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SPACE OPERATIONS CENTER

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SYSTEM ANALYSIS

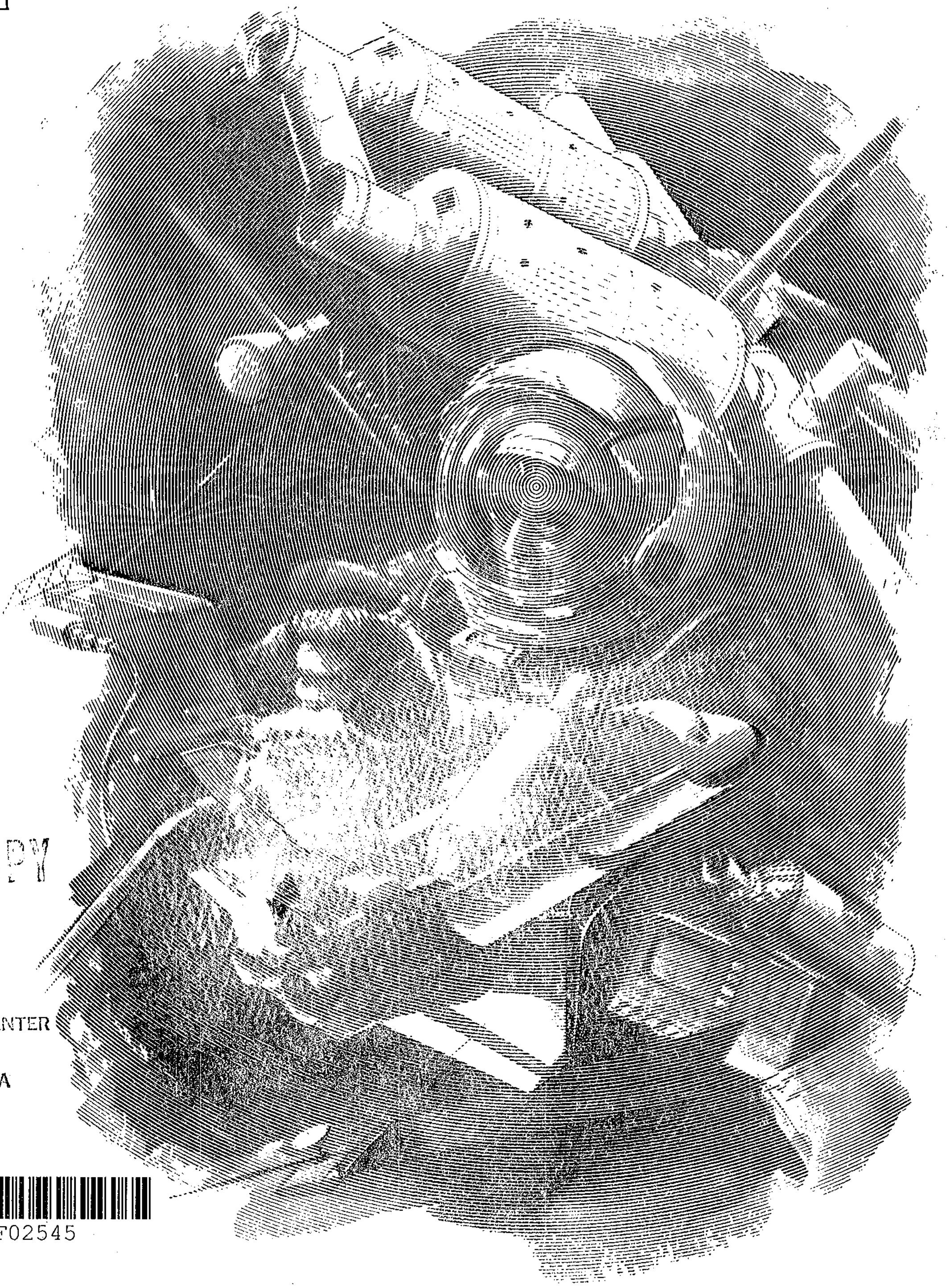
FINAL REPORT VOLUME III

BOOK 2 of 2

SOC SYSTEM DEFINITION REPORT

D180-26495-3
REV. A

JANUARY, 1982



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THE BOEING COMPANY

HAMILTON STANDARD Division of UNITED TECHNOLOGIES

GRUMMAN

D180-26495-3
Rev A

SPACE OPERATIONS CENTER
SYSTEM ANALYSIS

Conducted for the NASA Johnson Space Center

Under Contract NAS9-16151

FINAL REPORT

VOLUME III

BOOK 2 OF 2

SOC SYSTEM DEFINITION REPORT

D180-26495-3

Rev A

January, 1982

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Approved by
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N82-20202 #

FOREWORD

The Space Operations Center System Analysis Study (Contract NAS9-16151) was initiated in June of 1980 and completed in May of 1981. A separately funded Technology Assessment and Advancement Plan study was conducted in parallel with the System Analysis Study. The study was conducted by the Boeing Aerospace Company with Hamilton Standard as the subcontractor. These studies were documented in 5 final reports:

D180-26495-1	Vol. I	-	Executive Summary
D180-26495-2	Vol. II	-	Requirements (NASA CR-160944)
D180-26495-3	Vol. III	-	SOC System Definition Report
D180-26495-4	Vol. IV	-	SOC System Analysis Report (2 volumes)
D180-26495-7		-	Space Operations Center Technology Identification Support Study, Final Report

The System Analysis Study was extended by a Study Extension contract (Contract NAS9-16151, Exhibit B) that was initated in August of 1981 and completed in January 1982. The study was conducted by the Boeing Aerospace Company with Hamilton Standard and Grumman Aerospace Company as subcontractors. The study extension results are reported in 6 final reports (eight books total):

D180-26785-1	Vol. I	-	Executive Summary
D180-26785-2	Vol. II	-	Programmatics
D180-26785-3	Vol. III	-	Final Briefing
D180-26785-4	Vol. IV	-	System Analysis Report (two books)
D180-26495-2A*	Vol. II	-	SOC System Requirements
D180-26495-3A*	Vol. III	-	SOC System Definition Report (two books)

These studies were managed by the Lyndon B. Johnson Space Center. The Contracting Officer's Representative and Study Technical Manager is Sam Nassiff.

