1. Herb ~~Bockman~~ Patterson EB#

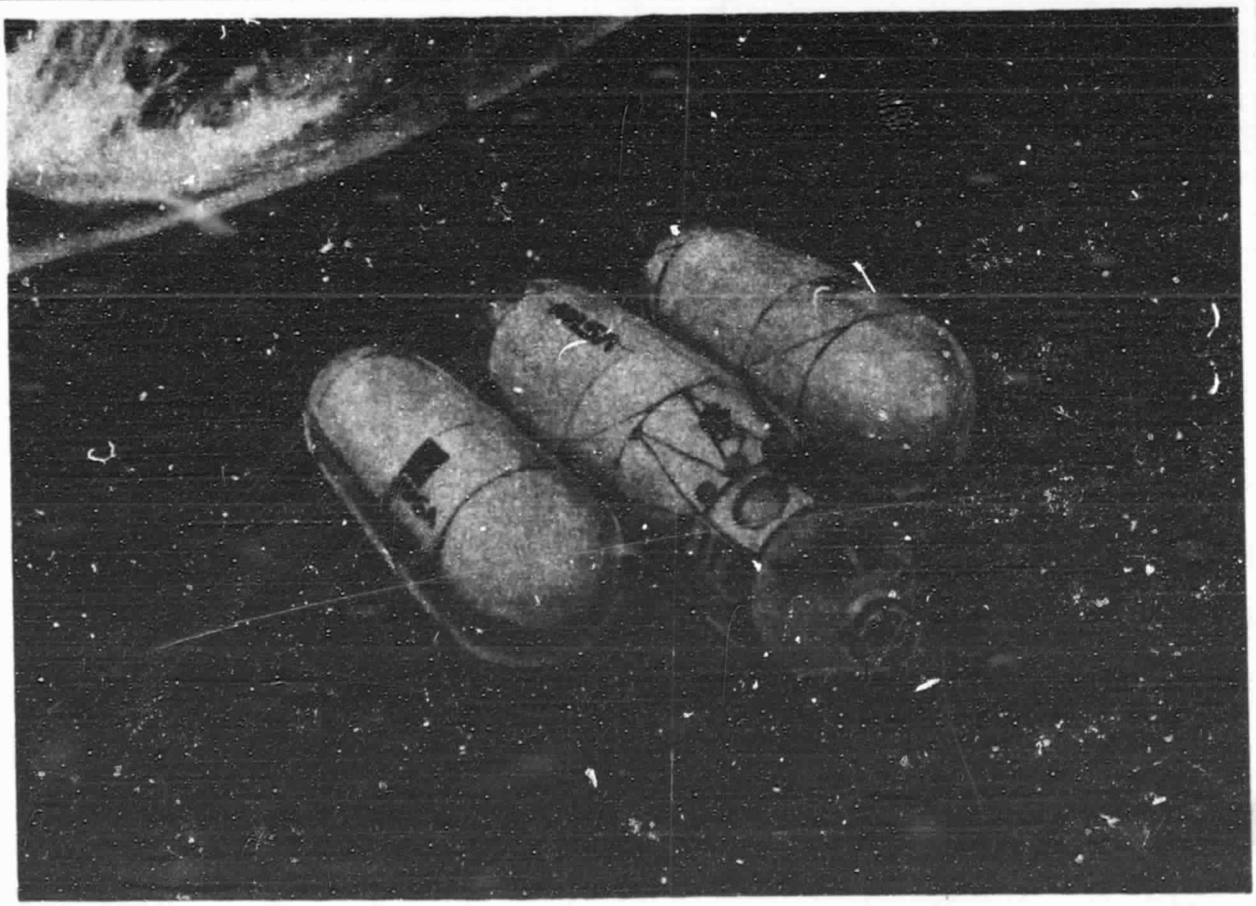
2. # MANNED GEOSYNCHRONOUS MISSION REQUIREMENTS & SYSTEMS ANALYSIS STUDY EXTENSION

NASA-CR-160955

volume 1
executive summary

5. NAS 9-15779

6. 2/1981



4. **GRUMMAN AEROSPACE CORPORATION**

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MANNED GEOSYNCHRONOUS MISSION REQUIREMENTS & SYSTEMS ANALYSIS STUDY EXTENSION

volume 1
executive summary

prepared for
National Aeronautics and Space Administration
Johnson Space Center
Houston, Texas

prepared by
Grumman Aerospace Corporation
Bethpage, New York 11714

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ILLUSTRATIONS

ILLUSTRATIONS (Contd)

FOREWORD

This final report documents the results of a study extension performed under NASA Contracts NAS 9-15779. The study was conducted under the technical direction of the Contracting Officer's Representative (COR), Herbert G. Patterson, Systems Design, Johnson Space Center. Mr. Lawrence Edwards, NASA Headquarters, Office of Space Transportation Systems, Advanced Concepts, was the cognizant representative of that agency.

The Grumman Aerospace Corporation's study manager was Ronald E. Boyland. The major contributors and principal investigators were Stanley W. Sherman and Henry W. Morfin.

The final report consists of the following volumes:

- Executive Summary - Volume 1
- MOTV Capabilities Handbook and Users Guide - Volume 2

1 - BACKGROUND

NASA is presently devloping a manned space transportation system to low earth orbit. However, advanced space mission planning includes both manned low earth orbit and manned geosynchronous earth orbit missions. The activities potentially requiring manned participation in both orbits consist of construction, inspection, servicing, repairing, and operation of large space systems such as communication, solar power, and earth observation satellites. In order to exploit the capabilities of the Space Transportation System and develop the full potential of space operations it is essential that development planning of orbit transfer vehicles be expanded to include manned capability.

A NASA founded study was performed by Grumman during 1979 to determine the types of manned missions that will likely be performed in the late 1980's or early 1990's timeframe, to define MOTV configurations which satisfy these missions requirements, and to develop a program plan for its development. Figure 1-1 shows the All Propulsive OTV (APOTV) resulting from the study while Fig. 1-2 shows its crew capsule. This report covers a nine month extension to that study.

The primary focus of this extension centered on the selection of a preferred MOTV configuration and mission mode to perform the generic missions identified in the main study. Twenty generic missions were originally defined for MOTV but, to simplify the selection process, five of these missions were selected as typical and used as Design Reference Missions. Systems and subsystems requirements were re-examined and sensitivity analyses performed to determine optimum point designs. Turnaround modes were considered to determine the most effective combination of ground-based

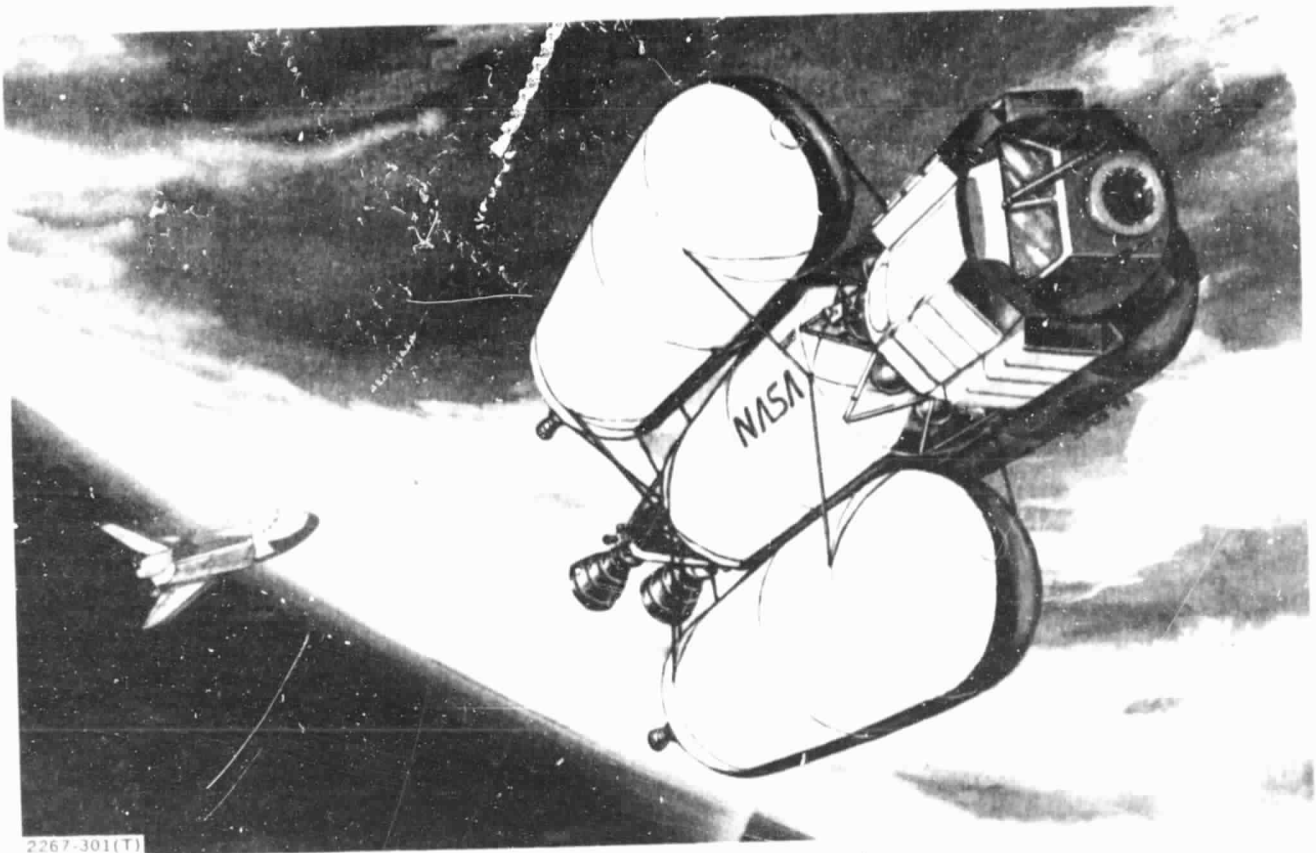
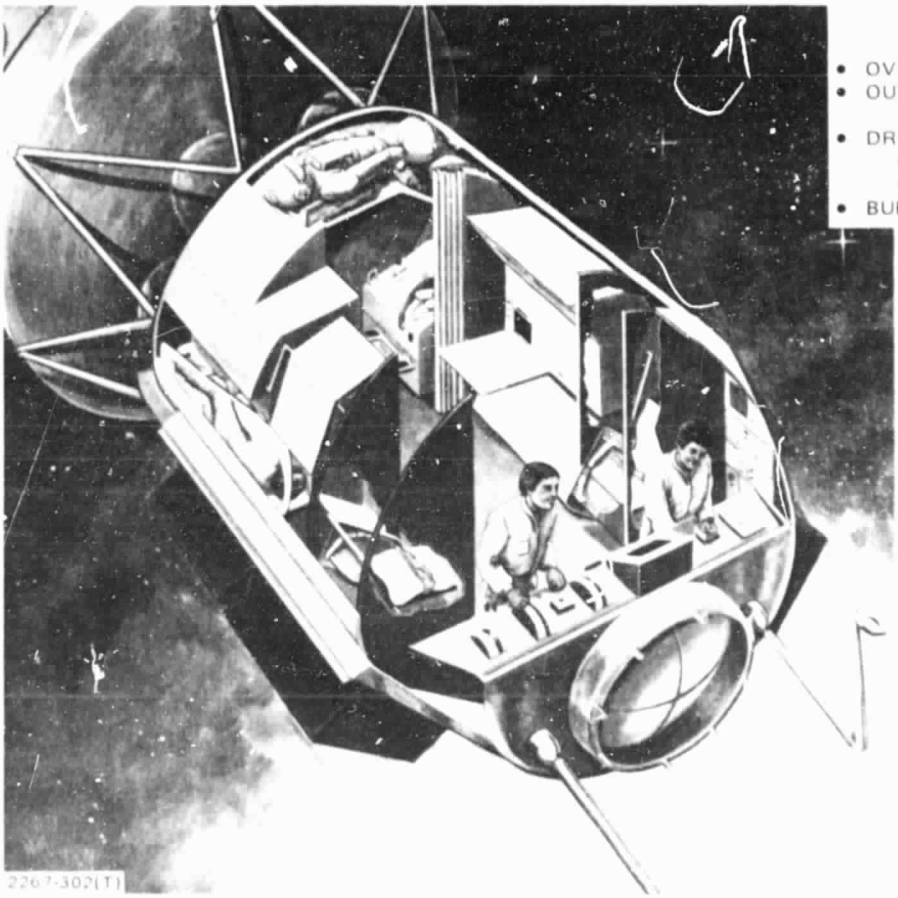


Fig. 1-1 All Propulsive OTV (APOTV)



CHARACTERISTICS

• OVERALL LENGTH	=	4·35 m
• OUTSIDE DIA	=	3·0 m
• DRY WEIGHT	=	3584 kg
CREW	=	245 kg
CONSUMABLES (19 DAYS)	=	343 kg
• BURNOUT WEIGHT	=	4172 kg

Fig. 1-2 Three-Man Basic Crew Capsule

and space-based activities. With these inputs, a preferred concept for the crew capsule and for the mission mode was developed. Figure 1-3 depicts the selected vehicle and Fig. 1-4 shows its two man crew capsule. The sections which follow summarize the salient results of this study extension. All costs quoted in this report are in 1979 dollars.

