mode would probably involve the least expense of any conversion method, but it requires maximum time before launch for a change decision.

2) In the second case, vehicle assembly has progressed to the point where portions would actually have to be modified upon receipt of conversion notification if the same vehicle is to be used for the particular flight. A kit of peculiar parts would presumably be on hand to accomplish the modification. Some systems or integrated tests might have to be repeated, depending on the stage of vehicle production reached.

3) The vehicle configuration for a particular flight could also be changed by substitution of mode-peculiar modules. The extent of launch date impact for the flight would depend on the amount of integrated testing that would have to be repeated (assuming alternate modules were on hand in some comparable stage of readiness). Modules involved in this case are the Gemini, Support Module, and Lab Module -- the Mission Module and Titan booster being essentially identical whether the flight is manned or unmanned. The module substitution could even be accomplished at the launch site, if an integrated set of modules (including the Mission Module) was made available on a contingency planning basis.

4) A final and somewhat extreme method for achieving convertibility would be to have two launch pads with both kinds of vehicles in parallel readiness. The decision-maker could then choose the launch pad (and vehicle mounted thereon) which suited the conditions influencing his decision.

The above description of methods addresses the basic techniques, but of course there are combinations and permutations that might optimize conversion advantages and effects one way or another. However, any conversion method that might be devised, within the bounds of the fundamental definition of convertibility, is bound to involve time, money and vehicle system considerations. The combination of these considerations with the motivations for making flight modal changes produces a decision problem varying in complexity and difficulty. The underlying assumption of this paper is that appropriate program planning now can ease the problem for the decision-maker in the future.

The Decision Problem

The discussion thus far has addressed the need for thinking about convertibility, what it means, the different reasons that may motivate the decision-maker to exercise a conversion capability, and finally, how it might be accomplished. The section that follows attempts to relate these factors one to another such that the decision problem is defined. With a factorial definition of the influences on such a decision, the quantitative and qualitative assessments of where we stand and what we can do will take on more meaning.

The primary elements of the problem are motivation, time, money and hardware features that exist. The relationship of these variables is such that:

1) The cost of a decision to convert is inversely proportional to the amount of time from the decision to the planned or desired launch date. This is to say that more decision lead time results in less cost to convert.

2) The degree of certainty in the motivation to convert will usually be inversely proportional to the amount of time before launch. That is, the longer the time before launch the less certainty there will be in the need to convert.

3) The direct cost of conversion (disregarding increased costs resulting from extension of total program time) is inversely proportional to the amount of launch delay that is acceptable. In essence, this means that acceptance of greater launch date slippages will tend to reduce the cost of converting.

The decision-maker must simultaneously consider the cost of conversion, the strength of his belief that conversion is necessary or prudent, the safety of the crew and the probability of mission success, the acceptability of launch delay, and how long he can wait before making a decision. The flexibility that the decision-maker desires, in terms of integrating these factors into a course of action, will establish the conversion features to be embodied in the dual-mode MOL program.

II. BASELINE CONVERTIBILITY

Turning now from the generalized treatment of convertibility, the examination of the proposition focuses on the hard realities of hardware, costs and schedules.

As was stated earlier, the dual-modality of the current baseline MOL program involves two separate and distinct Orbiting Vehicle (OV) configurations. The manned version, or the Manned Automatic Mode (MAM), consists of a Mission Module (MM), a Laboratory Module (LM) equipped for manned operation, and a Gemini B capsule. The unmanned configuration, identified as the Automatic Mode (AM) consists of an MM, an LM operable without man aboard, and an Automatic Support Module (ASM) which replaces the Gemini B.

Module Differences

Major differences between the two configurations are summarized below and are shown in Figure 1.

Mission Module

Identical MM's are used in both the MAM and AM configuration so the same MM can be used for either type of flight.

Lab Module

In the MAM LM there are about 1000 pounds of major components and subsystems, required for manned operation, which are deleted in the AM configuration. Included in this category are the GE panels, DRV and launch tube, Acquisition and Tracking Scope, transfer tunnel and the transfer tunnel hatch in the forward bulkhead. In the AM configuration, a film chute, GE and EKC electronics and wiring harnesses are added and

