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VEHICLE (MOTV). VOLUME 3: PROGRAM
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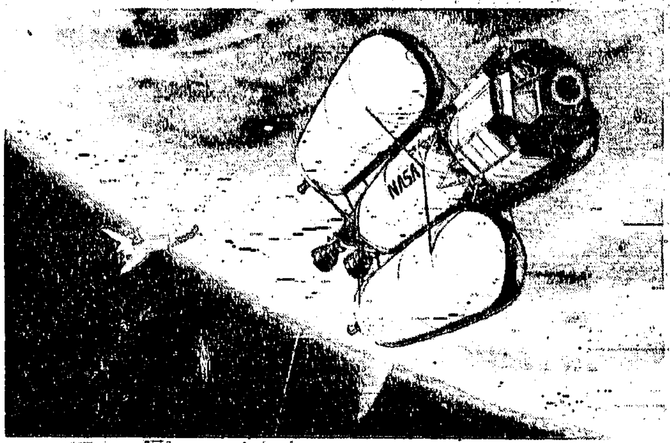
MANNED ORBITAL TRANSFER VEHICLE (MOTV)

volume 3

program requirements document



GRUMMAN AEROSPACE CORPORATION

MANNED ORBITAL TRANSFER VEHICLE (MOTV)

volume 3
program requirements document

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

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Bethpage, New York 11714

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Contents

Contents (Contd)

FOREWORD

This final report documents the results of a study performed under NASA Contract 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. Lester K. Fero, NASA Headquarters, Office of Space Transportation Systems, Advanced Concepts, was the cognizant representative of that agency.

The Grumman Aerospace Corporation's study manager was Charles J. Goodwin. The major contributors and principal investigators were Ron E. Boyland, Stanley W. Sherman and Henry W. Morfin.

This final report consists of the following volumes:

- Executive Summary - Volume 1
- Mission Handbook - Volume 2
- Program Requirements Document - Volume 3
- Supporting Analysis - Volume 4
- Turnaround Analysis - Volume 5
- Five Year Program Plan - Volume 6

INTRODUCTION

Development of the Shuttle provides the opportunity for the imaginative and aggressive exploitation of space for the benefit of mankind. Practical utilization of space requires manned low earth orbit and geosynchronous earth orbit mission for construction, servicing, repair and operation of communications, solar power and earth observation satellites. This document defines the requirements for a manned system necessary to extend man's mission capability to geosynchronous orbit.

The document is structured "top-down" starting with program requirements, followed by mission, system and subsystem requirements. The rationale and/or source for each requirement is identified by a reference number to the left of the requirement. Appendix A contains the full title page and paragraph reference.

This document reflects the requirements developed for the MOTV during the performance of the Manned Geosynchronous Mission Requirements And Systems Analysis Study (MGMRSAS), Contract NAS 9-15779. The requirements fall into three general categories:

(1) Well established requirements

(2) "Soft" requirements which require further analysis
  - An asterisk (*) is used to identify these.

(3) TBD values.

1 - PROGRAM REQUIREMENTS

This section contains the program requirements for the MOTV derived from the contract Statement of Work (SOW) guidelines and discussions with the NASA Program office.

1.1	The Manned Orbital Transfer Vehicle (MOTV) shall provide the necessary manned capability associated with the inspection, servicing, repair modification as well as construction of large geospace systems such as communications, solar power and earth observation satellites.	SOW (A/1.0/-)
1.2	The MOTV will include a manned module element, an orbital transfer propulsion element and a mission turnaround support system.	
1.3	Initial MOTV configurations will utilize the Space Shuttle Transportation System (STS) including available launch facilities.	SOW (A/4.3/-)
1.4	Evolutionary concepts may utilize projected growth versions of the STS and projected propulsion units.	SOW (A/2.0/-)
1.5	Existing OTV propulsion concept definitions supplied by NASA will be utilized.	
1.6	The MOTV will integrate crew habitation and safety requirements with other mission related functional requirements.	SOW (A/4.3/-)
1.7	Crew sizing and accommodations shall be determined by the satellites being serviced.	SOW (A/4.5/-)

REQUIREMENTS		RATIONALE/SOURCE
1.8	General purpose MOTV Payload equipment shall be determined by the common satellite functions required.	A/4.7-
1.9	Missions will be of relatively short duration with no requirement for a permanent space habitation structure.	SOW A/4.6/-)
1.10	MOTV evolution shall minimize peak annual spending.	A/2.6/-
1.11	The MOTV IOC date shall be 1988.	SOW (A/4.8/-)

2 - MOTV MISSION REQUIREMENTS

MOTV Mission shall emphasize manned GEO sortie missions and consider the following functions:

- Inspection
- Checkout
- Deployment
- Manufacture
- Processing
- Assembly
- Construction
- Rendezvous
- Docking/Berthing
- Servicing
- Maintenance
- Repair
- Retrieval
- Equipment Operation
- Passenger Transport
- Cargo Transport

2.1 REFERENCE GENERIC MISSIONS

The MOTV shall be capable of supporting the generic missions listed in Table 2-1, i.e.,

- Inspection, Service & Repair
- Operation of a Large Space System
- Debris Removal
- Construction
- Unmanned Cargo

MOTV Mission Handbook

RFP List Survey References

MGMRSAS Data Package 1.1

2.1.1 Generic Missions Characteristics

The MOTV shall accommodate the generic mission orbits, crew sizes, and durations, defined in Table 2-1.

2.1.2 Orbit

The MOTV shall be capable of operating in earth orbit space primarily between the altitude of 200 and 40,000 km, at any inclination. The primary orbit of operation shall be GEO. Other oribts of interest include 12 hr/63° elliptic orbit and a deep space circular 400,000 n mi orbit.

MOTV Mission Handbook

GENERIC MISSION		SCENARIO CHARACTERISTICS				
CATEGORY	SYMBOL	ORBIT	MISSION HDWR (kg)	CREW	DURATION (DAYS)	DESCRIPTION
INSPECTION SERVICE & REPAIR	IN1	GEO	610	2	4	SCIENTIFIC SATELLITE REVISIT
	$\boxed{\text{S1}}$	GEO	1884	3	19	MODULAR LEVEL SERVICE
	S2	GEO	2866	3	27	COMPONENT LEVEL SERVICE & UPDATE
	S3(a)	GEO	2600	2	21	SERV & UPDATE NUCL PWRD SATS
	(b)	GEO	2000	2	3	REPLACE NUCL REACTOR
	ER1	GEO	453	2	4	EMERGENCY REPAIR (GEO)
	$\boxed{\text{ER2}}$	12 HR/63	272	2	4	EMERGENCY REPAIR (HEO)
	R1	12 HR/63	4100	3	2	FAILED SATELLITE
OPERATION OF A LARGE SPACE SYSTEM	OP1	GEO	660	2	16	TENDED STO
	P1	GEO	1663	2	4	3 MAN CREW ROTATION/RESUPPLY
	$\boxed{\text{P2}}$	GEO	4486	2	4	10 MAN CREW ROTATION/RESUPPLY
	P3	GEO	16,819	2	4	30 MAN CREW ROTATION/RESUPPLY
	$\boxed{\text{P4}}$	DEEP SPACE	3364	2	30	6 MAN CREW ROTATION/RESUPPLY
DEBRIS REMOVAL	$\boxed{\text{DR1}}$	GEO	5500	2	9	REMOVE DEBRIS FROM A 45° SECTOR OF GEO
CONSTRUCTION	C1	GEO	10,000	2	3	UNFOLD WIRE WHEEL ANTENNA
	C2		16,000	3	6	UNFOLD COMMUN PLATFORM
	$\boxed{\text{C3}}$		17,000	3	6	PREFAB COMMUN PLATFORM
	C4		15,000	3	7	AUTOFAB COMMUN PLATFORM
	C5		110,536	3	14/6/6/6	AUTOFAB SPDA
	$\boxed{\text{C6}}$		--	2	17	MODULAR ASSY SPDA
UNMANNED CARGO	UC	VARIOUS	16,000 65,000	NONE		SECONDARY ROLE

1776-406W

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

☐ SELECTED FOR DETAILED STUDY

Table 2-1 Generic Missions

REQUIREMENT		RATIONALE/SOURCE
2.1.3	Mission Payload Requirements	
	Payload requirements are defined as those weight, and volume requirements, above the MOTV propulsion module. Fig. 2-1 identifies those requirements for each generic mission. Standard weights and crew cabin volume requirements from which these requirements are derived are shown in Fig. 2-2 and Table 2-2.	Fig. 2-1
2.1.4	Orbit Phasing Requirements	
	MOTV orbit phasing expendable weight requirements are specified in Fig. 2-3 for a nominal mean on-orbit weight of 30,000 kg.	Fig. 2-3
2.1.5	Mission Duration, Crew Size & Skills	
2.1.5.1	Mission Duration - Shall support the generic mission timelines specified in Table 2-1 for on orbit, orbit phasing, LEO operations and transfer times.	MGMRSAS Mid Term Review (Phase I)
2.1.5.2	Crew Size - Shall vary between 2 and 3 persons except for crew rotation/resupply missions requiring a crew of two, with passengers, see Table 2-1.	Table 2-1
2.1.5.3	Crew Skills - Include pilot, co pilot and mission specialists per Fig. 2-4.	Fig. 2-4
2.1.6	Mission Equipment Requirements	
2.1.6.1	Equipment - Major common support equipment for the various generic missions are listed in Table 2-3.	Table 2-3
2.1.6.2	Tools - Typical candidate tools common to servicing and construction missions are listed in Table 2-4.	Table 2-4

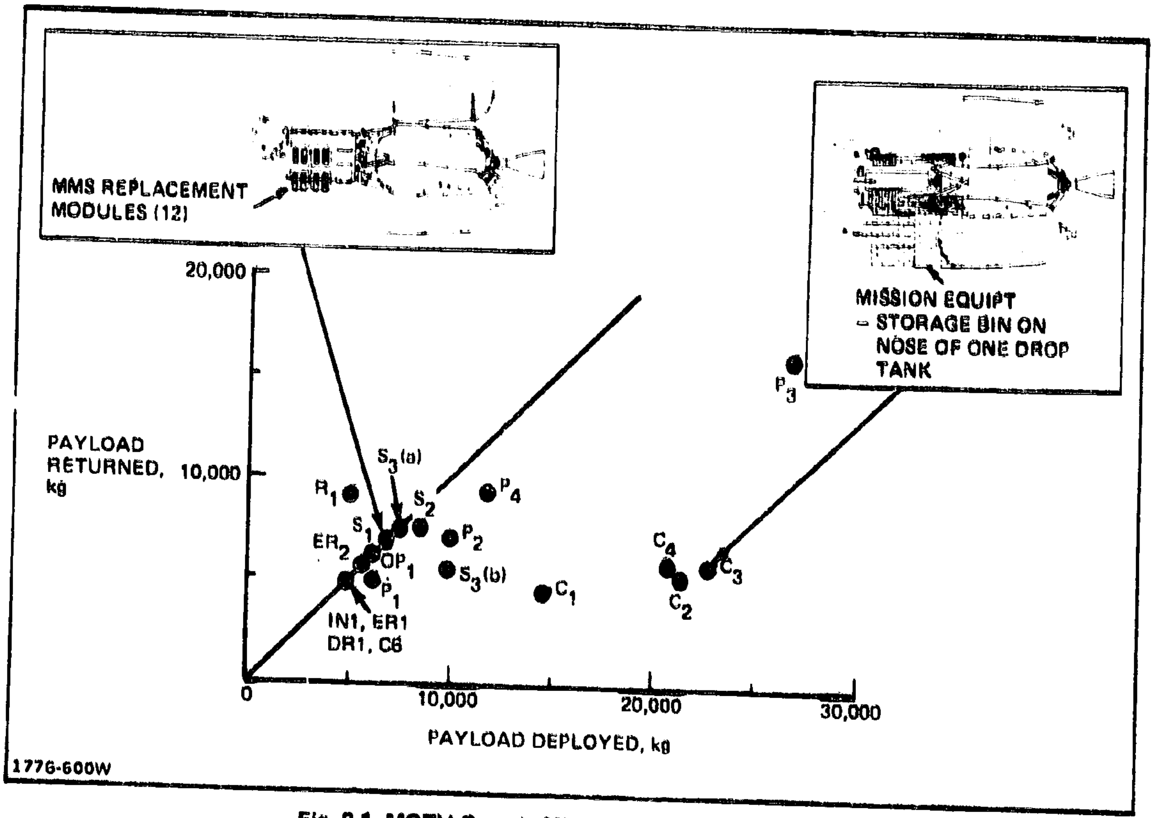

Fig. 2-1 MOTV Generic Mission Payload Requirements

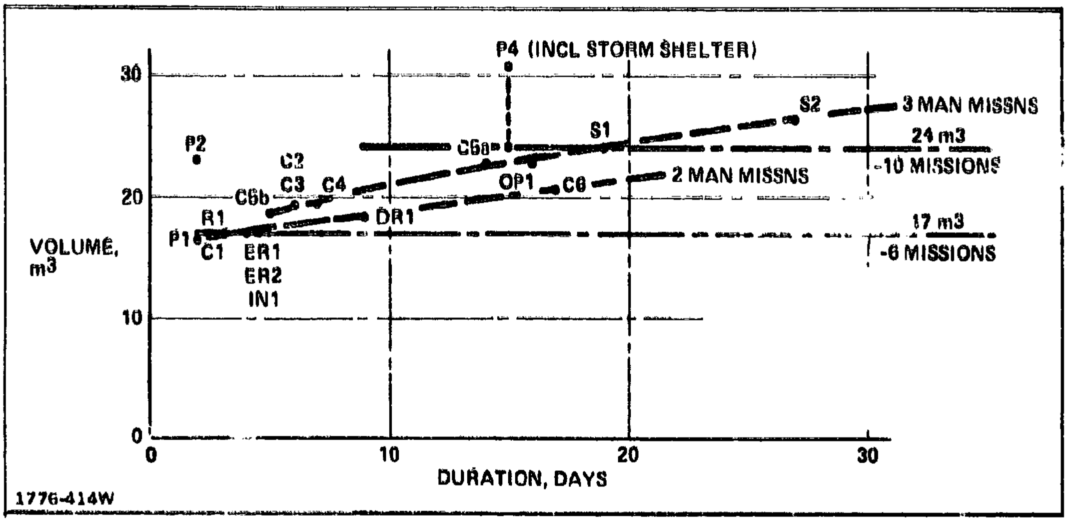

Fig. 2-2 Crew Cabin Volume vs Duration

Table 2-2 Standard Weights (kg)