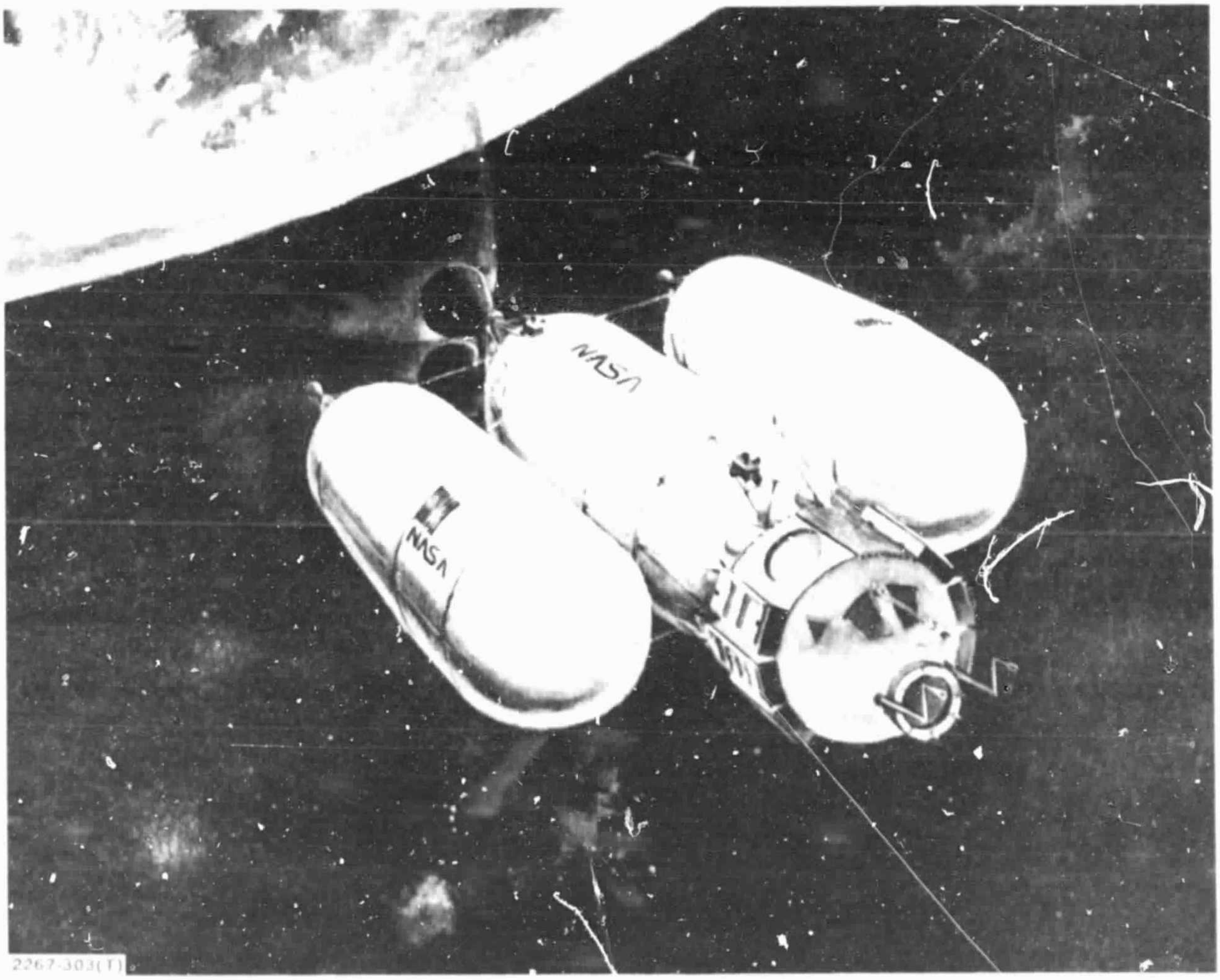
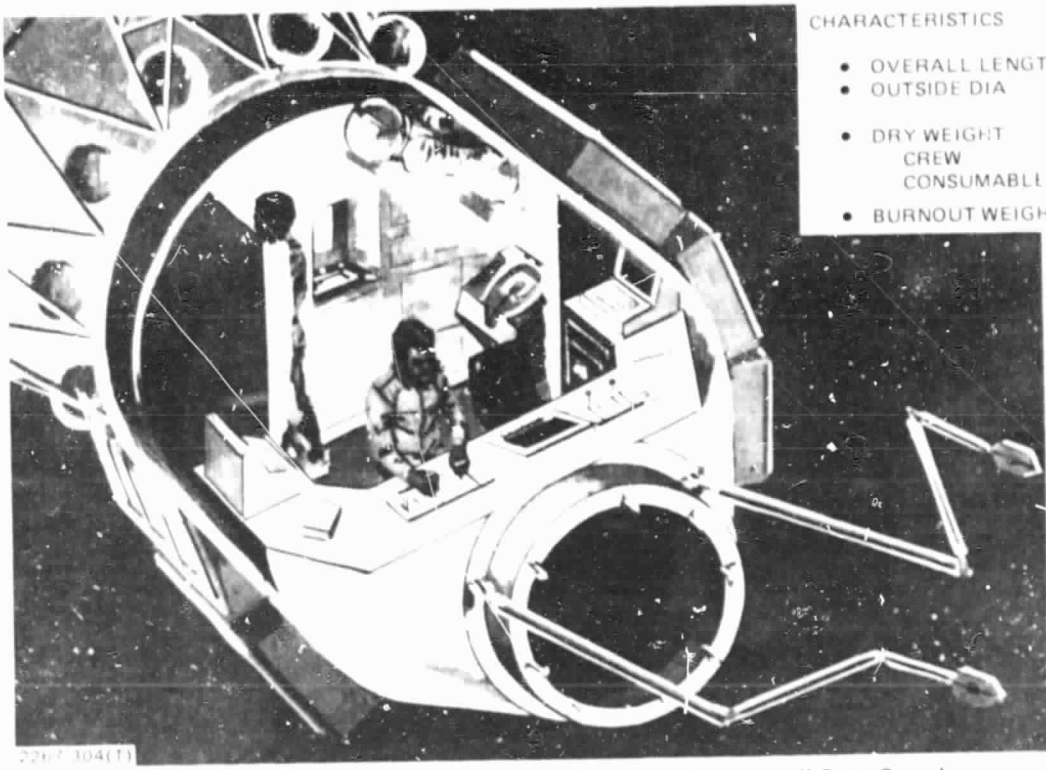


Fig. 1-3 MOTV Transfer to GEO



CHARACTERISTICS

- OVERALL LENGTH = 2.85 m
- OUTSIDE DIA = 3.0 m
- DRY WEIGHT = 2775 kg
  - CREW = 163 kg
  - CONSUMABLES (4 DAYS) = 114 kg
- BURNOUT WEIGHT = 3052 kg

Fig. 1.4 Two-Man "Functional Minimum" Crew Capsule

2 - CONCLUSIONS AND RECOMMENDATIONS

2.1 CONCLUSIONS

Re-examination of missions task performance confirmed the main study conclusion that external manipulators, operated from within the crew capsule, could adequately perform routine satellite service, repair and construction. Thus, IVA is baselined with EVA available on each mission for contingency and emergency operations.

The number of men necessary to operate the IVA system was found to be two for 75% of the generic missions, including the five DRMs. It is felt that EVA with either one man out and one man in the capsule or with both men out and the MOTV controlled by voice recognition/synthesis is acceptable for emergency or contingency operations. Accommodations for the two men can be adequately provided by the 'functional minimum' crew capsule which has a free volume of $3M^3$ per man and is lowest cost.

Regarding mission modes, APOTV requires no technological breakthrough and is considered, therefore, to have the least risk development. It can be evolved later to a more demanding mission mode, such as Aeorballute OTV (ABOTV) or Lifting Brake OTV (LBOTV), which may have performance and cost advantages. Emergency return from GEO of the APOTV is less hazardous than the alternate modes considered and is more comfortable for an ailing crewman. It is also the lowest cost. However, it can take up to 18 hours longer than a direct entry capsule to return from GEO to ground but the benefit of faster return time has not been identified except for an obvious life or death situation.

Turnaround of the vehicle is less costly if space-based at SOC for routine servicing, with periodic return to the ground for labor-intensive tasks such as major overhaul. Assuming SOC turnaround, a pressurizable hangar for MOTV servicing can reduce the total labor costs by about 50%.

2.2 RECOMMENDATIONS

Mission costs derived during the study have been based on whole numbers of STS flights. Development of a traffic model for OTV and MOTV missions would allow manifesting of STS payloads, perhaps reducing the number of STS launches per mission and thus, costs per mission. Such a traffic model would also enable the amortization of production and DDT&E cost over operational flights.

More detailed definition of SOC would lead to more refined turnaround analyses and SOC vs ground tasks mix. It would also allow better definition of MOTV turnaround requirements for SOC. Further study of a pressurized hangar on SOC leads to better definition of its advantages and its impact on SOC.

Grumman LASS facility is currently being used to investigate master/slave manipulator operations for the MRWS contracted study. It would be beneficial to extend and augment these investigations to include MOTV mission task requirements.

A crew capsule mock-up to include work stations for the manipulator investigations and to include living accommodations for the crew, would help resolve many of the doubts that have been expressed regarding the free volume requirements for the crew.

ABOTV and LBOTV are mission modes which have been proposed by the contractors studying OTV propulsion for MSFC. The impact of these aero-assist modes on the crew capsule should be investigated as part of the assessment as to their practicability.

3 - SYSTEMS REQUIREMENTS AND SENSITIVITY

3.1 GENERIC AND DESIGN REFERENCE MISSIONS

For this study, mission features of interest are the services that the MOTV will be called upon to provide. Based on analysis of the Potential User Programs, 20 generic MOTV missions were defined in Phase 1, each providing a specific service. Details of these 20 missions are included in the Mission Handbook, issued at the end of Phase 2. The salient characteristic of each generic mission are shown in Fig. 3-1. Five generic categories are identified, and within each category is a wide sampling of missions. They range from short duration, small crew size and low mission hardware weight to orbit, to long duration, large crew size and heavy mission hardware weight to orbit. Mission orbits range from GEO to 12 hr/63° elliptic to deep space (400,000 n mi circular).

In this study extension, we have concentrated on the five Design Reference Missions (DRM) identified in the chart, and which typify the range of performance requirements of the other of generic missions. The number of crewmen quoted are the minimum necessary to perform each mission, assuming IVA for the tasks. In general, two men can perform the tasks although the guidelines defined a minimum crew size of three.

3.2 CREW CAPSULE ACCOMMODATIONS SENSITIVITIES

Over the course of the study and this extension, four baseline crew capsules have been developed and are summarized in Fig. 3-2. Between them, they house two or three men with accomodations ranging from provisions for privacy quarters for each crewman, termed 'basic' capsule, to a more spartan layout with no privacy quarters, termed 'functional minimum'. The three man basic crew capsule has a dry

GENERIC MISSION		SCENARIO CHARACTERISTICS				
CATEGORY	SYMBOL	ORBIT	MISSION HOWR. Kg	CREW*	DURATION, DAYS	DESCRIPTION
INSPECTION SERVICE & REPAIR	IN1	GEO	510	2	4	SCIENTIFIC SATELLITE REVISIT
	[S1]	GEO	1684	2	19	MODULAR LEVEL SERVICE
	S2	GEO	2966	2	27	COMPONENT LEVEL SERVICE & UPDATE
	S3(a)	GEO	2600	2	21	SERV & UPDATE NUCL PWRD SATS
	S3(b)	GEO	2600	2	3	REPLACE NUCL REACTOR
	[ER1]	GEO	453	2	4	EMERGENCY REPAIR (GEO)
	[ER2]	12 HR 63	272	2	4	EMERGENCY REPAIR (HEO)
	R1	12 HR 63	4100	2	2	FAILED SATELLITE
OPERATION OF LARGE SPACE SYSTEM	OP1	GEO	440	2	16	TENDED STO
	P1	GEO	1683	2	4	3 MAN CREW ROTATION/RESUPPLY
	P2	GEO	4485	2	4	10 MAN CREW ROTATION/RESUPPLY
	P3	GEO	16,819	2	4	30 MAN CREW ROTATION/RESUPPLY
	P4	DEEP SPACE	3364	2	30	6 MAN CREW ROTATION/RESUPPLY
DEBRIS REMOVAL	[DR1]	GEO	550	2	9	REMOVE DEBRIS FROM 45 SECTOR OF GEO
CONSTRUCTION	C1	GEO	10,000	2	3	UNFOLD WIRE WHEEL ANTENNA
	C2		16,000	2	6	UNFOLD COMMUN PLATFORM
	[C3]		17,000	2	6	PREFAB COMMUN PLATFORM
	C4		15,000	2	7	AUTOFAB COMMUN PLATFORM
	C5		110,535	3	14/5/5/5	AUTOFAB SPDA
	C6			2	17	MODULAR ASSY SPDA
UNMANNED CARGO	UC	VARIOUS	15,000 55,000	NONE		SECONDARY ROLE

SYMBOLS

IN INSPECTION
S SERVICE
ER EMERG REPAIR
R RETRIEVAL
OP OPER LG SPACE SYSTEM
P PASS TRANSPORT
DR DEBRIS REMOVAL
C CONST
UC UNMAN CARGO

[ ] DESIGN REFERENCE MISSIONS

*MIN. TO PERFORM TASKS IVA

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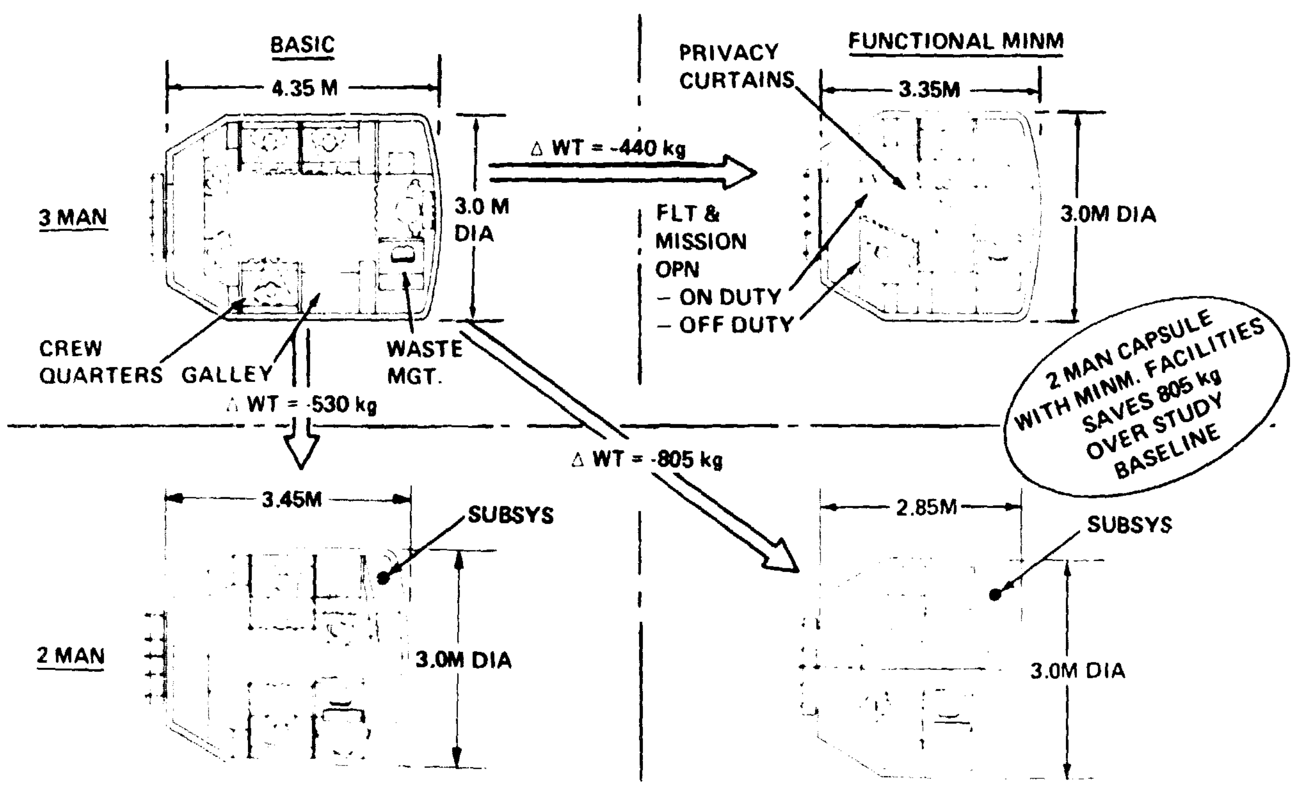
Fig. 3-1 Generic Mission Summary



2267-127(T)

Fig. 3-2 Crew Capsule Candidates

weight of 3584 Kg. The 'functional minimum' version of this 3-man capsule, eliminates the three privacy quarters for the crew by combining work and sleep stations, and saves 1 m in capsule length and, 440 Kg dry weight. As shown in Fig. 3-1, a crew of two is adequate to carry out most missions. Therefore, two capsule concepts were introduced in this extension study, a two man version of the 'basic' capsule and a 'functional minimum' capsule. The two man 'basic' capsule is 0.9m shorter than the original Phase 2 three man capsule and weighs 530 Kg less. The two man 'functional minimum' is 1.5m shorter than the three man 'basic' and saves 805 Kg dry weight.