MANNED → AUTOMATIC CONVERSION

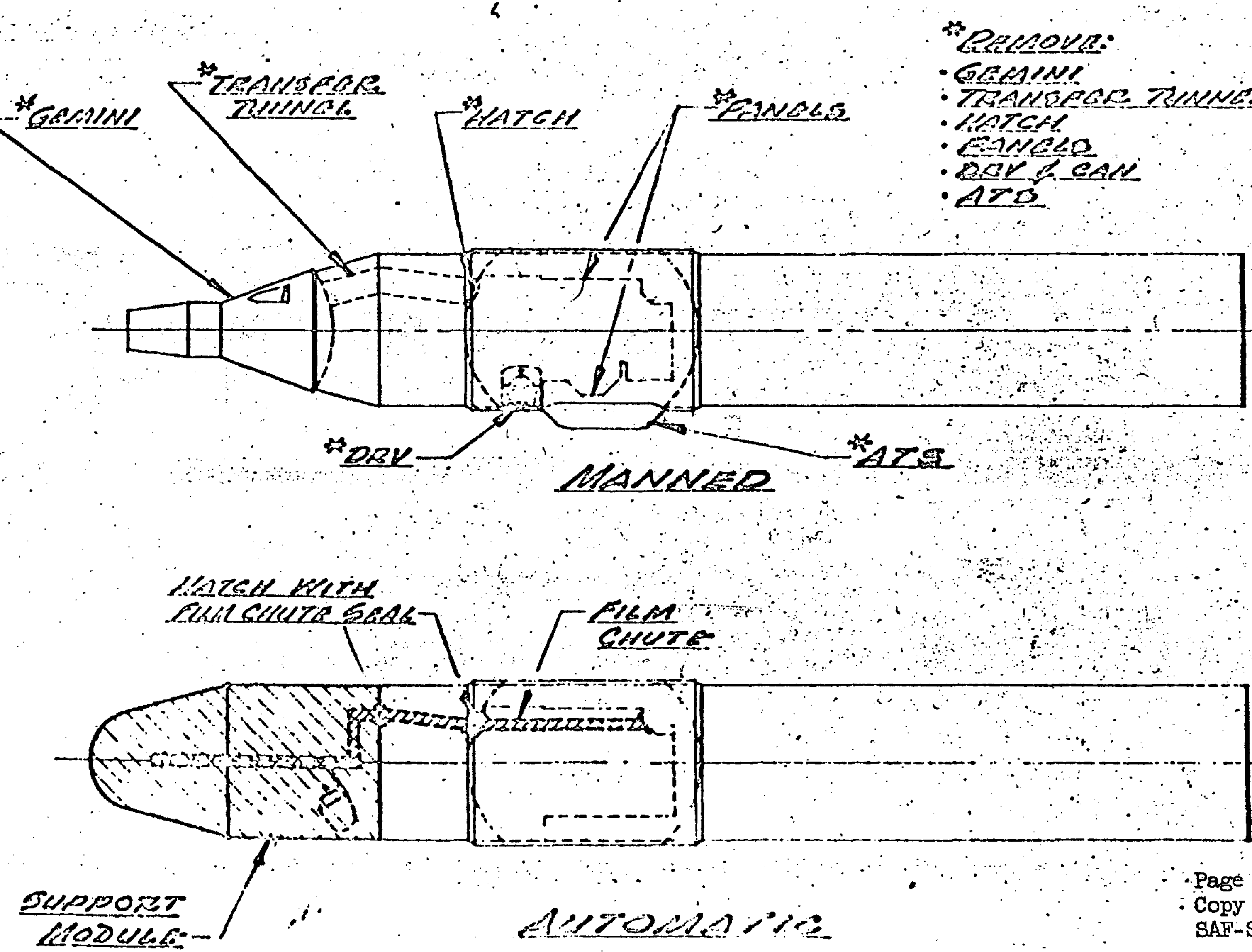

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Figure 1

the MAM transfer tunnel hatch is replaced by one which has a film chute seal. In addition, provisions are made for interfaces with the expendables that will be carried in the extended lifetime configuration ASM.

Gemini B and ASM

The Gemini B and ASM serve entirely different functions and are therefore completely different. Conversion of a vehicle from one mode to the other obviously requires interchange of these two modules.

The Conversion Problem

Each vehicle in the MOL baseline program has been ordered in a specific configuration -- either MAM or AM. In order to provide a convertibility capability in the MOL baseline vehicles as currently designed, it would be necessary to either (1) procure in advance a preplanned additional complement of hardware that can be used to modify the configuration of each vehicle, or (2) procure substitute system modules with properly phased lead times so that appropriate modules are available in both configurations for a particular launch. No such spare hardware or substitute modules are now being procured, so the current MOL baseline program has no convertibility capability.