ITEM	WEIGHT	SOURCE
CREW MODULE	PARAMETRICS	GAC IN-HOUSE + DATA PKG 1.4
AIRLOCK	381	DATA PKG 1.4
DOCKING MODULE		
– INT'L DOCKING ADAPTER	408	DATA PKG 1.4
– BERTHING RING: PASSIVE	60	GAC IN-HOUSE
ACTIVE	150	
MANIPULATOR		
– RMS SHUTTLE (15.3 M)	393	DATA PKG 1.4
– MRWS (2.2 M)	90	DATA PKG 1.4
– MOTV (2.5 M)	195	
(4.0 M)	237	
GRAPPLER/STABILIZER (2M)	50	MRWS ESTIM.
(3M)	60	
TELEOPERATOR		
– RETRIEVAL SYSTEM	612	MSFC PRESENTATION
– MARTIN'S-2 TANK SYSTEM	2700	"TELOP RETRIEVAL/
-4 TANK SYSTEM	5460	SKYLAB." AUG 77
CHERRY PICKER (MRWS)		
– OPEN	180 + ARM	GAC MRWS
– CLOSED	3500 + ARM	PROG OFFICE
BEAM BUILDER	7500	GAC PROG OFFICE
MMU	94 + 18 (PROP.) + 23 (FLT SUP STAT) = 135	DATA PKG 1.4
EVA SUIT		
– LEO	104	DATA PKG 1.4
– GEO	137	HAM STD MEMO 2/9/7
– IN-CABIN	8	HAM STD MEMO 2/9/7
EQUIP. STOWAGE RACKS	10/RACK	GAC IN-HOUSE
PAYLOAD RET/REL DRIVES	20	GAC IN-HOUSE
FIXTURES/JIGS/TURN TBL	60 (TURN TBL)	GAC IN-HOUSE
THERMAL EVA SHIELD	20	GAC IN-HOUSE
RADIATORS 3-MAN CREW MODULE	30	
8-MAN CREW MODULE	58	
STORM SHELTER	1369	GAC IN-HOUSE
C/O & CALIB EQUIP.	10	GAC IN-HOUSE
SPEC DIAGNOSTIC EQUIP.	30	
EQUIP. HOLDOWN LATCHES (1m^3 BOXES) (MIN 3 REQD)	5 EACH	

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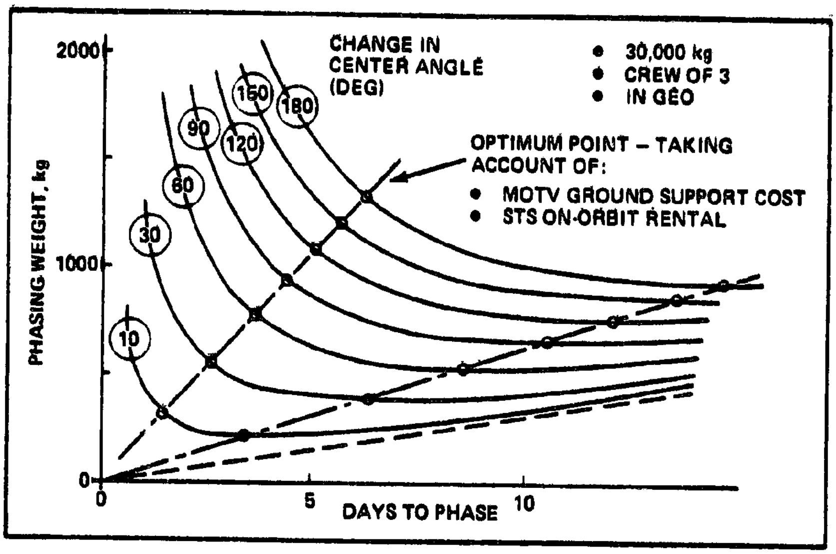

Fig. 2-3 Phasing Weight (ΔV Propellant Plus Food, Water, Atmos Make-up, RCS Prop.) vs Days to Phase

	INSPECTION, SERVICE & REPAIR						
EQUIPMENT	IN1	S1	S2	S3(a)	S3(b)	ER1	E
• MANIPULATORS							
- REACH (m)	2.5	2.0	2.5	2.5	2.5	2.5	
- DOF	7	7	7	7	7	7	
- NO. REQD.	2	2	2	2	2	2	
- UNIT WGT (kg)	195	178	185	195	195	185	
• STABILIZER FOR BERTHING							
- REACH (m)	2	2	2	2	2	2	
- DOF	4	4	4	4	4	4	
- NO. REQD.	1	1	1	1	1	1	
- UNIT WGT (kg)	50	50	50	50	50	50	
• EVA SUITS							
- TYPE/NO. REQD.	GEO/2	GEO/2	GEO/2	GEO/2	GEO/2	GEO/2	GEO/2
- NO. EVA'S PERMISSION (NORM OR EMERG)	2 (EMERG)	2 (EMERG)	2 (EMERG)	2(EMERG)	2 (EMERG)	1 (EMERG)	1 (EMEF
- ENDURANCE TIME/EVA (HR)	6	6	6	6	6	6	
- RAD PROTECTION REQD.	NO	NO	NO	YES	YES	NO	
- TETHER	YES	YES	YES	YES	YES	YES	
- UNIT WGT (kg)	137.5	137.5	137.5	137.5	137.5	137.5	
• MMU'S							
- NO. REQD.	–	–	–			–	
- MAX. RANGE/EVA (m)	–	–	–			–	
- UNIT WGT (kg)	–	–	–			–	
• DOCKING							
- TYPE	–	–	–			–	
- NO. REQD.	–	–	–			–	
- UNIT WGT (kg)	–	–	–			–	
• C/O & CALIB EQUIP.							
– TYPE OF C/O REQD.	SUBSYST C/O	MMS + ANT. FEED C/O	COMP. + ANT. FEED C/O	COMP. + ANT FEED C/O	– –	ANT. FEED + COMP. C/O	SURV S SUBSYS
– CRYO FLUID REPLENISHMENT	.	.	-		–	-	
– WGT ALLOCATION (kg)	10	10	10	30	–	10	
• EQUIP. STOWAGE RACKS, CONTAINERS							
– TYPE	EXP TRAY RACK	MMS HOLDERS	TWT HOLDERS	BLACK BOX RACKS	– –	ANT.+EQUIP. HOLD.	SENSO S/A +
NO. REQD.	1	12	40		–	2 HOLDERS	2 HOL
– SIZE (m)	1 x 1	1.2x1.2x0.46	0.4x0.6x0.9			30 m ANT.+COMP.	VARIO
– UNIT WGT (kg)	20	8	3	200	–	20	

1776-410(1)

FOLDOUT FRAME

Table 2-3 Generic Missions Equipment Requirements

	INSPECTION, SERVICE & REPAIR					OPER OF A LG SPACE SYST		DEBRIS REMOVAL	
	S3(a)	S3(b)	ER1	ER2	R1	OP1	P1-P4	DR1	
	2.5 7 2 195	2.5 7 2 195	2.5 7 2 185	3.0 7 3 210	2.5 7 2 195	2.5 7 2 195	– – – –	4.0 7 2 237	
	2 4 1 60	2 4 1 60	2 4 1 50	2 4 1 50	2 4 1 50	– – – –	– – – –	2 4 1 50	
) S .6	GEO/2 2(EMERG) 6 YES YES 137.5	GEO/2 2 (EMERG) 6 YES YES 137.5	GEO/2 1 (EMERG) 6 NO YES 137.5	GEO/2 1 (EMERG) 6 NO YES 137.5	GEO/2 1 (EMERG) 6 NO YES 137.5	GEO/2 2 (EMERG) 6 NO YES 137.5	1 LEO+1 IN-CABIN/CREWMEN 6 NO NO 137.5	GEO/2 1 (EMERG) 6 NO YES 137.5	GE 2 (E
			– – –	– – –	2 100 135	– – –	– – –	– – –	
			– – –	– – –	– – –	INT'L DOCK 1 408	INT'L DOCK 1 408	– – –	
NT.	COMP. + ANT FEED C/O 30	– – – –	ANT. FEED + COMP. C/O . 10	SURV SAT. SUBSYST C/O - 10	SAFING & C/O . 10	SUBSYST + INSTR C/O 5 kg CH2+5 kg CH4 10 + 10 = 20	- - - -	SAFING & C/O . 10	ANT ANT
ERS 0.9	BLACK BOX RACKS 200	– – – –	ANT.+EQUIP. HOLD. 2 HOLDERS 30 m ANT.+COMP. 20	SENSOR MCD + S/A + RCS 2 HOLDERS VARIOUS 20	P/L RET. LATCHES 4 LATCHES . 20	SAMP TRAY + RCS + SUBSYS LATCHES + BRACKETS VARIOUS 40	RESUPPLIES 49 LATCHES 16 BOXES (3 EA) 5	STOW.RACK 1 3 m TRIANGLE 100	

FOLDOUT FRAME 2

ment Requirements

	DEBRIS REMOVAL	CONSTRUCTION						UNMANNED CARGO
P4	DR1	C1	C2	C3	C4	C5	C6	UC
	4.0 7 2 237	4 7 1 237	4 7 2 237	4 7 2 237	4 7 2 237	4 7 2 237	25 7 2 502	– – – –
	2 4 1 50	– – – –	– – – –	2 4 1 50	– – – –	2 4 1 50	– – – –	– – – –
EWMEN JO JO 37.5	GEO/2 1 (EMERG) 6 NO YES 137.5	GEO/2 2 (EMERG) 6 NO YES 137.5	GEO/3 2 (EMERG) 6 NO YES 137.5	GEO/3 2 (EMERG) 6 NO YES 137.5	GEO/3 2 (EMERG) 6 NO YES 137.5	GEO/3 2 (EMERG) 6 NO YES 137.5	GEO/2 2 (EMERG) 6 NO YES 137.5	– – – – – –
	– – –	2 100 135	– – –	2 100 135	2 100 135	2 100 135	– – –	– – –
X B	– – –	– – –	– – –	– – –	– – –	– – –	– – –	– – –
	SAFING & C/O - 10	ANT.FEED + ANT.PATTERN C/O - 10	SUBSYST + ANT. FEED C/O - 10	SUBSYST + ANT.FEED C/O - 10	SUBSYST + ANT.FEED C/O - 10	SUBSYST C/O - 10	SUBSYST C/O - 10	– – – –
S S EA)	STOW.RACK 1 3 m TRIANGLE 100	– – – –	17 ANT.PACKAGES + 2 S/A + SS 60 LATCHES VARIOUS 5	SAME AS C2 VARIOUS 5	SAME AS C2 VARIOUS 5	TBD	– – –	– –

FOLDOUT FRAME 3

2

	INSPECTION, SERVICE & REPAIR						
EQUIPMENT	IN1	S1	S2	S3 (a)	S3 (b)	ER1	ER2
• FIXTURES/JIGS							
· TYPES	–	–	–	–	–	–	–
· WGT (kg)	–	–	–	–	–	–	–
• BEAM BUILDERS							
· NO. REQD.	–	–	–	–	–	–	–
· BEAM SIZE (m)	–	–	–	–	–	–	–
· UNIT WGT (kg)	–	–	–	–	–	–	–
• EVA TOOLS							
· TYPES	TOOL LIST	TOOL LIST	TOOL LIST	TOOL LIST	TOOL LIST	TOOL LIST	TOOL LIST
· EST TOTAL WGT (kg)	25	25	25	25	25	25	25
• SPEC. DIAGNOSTIC EQUIP.							
· TYPE	–	–	–	PART. DET	PART. DET	ELECT. ANALYZER	ELECT. & F SCANNE
· EST WGT (kg)	–	–	–	10	10	20	30
• AIRLOCK							
· TYPE	–	–	–	–	–	–	–
· UNIT WGT (kg)	–	–	–	–	–	–	–
• TELEOPERATORS/PROP STAB.UNITS (PSU)					TELEOPER.		PSU
· CONTROL STATION LOCATION/NO.REQD.	–	–	-	–	MOTV/1	–	MOTV/1
· MAX RANGE (m)	–	–	–	–	1000	–	100
· EST UNIT WGT (kg)	–	–	–	–	1100/1481	–	612
• CHERRY PICKER							
·OPEN/CLOSED	–	–	–	–	–	–	–
· NO.MANIP. ARMS/REACH (m)	–	–	–	–	–	–	–
·NO. GRAPPLERS/REACH (m)	–	–	–	–	–	–	–
· EST WGT (kg)	–	–	–	–	–	–	–
• STORM SHELTER							
· NO. OCCUPANTS				–	–		
· WGT (kg)				–	–		
• OTHER				–	–		