Cost sensitivity for these capsules is shown in Fig. 3-3. The data is for DRM ER1, but a similar sensitivity is exhibited for the other DRMs. The impact of crew size on crew capsule cost results in less than a 7% difference for DDT&E and production costs.

3.3 EVA VS IVA SENSITIVITIES

The question of mission task performance using Extra Vehicular Activity (EVA) or Intra Vehicle Activity (IVA) was also re-examined in the extension study. The main study recommendation was that IVA should be baselined, since it carried less weight penalty and higher productivity. This recommendation still holds and current mission scenario analysis shows that all generic missions can be performed IVA. However, a change in mission tasks to be performed or the addition of other missions may require some planned EVA's.

Figure 3-4 shows weight penalties for performing a mission using planned EVA as compared to the baseline IVA weight penalty. IVA recognizes that contingencies may arise where, rather than abandon the mission, EVA would rectify a problem. This, weight, therefore, includes capability for two contingency EVA's. Eva with a two man crew requires either both men outside using the buddy system, leaving the vehicle unattended but controlled via voice synthesis, or one man outside while the other remains to monitor the vehicle, but space suited, ready to go to his companion's aid if required.

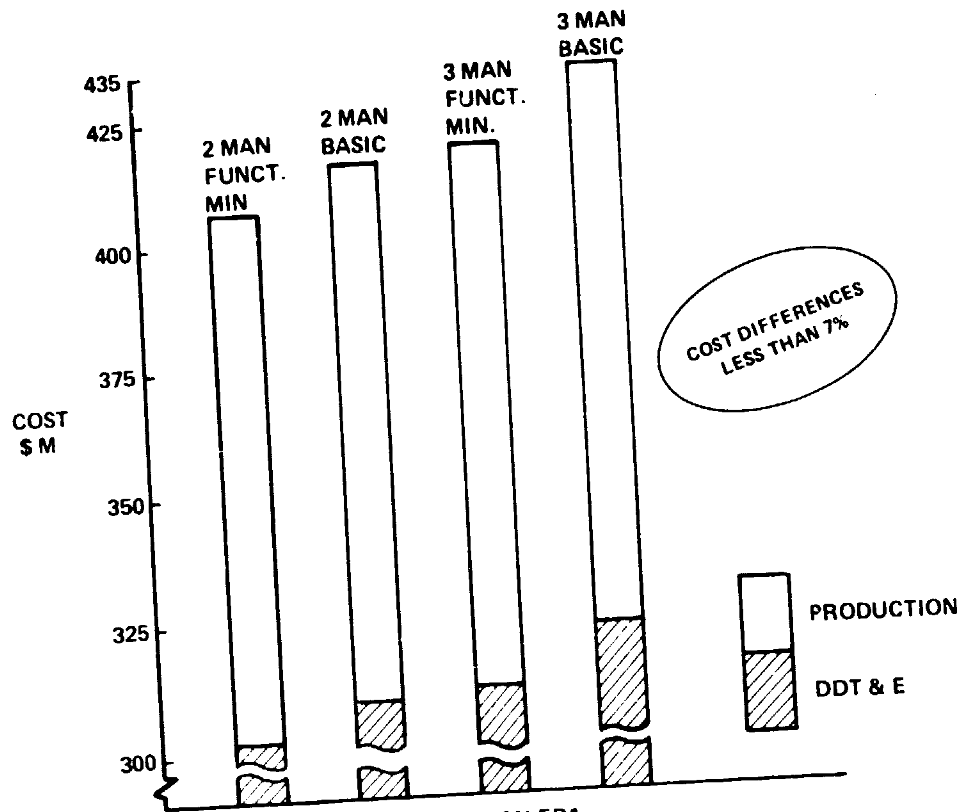


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Fig. 3-3 Crew Capsule Cost Sensitivity

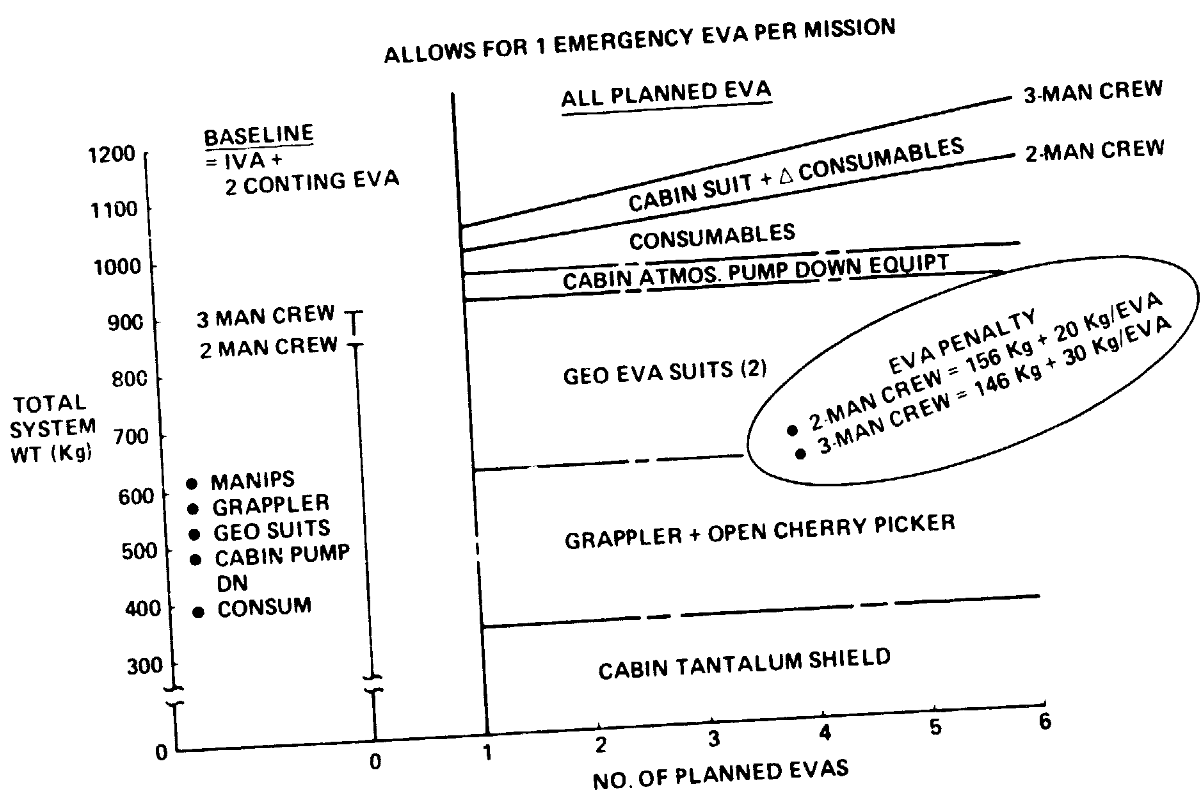

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Fig. 3-4 IVA vs EVA Weight Trends

The other parameter, when considering EVA or IVA for task performance, is productivity. Based on the times required to service one MMS satellite, the total elapsed time to perform a task of short duration using EVA is typically 2.57 times longer than performing it IVA. With longer duration tasks requiring multiple work-days, EVA is typically 2.72 times longer than IVA.

3.4 STS LAUNCHES PER MISSION

In our recently completed main study, the standard STS, with a 65,000 lb payload capability, was used to launch the APOTV and its associated mission hardware to LEO. The numbers of launches required to accomplish each of twenty generic missions were reported during the main study. They have been updated, as shown in Fig. 3-5, to reflect revised crew capsule weights. For some construction missions this lead areduction in shuttle launches required from that previously reported.

In light of the propulsion studies being conducted under contract from MSFC, we have calculated the number of Advanced Shuttle (100,00 lb payload) launches required to accomplish each generic mission using an Aero Assist ABOTV. Introduction of an advanced, 100K, STS in conjunction with an ABOTV reduces the maximum number of launches to two for any generic mission.

3.5 CONCLUSIONS

The analyses summarized in the preceding paragraphs are the main sensitivities traded in this study extension. Conclusions drawn from these analyses indicate:

- A two man crew and crew capsule is a viable alternative to the three man baseline defined in the previous study, provided that groundrules for EVA are modified to allow one man to go out EVA and the second man remain in the capsule, space-suited, ready to assist if necessary. Or that the capsule can be left unattended provided that voice synthesis and recognition is developed to allow vehicle control by an EVA man and communication with the ground via the capsule.

These relaxations are more acceptable if applied to IVA missions where EVA is provided for contingency or emergency situations.

o IVA carries less weight penalty than EVA for the performance of mission tasks and has higher productivity. IVA is, therefore, recommended as the baseline.

o There is less than 7% difference in crew capsule production and DDT&E cost between two or three man crew capsules.

o Half the generic missions require four Standard STS launches 40% require three launches, and 10% require two launches. With the introduction of an advanced STS, 100K payload capability, and an aero assisted OTV, 50% of the missions will require two launches with the remainder only needing one launch.

GENERIC MISSION		SCENARIO CHARACTERISTICS			
CATEGORY	SYMBOL	ORBIT	DURATION DAYS	STS LAUNCHES *65K	STS LAUNCHES 100K**
INSPECTION SERVICE & REPAIR	IN1	GEO	4	3	1
	S1	GEO	19	4	2
	S2	GEO	27	4	2
	S3(a)	GEO	21	4	2
	S3(b)	GEO	3	4	2
	ER1	GEO	4	3	1
	ER2	12 HR/63	4	2	1
	R1	12 HR/63	2	2	1
OPERATION OF LARGE SPACE SYSTEM	OP1	GEO	16	3	1
	P1	GEO	4	3	1
	P2	GEO	4	4	2
	P3	GEO	4	NA	NA
	P4	DEEP SPACE	30	4	2
DEBRIS REMOVAL	DR1	GEO	9	3	1
CONSTRUCTION	C1	GEO	3	3	1
	C2		6	4	2
	C3		6	4	2
	C4		7	4	2
	C5		14/5/5/5	–	·
	C6		17	3	1
UNMANNED CARGO	UC	VARIOUS			

STANDARD STS LAUNCHES PEAK AT 4

*BASED ON ALL PROPULSIVE MOTV
**BASED ON AEROBRAKING MOTV
2267-126(T)

Fig. 3-5 OTV Payload: No. STS Launches

4 - CONCEPTS EVALUATION

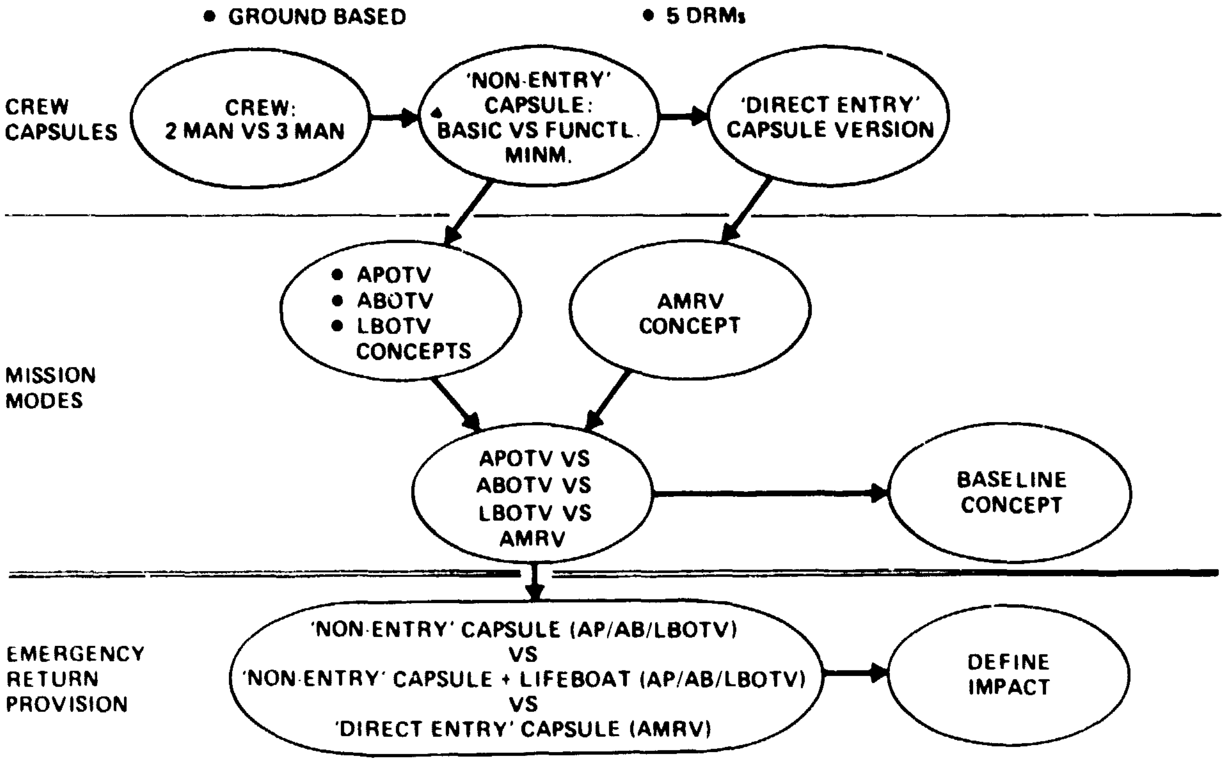
The primary objective of the study extension was to select a preferred MOTV configuration and mission mode based on MOTV capability and potential application. This section summarizes the concept evaluation process and subsequent study findings.

At the outset, the evaluation process was geared to identify the crew size crew capsule, and mission mode combination which best performed the five DRMs. Figure 4-1 shows the logic flow used. Two types of capsule were considered, a 'non-entry' type which must be returned to earth by the shuttle and a 're-entry' type which can return directly. The 'non-entry' type was evaluated by first defining the number of men necessary to perform the mission tasks and then determining whether that size crew could cope with emergency or contingency EVA. Optional levels of comfort for the crew were then evaluated using criteria of cost, mission success, and growth potential. The preferred capsule then becomes the baseline crew capsule for each of three mission modes considered; the APOTV, ABOTV and LBOTV.

A 're entry' type capsule which returns directly to earth was also defined which houses the same crew size and provides the same facilities as the selected 'non-entry' type. This capsule was baselined for the Aero Maneuvering Re-entry Vehicle (AMRV).

A mission mode trade was then performed among competing concepts i.e. APOTV vs ABOTV vs. LBOTV vs. AMRV, and based on this trade, a baseline concept selected for mission mode and crew capsule.