Earlier in the program, a "kit" approach was included in the baseline so that the LM could be converted by modification. However, this capability was eliminated during a cost reduction exercise in September 1966.

As previously indicated, the capability to convert a particular flight might be achieved in a number of ways. In all approaches to convertibility it is necessary to procure both a Gemini B and an ASM since they are completely different. As stated earlier no additional procurement or modification of the MM is required. Although the two types of LM's are different, there is sufficient hardware commonality between the MAM and AM configurations so that modification is feasible. Therefore, the LM is the one module in the OV that is susceptible to both approaches to convertibility.

In following sections the various methods of achieving convertibility are discussed in some detail, together with funding and schedule implications and the pros and cons of each approach. Convertibility is considered both for flights 6 and 7 of the current baseline program, and for a follow-on operational program. Convertibility is not considered for baseline flights 3, 4, and 5 in view of the relatively low probability that conversion will be desired -- and also because of the immediate, serious impact on program funding if convertibility were to be incorporated on the early flights.

Conversion Before LM Assembly

Applicable Period

From T-26 months (LM order lead time) to T-14 months (assembly of LM components into the birdcage, i.e., the internal framework for the LM pressurized section) with no launch delay.

Method

LM components peculiar to each configuration are ordered so as to be available for assembly in the desired configuration. This method could be used without preordering peculiar components but this would cause a launch delay depending upon the elapsed lead time. Available spare parts and/or overtime could be used to minimize slippage or, if there is a mixed configuration follow-on program, delivery of components for subsequent vehicles could be expedited. Upon completion, the LM would be mated with appropriate modules and launched in the desired configuration.

Cost Impact

The cost of ordering peculiar MAM LM components for flights 6 and/or 7 has not been precisely estimated. This would, however, be the least expensive approach to convertibility because it involves no disassembly and reassembly of LM components. Since this method requires the maximum time before launch for a change decision (14 months minimum), it does not cover most of the situations in which a conversion capability might be needed.

For this approach, it would be necessary to procure both an ASM ($4.0M) and a Gemini B ($20.0M) for each flight. In addition, funding of the extra $0.5M required for a TIIIM manned flight must be planned. Thus for flight 6 or 7 a funding increment of $20.5M over the current baseline must be provided. For a mixed configuration follow-on program, additional Gemini B's would not be required, as long as one remains in the inventory. However, delivery of Gemini B's would have to be expedited so as to be available at the same time as the AM configured modules.

Discussion

This option does not provide a realistic, usable conversion capability because of the long lead time necessary for a change decision.

Modification

Applicable Period

Up to T-5½ months (LM/MM mate) with no launch slip if extensive overtime is used and the test flow is expedited to the maximum extent. Beyond T-5½ months, all of the lost time cannot be made up through the use of overtime.

Method

Basically, this option involves recycling the LM in the production and test flow for modification to the desired configuration, using a pre-purchased complement of peculiar components. After modification to the alternate configuration, the LM is mated with other appropriate modules and proceeds through the remaining test flow to launch.

The principal differences between the MAM and AM configurations, as shown in Figure 1 and discussed earlier, result in the deletion of about 1000 pounds of MAM-peculiar equipment when modifying to the AM configuration, plus the addition of a few AM-peculiar items. Consequently, for this option the LM must be assembled in the MAM configuration since it would be prohibitively expensive in both time and money to recycle an AM configured LM for the addition of MAM-peculiar components. Upon deciding to convert, as much MAM-peculiar equipment as possible would be removed, a pre-purchased "kit" of AM-peculiar equipment would be installed, and the LM would then be tested in the new configuration.

At T-10½ months, the "birdcage" loaded with equipment, is installed in the pressurized section and the forward bulkhead is welded in place.

Subsequent to this step the only access to the LM pressurized section is through the two hatches. Although the MAM-peculiar components are sized so that they can be removed through the DRV hatch, the job of removing equipment without removing the welded bulkhead is considerably more complex and time consuming than it is prior to T-10½ months.

Cost Impact

For flight 6 or 7 the baseline cost increment is $54.3M, as shown in Table 1. For this option, $9.0M of nonrecurring costs are required for planning, tooling and equipment necessary for modification. Adding this cost to those for MAM-peculiar hardware (most of which is not recoverable), and for dual planning of MAM and AM operations for a specific launch produces a nonrecoverable incremental cost of $21.3M which is expended whether a flight is configured AM or MAM.