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*These documents are Revision A of the documents published at the end of the previous study. These revisions include requirements and configuration additions and modifications that resulted from the study extension analyses.

The Boeing study manager is Gordon R. Woodcock. The Hamilton Standard study manager is Harlan Brose. The Grumman study manager is Ron McCaffrey.

For convenience to the reader, a complete listing of all of the known Space Operations Center documentation is included in the Reference section of each document. This includes NASA, Boeing, and Rockwell documentation.

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SECTION II - OPERATIONS

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SECTION III - PROGRAMMATICS AND COST

REFERENCES

REVISIONS

LTR	DESCRIPTION	DATE	APPROVAL
A	Foreword - Revised to include study extension	Dec 81	
	Key Team Members - Revised to include study extension study team members		
	Table of Contents - Revised to include new elements defined in extension study		
	List of Acronyms and Abbreviations - revised to include new items from extension study		
	p.2 - Modular SOC concept added		
	p.3/4 - WBS numbers added to table		
	p.6 - Operational SOC illustration changed to reflect revised concept (new hangars, offset habitat modules)		
	p.7 - Growth SOC illustration changed for same reasons as given above.		
	p.11 - WBS Elements table updated to include Mini-Habitat and Portable IVA Tunnel		
	p.14 - Mass table updated to include corrections and new elements		

REVISIONS

LTR	DESCRIPTION	DATE	APPROVAL
A	p.15-19 - Habitat module descriptions and illustrations revised to include offset berthing parts p.20 ff - Habitat module mass table revised to include ECLS updates p.49 ff - Radiator performance curves added p.99 - Refrigerator and freezer volumes revised to match ECLS descriptions p.100 - Volumes of ECLS and EVA spares and supplies revised p.110 - Fourth sentence from bottom, item 1) should read: "seven emergency nitrogen tanks and four emergency oxygen tanks" p.114 - Should have 4 - 0_2 Emergency Tanks 7 - N_2 Emergency Tanks p.119-120 - Table changes p.122 - Item 3) ". . . ensure that temperature control . . . is not completely lost . . ." last line: ". . . equipment from damage . . ."		

REVISIONS

LTR	DESCRIPTION	DATE	APPROVAL
A	p.124 - Under Performance And Design Data should be: - 21 Day Emergency (^{o}F) - 21 Day Emergency (ft/min) p.134 - Performance And Design Data - 21 Day Emergency (mmHg) - 21 Day Emergency (^{o}F) - 21 Day Emergency - 8 Hr. Ind. Std. p.135 - Under CO_2 Control Should read: (2 units) in 3 places under Catalytic Contaminant Burner 64 should be 108 3 should be 12.5 70 should be 381 should be Sabatier/CO_2 Reduction 40 should be 107 6.3 should be 12.5 under Atmospheric Monitor Nominal power consumption 100 p.144 - Rewritten first sentence under Habitat Space Radiators: "Each habitation module has a radiator containing two integral freon coolant loops which, together are capable . . ." p.145 - Rewritten paragraph p.146 - Under Habitat Space-Radiators Heat rejection capacity (per Hab) .24-30	Dec 81	

REVISIONS

LTR	DESCRIPTION	DATE	APPROVAL
A	p.152 - Second paragraph, last line: replace "300 hour" with "21 day" Performance And Design Data: replace 2.6 - 3.1 with 2.73 - 2.93 replace "Degraded" with "Acceptable" replace 2.4 - 3.8 with 2.66 - 3.05 replace "300 hour" with "21 day" replace 2.3 - 3.9 with 2.3 - 3.05 replace 10.0 - 14.7 with 11.8 ± 0.2 Electrolysis: replace 3950 with 3980 replace 3500 with 3530 Bottom line: replace 28 with 26 p.153 - N_2 Generator replace 23 with 67 replace 25 with 50 $0_2/N_2$ Emergency Storage replace 198 with 66 replace 296 with 58 replace 1430 with 1650 replace 113 with 378 paragraph: eliminate "however emergency oxygen and nitrogen supplies are needed only outside one service module" last 2 items under Mechanical should be: Emergency Oxygen (seven/SOC) 3' x 3' x 3'	Dec 81	

REVISIONS

LTR	DESCRIPTION	DATE	APPROVAL
A	Emergency Nitrogen (seven/SOC) 3' x 3' x 3' p.156 - top of page replace 39.7 with 47.7 replace 1080 with 1086.6 p.161 - under Performance And Design Data replace 90 Day Degraded with 90 Day Acceptable replace 14 with 21 p.174 - Under Refrigerator should be 15 watts DC cont. Under Oven: add Oven Weight - 37.5 pounds p.175 - Is a duplicate of p.174 p.187 - Under Baseline EMU support equipment elements are: replace "Airlock Adapter Plate (AAP)" with "Suit Adapter Plate (SAP)" p.188- Replace "Airlock Adapter Plate" with "Adapter Plate" p.193 - Replace "Airlock Adapter Plate (AAP)" with "Suit Adapter Plate (SAP)"	Dec 81	

REVISIONS

LTR	DESCRIPTION	DATE	APPROVAL
A	last paragraph, first line: replace "AAP" with "SAP" p.195 - Under FIGURE C: replace "AIRLOCK ADAPTER PLATE (AAP)" with "SUIT ADAPTER PLATE (SAP)" p.209A - Mini-Habitat Module added p.213/214 - Service Module illustration revised to show corrected no. of 0_2 and N_2 tanks p.216,217 - Water pump and waste water storage deleted p.219 ff - Service Module mass table revised to include ECLS updates p.239 ff - Radiator performance curve added p.240 - Radiator loads changed to eliminate ECLS loads p.248 ff - Electrical power system description enhanced by addition of power availablility vs. time data, improved solar cell performance estimate.	Dec 81	