The impact of emergency return was considered as a side issue. If the baseline concept was APOTV, ABOTV or LBOTV, then, even in an emergency, the crew returns to LEO for rendezvous with a shuttle. Alternatively, a lifeboat can be added to the capsule for direct return of the crew. A third alternative was the use of an AMRV in which the crew always returns directly to Earth. These alternates were considered in terms of safety, time-to-return, and cost.



2267-137(T)

Fig. 4-1 MOTV Concept Evaluation Logic Flow

4.1 CREW CAPSULE EVALUATION

As shown in the logic, flow chart Figure 4-1, the first trade determined the baseline crew size and the corresponding capsule to accommodate them.

2-Man vs 3 Man Crew: Five DRMs were used for this evaluation. Figure 4-2 identifies the criteria considered in this evaluation and the minimum crew necessary to perform the DRM mission tasks. It also considers whether that crew number could cope with emergency or contingency EVA.

Original manpower requirements, conducted during Phase I of the study, found that two men could perform four out of five DRMs. The fifth DRM, C3, called for three men since some observation of the work-piece was necessary during final checkout. It was felt that a third man would be useful for this task. On re-examination it was found that two men could perform this mission provided the observation task was done sequentially. This resulted in a 55 min. time penalty added to the 'on orbit' mission time.

EVA was provided on a contingency basis where for some unforeseen circumstance the mission could not be completed and could not be handled by the IVA prime mode. It might be an emergency affecting crew safety or critical MOTV subsystems. In any event, for this failure mode both crewmen would go EVA, using the buddy system, to rectify the problem. Communication with the ground would be maintained via the vehicle. An alternative mode is for one man to go EVA while the other remains in the capsule, but he is space-suited, ready to go to the assistance of his mate if needed.

Our evaluation showed that 2 men could perform all DRMs without significant penalty and is, therefore, the base crew size.

DRMS – S1:ER1:ER2:DR1:C3

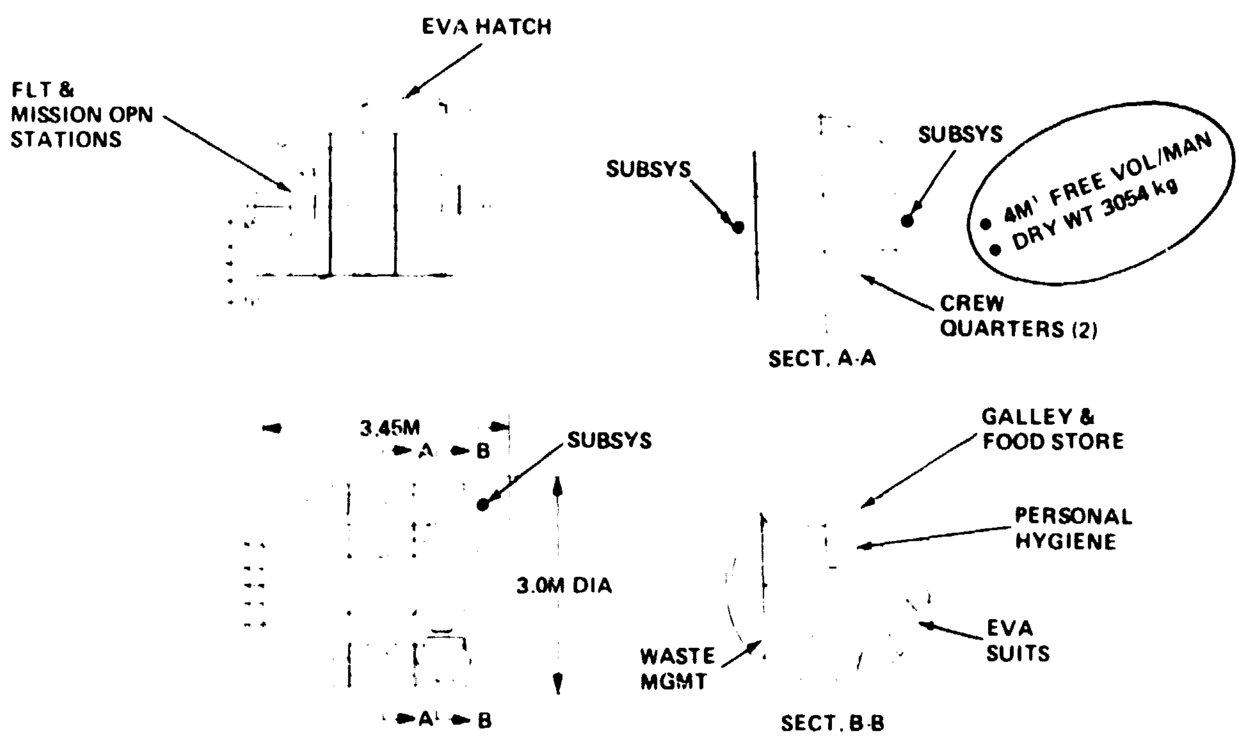
CRITERIA	2 MAN CREW	3 MAN CREW	JUDGMENT
• MISSION PERFORMANCE			
– 'MAIN STUDY' CREW REQUTS	• S1:ER1:ER2:DR1	C3	
– REVISED CREW REQUTS	• ALL DRMS (55 MIN. PENALTY FOR C3)		ACCEPTABLE
• CONTINGENCY/EMERGY EVA	• 1EVA + 1 IN CAPSULE	• 2EVA + 1 IN CAPSULE	
	• 2EVA + UNTEND. CAPSULE		ACCEPTABLE • FAILURE MODE • BUDDY SYST. • GROUND COMM. VIA MOTV

✔

2 MEN
CAN PERFORM
DRMs WITHOUT
SIGNIFICANT PENALTY

2267-110(T)

Fig. 4-2 Two-Man vs Three-Man Crew



2267-129(T)

Fig. 4-3 Two-Man "Basic" Crew Capsule

"Non-entry" capsule: basic vs. functional minimum: Having selected a crew size of 2 the question arises as to the standard of accommodation necessary for efficent handling of their duties and required storage volume for mission equipments, and associated life support subsystems. Figure 4-3 shows the 'basic' and 'functional minimum' versions of a 2-man crew capsule. The following requirements were imposed on the design of these crew capsules:

- o Privacy for mixed crew bodily functions
- o Individual quarters for privacy
- o EVA suit donning volume and storage
- o Waste management system
- o Personal hygiene system
- o Galley

The 'basic' capsule has two main functional areas. The flight and mission station which is located at the forwarded and has two operators, side by side, with all necessary pilot and manipulator controls. The aft section provides privacy quarters for each crew number and can be closed off by curtains, a galley and food storage area, and a waste management facility. EVA suits are also stored and donned in this area. The aft wall of the capsule is lined with subsystems some of which are also located under the floor. A personal hygiene facility is in the rear bank of subsystems. Free volume per man for the 'basic' capsule is $4m^3$, and provides Celentano 'performance' level of comfort for a mission time of 27 days.

Most missions, including the DRMs were of shorter in duration and this led to consideration of reducing capsule volume without materially degrading crew comfort level. The result was a 'functional minimum' capsule which was considered to be about the minimum volume necessary to provide required facilities, store necessary subsystems, and have sufficient free volume for crew movement and donning of EVA suits. The free volume required was reduced to $3m^3$ per person. This compared to about

$2.2m^3$ per man for the Lunar Module and about $2m^3$ per man for the Apollo Command Module. The capsule was 0.6m shorter than the 'basic' capsule, and saved 279 Kg of structure, TPS, line-runs, and crew accommodations weight. In arriving at this configuration, the requirement governing the 'basic' configuration for privacy quarters was eased by combining work stations and living quarters together. Now, privacy was obtained by each crew member by pivotting 180° in his seat from his work position, and pulling curtains around his territory. The forward deck flight station remains essentially unchanged from the 'basic' capsule. The aft section which caters to crew services and subsystems stowage also remains the same except that the bank of subsystems located inside the rear dome has been increased in depth to allow for essential stowage volume lost by shortenging the capsule.

Figure 4-4 summarizes the evaluation of these two crew capsules. Some criteria were considered to be of more importance than others, particularly those affecting costs and safety. Usually, these were given twice the weight of the other criteria. Hence, DDT&E and cost per mission (CPM) have been given a factor of 2, but production costs which are not considered to have the same impact is not given extra weight. Although the cost differentials between the two capsules were small they showed that the 'functional minimum' capsule was less costly than the 'basic' capsule. Therefore they remain as discriminators. Safety, another high ranking criterion, was the same for both capsules and, consequently, was not a discriminator. Similarly, such criteria as flight and mission station utilization was the same for both capsules and, consequently, was not a discriminator. Similarly, such criteria as flight and mission station utilization was the same for both capsules, and was excluded from this summary evaluation chart.

- **2 MAN CREW**
- **DRM/DURATION (DAYS) S1/19:ER1/4:ER2/4:DR1/9:C3/6**

CRITERIA	WTG. FACTOR	BASIC CAPSULE	SCORE	FUNCTL. MIN CAPSULE	SCORE
• LENGTH	1	3.45 M		2.85 M ✓	1
• WEIGHT - DRY	1	3054 Kg		2775 Kg ✓	1
• UTILITY					
CREW COMFORT LEVEL					
• DAYS AT CELENTANO "PERFORMANCE"	1	29		16 ✓	1
• DAYS AT CELENTANO "TOLERANCE"		~50		26	
SUBSYS STOWAGE VOL EXCESS	1	12.5%		ZERO ✓	1
MISSN EQUIPT DIRECT MOUNT	1	S1 ER1 2 DR1 ✓	1	ER1 2 DR1	1
EVA PREPN EGRESS	1	COMFORTABLE		ADEQUATE ✓	1
• VERSATILITY					
ADD 1 MAN OR "IN CABIN" OPS	1	YES ✓	1	NO	
• COSTS					
DDT&E	2	$309M		$302M ✓	2
PRODN (2 SETS + SPARES)	1	$106M		$104M ✓	1
CPM - (AVERAGE)	2			$0.8M LOWER ✓	2
		FUNCTL. MIN —ADEQUATE PERFORMANCE AT LEAST COST/WT/LENGTH	2	✓	10

2267-142(T)

Fig. 4-4 Crew Capsule: "Basic" vs "Functional Minimum" Evaluation

Capsule length was a factor because of its demand on shuttle cargo bay length. Weight was reflected in cost figures, but was also a limitation on orbiter cargo manifest. 'Crew comfort level' indicates the maximum number of days each capsule is capable of accommodating a crew of two at various levels of habitability, using standard habitability curves. Since the 'functional minimum' capsule could adequately support the crew within the 'performance' habitability level set by Celentano for four of the five DRMs, and could support the fifth DRM at the Celentano 'tolerance' level it was selected as the winner for this parameter. The 'basic' capsule was oversized for the DRM's. Subsystems stowage in 'functional minimum' capsule was optimum with no excess volume as was the case with the 'basic' capsule. Area for EVA preparation was adequate in the 'functional minimum' capsule and was therefore preferred.

The 'basic' capsule won out in the area of direct mounting of external mission equipment to rail supports on the capsule shell. It also could accommodate an extra man or mount a work bench without adding to its external length; a feature not available with the 'functional minimum' capsule.

The 'functional minimum' capsule was thus the preferred capsule. It was the overall winner of this straight scoring system and provided adequate DRM performance at lower costs.

'Direct entry' capsule: The AMRV mission mode requires a crew capsule capable of returning directly to earth from GEO. A concept for this capsule is shown in Fig. 4 5. It is a 'direct entry' version of the selected 'non-entry' capsule i.e., 2 men occupying 'functional minimum' quarters. Its dry weight of 4,400 Kg includes a capsule heat shield, decelerating SRM, parachutes/parawing, landing gear and entry couches for the crew. This compares to a capsule weight of 2775 Kg for the non-entry 'functional minimum' capsule.

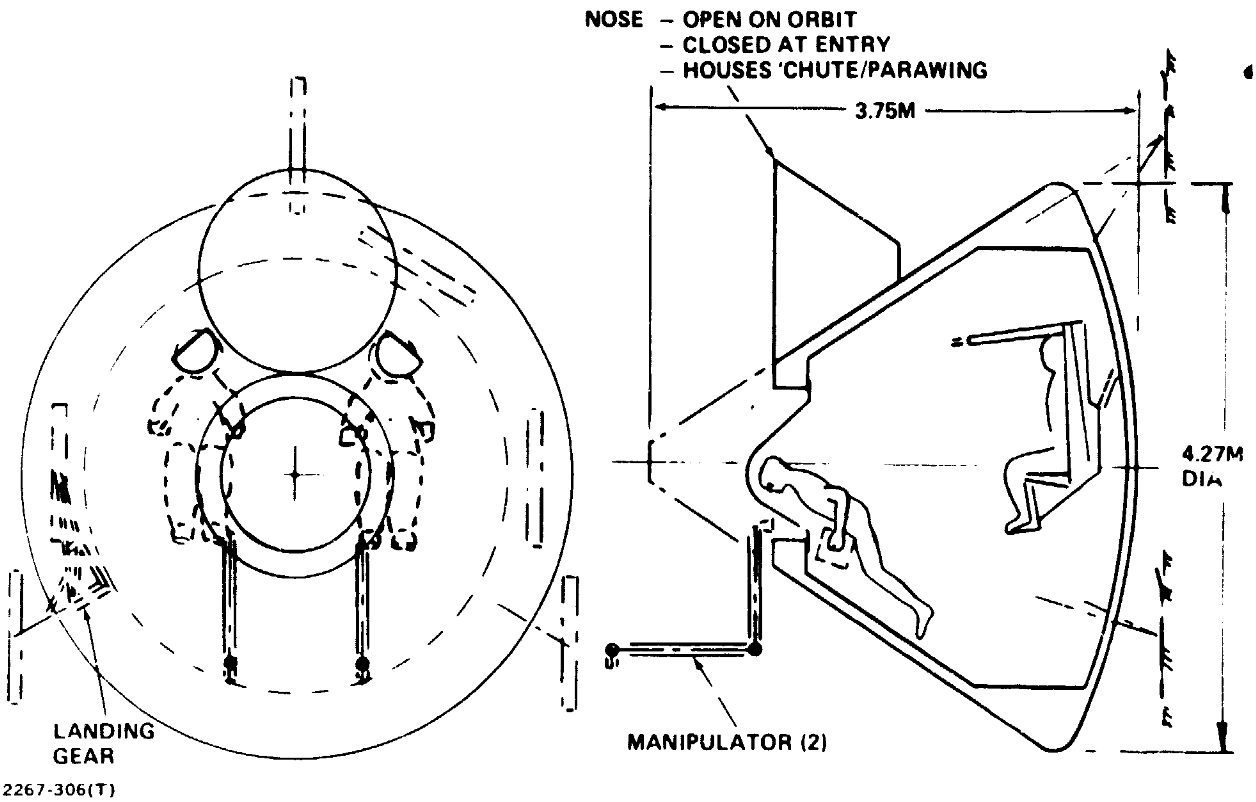


Fig. 4-5 Two-Man "Direct Entry" Crew Capsule – Functional Minimum

Crew Capsule Costs: As an input to the mission modes evaluation, Fig. 4-6 summarizes capsule production and DDT&E costs for 'non entry' and 'direct entry' capsules. The higher costs for 'direct entry' capsule are mainly attributable to its entry and recovery requirements.