In this option, positive action is required to convert the MAM-configured LM to the AM configuration. The estimate for modification labor and repeat of checkout in the AM configuration is $16.0M (which is a baseline cost increment). Thus, an additional $35.8M over current baseline costs must be spent for flight 6 or 7 if launched in the AM configuration. The recurring increment to the baseline cost for each such flight is $26.8M. (Table 2)

Discussion

There are a number of disadvantages to this method of achieving convertibility. The principal disadvantage results from the fact that the LM for flights 6 and/or 7 must be fabricated in the MAM configuration although, in the baseline program these launches are planned to

INCREASED COST OF MODIFICATION OPTION - FLIGHT 6 OR 7 AND FLIGHTS 6 AND 7

	Flight 6 or 7			Flights 6 and 7		
	MAM	AM	Baseline Δ	MAM	AM	Baseline Δ
Nonrecoverable Costs						
Additional Hardware						
LM						
DAC	22.2[1]	17.0	5.2*	44.4	34.0	10.4*
EK & GE eqp in LM	4.6	1.5	3.1*	9.2	3.0	6.2*
Other (crew eqp, etc.)	4.2	2.7	1.5*	8.4	5.4	3.0*
MM	22.0	22.0	-	44.0	44.0	-
TIIIM[2]	21.5	21.0	0.5*	43.0	42.0	1.0*
Sub Total	74.5	64.2	10.3*	149.0	128.4	20.6*
Modification Planning & Techniques[3]	6.0*	-	6.0*	6.0*	-	6.0*
Modification Tooling & Equipment[3]	3.0*	-	3.0*	3.0*	-	3.0*
Dual Planning for Operations, Software, Launch, Recovery, etc.[3]	2.0*	-	2.0*	4.0*	-	4.0*
Sub Total	85.5	64.2	21.3*	162.0	128.4	33.6*
Recoverable Costs**						
Additional Hardware						
Gemini B/ASM[4]	17.0	4.0	17.0	34.0	8.0	34.0
Launch/Operations Costs						
MAC - Gemini B	3.2	-	3.2	6.4	-	6.4
? - ASM	-	?	?	-	?	?
DAC - LM	4.0	3.0	1.0	8.0	6.0	2.0
GE & EK - MM	2.5	2.0	0.5	5.0	4.0	1.0
Tracking & Recovery	2.0	1.5	0.5	4.0	3.0	1.0
Other[5]	2.0	1.2	0.8	4.0	2.4	1.6
On-orbit Flight Evaluation (DAC)	3.0	2.0	1.0	6.0	4.0	2.0
Sub Total	33.7	13.7	24.0	67.4	27.4	48.0
Modification Labor & Repeat Assembly & C/O	-	16.0	9.0[6]	-	32.0	18.0[6]
TOTAL	119.2	93.9	54.3	229.4	187.8	99.6

* Nonrecoverable costs, i.e., spent whether or not conversion is made.
** Hardware and effort not expended unless conversion is made.
1 Excludes DAC provided MM structure ($800K)
2 Includes TIIIM launch cost
3 Cost for T-5½ month decision
4 Both Gemini B and ASM required
5 Flight crew support, test ops support, flight ops support, etc.
6 Cost of modifying from MAM back to AM configuration is $16.0M. If decide to go AM, $7M MAM launch/operations cost + this $9.0M will be required

TABLE 2

COST OF LAUNCH IN AM MODE WITH MODIFICATION METHOD - FLIGHT 6 or 7 AND FLIGHTS 6 and 7
($M)

	Flight 6 or 7			Flights 6 and 7		
	AM Baseline	Mod. Method	Baseline Δ	AM Baseline	Mod. Method	Baseline Δ
Hardware						
ASM	4.0	4.0	-	8.0	8.0	-
LM						
DAC	17.0	22.2[1&2]	5.2[1&2]	34.0	44.4[1&2]	10.4[1&2]
EK & GE	1.5	4.6[2]	3.1[2]	3.0	9.2[2]	6.2[2]
Other	2.7	2.7	-	5.4	5.4	-
MM	22.0	22.0	-	44.0	44.0	-
TIIIM[3]	21.0	21.5	0.5**	42.0	43.0	1.0**
Sub Total	68.2	77.0	8.8	136.4	154.0	17.6
Launch/Operations Costs	9.7	9.7	-	19.4	19.4	-
Modification Costs						
Modification Planning, Tooling and Equipment	-	9.0*	9.0*	-	9.0*	9.0*
Dual Planning for Operations, Software, Launch, Recovery, etc.	-	2.0**	2.0**	-	4.0**	4.0**
Modification MAM to AM	-	16.0**	16.0**	-	32.0**	32.0**
Sub Total	-	27.0	27.0	-	45.0	45.0
TOTAL	77.9	113.7	35.8	155.8	218.4	62.6