REVISIONS

LTR	DESCRIPTION	DATE	APPROVAL
A	p.283 - Emergency duration correction from 14 to 21 days.	Dec 81	
	p.300 - Docking Tunnel mass table revised to include ECLS updates		
	p.300A ff - WBS 1.2.2.4 Airlock Module description revised to include 2 types of airlocks plus a portable tunnel.		
	p.301 ff - Changed to Airlock Module No. 1 data		
	p.302 ff - Airlock Module No. 2 data added		
	p.302 ff - Portable IVA Tunnel data added		
	p.304 ff - General Purpose Support Equipment mass table revised to include satellite servicing equipment additions		
	p.307 ff - Mobility and Access System description revised to include satellite servicing operations		
	p.320 - Module cherrypicker illustration changed to eliminate sliding elbow joint		
	p.329A-C - Mobile Platform System added		
	p.329D-F - Handling and Positioning Aide added		

REVISIONS

LTR	DESCRIPTION	DATE	APPROVAL
A	p.357-365 - New hangar concept replacing previous concept.	Dec 81	
	p.373 - New Logistics Module concept		
	p.375 - 382 - LM Mass table revised to include new configuration and ECLS updates		
	p.386 ff - Crew job descriptions added		
	p.394 ff - The SOC buildup operations descriptions have been totally revised		
	p.425 ff - The Flight Support Operations section has been totally revised		
	p.453 ff - Satellite Servicing Operations section substantially revised		
	p.458 ff - Programmatics and Cost section totally deleted and a Modular SOC Concept description section added in its place		

KEY TEAM MEMBERS

Subject	JSC-Management Team	Contractor Team
SOC Technical Manager	S. H. Nassiff	G. R. Woodcock
SOC Technology Study Manager	R. Kennedy	R. L. Olson
System Design	S. H. Nassiff ✓	G. R. Woodcock
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Structures/Dynamic Control	13 R. Wren 2363	R. M. Gates
Stab/Control	J. Bigham	J. H. Mason
Propulsion/Propellant Storage	D. Kendrick	G. R. Woodcock
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Crew Habitat	M. Dalton	K. H. Miller
Operations	B. M. Wolfer	K. H. Miller
Space Construction Facility	L. Jenkins	K. H. Miller
Flight Support Facility	H. Patterson	G. R. Woodcock K. H. Miller
Crew Operations	M. Dalton	K. H. Miller
Orbital Altitude	F. Garcia	G. R. Woodcock
Operations Concepts/ Requirements	B. Wolfer	K. H. Miller
Transportation	B. Wolfer	K. H. Miller G. R. Woodcock

KEY TEAM MEMBERS (Continued)

Subject	JSC-Management Team	Contractor Team
Technology	R. Kennedy	E. A. Gustan R. L. Olson
Cost	W. H. Whittington	G. R. Woodcock T. Mancuso

LIST OF ACRONYMS AND ABBREVIATIONS

AAP	Airlock Adapter Plate
AC	Alternating Current
ADM	Adaptive Delta Modulation
AM	Airlock Module
APC	Adaptive Predictive Coders
APSM	Automated Power Systems Management
ACS	Attitude Control System
ARS	Air Revitalization System
ASE	Airborn Support Equipment
BIT	Built in Test
BITE	Built in Test Equipment
CAMS	Continuous Atmosphere Monitoring System
C&D	Controls and Displays
C&W	Caution and Warning
CCA	Communications Carrier Assembly
CCC	Contaminant Control Cartridge
CEI	Critical End Item
CER	Cost Estimating Relationships
CF	Construction Facility
CMG	Control Moment Gyro
CMD	Command
CMDS	Commands
CO_2	Carbon Dioxide
CPU	Computer Processor Units
CRT	Cathode Ray Tube
dB	Decibels
DC	Direct Current
DCM	Display and Control Module
DDT&E	Design, Development, Test, and Evaluation
DOD, DoD	Department of Defense
DT	Docking Tunnel
DM	Docking Module
DMS	Data Management System
DSCS	Defense Satellite Communications System

LIST OF ACRONYMS AND ABBREVIATIONS (Cont.)

ECLSS	Environmental Control/Life Support System
EDC	Electrochemical Depolarized CO_2 Concentrator
EEH	EMU Electrical Harness
EIRP	Effective Isotropic Radiated Power
EMI	Electromagnetic Interference
EMU	Extravehicular Mobility Unit
EPS	Electrical Power System
EVA	Extravehicular Activity
EVC	EVA Communications System
EVVA	EVA Visor Assembly
FM	Flow Meter
FMEA	Failure Mode and Effects Analysis
ftc	Foot candles
FSF	Flight Support Facility
FSS	Fluid Storage System
GN&C	Guidance, Navigation and Control
GEO	Geosynchronous Earth Orbit
GHZ	Gigahertz
GPS	Global Positioning System
GSE	Ground Support Equipment
GSTDN	Ground Satellite Tracking and Data Network
GFE	Government Furnished Equipment
GTV	Ground Test Vehicle
HLL	High Level Language
HLLV	Heavy Lift Launch Vehicle
HM	Habitat Module
HMF	Health Maintenance Facility
HPA	Handling and Positioning Aide
HUT	Hard Upper Torso
H_z	Hertz (cycles per second)
ICD	Interface Control Document
IDB	Insert Drink Bag
IOC	Initial Operating Capability
IR	Infrared

LIST OF ACRONYMS AND ABBREVIATIONS (Cont.)