4.2 MISSION MODES EVALUATION

After selecting a crew capsule concept the next task in the logic flow was the selection of a preferred mission mode. Four candidates were considered, the APOTV, ABOTV, LABOTV and the AMRV.

Guidelines for this trade were:

ΔV Reqmts:	- To GEO	= 14030 fps All Modes
	- To LEO	= 13816 fps APOTV
		= 6530 fps ABOTV & LBOTV
	- GEO Deorbit	= 8806 fps AMRV
	- LEO Circular	= 7798 fps AMRV Propn. Core
Engine Performance:	- I_{sp} = 458 SEC (RL10 Der 11B)	
Stage Type:	- 1 1/2 Stage Disciplined	
Recovery Modes:	- By STS In LEO (APOTV, ABOTV, LBOTV)	
	- Direct Entry For AMRV Crew Capsule: Propulsion Module Recovered By STS In LEO	
	- Return To SOC	
Payload:	- Picked Up In LEO & Delivered To GEO	

All vehicles were normalized to the 1 1/2 stage disciplined concept to evaluate payload performance. Furthermore, payload was considered to be picked up in the LEO, thus avoiding STS cargo manifest problems.

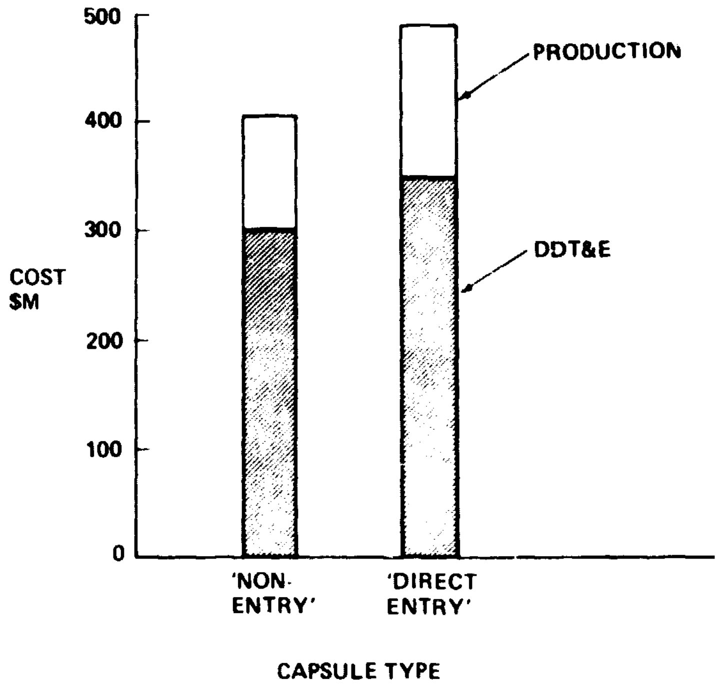


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Fig. 4-6 Crew Capsule Costs: "Non Entry" (AP/AB/LBOTV) vs "Direct Entry" (AMRV) – Two-Man " Functional Minimum" Capsule

Figure 4-7 shows the configuration for each mission mode option at LEO ignition. To reflect the change in number of drop tanks with mission mode, the configurations for ER1 mission at LEO ignition are shown. The ABOTV sketch shows, in phantom, the ballute used to decelerate the vehicle in the upper atmosphere on LEO return from GEO. Similarly, LBOTV shows the lifting brake. Alongside each sketch, a diagramatic representation of the particular mission mode is shown. In all modes except AMRV, a loitering shuttle (dotted line) was assumed waiting in LEO to bring the MOTV back to Earth. With AMRV, the loitering shuttle returns only the propulsion core since the crew would have returned directly to Earth in their direct entry capsule.

Mission mode payload capabilities: Deploy and return trip payload capabilities of the four candidate flight modes are given in Fig. 4-8. Each uses a propulsion core with 17,500 kg propellant capacity and an added drop tank with every subsequent STS launch. Each drop tank carries either 25,416 kg or 26,663 kg of propellant, depending upon other payload cahrgeable items carried by the shuttle. The payload performance quoted includes everything forward of the propulsion core including the crew capsule, mission hardware, etc. the crew capsule etc.

Mission mode costs. Costs for the candidate mission modes vary with mission. Figure 4-9 shows the vehicle costs and costs per mission for mission DRM ER1 flown as an APOTV, an ABOTV, an ABOTV, and LBOTV and an AMRV. Similar sensitivities would be demonstrated for each of the other DRMs. DDT&E deltas for ABOTV and LBOTV mainly reflect the added aeroballute and lifting brake systems. Production costs for all four modes vary by only $34M for two ship sets plus spares. Variation in cost per mission is mainly due to additional shuttle launches for the drop tanks, whose number varies with mission mode.

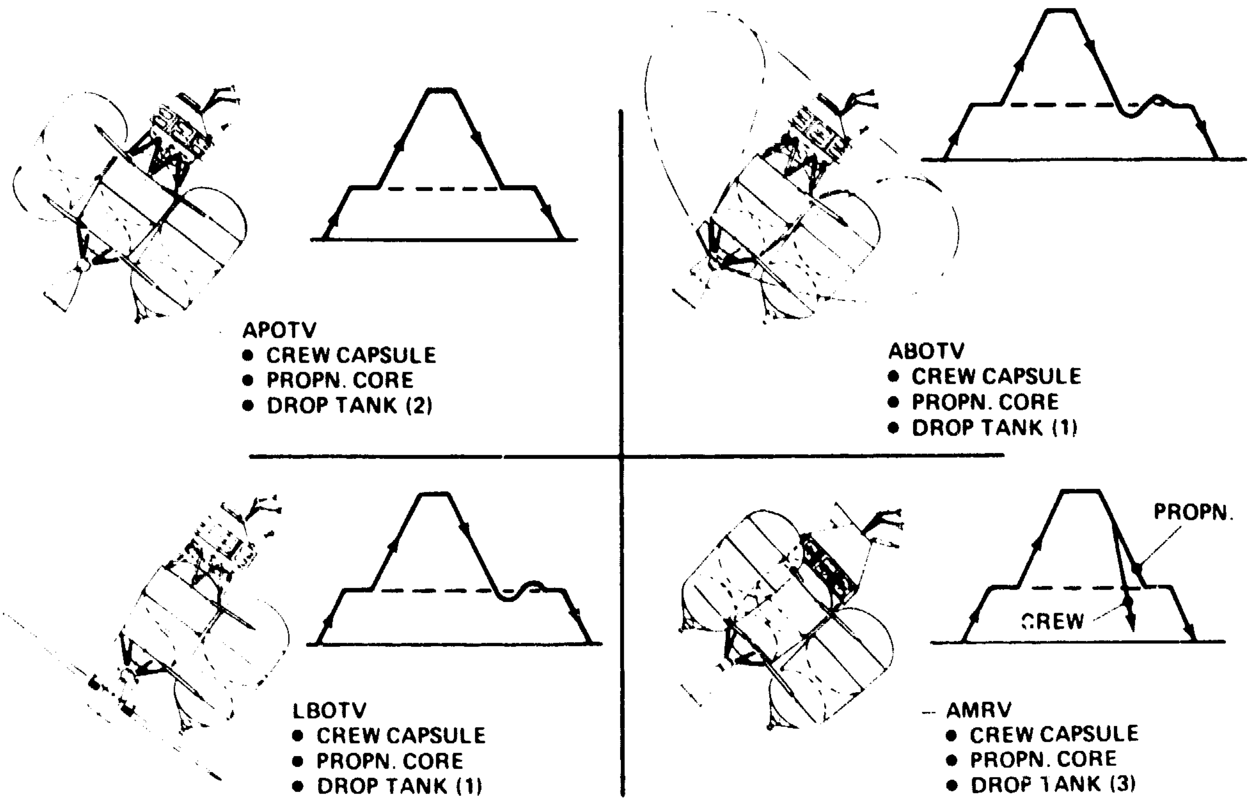
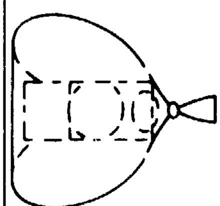
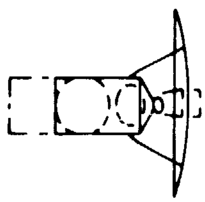


Fig. 4-7 Mission Mode Operations – LEO Ignition Configuration – Mission ER1 (Typical)

GAC CORE DESIGN: W_P = 17,500 kg

NO OF STS LAUNCHES	APOTV 		ABOTV 		LIFTING BRAKE 		AMRV 	
	$W_{PL\text{-}D}$	$W_{PL\text{-}RT}$	$W_{PL\text{-}D}$	$W_{PL\text{-}RT}$	$W_{PL\text{-}D}$	$W_{PL\text{-}RT}$	$W_{PL\text{-}D}$	$W_{PL\text{-}RT}$
1		–	2.64	1.38	0.46	0.24		–
2	11.79	3.93	14.45	9.28	12.67	8.13		–
3	22.74	8.68	25.40	16.31	23.62	15.16	12.32	3.77
4	33.69	13.19	36.35	23.34	34.57	22.20	23.27	7.54
5	44.64	17.48	47.30	30.37	45.52	29.23	34.22	11.09

2267-152(T) D:DEPLOYED RT:ROUND TRIP

ABOTV BEST DEPLOY & ROUND TRIP P.L. TO GEO

Fig. 4-8 Deployed and Round Trip Payload Capabilities (1,000s kg)

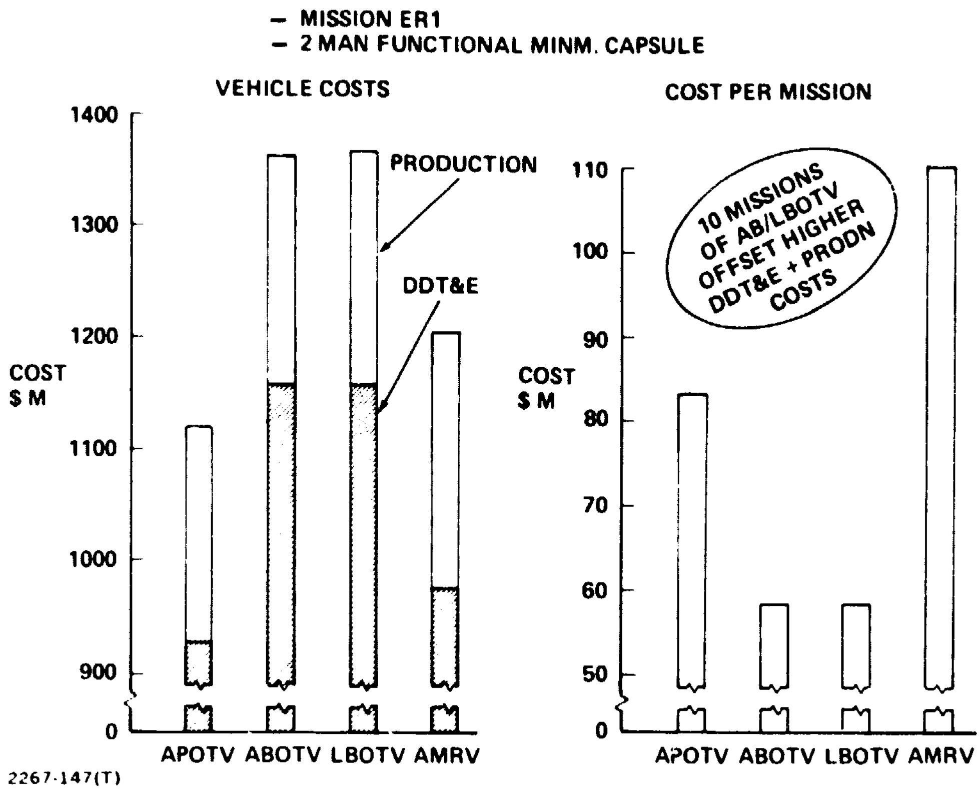


Fig. 4-9 APOTV vs ABOTV vs LBOTV vs AMRV Costs

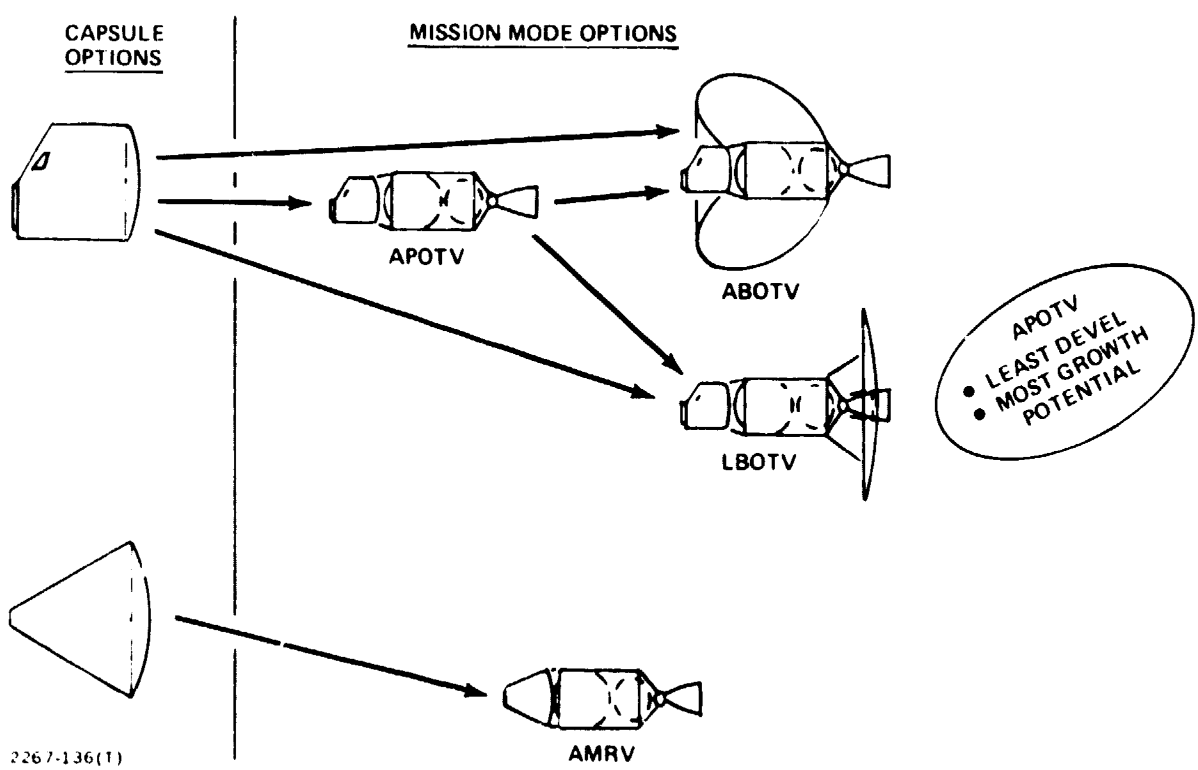


Fig. 4-10 Mission Mode Evolution Possibilities

Compared to APOTV, the higher DDT&E and production costs for AB/LBOTV are recouped within 10 missions.