* Nonrecurring nonrecoverable costs
** Recurring nonrecoverable costs
1 Excludes MM structure ($800K)
2 Some portion recoverable for MAM equipment removed for AM launch
3 Includes TIIIM launch cost

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be in the AM configuration. Thus, in order to launch in the planned AM mode, an "emergency" type operation has to be undertaken to modify the LM to the AM configuration. This increases the cost of launching flight 6 or 7 in the AM mode to $35.8M more than the current baseline cost (Table 2). Of this amount $26.8M is a recurring increment to the baseline cost for each such flight.

In effect, an expensive "emergency" type modification of the LM is required when the option to change a flight from the planned AM mode to MAM is not exercised. A "crash" effort of this type, which involves extensive overtime and shortened rechecks and tests wherever possible, tends to degrade vehicle reliability.

In summary, this conversion method gives rise to a program that is always in a state of expensive chaos. Although the baseline incremental cost is less than some of the other methods considered, much of the increased funding is recurring and nonrecoverable.

Substitution

In this method, the only modules which require substitution are the ASM/Gemini B and the MAM and AM configured LM's. Although the MM is identical for both modes, use of a substitute MM integrated with the other appropriate substitute modules will reduce the time before launch when a conversion decision can be made without causing a schedule slip. A special case of substitution, dual countdown, will be discussed in a separate section.

Gemini B/LM Substitution

Applicable Period -- Up to T-5½ months (LM/MM mate) with no launch slip. Beyond T-5½ months, the planned configuration LM would have to be demated from the MM, the desired LM mated and the test flow resumed at LM/MM mate. There would be at least a day-for-day slip, although overtime could reduce the slippage if sufficient urgency existed.

Method -- For flight 6 or 7, a spare MAM LM must be fabricated and checked out so as to be available for the scheduled LM/MM mate. Both the MAM and AM LM's are carried through their test flows, and at LM/MM mate a decision can be made as to the desired configuration. For a continuing, mixed configuration follow-on program, additional LM's would not be required as long as LM delivery dates were planned so that both configurations were available for each flight.

Cost Impact -- For flight 6 or 7, the cost increment over baseline funding is $68.5M, as shown in Table 3, if the conversion decision is made no later than T-5½ months. In addition to nonrecurring costs of $11.0M for engineering planning and labor for increased production, $2.5M recurring nonrecoverable funds are required per launch -- $2.0M for dual planning for both MAM and AM operations, and $0.5M for TIIIM hardware for the Gemini B and crew interfaces. The hardware and effort represented by the remaining dollars are expended only if the flight is converted to MAM; otherwise it is available for subsequent MAM flights. If a conversion decision is made after T-5½ months, additional costs would be incurred to cycle back to LM/MM mate. The baseline incremental cost is almost doubled ($126.0M) if a conversion capability is provided for both flights 6 and 7. For a continuing, mixed configuration follow-on program, the only additional recurring nonrecoverable cost would be

INCREASED COST OF SUBSTITUTION OPTION - FLIGHT 6 OR 7 AND FLIGHTS 6 AND 7
($M)

	Flight 6 or 7			Flights 6 and 7		
	MAM	AM	Baseline △	MAM	AM	Baseline △
Engineering Planning & Labor for Increased LM Production*	11.0	-	11.0	11.0	-	11.0
Hardware						
Gemini B/ASM[1]	17.0	4.0	17.0	34.0	8.0	34.0
LM[2]						
DAC[3]	22.2	17.0	22.2	44.4	34.0	44.4
EK & GE eqp in LM	4.6	1.5	4.6	9.2	3.0	9.2
Other (crew eqp, etc)	4.2	2.7	4.2	8.4	5.4	8.4
Sub Total	31.0	21.2	31.0	62.0	42.4	62.0
MM	22.0	22.0	-	44.0	44.0	-
TIIIM[4]	21.5	21.0	0.5*	43.0	42.0	1.0*
Launch/Operations Cost (MAM △)	16.7	9.7	7.0	33.4	19.4	14.0
Dual Planning for Operations, Software, Launch, Recovery	2.0[5]*	-	2.0[5]*	4.0[5]*	-	4.0[5]*
TOTAL	121.2	77.9	68.5	231.4	155.8	126.0

* Nonrecoverable costs, i.e., spent whether or not conversion is made
1. Both Gemini B and ASM required
2 Substitute MAM LM required each flight
3 Excludes DAC provided MM structure ($800K)
4 Includes TIIIM launch cost
5 Cost for T-5½ month decision

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$2.5M per flight for dual operations planning and TIIIM/Gemini B interface hardware. However, production funds must be phased earlier to provide both configurations for each flight.