IVA	Intravehicular Activity
JSC	Johnson Space Center
KBPS	Kilo Bits Per Second
KM, Km	Kilometers
KSC	Kennedy Space Center
lbm	Pounds Mass
LCD	Liquid Crystal Display
LCVG	Liquid Cooling and Ventilation Garment
LED	Light Emitting Diode
LEO	Low Earth Orbit
LiOH	Lithium Hydroxide
LM	Logistics Module
LPC	Linear Predictive Coders
LRU	Lowest Replaceable Unit
LSS	Life Support System
LTA	Lower Torso Assembly
LV	Launch Vehicle
lx	Lumens
MBA	Multibeam Antenna
mbps	Megabits per second
MHz	Megahertz
MMU	Manned Maneuvering Unit
MM-Wave	Millimeter wave
MOTV	Manned Orbit Transfer Vehicle
MRWS	Manned Remote Work Station
MSFN	Manned Space Flight Network
N/A	Not Applicable
NBS	National Bureau of Standards
NSA	National Security Agency
N	Newton
NiCd	Nickel Cadmium
NiH_2	Nickel Hydrogen
Nm, nm	Nautical miles
N/m^2	Newtons per meter squared

LIST OF ACRONYMS AND ABBREVIATIONS (Cont.)

OBS	Operational Bioinstrumentation System
OCS	Onboard Checkout System
OMS	Orbital Maneuvering System
OTV	Orbital Transfer Vehicle
PCM	Pulse Code Modulation
PCM	Parametric Cost Model
PEP	Power Extension Package
PIDA	Payload Installation and Deployment Apparatus
P/L	Payload
PLSS	Portable Life Support System
PM	Power Module
ppm	Parts per Million
PRS	Personnel Rescue System
PSID	Pounds per Square Inch Differential
RCS	Reaction Control System
REM	Reoentgen Equivalent Man
RF	Radio Frequency
RFI	Radio Frequency Interference
RMS	Remote Manipulator System
RPM	Revolutions Per Minute
SAF	Systems Assembly Facility
SAWD	Solid Amine Water Desorbed
scfm	Standard Cubic Feet per Minute
SCS	Stability and Control System
SCU	Service and Cooling Umbilical
SEPS	Solar Electric Propulsion System
SF	Storage Facility
SM	Service Module
SOC	Space Operations Center
SOP	Secondary Oxygen Pack
SSA	Space Suit Assembly
SSP	Space Station Prototype
SSTS	Space Shuttle Transportation System
STAR	Shuttle Turnaround Analysis Report

LIST OF ACRONYMS AND ABBREVIATIONS (Cont.)

STDN	Spaceflight Tracking and Data Network
STE	Standard Test Equipment
TBD	To Be Determined
TDRSS	Tracking and Data Relay Satellite System
TFU	Theoretical First Unit
TGA	Trace Gas Analyzer
TIMES	Thermoelectric Integrated Membrane Evaporation System
TLM	Telemetry
TM	Telemetry
TT	Turntable/Tilttable
TV	Television
UCD	Urine Collection Device
VCD	Vapor Compression Distillation
VDC	Volts Direct Current
WBS	Work Breakdown Structure
WMS	Waste Management System

WBS 1.2.3 GENERAL PURPOSE EQUIPMENT

1.0 WBS Dictionary

This element includes the equipment items that are used in all of the various SOC missions operations and in SOC build-up, maintenance, and resupply operations. Items included are the track system, manipulators, mobile cherrypicker, EVA workstation, turntable/tilttable, umbilical system, and storage systems.

2.0 Description

The equipment items included in this WBS are the items that have been identified to be useful during two or more of the following operations: construction, flight support, satellite servicing, logistics, module interchange, base maintenance, base build-up. Each item is fully described in lower-level WBS descriptions so further explanation here is not required.

3.0 Design Basis

This section is not pertinent at this level. Refer to corresponding sections for lower level WBS elements.

4.0 Mass

The mass statement for the General Purpose Support Equipment is given in Table A.

Table A – General Purpose Support Equipment Mass Statement

IN-DEX #	IN-DENT #	WBS #	TITLE	MASS KG(LB)	OFFSETS,M(FT) X	Y	Z	RATIONALE FOR ESTIMATE
1	1	1.2.3	GP SUPPORT EQUIP	7898	0	0	0	SUM
				(17410	0	0	0)	
2	2	1.2.3.1	MOB/ACCESS SYSTE	331	0	0	0	SUM
				(729	0	0	0)	
3	3	1.2.3.1.1	HM TRACKS	188	0	0	0	- 37.5M TOTAL LENGTH - 5 KG/M - ASSUMES RUGGEDIZED CAP SECTIONS AND TRACKS - NOTE: OFFSETS NOT USED IN THIS MASS STATEMENT AS MOST EQUIPMENT LOCATION IS VARIABLE.
				(414	0	0	0)	
4	3	1.2.3.1.2	DOCK TUNNEL TRAC	75	0	0	0	15 M TOTAL LENGTH @ 5 KG/M
				(165	0	0	0)	
5	3	1.2.3.1.3	INSTALLATION PRO	68	0	0	0	20% OF TOTAL TRACK MASS
				(150	0	0	0)	
6	2	1.2.3.2	HANDLING EQUIPME	5743	0	0	0	SUM
				(12660	0	0	0)	
7	3	1.2.3.2.1	ARMS	1749	0	0	0	SUM
				(3855	0	0	0)	
8	4	1.2.3.2.1.1	FIXED ARM	388	0	0	0	SCALED FROM SHUTTLE RMS MASS
				(855	0	0	0)	
9	4	1.2.3.2.1.2	BERTHING FIXTURE	136	0	0	0	ESTIMATE
				(300	0	0	0)	
10	4	1.2.3.2.1.3	MOBILE CARRIAGE	454	0	0	0	ROUGH ESTIMATE
				(1000	0	0	0)	
11	4	1.2.3.2.1.4	CHERRYPICKER ARM	771	0	0	0	TWICE RMS
				(1700	0	0	0)	