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Table 2-3 Generic Missions Equipment Requirements (Contd)

			OPER OF A LG SPACE SYST		DEBRIS REMOVAL	CONSTRUCTIC		
	ER2	R1	OP1	P1-P4	DR1	C1	C2	C3
	— —	— —	— —	— —	— —	3m D/A TURNTBL 50	DEPL. MAST & GRAPPLER 20	ASSY JIG STR CON 50
	— — —	— — —	— — —	— — —	— — —	— — —	— — —	— —
	TOOL LIST 25	TOOL LIST 25	TOOL LIST 25	TOOL LIST 25	TOOL LIST 25	TOOL LIST 25	TOOL LIST 25	TOOL LIS 25
ZER	ELECT. & REMOTE SCANNERS 30	REMOTE SCANNERS 30	ELECT. ANALYZER 20	— —	— —	— —	— —	— —
	— —	— —	— —	— —	— —	— —	— —	— —
	PSU MOTV/1 1000 612	PSU MOTV/1 1000 612	— — —	— — —	— — —	— — —	— — —	— — —
	— — — —	— — — —	— — — —	— — — —	— — — —	— — — —	— — — —	— — — —

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DEBRIS REMOVAL	CONSTRUCTION						UNMANNED CARGO
DR1	C1	C2	C3	C4	C5	C6	UC
– –	3m D/A TURNTBL 50	DEPL. MAST & GRAPPLER 20	ASSY JIG + STR CONT 50	FAB/ASSY JIG 100	CORNER ASSY JIG + BEAM SP 100	– – –	– – –
– – –	– – –	– – –	–	1 1 7500	1 1 7500	– – –	– – –
TOOL LIST 25	TOOL LIST 25	TOOL LIST 25	TOOL LIST 25	TOOL LIST 25	TOOL LIST 25	TOOL LIST 25	– –
– –	– –	– –	– –	– –	– –	– –	– –
– –	– –	– –	– –	– –	– –	– –	– –
– – –	– – –	– – –	– – –	– – –	– – –	– – –	– – –
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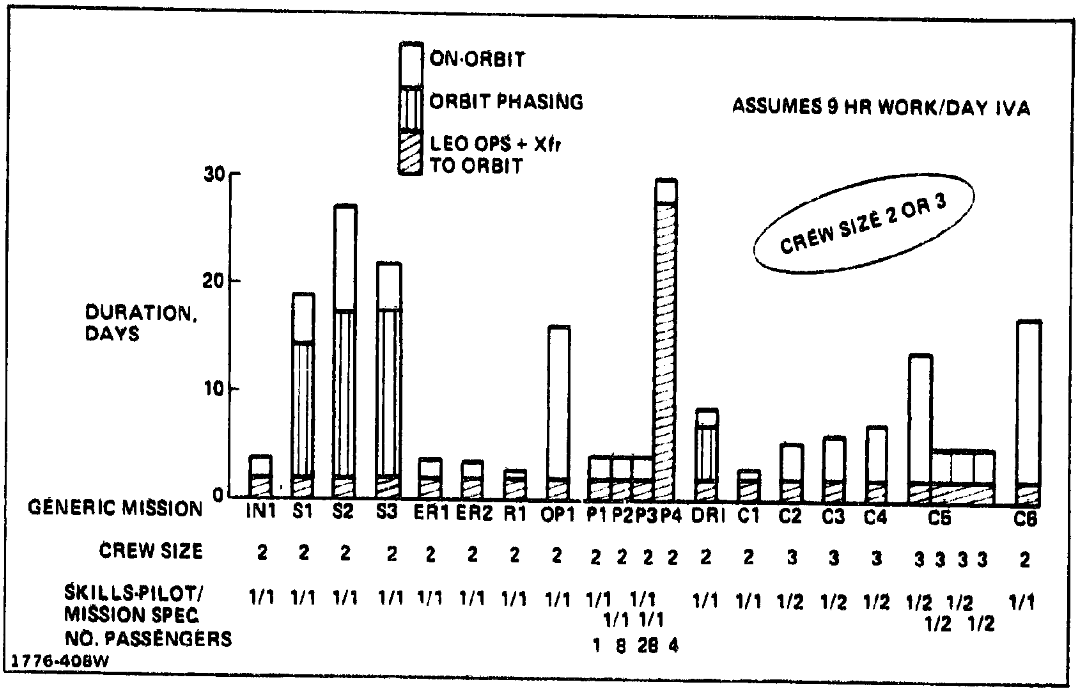

Fig. 2-4 Generic Mission Duration, Crew Size, & Skill Requirements

SMALL		MEDIUM		LARGE	
ITEM	WGT	ITEM	WGT	ITEM	WGT
1. RATCHET WRENCH	TBD	1. PINCH BAR	TBD	1. CABLE CUTTER	TBD
2. UNIVERSAL JOINT		2. ADJUSTABLE WRENCH		2. SHEARS	
3. SPINNER		3. PRONG TOOL		3. SHEPHERD'S HOOK	
4. RATCHET EXTENSION		4. BOLT INSTL (BIRT)		4. SPACE IMPACT TOOL	
5. SOCKET SET		5. INERTIA WHEEL		5. SPIN TORQUE SPACE TOOL	
6. ADAPTER		6. SPACE POWER TOOL			
7. SCREW DRIVER		7. SPACE TOOL MITTEN			
8. TORQUE WRENCH		8. MMS–S/S MODULE RELEASE TOOL			
9. PLIERS					
10. HAMMER – BALL PEEN					
11. SCISSORS					
12. TIN SNIPS					
13. DIAGONAL CUTTERS					

REF: 1 – JSC-10605 – "SHUTTLE EVA DESCRIPTION ON & DESIGN CRITERIA

2 – AIAA PAPER NO. 72-230 – "SPACE TOOLS AND SUPPORT EQUIPMENT – CURRENT TECHNOLOGY AND FUTURE REQUIREMENTS."

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HM2

Table 2-4 Candidate Tools for MOTV Servicing & Missions

2.2 OPERATIONAL REQUIREMENTS

MOTV operational requirements are based on a 1½ stage APOTV configured to support the specific geosynchronous generic mission.

2.2.1 Scenario

The APOTV overall mission activity from launch to recovery is defined in Fig. 2-5.

2.2.2 Shuttle Support

The standard STS support required for APOTV Operations shall include:

2.2.2.1	Standard - Ground maintenance and turnaround support: 2 weeks, 160 hours.	Fig. 2-5
2.2.2.2	*Ground to LEO Transportation, deployment assembly and mission preparations as specified in Figs. 2-5 and 2-6.	Fig. 2-6
2.2.2.3	*LEO rendezvous, retrieval, and transportation of APOTV elements back to earth following GEO mission as specified in Figs. 2-5 and 2-7.	Fig. 2-7
2.2.2.4	One STS support flight for each of the major APOTV modules. (For example, the configuration shown in Fig. 2-5 would require a total of 3 flights.)	Fig. 2-5

2.2.3 *Orbiter Non-Standard Support Required

Payload chargeable non-standard support provided by the Orbiter shall include but not be limited to, the following:

2.2.3.1	Crew accommodations in the Orbiter in addition to its standard 28 man days of expendables and crew equipment for four men required to support the Table 2-1 mission manpower and timeline requirements.	Table 2-1