Discussion -- In the existing LM production and checkout facilities, there are two critical areas -- LM final assembly and LM checkout. For this reason, care must be taken to phase additional substitute LM's so as to not overtax the capability of these areas. An examination of the current baseline production flow shows that two substitute LM's (for flights 6 and 7) can be accommodated, although one of these must be produced in advance of the need date unless additional production facilities are provided. Additional facilities are not considered to be justifiable on this basis. Similar care must be taken in phasing delivery of LM's for a follow-on program.

Gemini B/LM/MM Substitution

Applicable Period -- Up to T-50 days (OV/TIIIM structural mate at VAFB) with no launch slip. Beyond T-50 days, the planned configuration would have to be demated and the desired OV mated with the TIIIM. This would essentially cause a day-for-day slip, although overtime could reduce the slippage to some extent.

Method -- This method is not feasible for flights 6 and/or 7, and is probably not feasible for near-term follow-on flights since the maximum delivery rate for the mission payload during this period is four per year. Additional effort and funding would probably be required to increase this production rate for follow-on flights. However, if mission payload production were increased, OV's in both configurations could be procured and made available at VAFB for the scheduled structural mate with the TIIIM, at which time a decision could be made as to the desired configuration. It is feasible to delay the decision to this point in time since little more than receipt and inspection is done to the OV modules at VAFB prior to mating with the TIIIM and conducting the integrated system test.

Cost Impact -- For a follow-on program the cost impact would be essentially the same as described for Gemini B/LM substitution. However, since both configurations are taken considerably further through the test flow, more of the programmed test flow dollars for both configurations would be expended. Consequently, some additional funds would probably be required for rechecking the unused configuration prior to using it for a subsequent flight.

Discussion -- Comments relative to Gemini B/LM substitution are also pertinent to this option. In addition, the serious problem of increasing mission payload production must be considered in any decision involving this method of achieving convertibility.

Dual Countdown

Applicable Period

Up to just before lift-off with no launch delay.

Method

This method is not feasible for flights 6 and/or 7, nor for early follow-on flights because of the maximum mission payload delivery rate of four per year. For later follow-on flights, an additional launch stand must be constructed so that two differently configured Flight

Vehicles (FV) are counted down simultaneously. A decision can be made up to just before lift off as to which configuration is launched.

With respect to facilities, only a new launch stand, together with an additional set of ASM/LM/MM/TIIIM AGE is required for this method since all of the other facilities can handle a dual countdown. For a continuing, mixed configuration follow-on program, FV deliveries would have to be planned so that both configurations are available for a flight.

Cost Impact

If additional mission payloads could be made available for flights 6 or 7, the baseline cost increment for this method, as shown in Table 4, would be $235.7M. Of this amount, $118.0M is required for launch stand construction and additional AGE. In addition to these facility costs, other nonrecoverable costs are required for engineering planning and labor for increased LM production and the countdown of two vehicles simultaneously. For a mixed configuration follow-on program, the additional nonrecoverable cost would be the same. Furthermore, production funds would have to be phased earlier to provide both vehicle configurations for each flight.

Discussion

Although this option offers the ultimate in capability to change the configuration of a mission, the large initial investment cost for an additional launch stand makes this option very unattractive, unless it is extremely important that a conversion capability be available up to just before lift-off.

TABLE 4

INCREASED COST OF DUAL COUNTDOWN OPTION - FLIGHT 6 OR 7 AND FLIGHTS 6 AND 7
($M)

	Flight 6 or 7			Flights 6 and 7		
	MAM	AM[1]	Baseline Δ	MAM	AM[1]	Baseline Δ
Additional Hardware AVE						
Gemini B/ASM	17.0	4.0	17.0	34.0	8.0	34.0
LM	31.8	21.2	31.8	63.6	42.4	63.6
MM	22.0	22.0	22.0	44.0	44.0	44.0
TIIIM[3]	21.5	21.0	21.5	43.0	42.0	43.0
Sub Total	92.3	68.2	92.3	184.6	136.4	184.6
Launch/Operations Costs[2]*	16.7	9.7	14.4	33.4	19.4	28.8
New Launch Facility*						
Facility	20.0	-	20.0	20.0	-	20.0
VAFB AGE	98.0	-	98.0	98.0	-	98.0
Sub Total	118.0	-	118.0	118.0	-	118.0
Engineering Planning & Labor for Increased LM Production*	11.0	-	11.0	11.0	-	11.0
TOTAL	238.0	77.9	235.7	347.0	155.8	342.4