Table A – General Purpose Support Equipment Mass Statement (Continued)

IN-DEX #	IN-DENT #	WBS #	TITLE	MASS KG(LB)	OFFSETS,M(FT) X	Y	Z	RATIONALE FOR ESTIMATE
12	3	1.2.3.2.2	TOOLS & END EFF	1028	0	0	0	SUM
				(2266	0	0	0)	
13	4	1.2.3.2.2.1	OPEN MRWS	273	0	0	0	MASS OF EXPERIMENTAL
				(602	0	0	0)	GRUMMAN MRWS
14	4	1.2.3.2.2.2	TYPE A END EFFEC	50	0	0	0	ESTIMATE
				(110	0	0	0)	
15	4	1.2.3.2.2.3	TYPE B END EFFEC	250	0	0	0	ESTIMATE
				(551	0	0	0)	
16	4	1.2.3.2.2.4	RMS-TYPE END EFF	45	0	0	0	3 UNITS @ 15 KG EACH
				(99	0	0	0)	
17	4	1.2.3.2.2.5	EVA WORKSTATION	410	0	0	0	- MODIFIED MRwS
				(904	0	0	0)	- 1.5 X MRWS MASS
18	3	1.2.3.2.4	MOBILE PLATFORM	1518	0	0	0	SUM
				(3347	0	0	0)	
19	4	1.2.3.2.4.1	CARRIAGE	454	0	0	0	WBS 1.2.3.2.1.3
				(1001	0	0	0)	
20	4	1.2.3.2.4.2	ARMS	771	0	0	0	TWICE RMS
				(1700	0	0	0)	
21	4	1.2.3.2.4.3	OCP	273	0	0	0	GRUMMAN RMS
				(602	0	0	0)	
22	4	1.2.3.2.4.4	SNARE END EFFECT	20	0	0	0	GIVEN RMS
				(44	0	0	0)	
23	3	1.2.3.2.5	HANDLING & POSIT	1448	0	0	0	SUM
				(3192	0	0	0)	
24	4	1.2.3.2.5.1	ARTICULATING ARM	1000	0	0	0	GRUMMAN HPA DTA
				(2205	0	0	0)	
25	4	1.2.3.2.5.2	OCP	273	0	0	0	GRUMMAN MRWS
				(602	0	0	0)	

Table A – General Purpose Support Equipment Mass Statement (Continued)

IN-DEX #	IN-DENT #	WBS #	TITLE	MASS KG(LB)	OFFSETS,M(FT) X	Y	Z	RATIONALE FOR ESTIMATE
26	4	1.2.3.2.5.3	OCP SUPPORT	75 (165	0 0	0 0	0 0)	ESTIMATE
27	4	1.2.3.2.5.4	UMBILICAL & LINE	50 (110	0 0	0 0	0 0)	ESTIMATE
28	4	1.2.3.2.5.5	END EFFECTOR	50 (110	0 0	0 0	0 0)	TYPE A ESTIMATE
29	2	1.2.3.3	TURN/TILTTABLE	1204 (2654	0 0	0 0	0 0)	SUM
30	3	1.2.3.3.1	CARRIAGE	454 (1001	0 0	0 0	0 0)	SAME AS CHERRYPICKER CARRIAGE
31	3	1.2.3.3.2	TURN/TILTTABLE	750 (1653	0 0	0 0	0 0)	SAME AS DORNIER INSTRUMENT POINTING SYSTEM
32	2	1.2.3.4	UMBILICALS	545 (1202	0 0	0 0	0 0)	SUM
33	3	1.2.3.4.1	UMBILICAL STATIO	45 (99	0 0	0 -0	0 0)	- OPERATIONAL SOC - TWO STATIONS - ROUGH ESTIMATE
34	3	1.2.3.4.2	UMBILICAL ARMS	500 (1102	0 0	0 0	0 0)	- OPERATIONAL SOC - TWO ARMS - THESE ARMS INCLUDE CRYO TRANSFER PROVISIONS - ROUGH ESTIMATE
35	2	1.2.3.5	STORAGE FACILITI	75 (165	0 0	0 0	0 0)	SUM

Table A — General Purpose Support Equipment Mass Statement (Continued)

IN-DEX #	IN-DENT #	WBS #	TITLE	MASS KG(LB)	OFFSETS,M(FT) X	Y	Z	RATIONALE FOR ESTIMATE
36	3	1.2.3.5.1	STORAGE RACK	75	0	0	0	- 2.5 M X 5 M GRIDWORK - 5 KG/M2 + 20% FOR INSTALLATION PROVISIONS AND HOLDDOWN MECHANISMS
				(165	0	0	0)	
37	1	1.2.4	CONSTR SUP EQUIP	582	0	0	0	SUM
				(1283	0	0	0)	
38	2	1.2.4.1	POSITIONING ARM	582	0	0	0	1.5 X SHUTTLE RMS
				(1283	0	0	0)	
39	1	1.2.5	FLIGHT SUP EQUIP	2954	0	0	0	SUM
				(6511	0	0	0)	
40	2	1.2.5.1	HANGAR	2954	0	0	0	SUM
				(6511	0	0	0)	
41	3	1.2.5.1.1	STRUCTURES	832	0	0	0	SUM
				(1834	0	0	0)	
42	4	1.2.5.1.1.1	WALL PANELS	581	0	0	0	- SIX PANELS - 15 M X 4.2 M X 0.46MM - ALUMINUM - 20% FOR STIFFENERS AND ATTACHMENT PROVISIONS
				(1281	0	0	0)	
43	4	1.2.5.1.1.2	END PANELS	141	0	0	0	- TWO HEXAGONAL PANELS - 4.2 M HEX SIDE - 0.46 MM THICK - ALUMINUM - 20% FOR STIFFENERS AND ATTACH PROVISIONS
				(311	0	0	0)	
44	4	1.2.5.1.1.3	END FRAMES	110	0	0	0	- FRAME AT EACH END - ROUGH ESTIMATE
				(243	0	0	0)	