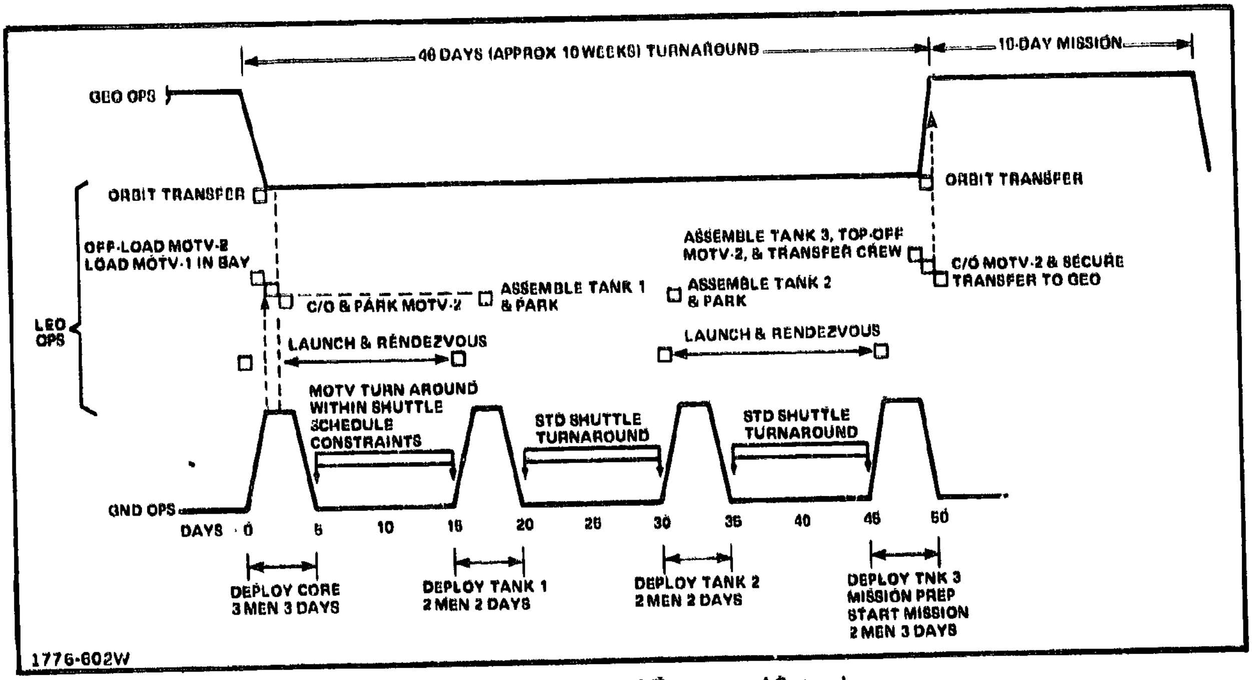


Fig. 2-5 MOTV Ground Turnaround Scenario

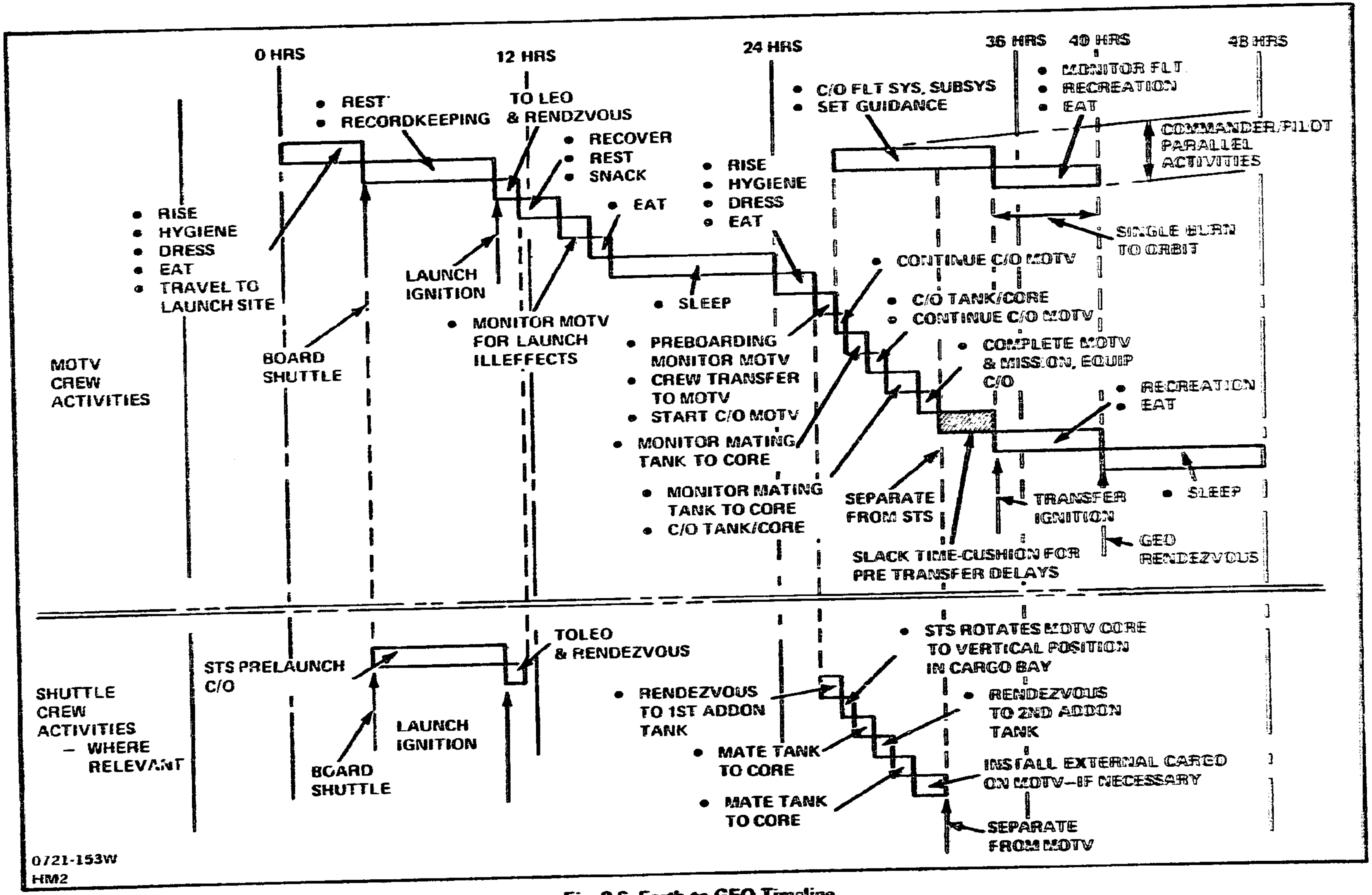


Fig. 2-6 Earth to GEO Timeline

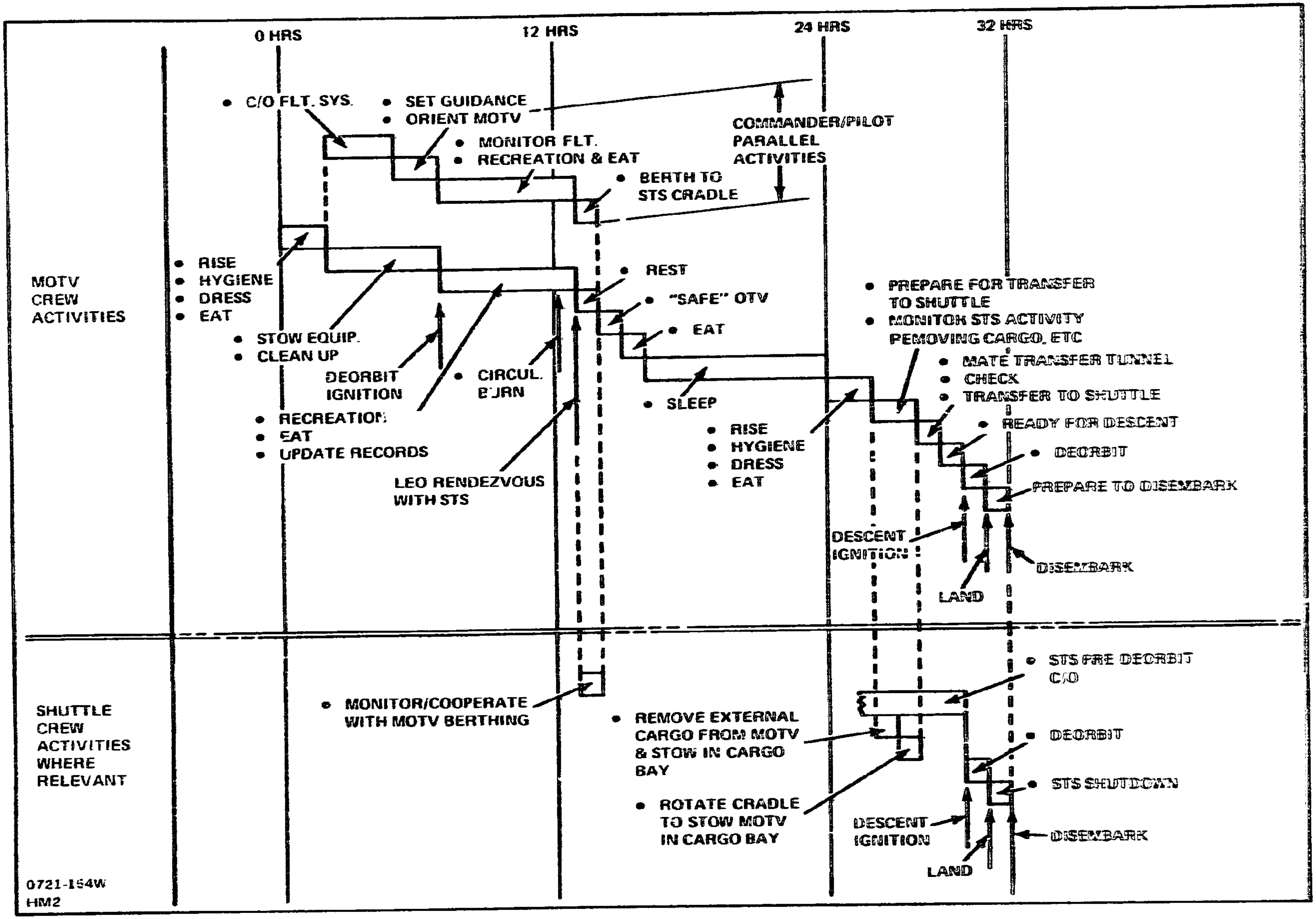


Fig. 2-7 GEO to Earth Timeline

REQUIREMENT	RATIONALE/SOURCE
2.2.3.2 *Extra (2nd) Remote Manipulator, System (RMS) to support activities shown in Figs. 2-6 & 2-7.	Figs. 2-6 & 2-7
2.2.3.3 Transfer tunnel to connect the APOTV manned module to the Orbiter cabin for crew transfer.	
2.2.3.4 Power required (TBD) in support of APOTV activities indicated in Figs. 2-6 & 2-7.	Figs. 2-6 & 2-7
2.2.3.5 Payload bay lighting (TBD) consistent with the LEO ACTIVITIES Figs. 2-6 & 2-7.	Figs. 2-6 & 2-7
2.2.3.6 Propellants and other fluids required for Orbiter loiter mode and support of APOTV turnaround assembly operations.	Figs. 2-5, 2-6 & 2-7
2.2.3.7 Specific payload chargeable items required to support each mission will be based on the STS Chargeable Items List.	JSC 07700 B/Table 3-1/3-41
2.2.4 <u>APOTV Operational Requirements</u> APOTV operational requirements shall include:	
2.2.4.1 Support of generic missions described in Table 2-1, Figs. 2-2 and 2-4 plus a reserve of 4 days for a crew of 3 for contingencies.	Table 2-1 Figs. 2-2 & 2-4
2.2.4.2 A low energy deorbit transfer propulsion system for each drop tank.	Fig. 2-5
2.2.4.3 APOTV Turnaround requirements, i.e., scheduled, unscheduled maintenance, and prelaunch operations, shall be conducted on the ground within the 160-hour standard Shuttle time-line turnaround constraints.	C/Fig. 3-4/3-10

3 - SYSTEM REQUIREMENTS

This section provides the overall hardware system requirements which will satisfy the program and mission requirements delineated in Sections 1 and 2.

3.1 CONFIGURATION

3.1.1 Overall Vehicle Configuration

Figs. 3-1, 3-2, 3-3

All of the system and subsystem requirements developed in this and subsequent sections are based on the APOTV. Figure 3-1 illustrates the general characteristics of the typical 1½ stage APOTV configuration. Figure 3-2 illustrates variations in the APOTV Configuration tailored to support specific generic mission and related functions. Figure 3-3 illustrates the characteristics of crew module design required to accomodate most generic missions.

3.1.2 Subsystem Configuration

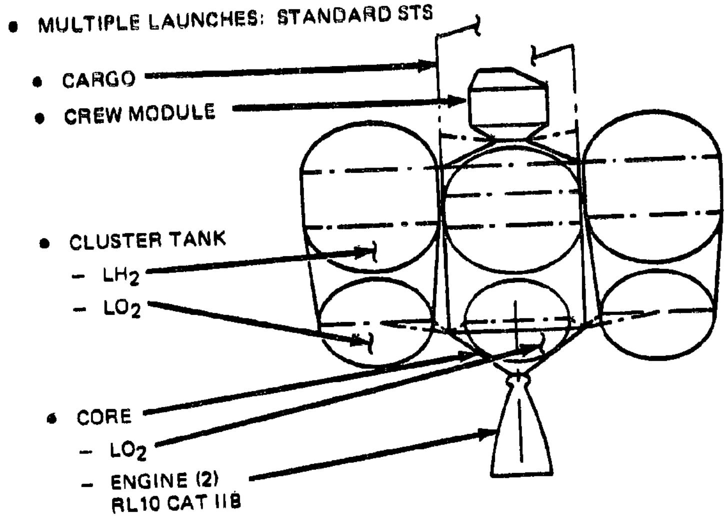
Fig. 3-4

Figures 3-4 illustrates the major subsystem elements and the typical distribution of the subsystems. Specific subsystem configurations for the individual generic missions vehicle configurations are covered in Section 4.

3.2 SAFETY & MISSION SUCCESS

Both safety - (man rating) and mission success involve reliability requirements but from different points of view.

Safety is chiefly concerned with only those system capabilities that are needed to get the crew back to Earth unharmed. These fail safe capabilities, which may be degraded from nominal, must have - as a minimum - an overall reliability level at which



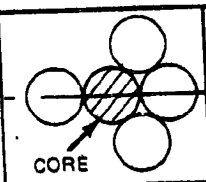
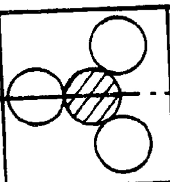
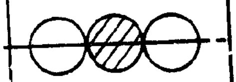
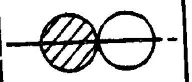
MULTIPLE CLUSTER TANKS				
NO. TANKS:	4	3	2	1
ENGINE MAX GIMBAL:	±10°	0°	0°	±20°

Fig. 3-1 1-1/2 Stage APOTV

GENERIC MISSION		FUNCTIONS
INSPECTION SERVICE & REPAIR	IN1	RENDEZVOUS
	S1	INSPECTION
	S2	DOCKING/BERTHING
	S3	SERVICING
	ER1	MAINTENANCE
	ER2	REPAIR
	R1	
OPERATION OF A LARGE SPACE SYSTEM	OP1	RENDEZVOUS
	P1	DOCKING/BERTHING
	P2	PROCESSING
	P3	EQUIPMENT OPS
	P4	MANUFACTURE
		PASSENGER TRANSPORT

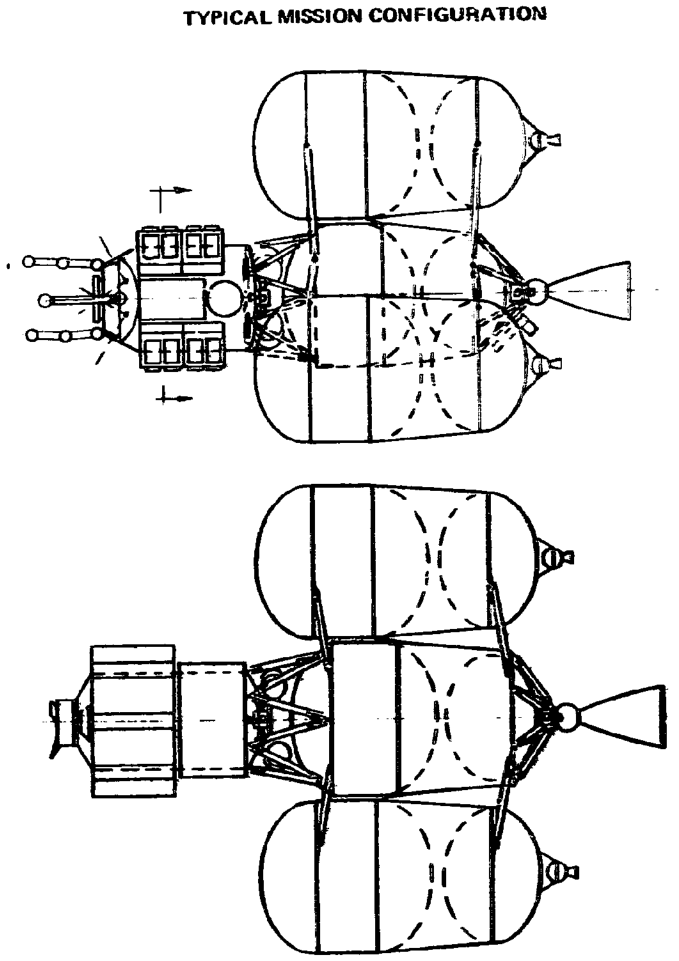


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Fig. 3-2 APOTV Missions Typical Configurations