* Nonrecoverable costs, i.e., spent whether or not coversion is made
1. Funded in current baseline
2. Operations cost will depend on mode launched (estimate additional dual countdown cost equals AM launch plus 2/3 MAM Δ)
3. Includes TIIIM launch cost

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III. CONCLUSIONS

The baseline cost increments for the four methods considered are compared in Table 5. The "conversion before LM assembly" method is the least expensive alternative, but it is not responsive to a real need for convertibility because a decision is required so far in advance of the launch date. The dual countdown method is discarded because it is not feasible for either flights 6 and 7 or any early follow-on flights. Even if additional payloads become available further out in the future, this method is still unattractive because of the large initial investment required for an additional launch stand.

Elimination of these two alternatives leaves modification and substitution as the competitive methods. The baseline incremental cost for flight 6 or 7 using the substitution method is $14.2M more than the baseline cost increment for modification. If there is to be no follow-on program, modification would be the desired option, based solely on this cost differential. However, modification requires considerable nonrecoverable funds and inherently degrades reliability. In addition, this method requires early funding for modification planning, tooling and equipment.

The substitution method (Gemini B/LM substitution) offers the same decision leadtime (with no slip in launch date) as does the modification alternative. Although the substitution method baseline cost impact is greater, the funds expended on any particular flight are less, since this method inolves only $2.5M of recurring, nonrecoverable funds.

T E 5

COMPARISON - INCREASED COST OF VARIOUS OPTIONS - FLIGHT 6 or 7
(Δ Baseline $M)

	Before LM Assembly	Modification	Substitution	Dual Countdown
Nonrecoverable Costs*				
Additional Hardware AVE				
Gemini B	-	-	-	-
LM	-	9.8	-	-
MM	-	-	-	-
TIIIM	-	0.5	0.5	-
Sub Total	-	10.3	0.5	-
Modification Planning, Tooling, etc.	-	9.0	-	-
Engineering Planning and Labor for Increased LM Production	-	-	11.0	11.0
Dual Planning for Operations, Software, Launch, Recovery, etc.	-	2.0[1]	2.0[1]	-
New Launch Facility				
Facility	-	-	-	20.0
AGE	-	-	-	98.0
Sub Total	-	21.3	13.5	129.0
Recoverable Costs**				
Additional Hardware AVE				
Gemini B	17.0	17.0	17.0	17.0
LM	Nominal	-	31.0	31.8
MM	-	-	-	22.0[2]
TIIIM	0.5	-	-	21.5[2]
Sub Total	17.5	17.0	48.0	92.3
Launch/Operations Cost	7.0	7.0	7.0	14.4[3]
Sub Total	24.5	24.0	55.0	106.7
Modification Labor and Repeat A & C/O	-	9.0[4]	-	-
TOTAL	24.5	54.3	68.5	235.7

* Spent whether or not conversion is made.
** Hardware and effort not expended unless conversion is made.
1 Cost for T-5½ month decision
2 Includes TIIIM launch cost
3 Estimate additional countdown cost equals AM launch plus 2/3 MAM Δ. Operations cost will depend on mode launched
4 Cost of modifying from MAM back to AM configuration is $16.0M. If decide to go AM, $7M MAM launch/operations cost + this $9.0M will be required

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Substitution is clearly the superior method for achieving convertibility for flights 6 and/or 7 and for follow-on flights.

A substitution capability for either flight 6 or 7, and a similar capability for the case covering both flights, can be achieved with no cost impact on the baseline program, if there is a mixed configuration follow-on program. This can be done by ordering manned LM's for the follow-on program sufficiently early so that they will be available for flights 6 and/or 7. The FY funding breakout for this approach (using a flight schedule incorporating a 12 month slip; i.e., flight 6 in November 1971) is shown in Table 6.

The FY 69 funding required for this capability (for engineering planning associated with increased hardware production) amounts to only $2.0M. These funds could undoubtedly be absorbed in the baseline program without difficulty, so that follow-on program funding necessary to achieve the baseline convertibility capability would not be required until FY 70. The point to be emphasized is that this method primarily requires early funding of a mixed configuration follow-on program rather than increased funding. In essence, the nonrecoverable cost of a convertibility capability for flight 6 or 7 via the substitution method would be $13.5M, and for both flights 6 and 7 would be $16.0M. (2.0M in FY 69, 3.0M in FY 70, 7.0M in FY 71, 4.0M in FY 72). Of this amount, the recurring nonrecoverable cost is only $2.5M per flight.