Table A – General Purpose Support Equipment Mass Statement (Continued)

IN- DEX #	IN- DENT #	WBS #	TITLE		MASS KG(LB)	OFFSETS,M(FT) X	Y	Z		RATIONALE FOR ESTIMATE
45	3	1.2.5.1.2	MECHANISMS		560	0	0	0		SUM
				(	1235	0	0	0	)	
46	4	1.2.5.1.2.1	SIDE DOOR ACTUAT		60	0	0	0		SIX ACTUATORS AT 10 KG
				(	132	0	0	0	)	EACH
47	4	1.2.5.1.2.2	END DOOR ACTUATO		40	0	0	0		FOUR ACTUATORS AT 10
				(	88	0	0	0	)	KG EACH
48	4	1.2.5.1.2.3	PLATFORM DRIVE		60	0	0	0		- BALLSCREW DRIVE FOR
				(	132	0	0	0	)	MOVABLE WORK PLATFORM
										- 2 DRIVES 15M LENGTH
										EACH
										- 2 KG/M AVERAGE MASS
49	4	1.2.5.1.2.4	RETRACTION DRIVE		250	0	0	0		- THIS DRIVE RETRACTS
				(	551	0	0	0	)	ENTIRE HANGAR
										- ROUGH ESTIMATE
50	4	1.2.5.1.2.5	BERTHING FIXTURE		150	0	0	0		ESTIMATE
				(	331	0	0	0	)	
51	3	1.2.5.1.3	THERMAL CONTROL		25	0	0	0		SUM
				(	55	0	0	0	)	
52	4	1.2.5.1.3.1	THERMAL COATING		25	0	0	0		THERMAL CONTROL
				(	55	0	0	0	)	COATING ON HANGAR
										EXTERIOR
53	3	1.2.2.1.4	PRIMARY PROPULSI		0	0	0	0		(NO PRIMARY
				(	0	0	0	0	)	PROPULSION)

Table A – General Purpose Support Equipment Mass Statement (Con't)

IN- DEX #	IN- DENT #	ABS #	TITLE	MASS KG(LB)	OFFSETS,M(FT) X	Y	Z	RATIONALE FOR ESTIMATE
54	3	1.2.2.1.5	AUX PROPULSION	0	0	0	0	(NO AUXILIARY PROPULSION)
				(0	0	0	0)	
55	3	1.2.2.1.6	ORDNANCE	0	0	0	0	(NO ORDNANCE)
				(0	0	0	0)	
56	3	1.2.2.1.7	ELECTRICAL POWER	155	0	0	0	SUM
				(342	0	0	0)	
57	4	1.2.2.1.7.1	HARNESS	50	0	0	0	- POWER THRU BERTHING INTERFACE - SERVES LIGHTS & COM - ESTIMATE
				(110	0	0	0)	
58	4	1.2.2.1.7.2	INTERIOR LIGHTIN	80	0	0	0	- TWICE HAB MODULE - MORE VOLUME TO ILLUMINATE
				(176	0	0	0)	
59	4	1.2.2.1.7.3	EMERGENCY BATTER	25	0	0	0	SERVES EMERGENCY LIGHTS & COM
				(55	0	0	0)	
60	3	1.2.2.1.8	GN & C	0	0	0	0	(NO GN & C)
				(0	0	0	0)	
61	3	1.2.2.1.9	TRACKING & COMM	25	0	0	0	SUM
				(55	0	0	0)	
62	4	1.2.2.1.9.1	EVA REPEATER	20	0	0	0	REQUIRED FOR VOICE COM WITH EVA CREW INSIDE HANGAR
				(44	0	0	0)	
63	4	1.2.2.1.9.2	EVA ANTENNA	5	0	0	0	ESTIMATE
				(11	0	0	0)	
64	3	1.2.2.1.10	DATA MGMT	10	0	0	0	SUM
				(22	0	0	0)	

Table A – General Purpose Support Equipment Mass Statement (Con't)

IN-DEX #	IN-DENT #	WBS #	TITLE	MASS KG(LB)	OFFSETS,M(FT) X	Y	Z	RATIONALE FOR ESTIMATE
65	4	1.2.2.1.10.1	DATA BUS	10	0	0	0	DATA BUS FOR INSTRUMENTATION
				(22	0	0	0)	
66	3	1.2.2.1.11	INSTRUMENTATION	50	0	0	0	ALLOWANCE FOR NON-DEDICATED INSTRUMENTATION
				(110	0	0	0)	
67	3	1.2.2.1.12	CREW ACCOMM.	312	0	0	0	SUM
				(688	0	0	0)	
68	4	1.2.2.1.12.1	HANDHOLDS	20	0	0	0	40 HANDHOLDS @ 0.5 KG EACH
				(44	0	0	0)	
69	4	1.2.2.1.12.2	MOVABLE PLATFORM	292	0	0	0	29.2 M2 @ 10 KG/M2 AVERAGE UNIT MASS
				(644	0	0	0)	
70	3	1.2.2.1.13	EC/LSS	0	0	0	0	(NO EC/LSS)
				(0	0	0	0)	
71	3	1.2.2.1.17	MISSION EQUIPMEN	0	0	0	0	(NO MISSION EQUIPMENT)
				(0	0	0	0)	
72	3	1.2.2.1.18	GROWTH	985	0	0	0	- 50% OF IDENTIFIED MASS - HANGAR IS LESS WELL DEFINED THAN OTHER ELEMENTS
				(2170	0	0	0)	

WBS 1.2.3.1 MOBILITY/ACCESS SYSTEMS

1.0 WBS Dictionary

This element includes the piers, tracks, and track switch units.