Evolution: Evolution potential for the various mission modes was also factored into the evaluation. Referring to Fig. 4-10, the 'non-entry' type crew capsule can be used on APOTV, ABOTV or LBOTV, while the 'direct entry' type is of use only on AMRV. APOTV can evolve to ABOTV or LBOTV by merely adding a ballute or lifting brake system. Some upgrading of subsystems, such as GN&C, may also be necessary. AMRV, although it uses the sam propulsion system as the others, requires the special 'direct entry' capsule which is dead ended since it cannot be readily increased in size.

APOTV seems to have the highest growth potential.

Evalution: The criteria used in this evaluation were those which showed some discrimination between mission modes. Many criteria which were originally considered showed equal ranking for all four modes and were, therefore, not included in the evaluation tabulated in Fig. 4-11. Weighting factors were applied to some disciminators to emphasize their importance particularly those affecting safety and costs. The methodology used for this comparison took each mission mode concept and rated it with respect to the others for each discriminator. Each option was given a ranking number (i.e., 1 for first, 2 for second, etc.) with the sum of rankings = 1 + 2 + 3 + 4 = 10 for each evaluation. To determine the score for each mode, the ranking points are subtracted from 5, then multiplied by the weighting factor.

Rankings for payload capability, costs, and evolution were discussed in preceding paragraphs. Safety considers the number of single points failures as the discriminator between modes. In general, it was assumed that all systems and subsystems have redundancy built into them to avoid single point failures. There are, however, some areas where it is impractical to avoid potential single point failures.

DISCRIMINATORS	WTG FACTOR	APOTV RANK	APOTV SCORE	ABOTV RANK	ABOTV SCORE	LBOTV RANK	LBOTV SCORE	AMRV RANK	AMRV SCORE
• PAYLOAD CAPABILITY DEPLOY & R T	1	3	2	1	4	2	3	4	1
• COSTS DDT&E	2	1	8	3 5	3	3 5	3	2	6
PRODN (2 SETS + SPARES)	1	1	4	2	3	3	2	4	1
COST PER MISSION (ER 1)	2	3	4	1 5	7	1 5	7	4	2
• SAFETY SINGLE POINT FAILURES	2	1	8	2 5	5	2 5	5	4	2
• EVOLUTION LEAST DEVEL START	1	1	4	3	2	3	2	3	2
GROWTH POTENTIAL	1	1	4	3	2	2	3	4	1
• TECHN DEVEL MATERIALS	1	1	4	4	1	2	3	3	2
SYS SUBSYS	1	1	4	2 5	2 5	2 5	2 5	4	1
RETURN FLT MODE	1	1	4	4	1	3	2	2	3
• UTILITY GRND TURNAROUND	1	1	4	2	3	3	2	4	1
P L MTG IMPACT	1	1	4	3	2	2	3	4	1
• DEBRIS	1	3	2	2	3	1	4	4	1
			56		38 5		41 5		24

NOTE
SUM OF RANKINGS 1+2+3+4 = 10 FOR EACH DISCRIMINATOR
SCORE = (5 - RANK) x WTG FACTOR

APOTV
• LEAST DDT&E/PRODN COST
• LEAST RISK
• EVOLVABLE

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Fig. 4-11 Mission Modes Evaluation: APOTV vs ABOTV vs LBOTV vs AMRV

These occur mainly in subsystems which provide for deceleration prior to earth entry or LEO circularization. APOTV has two engines for deceleration and, therefore, has no potential single point failures. ABOTV uses a ballute system which has no back-up, nor does the lifting brake of LBOTV. AMRV relies on several systems to get the crew through atmospheric entry to landing including a heat shield, deceleration SRM, parawing, and landing gear.

Considering technology development, the materials discriminator reflects development necessary for deceleration systems and, in the case of AMRV, the heatshield. Compared to APOTV, a more accurate GN&C subsystem is required for ABOTV to control the skip-in the skip out maneuver at entry. The AMRV also has many elements in its entry and recovery system which need to be developed. The practicality of the aeromaneuvering flight return mode still must be investigated seriously and assessed.

Ground turnaround favors APOTV, a self-contained vehicle, followed by ABOTV which requires replacing the ballute; then LBOTV, where the lifting brake has to be inspected and serviced and, finally, the AMRV with its separate return capsule and all of its recovery system to be refurbished. Payload mounting, especially on return, has little problem for APOTV, but aerodynamic forces and c.g. problems present more difficulty for ABOTV and LBOTV. For AMRV, return cargo will be carried either inside the crew capsule or somewhere on the propulsion core for orbiter return.

The APOTV was a clear winner of this evaluation and is recommended as the baseline mission mode, particularly in the early stages of an MOTV program where it posses the least development risk and greatest evolution capability.

4.3 FINDINGS AND RECOMMENDATIONS

- 2 man 'functional minimum' crew capsule is preferred:
  - It can perform all of the DRMs
  - Provides adequate crew comfort (Celentano 'performance' level for missions up to 16 days)
  - Subsystems stowage is adequate for all DRMs
  - Marginally lower costs than the 'basic' capsule
    - \$9M lower DDT&E and production
    - \$0.80M lower cost per mission
- APOTV is the preferred mission mode for early missions:
  - Least development and operational risk
  - Greatest evolution potential
  - For the same number of STS launches, payload capability is
    - Deploy only = 85%-95% of ABOTV/LBOTV
    - Roundtrip = 50%-60% of ABOTV/LBOTV
  - DDT&E and production costs = \$82M lower than AMRV

    = \$240M lower than ABOTV/LBOTV

    Cost per mission = \$1.5M lower than AMRV

    = \$25M higher than ABOTV/LBOTV

Recommendations:

- o Continue definition of ABOTV and LBOTV, and determine impact on crew capsule with respect to aero heating requirements during skip-in, skip out maneuvers
- o Construct a crew capsule mock-up to help resolve habitability questions, work stations layout manipulator operations, and IVA task performance

4.4 EMERGENCY RETURN

The impact of mission abort, in the event of an emergency, was considered as a side issue. Flight mode options which cater to emergency return, are shown in Fig. 4-12. APOTV, ABOTV and LEOTV all use the 'non entry' capsule, therefore APOTV is used as typical. One option with this crew capsule, is to return in normal flight mode to rendezvous with a loitering shuttle. Alternatively, a lifeboat could be provided for direct entry of the crew back to earth if the emergency merits it. The third option is to accept the weight and performance penalties for AMRV and baseline it as the normal flight mode. Here the crew always returns directly to earth from GEO.

There are three postulated classes of emergencies which necessitate immediate return from GEO. First there is a severe solar storm for which it is necessary to descend to below three earth radii to reach safety. In this case, the MOTV would return to earth in its normal flight mode, either to rendezvous with a loitering shuttle (APOTV) or, in the case of AMRV, the crew returns directly to earth.

The current assumption is that subsystems will be designed to be fail operational/fail safe. If there is a malfunction, then the MOTV will abort the mission and return as it would for normal flight. With 'APOTV plus lifeboat' mode, the crew has the option of returning directly in the lifeboat.

In the case of an ailing crewman, the objective would be to get the crewman to Earth as soon as reasonably possible. With APOTV mode, the returning capsule has to return via the loitering shuttle but with a lifeboat included on the APOTV, or with AMRV mode, the crew returns directly to KSC.

Thus, for each of these three categories of emergency, the crew returns via the shuttle or directly

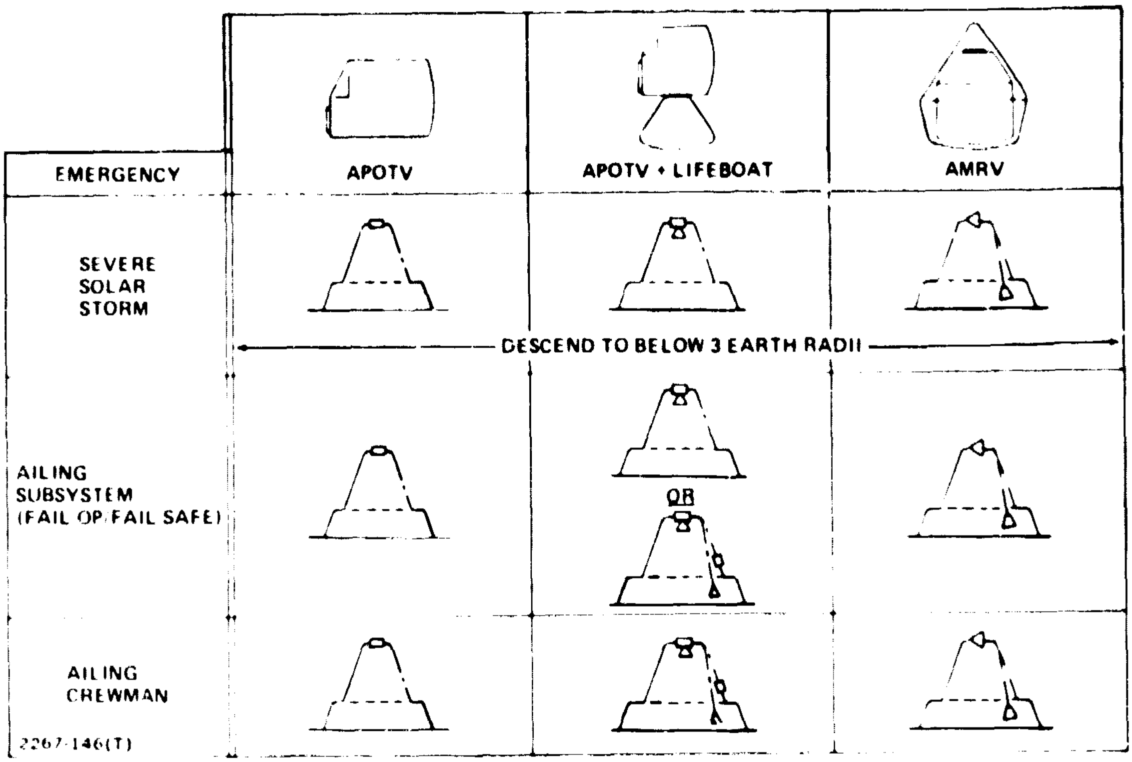

Fig. 4-12 "Emergency Return" Mode Operations

Figure 4-13 lists the requirements for handling each type of emergency. Both concepts can adequately handle any emergency, but the direct return concept can return to the ground twice as fast. However, there are very few emergencies we have identified which requires a fast return, therefore the significance of this additional performance capability is obscure at this time.

Using DRM ER1 as a typical mission, Fig. 4-14 shows costs sensitivities for adding a lifeboat to a 'non entry' capsule and for abandoning APOTV in favor of AMRV. DDT&E deltas reflect, mainly, the costs for developing two capsules in the case of 'APOTV' + Lifeboat' and the costs for entry and recovery systems in the case of AMRV. Production costs deltas follow the same reasoning. Cost per mission variation is mainly due to additional shuttle launches for the drop tanks, whose number varies with mission mode. To provide a lifeboat on each APOTV mission costs an additional $247M for DDT&E and production of two ship sets plus spares. Each flight has an additional cost of $26M. The alternative methods of providing for direct emergency return is to change to an AMRV capsule. Changing from APOTV to AMRV entails cost penalties of $82M for DDT&E plus production and $1.5M per mission.

In summary, APOTV, the baseline concept, is less hazardous than direct return; it is a more comfortable return for an ailing crewman since it pulls less g's; DDT&E and production costs are $82M lower than AMRV, $270M lower than APOTV with lifeboat; cost per mission is $1.5M lower than AMRV and $26M lower than APOTV with lifeboat. However, it takes between 7 hours and 18 hours longer from GEO to ground, dependant on GEO location, but the benefit of this quick return time has not been identified.

It is recommended, therefore, that APOTV be retained as the baseline, and carry no penalty for emergency return.

TYPE OF EMERGENCY	REQUIREMENT	TIME TO RETURN-WORST CASE	
		CAPSULE RETURN TO ORBITER	CAPSULE DIRECT TO EARTH
SEVERE SOLAR STORM	3-5 HR WARNING ABORT TO < 3 Re WITHIN 6 HR	< 3 Re IN 6 HR*	< 3 Re IN 6 HR
SEVERE CREW ILLNESS/ACCIDENT	RETURN TO STS OR EARTH ASAP	22.6 HR TO STS	10.6 HR TO EARTH
VEHICLE FAILURE	RETURN TO STS OR EARTH ASAP	22.6 HR TO STS	10.6 HR TO EARTH
*REQUIRES BACKUP STS LAUNCH			

Fig. 4-13 Capability of Mode Concepts to Handle Life Threatening Emergencies

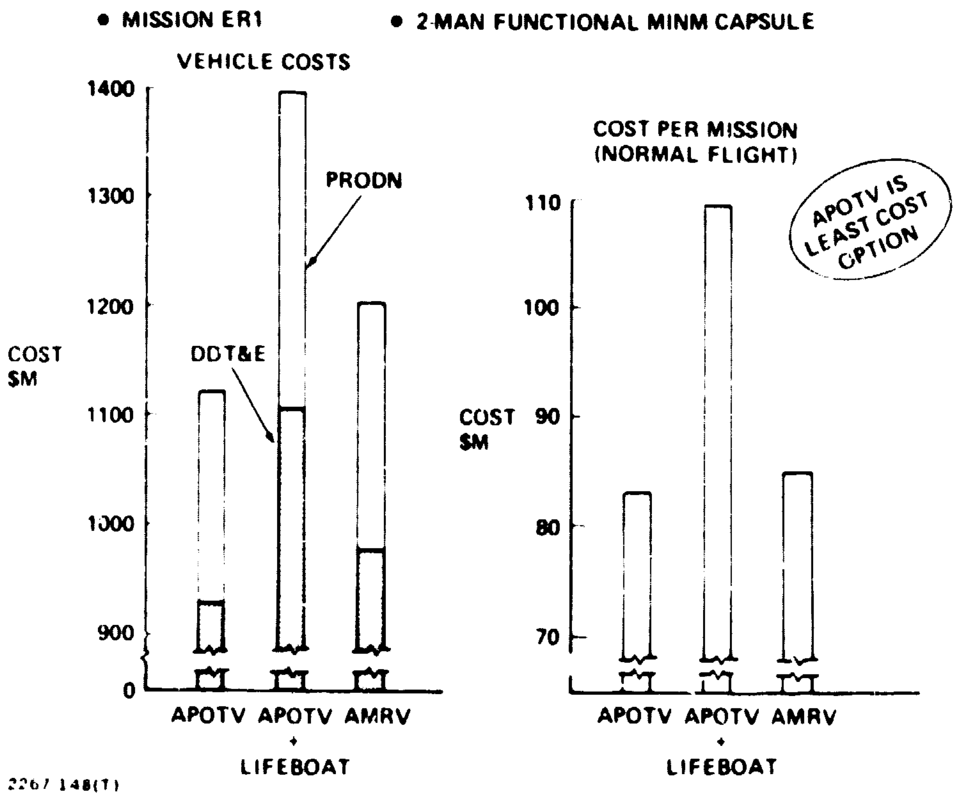

Fig. 4-14 Cost for Providing Emergency Return Capability – APOTV vs APOTV/Lifeboat vs AMRV

5 - POTENTIAL APPLICATIONS

The twenty generic missions, defined at the beginning of the main study, form the nucleus of potential applications for the MOTV. The five Design Reference Missions, selected from those twenty, were studued in some detail, as reported earlier in this summary. Weights, performance capability and costs were derived during the extension study for each of the DRMs.