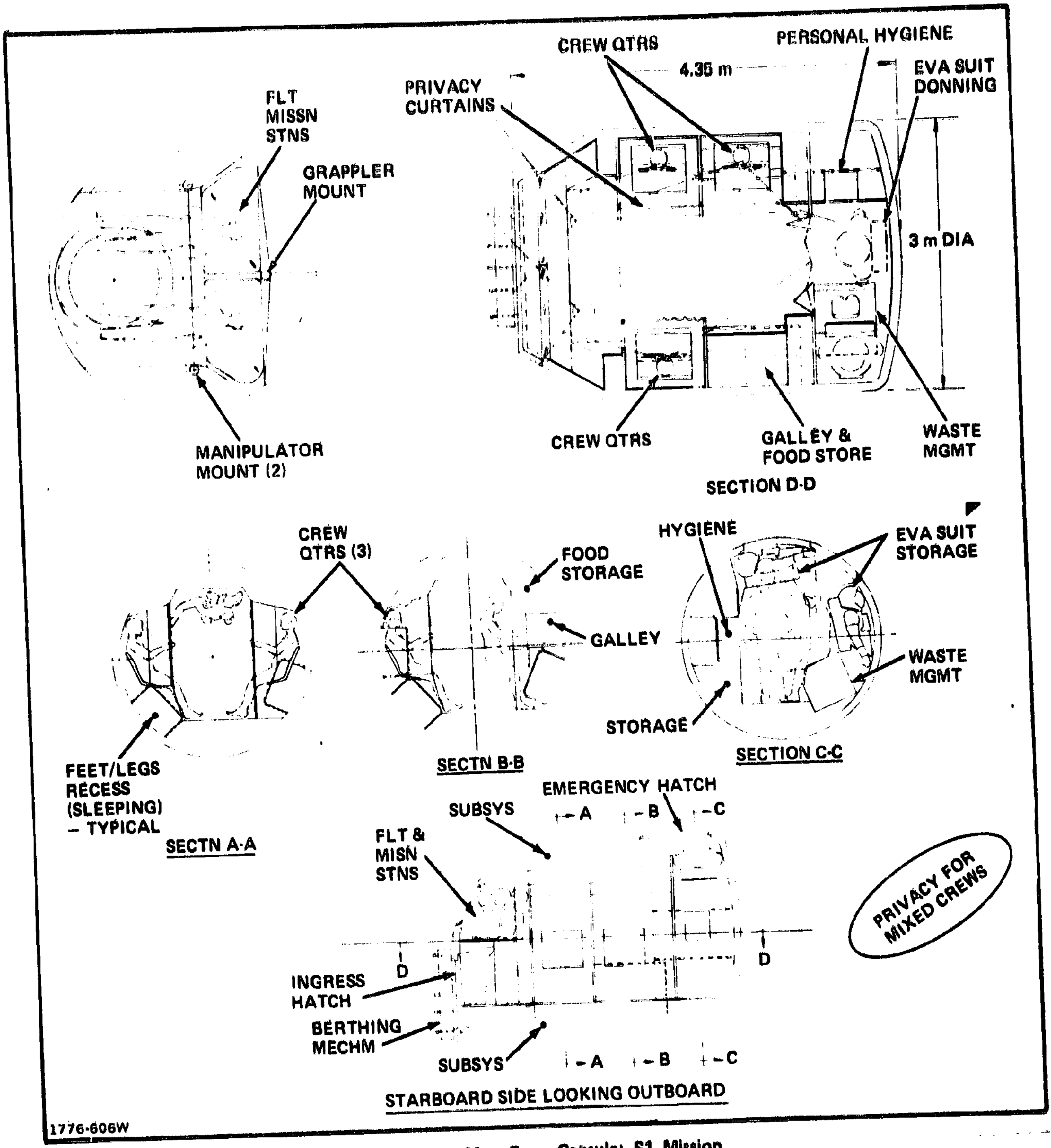

Fig. 3-3 3-Man Crew Capsule: S1 Mission

SUBSYSTEMS	MANNED MODULE	CORE MODULE	DROP TANKS	REMARKS
• STRUCTURE	34%	18%	48%	DISTRIBUTION FOR S1
• POWER				
SOLAR ARRAY		100%		MOUNTED ON CORE
EPS (DISTRIBUTION)	13%	87%		
BATTERIES		100%		MOUNTED IN CORE
FUEL CELLS		100%		MOUNTED IN CORE
• EXPLOSIVE DEVICES ORDINANCE & BATTERIES		100%		
• AVIONICS				
ACPS		100%		
G & N ELECTRONICS	30%	70%		
DATA MGT	30%	60%	10%	
CONTROLS/DISPLAYS	100%			
RENDEZVOUS RADAR	100%			
TRACKING, TELEM & COMMAND	15%	85%		
• ACTUATORS & MECHANISMS	89%	11%		MINIPS, GRAPPLER & ENG GIMBAL ACT.
• TANKS				
PROP.			1 TO 4	MISSION DEPENDENT
RCS		100%		
• ECLSS	100%			
• CREW EQUIP	100%			INCLUDES MANIP., SUITS & CONSUMABLES
• MAIN ENGINES		100%		
• SAFETY	100%			RADIATION PROTECTION

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Fig. 3-4 1½ Stage APOTV, MOTV Subsystem Requirements & Distribution

astronauts, program management and, ultimately, public opinion are prepared to see manned MOTV missions flown on a routine basis.

Mission Success, as distinguished from crew safety, is chiefly concerned with money. The benefits of a higher probability of mission success are traded against the cost of the increased reliability needed to achieve that success. All the system capabilities needed for a particular mission are involved, not just those necessary for crew survival.

In the system requirements paragraphs that follow, these two approaches are treated separately, but the design and development of each subsystem must take account of both.

3.2.1 Safety (Man-Rating)

To establish a frame of reference, the likelihood of commercial airline pilots, policemen, firemen, underground miners, losing their lives in job related incidents during the course of their entire careers, varies between one chance in 120 and one chance in 20. The safety level of the MOTV/STS combination shall be such that an MOTV space crew member will have a comparable chance of surviving his career number of MOTV missions.

The figures proposed for early MOTV operations are: -

● MOTV crew member career risk	1 in 50
i.e. crew career survival rate	0.98
● Assumed number of missions per crew members	10
● Hence crew mission survival rate	0.998 - 1 failure in 500

REQUIREMENT **RATIONALE/SOURCE**

This per mission survival figure has to be allocated between the STS and MOTV phases - making an arbitrary, even, division we have:

● survival rate for STS phase of mission	0.999 - 1 failure in 1000
● survival rate for MOTV phase of mission	0.999 - 1 failure in 1000

The initial crew member career risk of one chance in 50 was selected bearing in mind that the safety record of transport system improves with time, when developed dilligently; typically experiencing a halving of risk with 20 years of use. The program risk - one mission catastrophe in 500 - translates, at 6 missions per year, into one mission lost in about 80 years.

Turning now to the Man Rating of the MOTV, the overall catastrophic failure probability for the MOTV part of the mission is the sum of the failure probabilities of those particular subsystems that assure safe return of the space crew - (not those needed for mission success). "Failure" meaning that the subsystem performance, together with any alternate capability, has fallen below the minimum needed to get home.

Future feasibility and cost studies together with component development work shall establish the approximate distrubution of overall failure probability among these critical subsystems. In the meantime, as a guide to current studies, a first cut estimate of this distribution is given in Table 3-1. The percentage column shows the proportion of catastrophic failure "allowed" for each subsystem. The final column shows the same distribution in terms of the mean number of missions between fatal failures

Table 3-1 MOTV Man Rating – Preliminary Allocation of Catastrophic Failure Likelihood

CRITICAL SUBSYSTEM	% ALLOCATION	MISSIONS PER CATAST FAILURE
MAIN PROPULSION	50	2,000
R.C.S.	10	10,000
EPS	8	12,000
AVIONICS	7	14,000
ECLS	10	10,000
RADIATION PROTECTION	12	8,000
CREW TRANSFER	3	30,000
FOOD/WATER	0	∞
OVERALL STRUCTURE	0	∞

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REQUIRMENT	RATIONALE/SOURCE
scaled to match the previously discussed overall safety level of one fatal MOTV failure in 1000 missions.	
3.2.2 <u>Personnel</u>	
It is a design goal that no single malfunction or reasonable combination of malfunctions shall result in the potential of injury to MOTV, Orbiter and ground turnaround personnel.	Nominal Reqmts "D"
3.2.3 <u>Subsystem Malfunction</u>	Phase 1 Midterm Review
3.2.3.1 Warning of subsystem malfunctions shall be given to the "on" and "off duty" MOTV crew, the ground support personnel and the orbiter crew (when in the mated configuration).	
3.2.3.2 Redundancy criteria for the subsystems are covered by discipline in Section 4.	Phase I Midterm Review
3.2.3.3 When the functional system failure results in the significant depletion of a critical consumable (power, life support, etc.) reserves shall be provided for TBD hours (mission dependent)	
3.2.4 <u>Illness</u>	
3.2.4.1 Health Diagnostics/monitoring shall be provided for all crew critical functions with adequate data warning for the MOTV crew and ground personnel.	
3.2.4.2 In case of serious illness or accident the MOTV shall have the capability to return to the Orbiter within 24 hours.	
3.2.4.3 In case of serious illness or accident the Orbiter shall have the capability to return to the ground within an additional 24 hours.	
3.2.5 <u>Radiation</u>	

REQUIREMENT

RATIONALE/SOURCE

3.2.5.1 Current Dose Limits - The allowable crew dosage is given in Fig. 3-5, based on STS limits. If greater or lesser levels of risk are acceptable these limits shall be adjusted accordingly.

National Academy of Science, Radiobiological Advisory Panel (1970)

3.2.5.2 GEO & 12 Hour Orbits - The MOTV shall provide the following for GEO & 12 Hour Orbiter:

a) Warning of any event predicted to reach or exceed 10^8 p/cm^2 total even flux of protons ≥ 30 MEV

b) Deorbit capability to return to an altitude less than 3 earth radii within 7 hours

c) Crew shielding sufficient to survive a solar event of 10^9 p/cm^2 total event flux or protons ≥ 30 MEV

3.2.5.3 Deep Space Orbits - Since timely deorbit is impractical for deep space orbits the MOTV system shall provide crew shielding sufficient to survive a solar flare event of 10^{10} p/cm^2 total event flux of protons ≥ 30 MEV.

3.2.5.4 Dosimetry - Personal active/passive dosimetry and other on-board radiation instrumentation shall be such that depth-dose information is provided in real-time. Also it shall be able to identify the portion of the total dose attributable to radiation components with differing LET. The need to monitor exposure to HZE particles will be required.

3.2.5.5 Total Exposure Limits - The combined exposures for the total mission shall include accumulated doses during orbital transfer, possible EVA, IVA operations, and other possible unscheduled radiation environment.

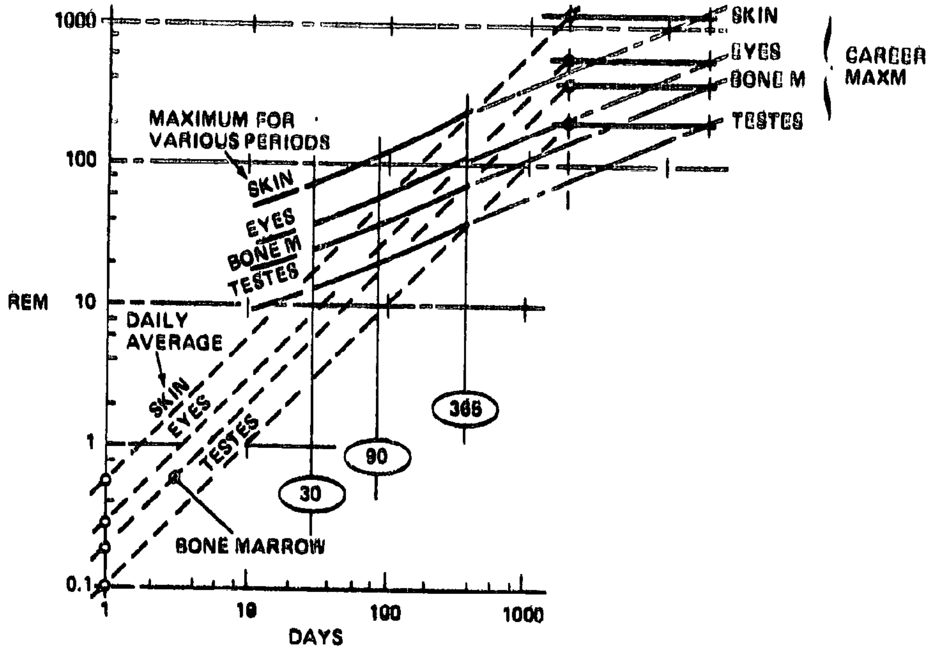

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Fig. 3-5 Current STS Crew Radiation Limits

REQUIREMENT	RATIONALE/SOURCE
3.2.5.6 Solar Flare Caution and Warning System - To minimize the radiation hazards the following telemetry/caution and warning displays shall be provided:	NASA Mission Control and NOAA, Space Environmental Laboratory Voice/Video Sound
• Early warning (minimum 2 days) advanced warning of an anomalously large (A.L.) solar flare event.	
• Continuous monitoring of dose rate limits	On-board Radiation Detectors and Personal Dosimeters
• Spacecraft charging monitoring	On-board Spacecraft Charging Sensors
3.2.5.7 Long Term Solar Flare Prediction - Deterministic capability (i.e., 100% probability) of long term solar flare prediction of at least TBD days "before" flare occurrence shall be developed.	
3.3 RELIABILITY	
3.3.1 Mission Goal The mission success reliability goal for the APOTV shall be 0.97 minimum for all missions (excluding radiation hazard aborts). Redundancy levels will be selected and defined to meet this criterion for all missions.	Nominal Reqmts "D"
3.3.2 Minimum Subsystem Operational Criteria	
Subsystem or component failures shall not propagate sequentially. With the exception of the Main Engines, equipment shall be designed, as a minimum, to be fail-operational/failsafe.	Nominal Reqmts "D"
3.3.3 Life Limited Components All critical life limited components and subsystems shall be designed to facilitate inspection. Redundant paths shall be located so that an	

event which damages one path is not likely to damage the other.

3.3.4 Critical Functions - Single Failure

The MOTV shall provide the capability for performing critical functions at a nominal level with any single component failed.