2.0 Description

Figure A illustrates the track network for the Operational and Growth SOC Configurations. Figure AA illustrates the Operational SOC modified for satellite service operations. These elements are not required for the Initial SOC Configurations. A

The track network meets the requirements described below:

1. Track Requirements

1.1 The track system provides the surface on which mobile carriages will operate.

1.2 The track gage (width between centerlines of the parallel rails) is nominally set at 2.5m. (This was based on a first-order analysis of the maximum width fully-assembled carriage that would fit inside the Orbiter cargo bay. This track gage is also influenced by the maximum gage that could be pre-installed on the Docking Module.

1.3 Track cross section is nominally selected to be a circular cross-section. Other cross sections may be considered as long as they are compatible with the carriage wheel system and the track intersection switch system requirements and constraints.

1.4 Maximum static and dynamic track loading conditions have not been determined. This will require a detailed analysis of the operations to be conducted from the track.

1.5 Interfaces -

1.5.1 On the piers - track interfaces with the track support structure. The track could be an integral element of the track support structure. As the piers cannot be delivered as one piece, the track rails will be joined end-to-end.

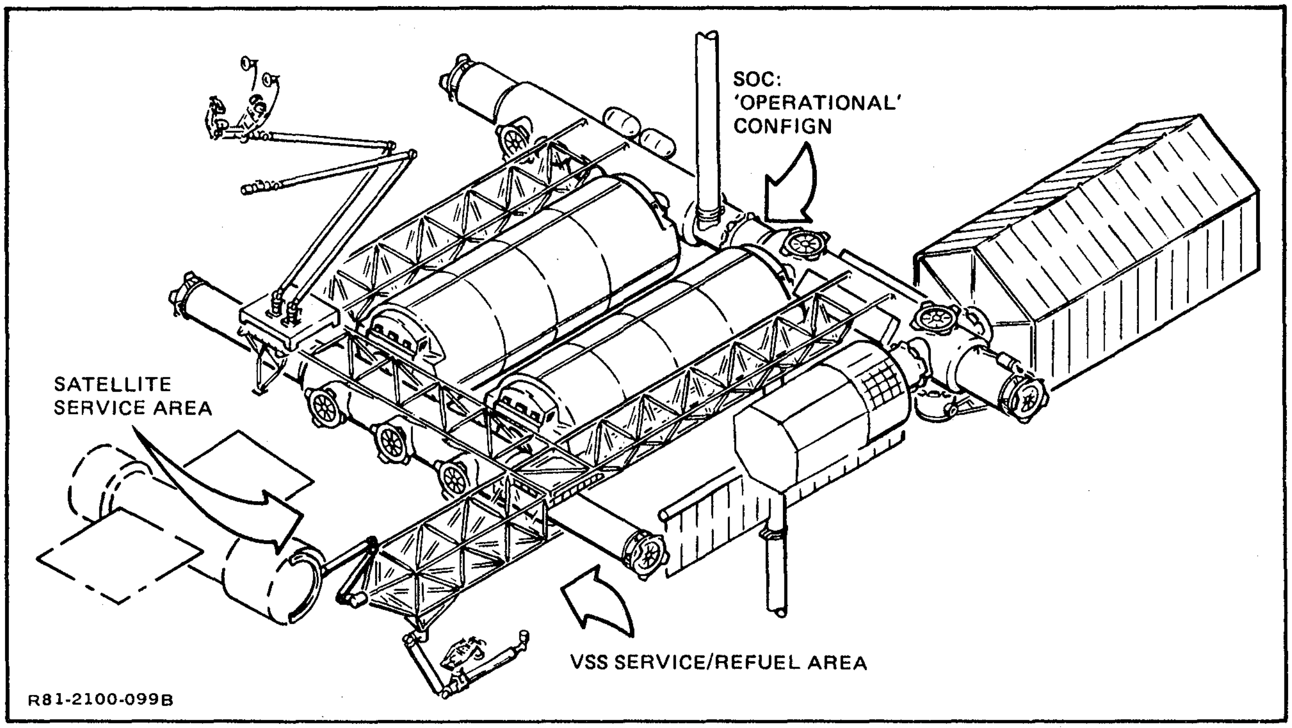

Fig. AA Operational SOC Modified for Satellite Service Operations

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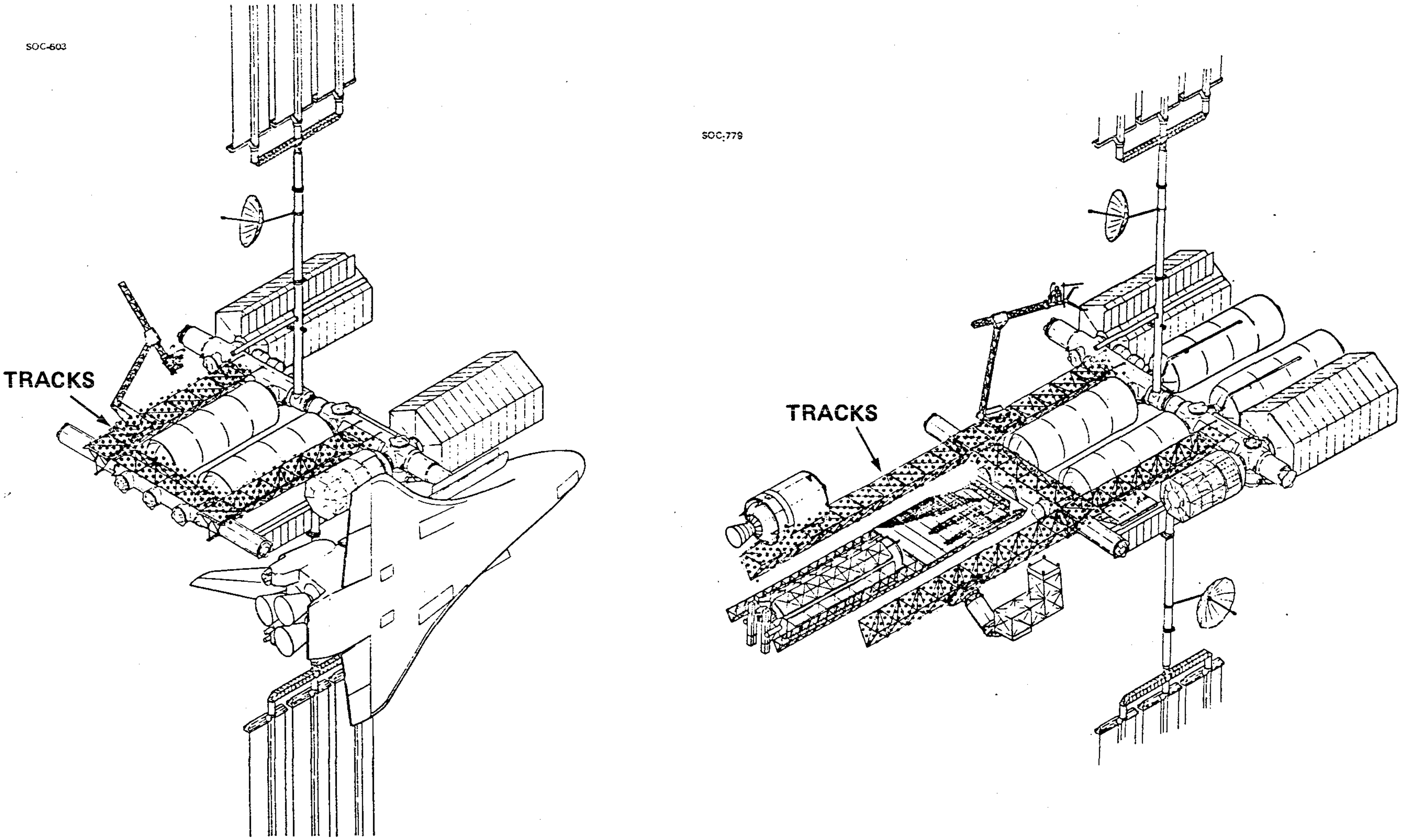

OPERATIONAL SOC

GROWTH SOC

Figure A. Track Network for the Operational and Growth SOC Configuration

1.5.2 On the track intersection switch mechanisms the track interfaces with the switch mechanism-to-track bracketry. There are some non-movable segments of track contained in the switch assembly so there will be a track-to-support structure interface.