To typify these results, DRM ER1 is given here in some detail using the baseline APOTV with a two man crew capsule. Figure 5-1 is a summary of the MOTV weights for that mission, broken down into component parts of the vehicle. The weights include 25% contingency on crew capsule related items and 15% on propulsion items. Using these weights, Fig. 5-2 shows a weight and ΔV budget history for the mission. The total ΔV is 28,535 fps including 2% for flight performance reserves. Two MOTV drop tanks, plus core stage, are required to accomplish this mission, supported by three STS launches to get the total vehicle to LEO, assuming ground turnaround. The first drop tank is depleted and jettisoned during transfer to GEO. The second tank is depleted during circularization burn at GEO but is retained until after de-orbit burn, when it is jettisoned to be burned up in the atmosphere.

Figure 5-3 shows a breakdown of the estimated cost of DRM ER1. It is broken down into the component parts of the vehicle. DDT&E and production costs have not been amortized over the operational flights because no traffic model is available. Such a model would enable the sharing of STS flights, thus potentially reducing costs significantly. Costs given in this table reflect charges for whole numbers of STS flights.

	CREW CAPSULE	PROPULSION CORE	DROP TANKS (2)	MISSION EQUIPT GENERAL PURPOSE	MISSION EQUIPT DEDICATED
DRY WEIGHT	2775	3087	2950	631	408
CREW/CONSUMABLES RESERVES/RESIDS	277	175 296	470		
BURNOUT WEIGHT	3052	3558	3420	631	408
MAIN PROP – (CAPACITY) LOADING		(17,500) 17,500	(54,540) 34,004		
ACPS PROP MISC		875 145			95
MOTV WEIGHT	3052	21,878	37,424	631	503
TOTAL MOTV WEIGHT	63,488				

Fig. 5-1 ER1 Summary Weight Statement, kg

• APOTV MISSION MODE

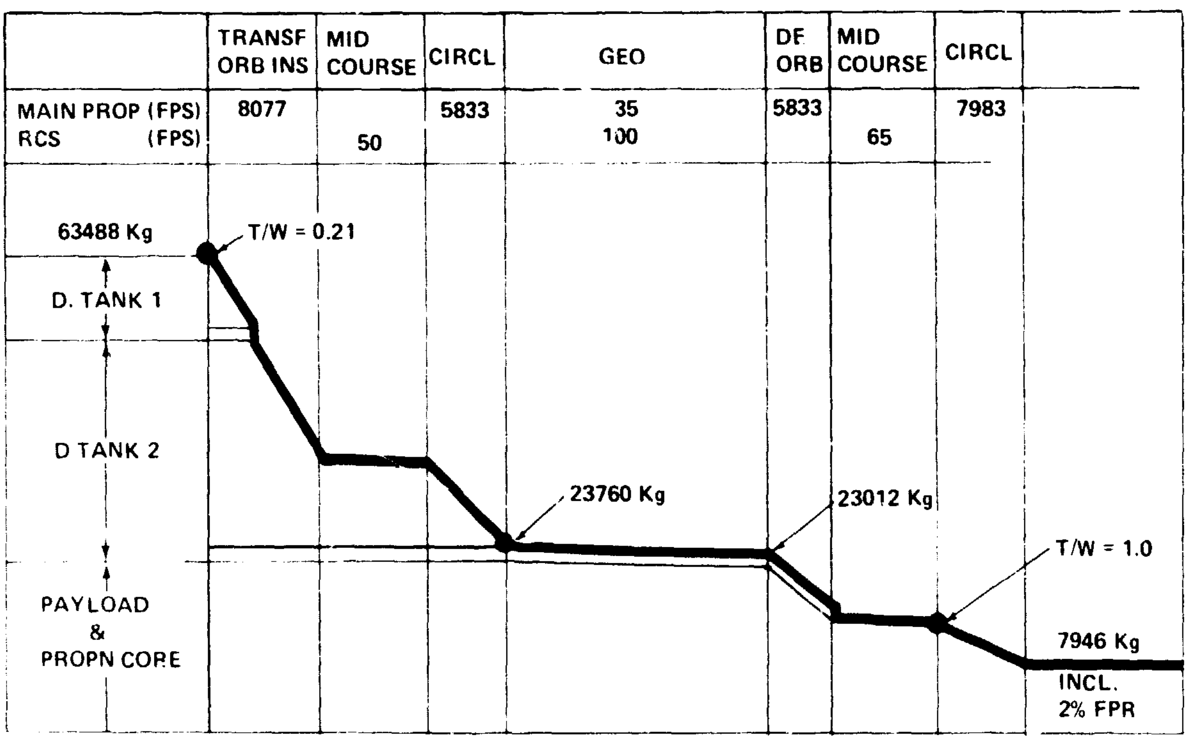

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Fig. 5-2 DRM ER1 – Performance

The information given above for DRM ER1, was also derived for the other four DRMs. This is summarized in Fig. 5-4 which presents data for all five DRMs.

Although the main thrust of the study and this extension was to consider manned missions, performance of the baseline APOTV as an unmanned vehicle can be obtained from Fig. 4-8. The payload capabilities quoted are for the OTV propulsion system alone. It should be borne in mind that the propulsion core is optimumly sized for the generic manned missions and its propellant capacity of 17,500 Kg reflects what is available from a single STS launch of propulsion core, crew capsule and mission equipments. Also, the propulsion core weight is penalized by being designed to carry four drop tanks. A vehicle designed specifically as a single stage for unmanned payloads would show better performance capabilities.

	CREW CAPSULE	PROPULSION CORE	DROP TANKS (2)	TOTALS
MANAGEMENT				0.08
CREW PROVISIONS	0.01			0.01
TURNAROUND				2.20
FUEL		0.03	0.06	0.09
DROP TANKS			3.38	3.38
MISSION OPS				1.80
OPS SPARES	0.60	0.40		1.00
STS OPS				74.40
TOTAL				82.92

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Fig. 5-3 ER1 – Cost per Mission ('79 $M)

DESIGN REF. MISSN	ORBIT	CREW	DURATN. (DAYS)	PAYLOAD REQUT. (kg)*		TOTAL ΔV (FPS)**		VEHICLE WT (kg)		NO. STS LAUNCH	EST. CPM $M
				DEPLOY	RETURN	MAIN	RCS	IGNITN.	BURN OUT		
• SERVICE – S1	GEO	2	19	2227	2227	29912	586	90540	8254	4	119.7
• REPAIR											
– ER1	GEO	2	4	1072	977	28316	219	63488	7649	3	82.92
– ER2	12 HR/63°	2	4	1756	1679	20058	214	36046	8291	2	56.84
• DEBRIS REMOVAL – DR1	GEO	2	9	824	824	29850	484	71054	7629	3	86.0
• CONSTRN – C3	GEO	2	6	18136	1136	28555	219	116551	8200	4	135.73

* THIS COMPRISES MISSION HARDWARE & EQUIPMENT

** INCLUDES 2% FLIGHT PERFORMANCE RESERVES

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Fig. 5-4 Performance Data for Five DRMs

6 - OTV/MOTV GROUND TURNAROUND

Figures 6-1 and 6-2 illustrates the ground turnaround scenario developed for the OTV/MOTV. The ground turnaround activity for this baseline turnaround mode is illustrated in Fig. 6-1. After being removed from the Orbiter in the OPF, the returning Core Manned Module (CMM) is put in a horizontal cannister. The cannister is routed directly to the OTV/MOTV Payload Processing Facility (PPF) for complete maintenance operations. At the PPF the crew module is demated and processed on a horizontal workstand. The propulsion core module is processed in a vertical work stand. For OTV flights the propulsion core module is taken to the VPF and integrated with other STS cargo in the vertical Cargo Integration Test Equipment (CITE). For MOTV flights the crew and core module are taken separately to the VPF and integrated in the vertical CITE. In either case the propulsion core module is fueled on the pad in parallel with STS fueling operations.

Figure 6-2 shows the prepellant tank assembly operations required at LEO to prepare an MOTV for an S1 generic mission to GEO. The first sequence shows the crew/core module being deployed at LEO. The altitude stabilization system incorporated in the crew/core module will be used to stabilize the vehicle. The next sequence shows the second tank being installed. The same operations are required for the second as for the first tank, which is not illustrated. These operations include: capture of the core/crew module, placing it and securing it to the berthing ring, installing the drop tank carried in the cargo bay of the Orbiter, checking out the interfaces (mechanical and functional) and deploying the configuration. This sequence is repeated for the last drop tank installation. The final tank assembly includes a crew transfer after the interfaces have been checked. Once the crew is aboard they will activate the MOTV systems and make final mission checks prior to transferring to GEO.

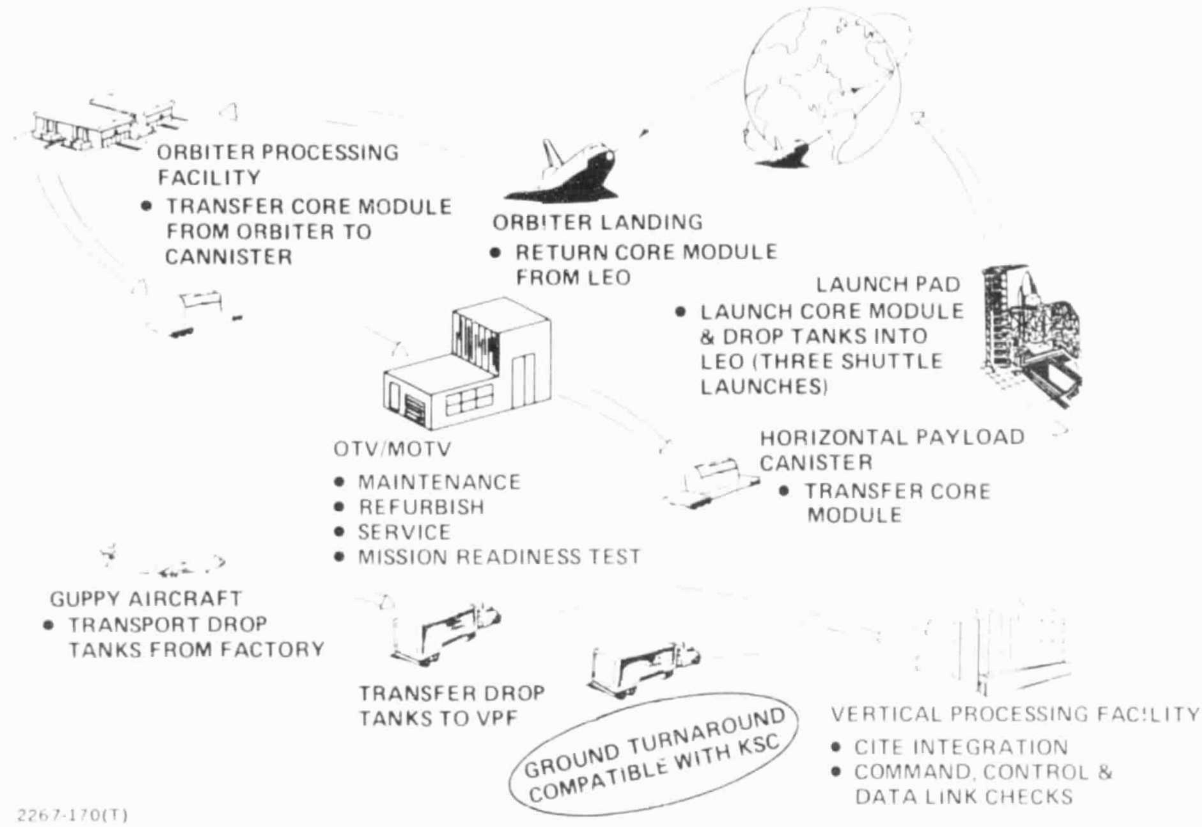

Fig. 6-1 OTV/MOTV Ground Turnaround Activity

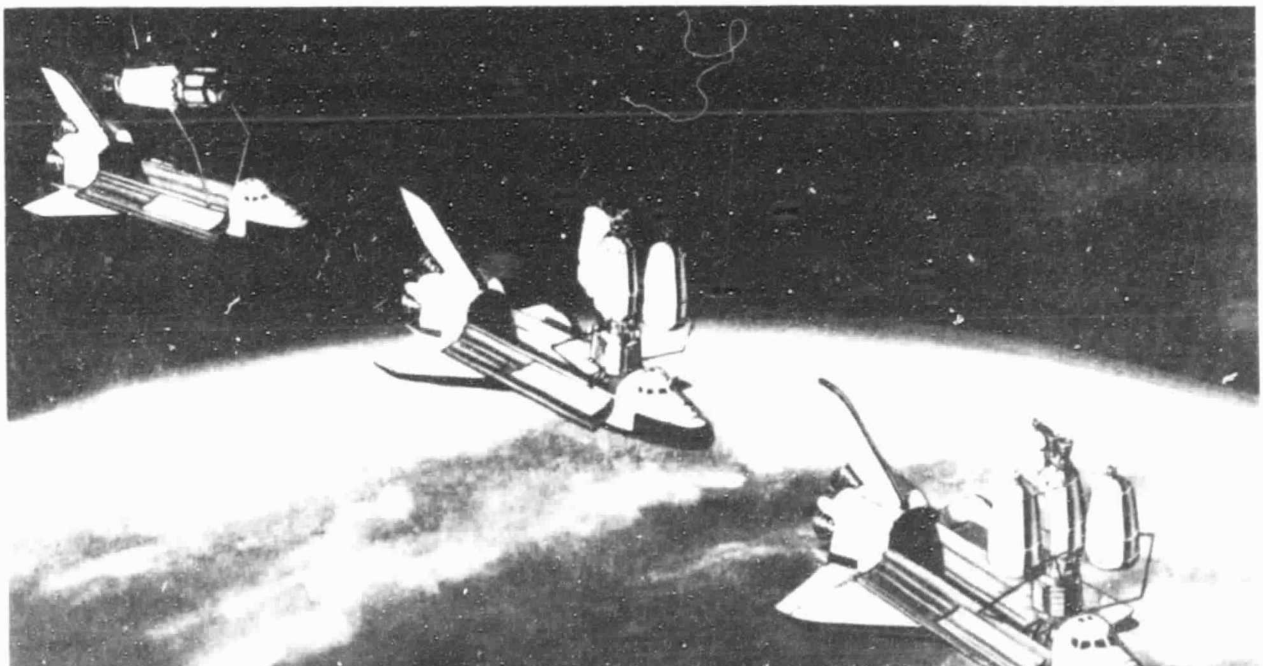

Fig. 6-2 MOTV Assembly Sequence

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Detail functional flows, timelines, and manpower estimates for this baseline turnaround mode were developed and analyzed relative to total time, manpower, GSE/facility requirements, and sensitivities.