3.3.5 Critical Functions - Two Component Failures

With the exception of the main engines, the MOTV shall provide the capability to perform critical functions at a reduced level with any credible combination of two component failures

REQUIREMENT		RATIONALE/SOURCE
3.4	MAINTAINABILITY	
3.4.1	Access	
	The MOTV shall be designed to provide access to equipment interfaces, equipment installations, and service umbilicals requiring inspection, servicing or verification during scheduled ground maintenance and pre-launch operations.	Nominal Reqmts "D"
3.4.2	LRUs	
	APOTV Line Replaceable Unit (LRUs) configuration and accessibility shall be designed to facilitate ground turnaround operations.	Nominal Reqmts "D"
3.5	ELECTROMAGNETIC COMPATIBILITY	
3.5.1	Intra Subsystems Compatibility	
	The MOTV operations shall not be limited by electromagnetic interactions due to the electromagnetic emissions and susceptibilities of its subsystem.	
3.5.2	Inter Systems Compatibility	
	The MOTV shall not be a source of interference to or a victim of interference from nearby electrical and electronic equipments and systems.	Nominal Reqmts "D"
3.6	INTERFACE REQUIREMENTS	
3.6.1	Shuttle	JSC Payloads Accommodations Document "B"
	The MOTV shall not degrade STS integrity/Safety and its elements shall fit within the Orbiter payload bay and be compatible with the shuttle structural, dynamic, mechanical, electrical, fluid and operational requirements.	

3.6.2 Launch Facilities

MOTV elements shall be compatible with the launch site facilities used for turnaround operations.

3.6.3 Communications

The MOTV communications uplink and downlink shall be compatible with the Orbiter, MSFN, STDN, TDRSS and SCB.

3.6.4 Docking System

The MOTV berthing/docking system shall be compatible with Orbiter and SCB.

3.6.5 MOTV Grapple Fixture/Berthing Attachments

AN RMS compatible grapple fixture shall be mounted on the MOTV for deployment and retrieval operations.

MGMRSAS Data
Pkg 1.1

Payload bay berthing attachments shall be installed on the MOTV to enable stowage and deployment.

3.7 FLIGHT OPERATIONS

3.7.1 Mission Equipment

Provisions shall be made for mission equipment stowage and deployment required to perform the functions listed in Table 2-1.

3.7.2 EVA Operations

Cabin design shall accommodate EVA operations.

3.7.3 Unattended Operations

The MOTV shall be capable of staying in LEO unattended for (20 days). Subsystem will therefore have capability of being restarted after manual servicing.

REQUIREMENT	RATIONALE/SOURCE
3.7.4 Crew Transfer Crew transfer between Orbiter or other habitability modules and the MOTV shall be in a shirt sleeve pressurized environment.	MGMRSAS Data Pkg 1.1
3.7.5 MOTV Life The MOTV shall have a minimum orbital lifetime of 10 years.	MGMRSAS Data Pkg 1.1
3.7.6 Manned/Unmanned Operation The MOTV shall be operated directly by a crew when configured with a manned module or remotely from Ground when configured for cargo transfer without a manned module.	MGMRSAS Data Pkg 1.1
3.7.7 Abort External appendages shall not inhibit mission abort during any phase of MOTV mission operations.	

4 - SUBSYSTEM REQUIREMENTS

This section provides the subsystem requirements for the APOTV configuration necessary to support the various missions. These requirements are presented by discipline and as indicated in the forward consist of established nominal requirements, starred (*) requirements which are soft at this time requiring further analysis and TBD requirements which are recognized but not defined at this time. Requirements for the main propulsion elements are summarized at the module level at the end of this section.

4.1 STRUCTURE/MECHANICAL

4.1.1 Safety

Nominal Reqmts "D"

4.1.1.1 All major load-carrying structures of the structural subsystems shall be designed to a safe life of a minimum ten years in orbit with a scatter factor of 4.0. Life limitations shall be identified.

4.1.1.2 As a goal, failsafe design concepts shall be applied to all critical structure so that failure of a single structural member shall not degrade the strength of stiffness of the structure to the extent that the crew is in immediate jeopardy.

4.1.1.3 The structure shall be designed to resist damage resulting from accidental impact during crew activities.

4.1.1.4 Material Flammability/Toxicity standards shall be the same as that specified for the STS.

4.1.1.5 Safety factors used for structural design shall be consistent with those currently used for manned operations.

Primary Structure

- Ultimate Strength: A factor of 1.5 x limit load shall be applied.

Nominal Reqmts "D"

REQUIREMENT	RATIONALE/SOURCE
• Yield Strength: A factor of 1.2 x limit load shall be applied.	Nominal Reqmts "D"
Cabin Pressure Structure • Ultimate Strength: A factor of 2.0 x maximum relief valve pressure shall be applied.	
Windows, Doors, etc. • Ultimate Strength: A factor of 3.0 x maximum relief valve pressure shall be applied.	
4.1.1.6 Fracture mechanics analyses shall be used to assess flaw growth, life and proof test requirements.	Nominal Reqmts "D" MGMRSAS M.O. Term Review Phase 1
4.1.1.7 Meteoroid protection shall be provided by the MOTV design consistent with the meteroid flux given in referenced document. The design goal will be to provide sufficient protection to assure an TBD probability of no mission failure resulting from meteroid penetration.	
4.1.2 Shuttle Interface Requirements	JSC Payloads Accommodations Document
4.1.2.1 The MOTV shall be designed to withstand berthing and docking loads of TBD.	
4.1.2.2 The structure shall be designed to withstand Orbiter launch and landing loads specified in JSC-07700, Vol. XIV.	B/4.2/4-7
4.1.2.3 Structures shall be designed to withstand temperature cycling between -433°K to 366°K.	
4.1.3 Functional Design Requirements	
4.1.3.1 Equipment - All subsystem equipment which does not require manned interface in the pressurized cabin shall be mounted externally.	

REQUIREMENT

RATIONALE/SOURCE

4.1.3.2 *Hatch Size - Nominal hatch size shall be 1 m. diameter. An alternate egress hatch shall be provided with a size not less than 0.8 m.

4.1.3.3 No external appendages shall block egress.

4.1.3.4 Windows - Windows shall be provided to permit viewing docking aids, grappling operations and manipulator assembly tasks. Size shall be minimized, consistent with previous requirements.

4.1.3.5 Window Material - Ceria doped fused silica glass (min. 1.5 cm thick) to provide 4 g/cm^2 shielding. Additional eye lens shielding shall be provided either by Hamilton Standard's Helmet Shield of 2 g/cm^2 or goggles.

4.1.3.6 Docking - Provide docking equipment to interface with the Orbiter docking module and withstand loads of TBD.

4.1.3.7 Manipulator - Install interface structure to mount two dexterous manipulators and one stabilizer.

4.1.3.8 Solar Array - Provide mounting for solar array.

4.2 AVIONICS

4.2.1 Displays and Controls Functional Requirements

4.2.1.1 Provide sufficient duplication of displays and controls to permit the vehicle to be piloted from either the pilot or copilot stations.

4.2.1.2 Provide manual flight controls including rotation and translation hand controllers at both the pilot and copilot stations.

4.2.1.3 Supply provisions for the selection of either manual or automatic flight control modes to meet mission objectives.

4.2.1.4 Display the caution and warning data obtained from Data Management S/S for malfunction identification.

4.2.1.5 Provide circuit breakers for control of AC and DC Power to all subsystems.

4.2.1.6 Display Closed Circuit TV (CCTV) during IVA and provide controls to operate the manipulators.

4.2.1.7 Accept color TV from a hand held camera during EVA for display in the cabin, and for transmission to the ground along with CCTV pictures.

4.2.1.8 Provide a Computer CRT Display and a keyboard for entrance into the Digital Computer (CPU).

4.2.1.9 Supply dedicated switches, controls and instruments to monitor, command and control all the vehicle subsystems during operation of the MOTV.

4.2.1.10 Display the range and bearing information from the passive and cooperative targets during the rendezvous operation.

4.2.1.11 Provide a Data Distribution Center for routing and switching the various electrical signals which enter and leave the Cabin displays and controls for other systems in the vehicle.

4.2.2 Data Management Functional Requirements

4.2.2.1 Accept status inputs from the various electronic subsystems, main engine, ACPS, fuel distribution system and the drop tanks.

4.2.2.2 Signal condition the status inputs so that they may be converted from analog to digital.

REQUIREMENT

RATIONALE/SOURCE

4.2.2.3 Electronically sample the status inputs by an electronic commutator to be applied to the Pulse Code Modulation Electronics.

4.2.2.4 Provide a data stream via the data distribution center to the Communication Subsystem for modulating a sub-carrier oscillator (SCO) for transmission to the ground.

4.2.2.5 Utilize the conditioned status inputs so that the Caution and Warning Electronics (C & WE) can drive the crew displays of caution and warning data on the vehicle.

4.2.2.6 Accept Bio-Med Inputs from the crew for transmission to the ground regarding the health status of the crew members.

4.2.2.7 Accept ECS and Life Support inputs for display in the cabin and transmission to the ground.

4.2.2.8 Provide a tape recorder to work in conjunction with the Data Distribution Center to record data and voice, and to playback to the ground as required.

4.2.3 Attitude Control Determination Functional Requirements

4.2.3.1 Provide attitude information obtained from the inertial measuring unit (IMU).

4.2.3.2 Mechanize the IMUs to supply vehicle attitude information and incremental velocity change information.

4.2.3.3 Place the IMUs under the control of the Digital Computer and have them provide leveling and gyrocompassing capability beside the flight-monitoring function.

REQUIREMENT **RATIONALE/SOURCE**

4.2.3.4 Mount the IMU to a navigation base along with the Star Scanners.

4.2.3.5 Mechanize the Star Scanners to provide star-angle measurements for alignment of the IMU.

4.2.3.6 Utilize the horizon sensor to provide redundant attitude information to the Digital Computer.

4.2.3.7 Provide automatic and manual control capability for all mission phases except docking, which is manual only.

4.2.3.8 Generate guidance commands that drive control loops to actuate valves in the main propulsion system and the RCS.

4.2.3.9 Provide attitude and steering displays for the crew.

4.2.3.10 Provide a keyboard for the crew with entrance into the Digital Computer for calling up information to be displayed on the Computer CRT Display.

4.2.4 Tracking, Telemetry & Communication Functional Requirements

4.2.4.1 Provide voice communication among crew stations in the MOTV.

4.2.4.2 Provide voice communication to outside manned activities via hardwire.

4.2.4.3 Provide voice communication between the MOTV, the ground stations and the Shuttle via RF Link.

4.2.4.4 Transmit high bit data from MOTV to the ground via RF Link.

4.2.4.5 Generate, transmit and distribute closed-circuit television (CCTV) in the MOTV.

REQUIREMENT

RATIONALE/SOURCE

4.2.4.6 Generate and transmit color TV or CCTV to the ground via the RF Link.

4.2.4.7 Provide a turnaround ranging signal for tracking by ground stations using the RF Link carriers.

4.2.4.8 Receive command data signals from the ground via RF Link annd distribute them for use by the supporting avionics.

4.2.4.9 Transmit MOTV status and crew health to the ground via RF Link.

4.2.4.10 Provide for location and interfacing of GFE decryptors and eneryptors for DOD missions for processing voice and data from and to the ground stations.

4.2.5 Rendezvous Radar Functional Requirement

4.2.5.1 Acquire and track passive targets for supporting rendezvous with other manned and unmanned vehicles in space.

4.2.5.2 Acquire and track cooperative targets with beacon transponders for supporting rendezvous between the MOTV, the Shuttle and other vehicles.

4.2.5.3 Provide range and bearing information to the attitude Control and Determination subsystem and for the Rendezvous Display on passive and cooperative targets during the rendezvous operation.

REQUIREMENT

RATIONALE/SOURCE

4.3 ELECTRICAL POWER SUBSYSTEM

4.3.1 Configuration

4.3.1.1 Schematic

Figure 4-1 depicts the MOTV electrical power subsystem configuration. The primary source of electrical power shall be fuel cells. A solar array recharge system will be used on missions with high energy requirements when there is a weight advantage.

4.3.1.2 Hardware Location

All prime power generation, storage, control and conditioning functions shall be located on the propulsion module. Cabin module electrical power requirements shall be provided by the propulsion module EPS via a remote load control and distribution center, located within the cabin module.

4.3.2 Safety

4.3.2.1 Redundancy

Redundancy shall exist in the EPS to provide for mission success in the event of a single failure and provide for a safe return if a second failure occurs in the same section.

4.3.2.2 Reliability

The overall mission success reliability of the electrical power subsystem shall be TDB .
The crew safety reliability shall be TBD .