The additional hardware and effort is expended only if a decision is made to convert to the manned mode. If the capability is not

TABLE 6

INCREASED COST OF SUBSTITUTION OPTION - FLIGHTS 6 or 7 AND 6 and 7
($M)

	$(M) FY 69	FY 70	FY 71	FY 72	TOTAL
Flights 6 or 7					
Engineering Planning for Increased Production*	2.0	2.0			4.0
Additional Labor for Increased Production*			3.0	4.0	7.0
Gemini B		9.0	8.0		17.0
LM		17.0	14.0		31.0
TIIIM MAM △*		0.5			0.5
MAM Launch △				7.0	7.0
Dual Planning for Operations, Software, Launch, Recovery*	—	—	2.0	—	2.0
TOTALS	2.0	28.5	27.0	11.0	68.5
Flights 6 and 7					
Engineering Planning for Increased Production*	2.0	2.0			4.0
Additional Labor for Increased Production*			3.0	4.0	7.0
Gemini B		18.0	16.0		34.0
LM		34.0	28.0		62.0
TIIIM MAM △ *		1.0			1.0
MAM Launch △				14.0	14.0
Dual Planning for Operations, Software, Launch, Recovery*	—	—	4.0	—	4.0
TOTALS	2.0	55.0	51.0	18.0	126.0

* Nonrecoverable costs, i.e., spent whether or not conversion is made

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exercised on flight 6 or flight 7, the accumulated hardware and additional effort remain available to provide a conversion capability for subsequent flights.

IV. RECOMMENDATIONS

The following recommendations are based on consideration of the potential use of a conversion capability, the decision lead times that might be applicable to the situation, the impact on baseline costs and schedules, and the potential for an extension of the MOL capability into a follow-on program.

1. A capability for conversion of flights 6 and 7 by Gemini B/LM substitution should be incorporated into the baseline MOL program. This capability should also be a key feature of the follow-on program that is assumed to be forthcoming.

2. The conversion capability for flights 6 and 7 should be funded in the follow-on program, with the exception of an initial requirement of $2.0M needed in FY 69 for engineering planning for increased production. FY 69 funding should be absorbed in the baseline program funding. Initial follow-on program funding to provide this capability will be needed in FY 70.

3. The Systems Office should be directed to include this capability now in the internal planning for the baseline program. However, it is neither necessary nor desirable to incorporate this capability at present in formal program documents such as the planned revision to the MOL Program Plan and Funding Requirements (Blue Book).

4. A proposal for a follow-on program, which includes the conversion capability for flights 6 and 7, should be prepared and submitted to Dr. Flax in early CY 1968. Funding for this program should be included in MOL FY 70 budget proposals that are initiated in mid CY 1968.

V. GLOSSARY

AGE	Aerospace Ground Equipment
AM	Automatic Mode (Unmanned MOL flight of vehicle)
ASM	Automatic Support Module (Module which replaces the Gemini B in the unmanned configuration. Carries data return vehicles and other equipment.)
ATS	Acquisition and Tracking Scope
Birdcage	Major structural framework inside pressurized compartment of the Laboratory Module
C/O	Checkout
DAC	Douglas Aircraft Company
DORIAN	Project or code name used in this sense for the camera/optical system carried by MOL.
DRV	Data Return Vehicle
EKC	Eastman Kodak Company
FV	Flight Vehicle
GE	General Electric
LM	Laboratory Module
MAC	McDonnell Aircraft Company
MAM	Manned Automatic Mode (Manned version of the MOL vehicle or flight)
MM	Mission Module (houses the major portion of the camera/optical system)
Mode	Term used to refer to the manned (MAM) or unmanned (AM) flight or vehicle configuration.

nonrecurring cost	A cost that occurs only once.
nonrecoverable cost	Costs for hardware or services which are expended whether or not the conversion capability is exercised.
OV	Orbital Vehicle (that portion of the total MOL vehicle which goes into orbit)
recoverable cost	The converse of nonrecoverable. Costs for hardware and services which are available for subsequent flights if conversion is not accomplished.
T-x months or days	Time before launch.
TIIIM	Titan III-M booster
VAFB	Vandenberg Air Force Base