The extension study concentrated on developing a turnaround scenario for a space based (SOC) MOTV. Figure 6-3 is an artist's rendering of a SOC MOTV turnaround facility used to evaluate space based operations. It would include work platforms, berthing capability, logistics modules and drop tank plus crew core modules work stands. The ground rules listed below were established to provide consistency in evaluating the ground and space based options. The costing groundrules were obtained from JSC. The EVA/IVA conversion factors used in the analysis were derived from Space Lab and other data, plus discussion with the JSC crew training personnel. The engine life between overhaul of 8 missions per engine were derived based on mission engine firing requirements and the engine manufacturer's projected engine life of 5 hours between overhaul.

- o Man working on the ground is the baseline - his rate is $30/wk hr
- o For SOC on-orbit IVA operations; man hours are 1.1 x the baseline & cost is $900/wk hr
- o For routine EVA operations; man-hours are 3 x the baseline & cost is $2400/wk hr
- o For EVA non-routine operations; man-hours are 5 x the baseline & cost is 16,000/wk hr plus a fixed cost of $96,000
- o OTV/MOTV IOC is 1992; OTV/MOTV flt rate = 3/1; OTV traffic will build up from 3 - 5 flt in 5 yr
- o Cost Per Shuttle flt in '79 $ = 23.8M; shuttle on-orbit costs is 500 k/day
- o SOC crew size is 8 men with 2 men reqd for housekeeping & 6 men available for other activities

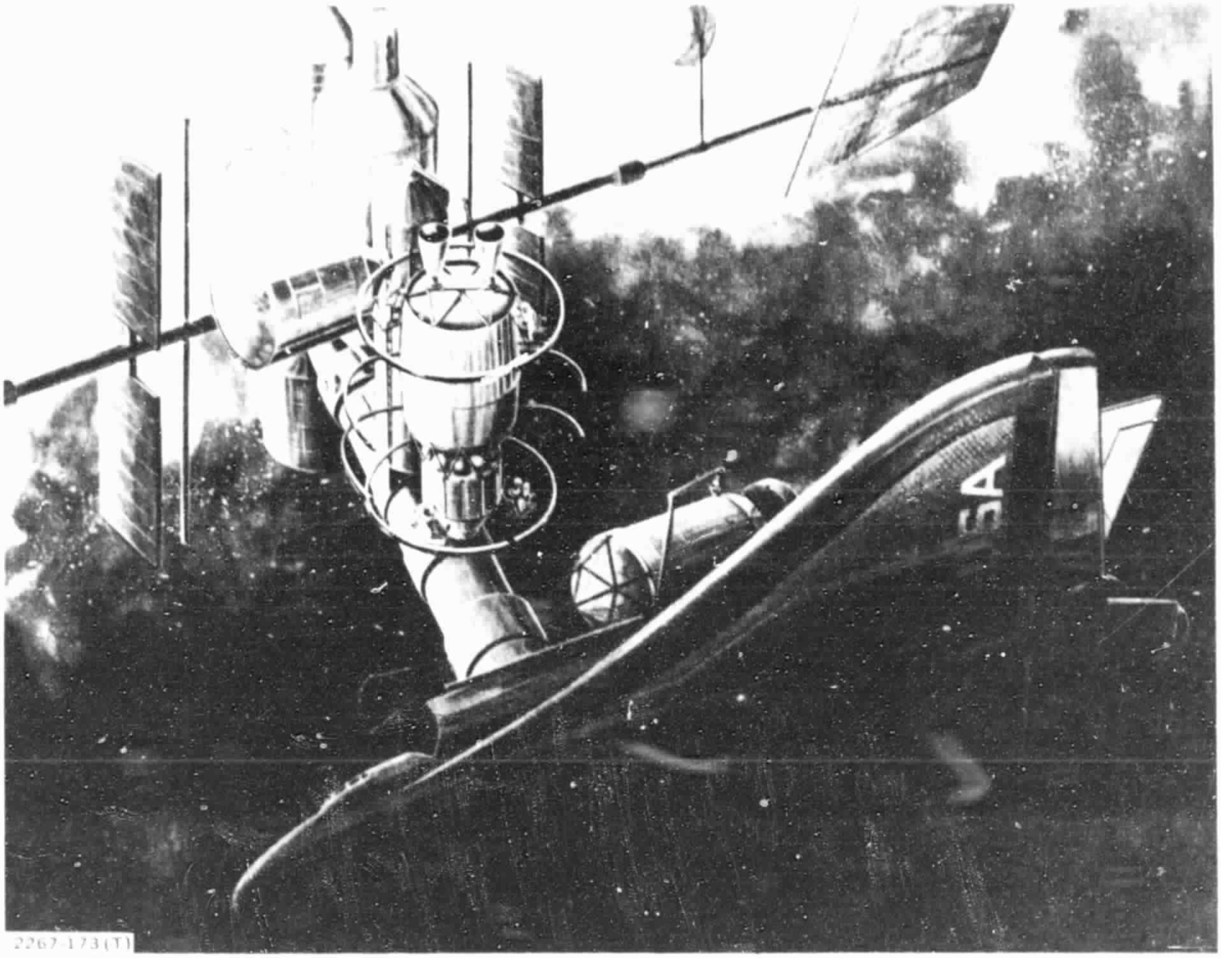
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Fig. 6-3 SOC MOTV Turnaround Facility

- o SOC and MOTV crew/propulsion module design will facilitate SOC operation
- o Engine good for 8 missions between overhaul

Using these groundrules functional flows were developed and analyzed for the turnaround options listed in Fig. 6-4. These included: turning the crew module around at SOC and the propulation module on the ground, the amount of maintenance required for routine and overhaul operations, use of a pressurized hangar at SOC, and a mix of ground vs SOC operations. The optimum mix was found to utilize SOC for turning around the OTV/MOTV flights as often as possible providing minimum maintenance as required and use ground turnaround for labor intensive maintenance or modifications of the MOTV.

Figure 6-5 translates the conclusions reached during our study to a projected traffic scenario. Operationally, it answers the question, "How would we expect to handle the projected OTV/MOTV flights?" The traffic scenario assumes a 1992 IOC; a 3/1 ratio of OTV to MOTV flights and a 3/1 ratio of short duration mission (ER1 type); to long duration (S-1 type) - and a gradual build-up from 3 to 6 flights in 4 years. For this scenario we propose to perform:

- o Post Flight (PF) Only - Safety & damage inspection, service and go - on every flight at SOC
- o Periodic - PF plus limited maintenance - on every fourth flight at SOC
- o Overhaul - Complete inspection, performance checks, calibration of sensors, change out of limited life (include engine) and sensors - on the ground

This mix of GND/SOC turnaround activities is recommended because it makes use of SOC for routine and non-labor intensive tasks to reduce the degree of shuttle support required. Figure 6-6 illustrates the turnaround savings acrued with the recommended ground/SOC mix based on the assumed traffic model. It summarizes the turnaround operational recurring costs for both the "ground based only" and the recommended GND/SOC mix on a yearly and cumulative basis. For this rather

OPTION \ LOCATION OF ACTIVITY	GND	SOC
1 VEHICLE CONFIGURATION		
– COMPLETE MOTV	X	X
– PROPULSION CORE MODULE	X	X
– CREW MODULE	X	X
2 AMOUNT OF MAINTENANCE		
– BARE MINIMUM – GAS & GO – (PRE FLT)		X
– MINIMUM SCHED/UNSCHED (PERIODIC)		X
– COMPLETE MAINT & OVERHAUL	X	
3 SOC MAINT WITH/WITHOUT PRESSURIZED HANGAR		X
4 GND/SOC MIX	X	X

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Fig. 6-4 MOTV Turnaround Maintenance Options

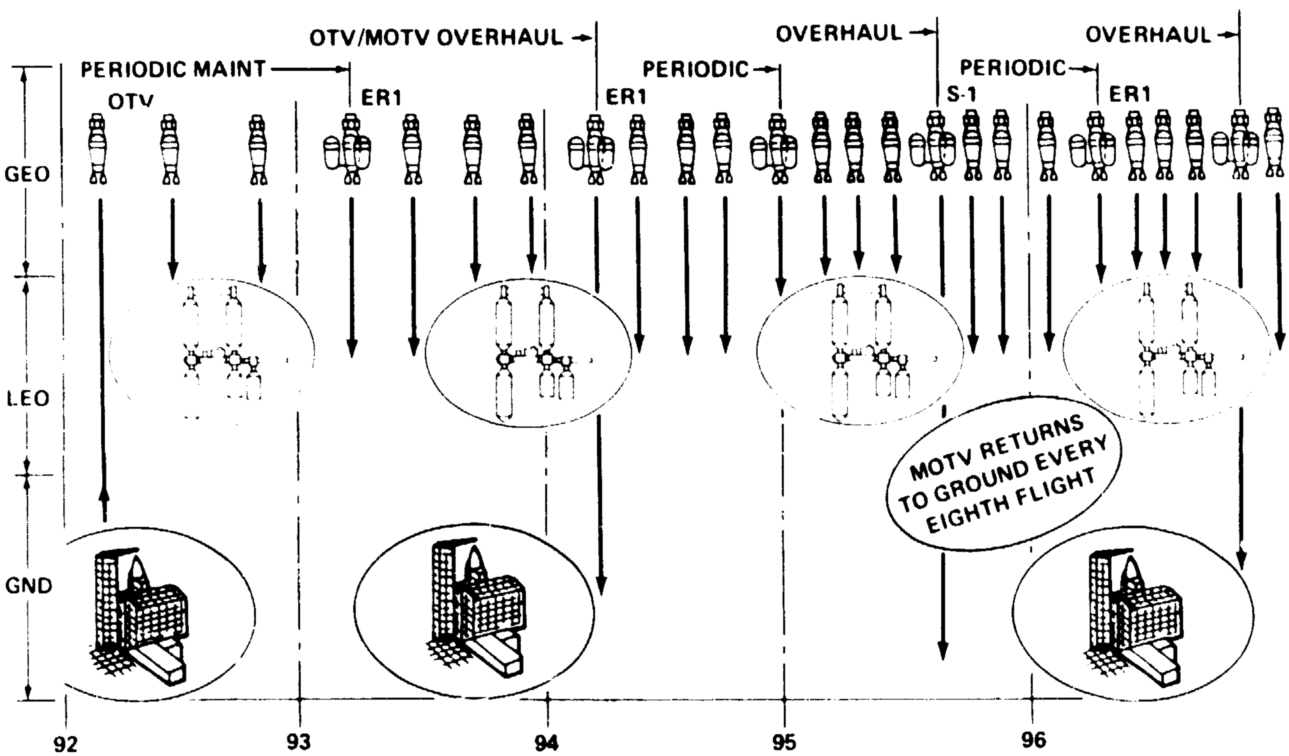

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Fig. 6-5 Ground/SOC Turnaround Mix – Option 4 Traffic Scenario

YEAR	1992	1993	1994	1995	1996
NO. OF MISSIONS PER YEAR	3	4	5	6	6
COST MIX PER YEAR M S	72	135	225	184	184
GND	78	148	255	200	200
CUMULATIVE MIX COSTS M S	72	207	432	616	800
GND	78	226	481	665	865

Fig. 6-6 Cumulative Recurring Costs for SOC/GND Mix vs Ground Turnaround

conservative traffic model a savings of $300M is achieved over a five year period which breaks down to an average of $62M/year or $13M/flight. Although the actual dollars saved is traffic sensitive the recommended ground/SOC mix will always provide a net savings.

Our analysis also indicated that a pressurized hanger could further enhance SOC operation. Figure 6-7 shows the effect on manhours of a pressurized hangar maintenance at SOC. As indicated, the pressurized hangar reduces the manhours significantly - approximately 50%. The reduction reflects the efficiency of the IVA vs EVA to accomplish maintenance tasks at LEO. Since manpower costs are a recurring operational liability, the pressurized hangar is a viable consideration for SOC and should be investigated further.

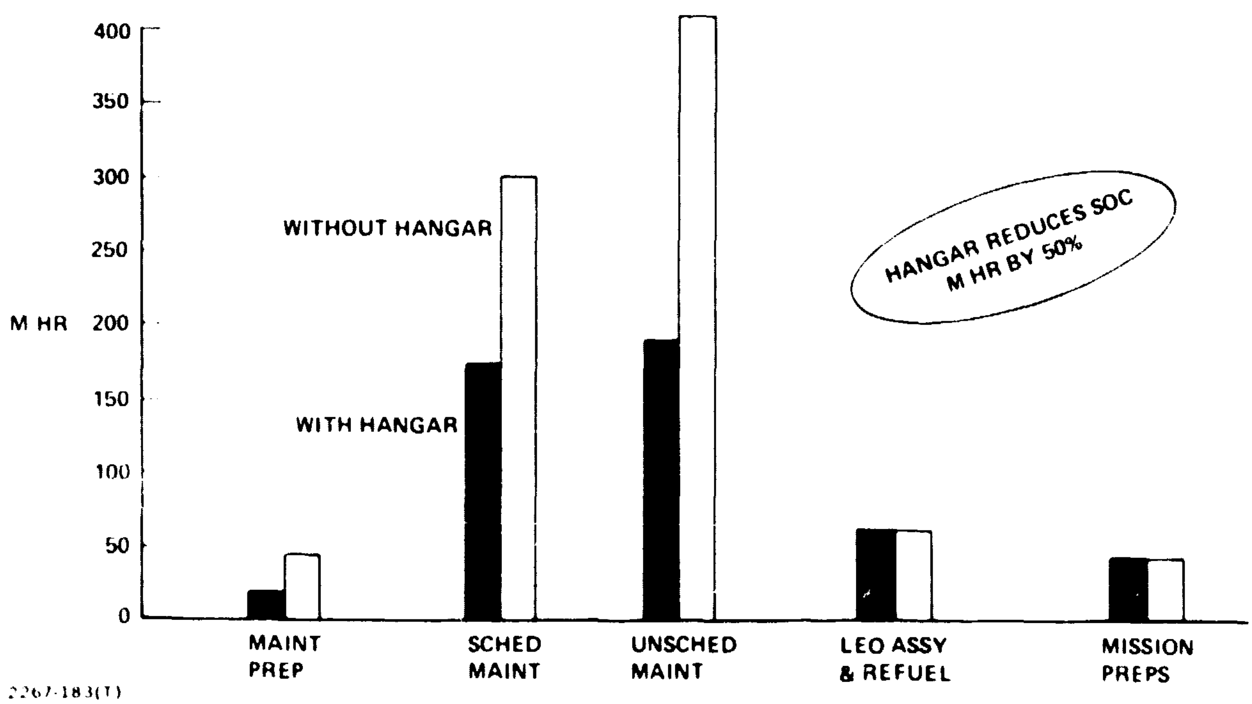

Fig. 6-7 SOC Pressurized Hangar-Option