4.3.2.3 Distribution and Control

Distribution and control of the primary power shall be such that a malfunction in the generation or storage section shall not cause loss

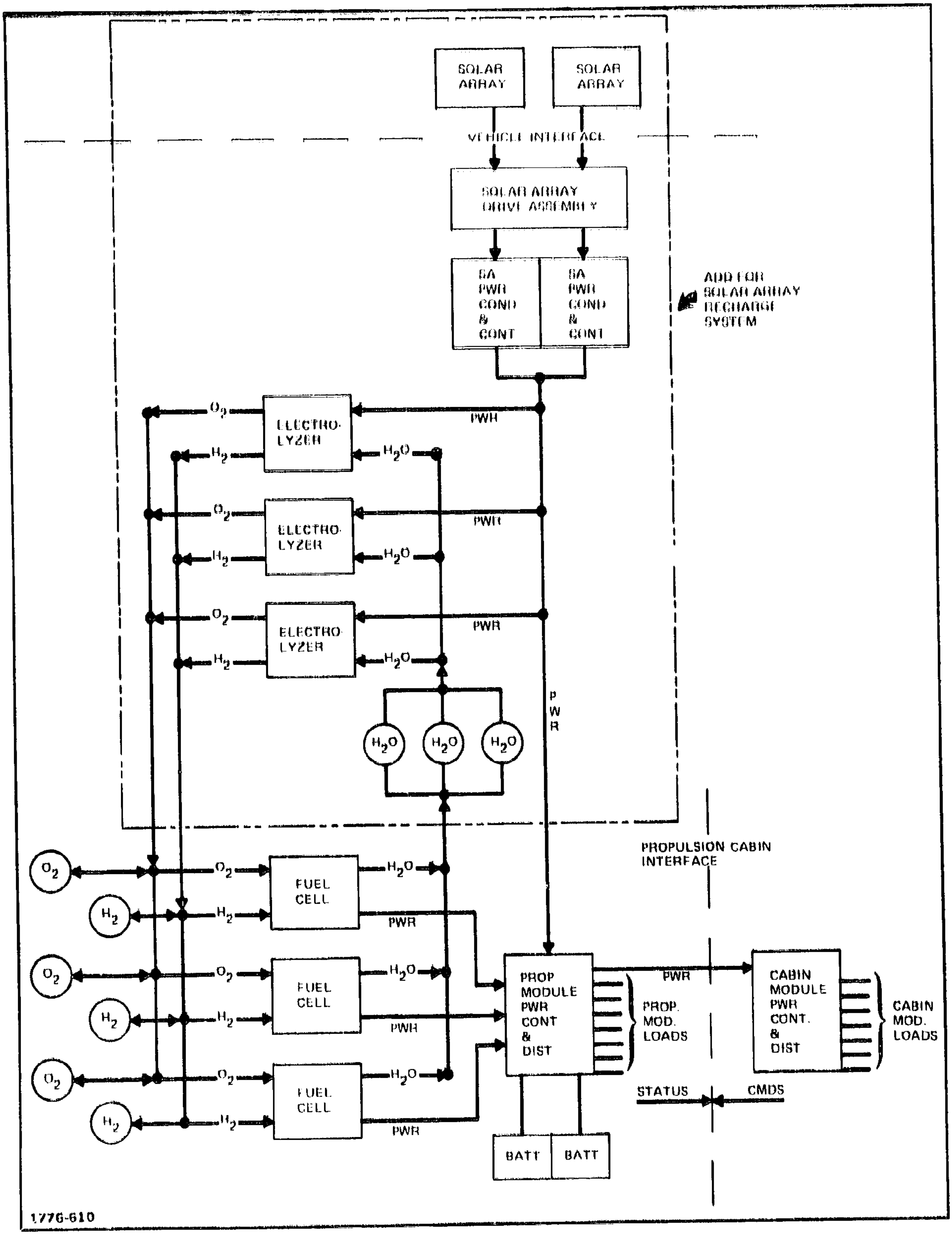

Fig. 4-1 EPS Schematic

or interruption of total vehicle power during critical mission phases. The main busses shall be capable of being powered from more than one source.

4.3.3 Functional Requirements

4.3.3.1 Operational

The MOTV prime power subsystem, located in the propulsion module, shall be capable of autonomous operation. Over-ride control of the prime power subsystem shall be provided within the cabin module and to ground support personnel.

4.3.3.2 Voltage

The primary voltage shall be a nominal TBD volts, dc. Secondary voltage requirements shall normally be the responsibility of the user.

4.3.3.3 Power

The maximum power to be made available to MOTV user loads shall be 5.0 kW.

4.3.3.4 Energy

The maximum energy requirement will be 3000 kW-hr for missions up to 30 days in duration.

4.3.3.5 Energy Reserve

A minimum of 50 kW-hr of emergency energy shall be continuously held in reserve during a mission.

4.3.3.6 Growth Capability

The EPS shall have the capability for power and energy growth by the addition of modular equipment.

4.3.3.7 Lifetime

The EPS shall have a maintained lifetime of not less than 10 years. Maximum duration of a single mission shall be 30 days.

4.3.4 Interfaces

4.3.4.1 Orbiter

The MOTV shall be capable of receiving up to 2.0 kW of Orbiter power. The interface shall include provisions for monitoring and control of critical MOTV EPS functions.

4.3.4.2 Ground

The MOTV shall be capable of full power operation using ground facility interfaces.

4.4 ENVIRONMENTAL CONTROL & LIFE SUPPORT

4.4.1 Functional

4.4.1.1 Provide Shirtsleeve Environment for 2 to 8 Men

4.4.1.2 Mission Durations Up to 30 Days

4.4.1.3 Cabin Conditions - The cabin shall be maintained at the following conditions:

Temperature:	Normal	18°C - 24°C	62° - 75°F
	Emergency	10°C - 32°C	50° - 90°F
Humidity	Dew Point	10°C - 162°C	50° - 60°F
Pressure	(O_2/N_2)	0.5 bar - 0.6 bar	7.5 - 8.5 psia
CO_2 pp		3 - 5 mm Hg.	
Cabin Leakage		1 kg/Day	2.2 lb/Day

4.4.1.4 Crew Metabolic Requirements - The subsystem shall be designed to provide for the following crew metabolic rates:

STS Design Criteria

Avg Metabolic Rate	11,200 Btu/Man Day
CO_2 Produced	0.96 kg/Man Day

REQUIREMENT

RATIONALE/SOURCE

Condensate	1.58 kg/Man Day
O_2 Required	0.83 kg/Man Day
Potable Water Req'd	2.35 kg/Man Day
Urine Produced	2.06 kg/Man Day

4.4.1.5 Redundancy Philosophy - Subsystem shall be designed to be fail safe with 96 hour survival provisions.

STS Design Criteria

Additional redundancy for less reliable components (e.g., pumps, fans, regulators) shall be provided as required.

4.4.1.6 Design Goal - As a design goal, the subsystem shall use regenerable system concepts to minimize expendables and resupply requirements. In particular, the following concepts shall be stressed:

- Regenerable CO_2 removal system
- Reclamation of waste water for all uses except drinking
- Store potable water
- Electrolysis of reclaimed water for O_2 generation

Figure 4-2 illustrates the subsystem schematic utilizing the above concepts.

4.4.2 Safety Requirements

Emergency pressurization shall maintain the cabin at 8 ± 0.5 psia for 1/2 hour when leakage equivalent to 1/4 inch diameter hole.

STS Design Criteria

4.4.3 High Pressure Storage Vessels

High pressure storage vessels shall be mounted externally with a minimum ultimate strength of 2 times the relief valve setting.

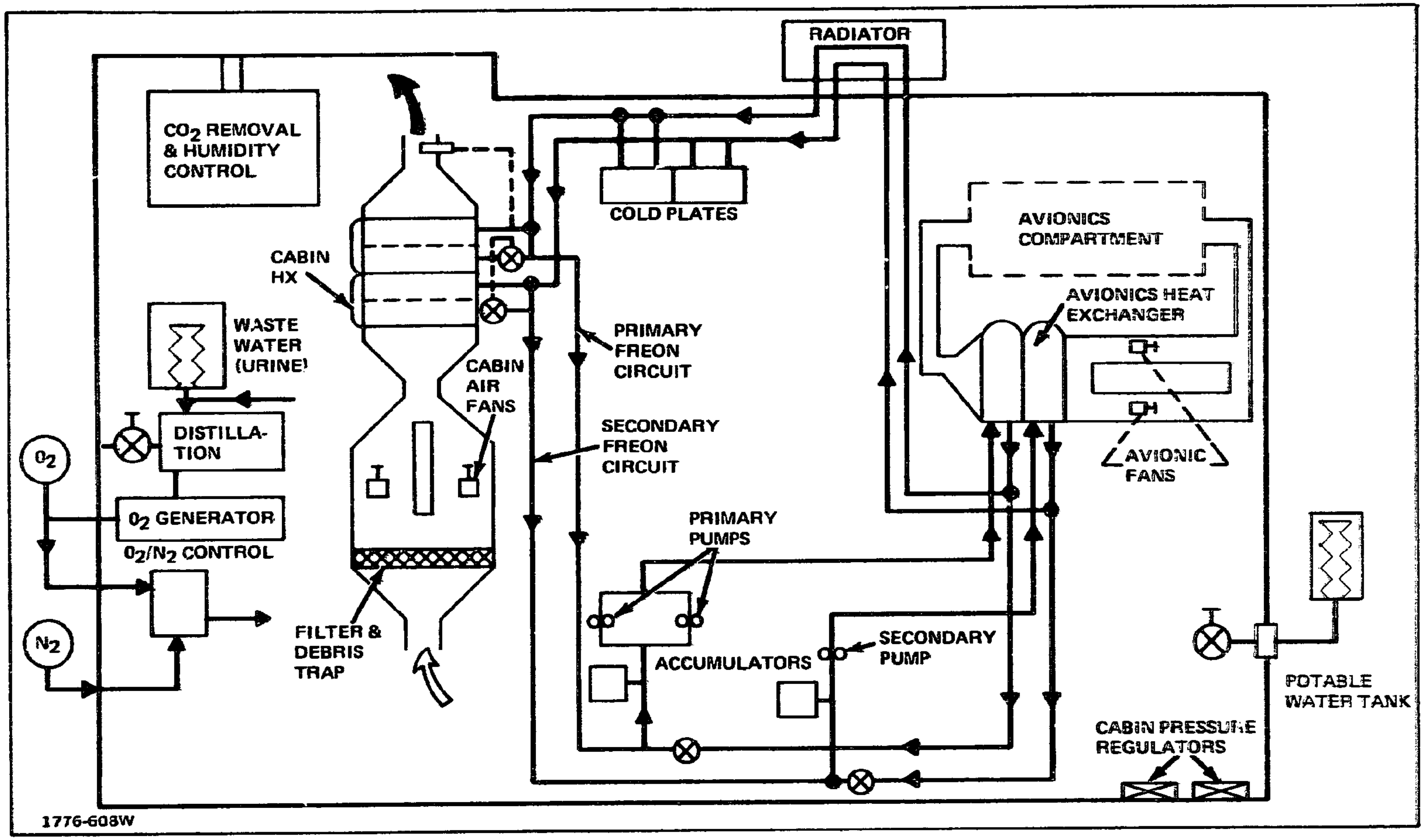

Fig. 4-2 ECLS Subsystem ~ Typical Schematic

REQUIREMENT	RATIONALE/SOURCE
4.4.4 *Orbiter Interfaces	
For crew rotation missions, the Orbiter shall provide ECLS services for up to 8 passengers and crew ascending and descending in the MOTV crew capsule carried in the Orbiter cargo bay.	
4.5 THERMAL CONTROL	
4.5.1 Functional Requirements	
4.5.1.1 Design Goal - Passive thermal control approach should be utilized where appropriate, or if not feasible, the design should minimize system complexity and weight.	Nominal Reqmts "D"
4.5.1.2 System Requirement - Provide thermal heat rejection system to maintain/remove cabin heat and electrical/electronic equipment heat (TBD).	
4.5.1.3 Orientation Requirement - The subsystem shall not require selected cabin orientation in orbit to maintain its thermal control function.	Nominal Reqmts "D"
4.6 CREW ACCOMMODATIONS	
4.6.1 Safety Requirements	
4.6.1.1 Loss of Cabin Pressure - Sudden loss of cabin pressure integrity shall initiate warning.	
4.6.1.2 MOTV Contingency Egress - An alternate means of egressing the MOTV shall be provided.	
4.6.1.3 Fire Detection - Fire detection and suppression shall be provided.	
4.6.2 Functional Requirements	
4.6.2.1 Habitability - Provide habitability volume for TBD crew to meet the requirements shown in Fig. 4-3.	H

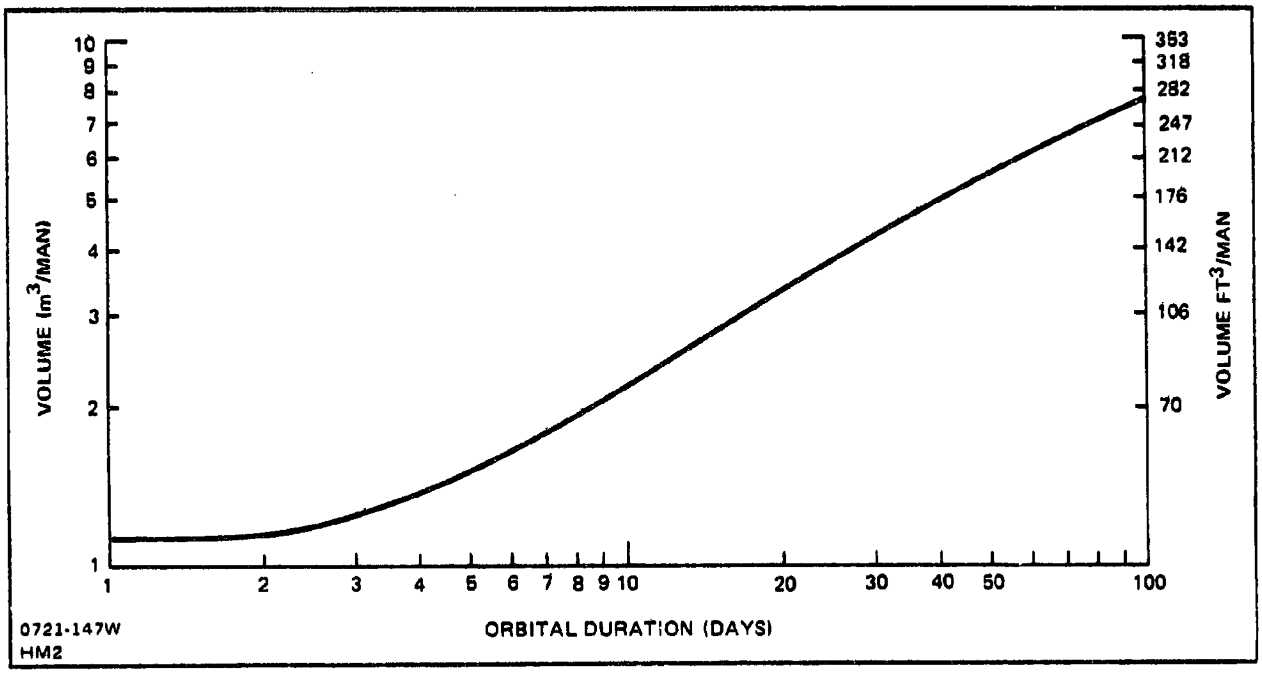

Fig. 4-3 Habitability Volume Requirements

REQUIREMENT	RATIONALE/SOURCE
4.6.2.2 Anthropormeric - Accommodate male and female operators in the 5th to 95th percentile anthropormeric range.	Nominal Reqmts "D"
4.6.2.3 Noise Levels - Continuous noise levels will not exceed 50 dB in the 600 to 4800 Hz range, and 70 dB above 4800 Hz.	
4.6.2.4 Body Position - Design for crew neutral body position in zero gravity shown in Fig. 4-4.	I
4.6.2.5 Visibility - Windows sized to provide view of manipulator slave arms and stabilizer through full range of expected servicing and construction tasks.	
4.6.2.6 Personal - Provide the following: a) EMU stowage and donning station b) Waste management system (toilet, urinal) c) Food preparation/eating/storage area (hot & cold) d) Sleep accommodation & storage for personal items (Hygiene, recreation, clothing).	
4.6.2.7 Work Station - Work station restraints and IVA handholds.	
4.7 GUIDANCE NAVIGATION & CONTROL	
4.7.1 Functional Requirements	
4.7.1.1 Rendezvous - The MOTV shall have the capability of departing LEO and rendezvousing with a satellite located in GEO. The reverse sequence capability shall also be provided; the MOTV departs GEO for rendezvous with Orbiter in LEO.	
4.7.1.2 Docking - Docking capability shall be provided to mate with Orbiter and other cooperative spacecraft.	

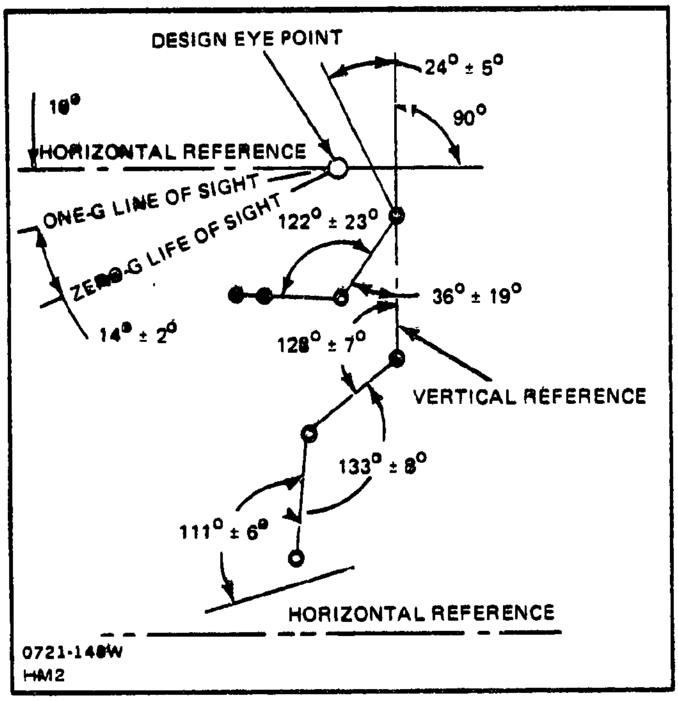

Fig. 4-4 Crew Neutral Body Position in Zero Gravity

REQUIREMENT	RATIONALE/SOURCE
4.7.1.3 Control Authority - Provide control authority: - Rotational Acceleration $10^\circ/\mathrm{sec}^2$ - Translation 0.3 $\mathrm{ft}/\mathrm{sec}^2$ Attitude deadband shall be ±0.1°	MGMRSAS DATA Pkg. 1.1
4.8 ATTITUDE CONTROL	
4.8.1 Thrusters - Thrusters shall be provided for attitude control mounted on the propulsion module	
4.8.2 Thruster Plumes - Thruster Plumes shall avoid work volumes.	
4.9 CONTROLS & DISPLAYS	
4.9.1 Safety Requirements	
4.9.1.1 Automatic Switchover - Visual and/or audio caution and warning shall be provided to the crew, in the event of any automatic subsystem switching to alternate/backup modes of operation, and when critical components fail or malfunction.	Nominal Reqmts "D"
4.9.1.2 Redundancy - The critical command and control circuitry shall be designed to a fail-operational/failsafe as a minimum.	Nominal Reqmts "D"
4.9.2 Functional Requirements	
4.9.2.1 Design Eye Point - The design eye point is specified in Fig. 4-2.	Nominal Reqmts "D"
4.9.2.2 Layout - Cabin displays shall minimize excursion into the manipulator controller working volume and crew line-of-sight to assembly tasks.	Nominal Reqmts "D"
4.9.2.3 Commands - Provide computer entry keyboard and read out displays for interface with the guidance and control subsystem.	Nominal Reqmts "D"

REQUIREMENT	RATIONALE/SOURCE
4.9.2.4 Closed Circuit TV - A closed circuit TV monitor display shall be located adjacent to the cabin windows.	Nominal Reqmts "D"
4.10 ILLUMINATION	Nominal Reqmts "D"
4.10.1 Manipulator Lighting Lights shall be mounted on the cabin to provide 50 f-c of luminous intensity within reach of the manipulators.	
4.10.2 Exterior Lights Position lights shall be mounted on the exterior of the MOTV for determination of vehicle orientation. Each light shall have luminous intensity of 2.5 candlepower.	Nominal Reqmts "D"
4.10.3 MOTV Cabin Lighting - TBD	Nominal Reqmts "D"
4.11 DEXTEROUS MANIPULATOR	
4.11.1 Slave Manipulators The MOTV shall have two slave manipulators, located on the exterior front face of the crew module, see Fig. 3-3, and shall be capable of being installed/detached in orbit.	Nominal Reqmts "D"
4.11.2 Manipulator Dexterity & Reach The 7 DOF manipulators shall have a maximum reach of 4.0 m.	Nominal Reqmts "D"

REQUIREMENT RATIONALE/SOURCE

4.11.3. Interfaces

Nominal Reqmts "D"

The tip shall have mechanical and electrical interfaces to accept a variety of end effectors.

4.12 GRAPPLER (Stabilizer)

4.12.1 Grappler Controls

The MOTV shall have one grappler arm. Motion controls shall be panel mounted in immediate vicinity of the manipulator controls and displays. Position shall allow direct activity observation through windows provided.

4.12.2 Grappler Reach

The 4 DOF grappler must reach 2.0m.

4.12.3 Interfaces

The grappler tip shall have mechanical and electrical interfaces to accept a variety of end effectors.

4.12.4 Location

The grappler shall be mounted at the top center of the cabin windows as illustrated in Fig. 3-3.

4.13 PROPULSION MODULE CHARACTERISTICS

The propulsion module shall be an autonomous vehicle capable of operation in either a manned or unmanned mode. It is configured to handle four Shuttle compatible propellant drop tanks surrounding a central core as depicted in Fig. 3-1. Each drop tank has a usable capacity of 27,270 kg excluding boiloff. The core tank has a capacity of 17,500 kg. Therefore, with four drop tanks plus a fully loaded core, the total usable capacity of the MOTV propulsion stage is 126,580 kg. The

REQUIREMENT	RATIONALE/SOURCE
boiloff rate shall not exceed 19 kg/day per tank and tank sizing shall assure that a mixture ratio of 6.0 can be maintained. The stage shall be designed to operate with any number of drop tanks up to four either fully or partially loaded. The characteristics of the drop tank is summarized in Fig. 4-5. Each drop tank shall be provided with a deorbit propulsion and guidance system so that safe jettisoning and entry into earth's atmosphere can be assured when its propellant is depleted.	
The baseline propulsion system for MOTV shall use two RLIO Cat IIB type engines with an I_{SP} of 458 sec at a 6.0 M.R. Each engine delivers 15,000 lb of thrust and is gimbalable over a ±20 deg angle to enable tracking the C.G. depending on the number of drop tanks employed. The propulsion core shall also accommodate the new advanced space engine when it becomes available.	Aerojet CTV Engine Study
The propulsion core vehicle contains all of the necessary subsystems to permit its operation in an unmanned mode. It also contains appropriate interface electronics to allow manned operation from the MOTV crew cabin. The characteristics of the core stage are summarized in Fig. 4-6.	

- PROPELLANT CAPACITY
  - USABLE (EXCLUDING BOILOFF) = 27,270 kg
  - MAX LOADED (AT LAUNCH) = 27,606 kg
  - OPERATING MR = 6.0
- TANK PHYSICAL PROPERTIES
  - OAL = 8.08 m
  - DIAMETER = 4.27 m
  - VOL. LH_2 = 68.1 m^3
  - VOL. LO_2 = 20.8 m^3
  - EMPTY WEIGHT = 1100 kg
- MAX BOILOFF RATE = 19 kg/DAY
- COMPATIBILITY PROVISIONS = STS COMPATIBLE
- DEORBIT PROVISIONS
  - ST'D DEORBIT ΔV + ADDITIONAL ΔV FOR HIGHER ORBITS = 120 ft/sec + ΔV TBD
  - SRM WEIGHT = 107 kg
  - SPIN SYSTEM WEIGHT = 10 kg
  - NUTATION DAMPER = 10 kg

Fig. 4-5 Drop Tank Characteristics

- MAIN PROPELLANT CAPACITY = 17,500 kg
  - LH_2 TANK VOLUME = 36.36 m^3
  - LO_2 TANK VOLUME = 13.62 m^3
- MAXIMUM DIAMETER = 4.27 m
- OVERALL LENGTH = 9.8 m
- MAX BOILOFF RATE/TANK = 19.0 kg/DAY
- MAIN ENGINE (2) = RLIO CAT IIB
  - THRUST LEVEL EACH = 66,700 N
  - I_{SP} (EFFECTIVE) = 458 SEC AT 6.0 MR
  - GIMBAL ANGLE = ± 20°
- RCS PROPELLANT CAPACITY = 2600 kg
  - THRUSTERS (IN 4 MODULES) = HYDRAZINE
  - THRUST LEVEL EACH = 700 N
  - I_{SP} (EFFECTIVE) = 230 SEC
- MOUNTED INSIDE OR OUTSIDE INTERTANK SKIRT
  - FUEL CELL (3)
  - REACTANTS
  - RADIATOR = 4.63 m^2
  - SOLAR ARRAY (IF REQD) = 12 kW_e
  - OTHER SUBSYSTEMS
  - INTERFACE ELECTRONICS

1776-609W

Fig. 4-6 Propulsion Core Characteristics

APPENDIX A

Rationale/Source Explanation and Listings

Introduction

The requirements appearing in the body of this report result from the Manned Geosynchronous Mission Requirements Systems Analysis Study under Contract NAS 9-15779. Specifically, program requirements were derived from the SOW and communications with NASA and Grumman program personnel; mission requirements came from the Mission Requirements Definition Task; system and subsystem requirements from the Manned Systems Requirements and System Concept Definition Tasks and; turnaround support requirements came from the Support Requirements Definition Task. References identifying the requirement source(s) are listed next to each requirement. The source identification code used is defined along with the specific source documentation in the following paragraphs.

Source Code Definition

The code for the Rationale/Source column to the right of the requirements column in the body of this report is:

X/ X.X.X/X

Source Document Paragraph No. Page No.

Source Document Code

A. Manned Geosynchronous Mission Requirements System Analysis Study, NAS 9-15779, SOW, Exhibit A, dated May 26, 1978

B. STS Payloads Accommodations Document, JSC 0700 Volume XIV including Change #27, dated November 30, 1978

C. KSC Launch Site Accommodations Handbook, March 1978

D. Nominal values based on Grumman's experience with manned and unmanned space systems.

E. TMX-53865, second edition, dated August 1970.

F. Orbital Construction Demonstration Study, Final Report, Requirements Document, 6/77.

G. Figure supplied by Environmental Control & Life Support Branch, JSC.

H. Spacecraft Habitability Volume Requirements - Grumman Memo NSS-MG-M0016, dated 2/4/79.

I. Zero-G Workstation Design, JSC-009962, 6/76.