1.5.3 On the Docking Tunnel - the track is attached to the DT via an appropriate support structure bracketry.

1.5.4 The track interfaces with the drive and idler wheels of the carriages.

1.6 The track surface shall be composed of a material that will not cause "sticktion" with the carriage wheels.

2. Track Intersection Switch System - Figures B thru E illustrate a track switch concept which meets the following requirements:

2.1 The track intersection switch system shall provide the capability for the carriages to make a 90 degree change of direction.

2.2 The carriage will be stationary on the track switch during the direction change operation.

2.3 The track switching system must be designed to take into account the desired orientation of the carriage's payload both before and after the switching maneuver. (This will require a detailed analysis of the SOC operations.)

2.4 In the SOC Growth Configuration, it will be necessary to allow a carriage to pass through the track switch without changing direction.

2.5 The track switching operations shall be remotely controlled from the SOC Command Center via the SOC data bus network.

2.6 A positive, visual indication of switch orientation shall be visible from the Command Centers, observatories, and from the cherrypicker workstation (if the payload on the cherrypicker does not obstruct the operator's view).

2.7 A graphical display will be displayed to the operator in the Command Center that indicates all of the track switch orientations.

2.8 Maximum static and dynamic loads on the switching assembly are TBD.

2.9 One of the 2 track switch assemblies can be pre-installed on the Docking Tunnel. The other one has to be installed via EVA so structural and electrical interfaces should be designed to be simple.

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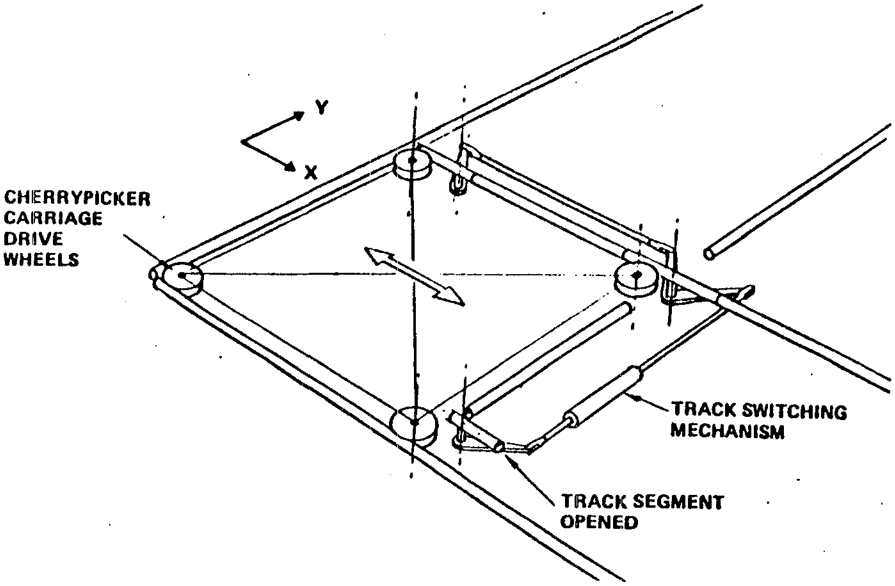

Figure B. Facility Track Intersection Switching Concept—X Direction Orientation

SOC-312

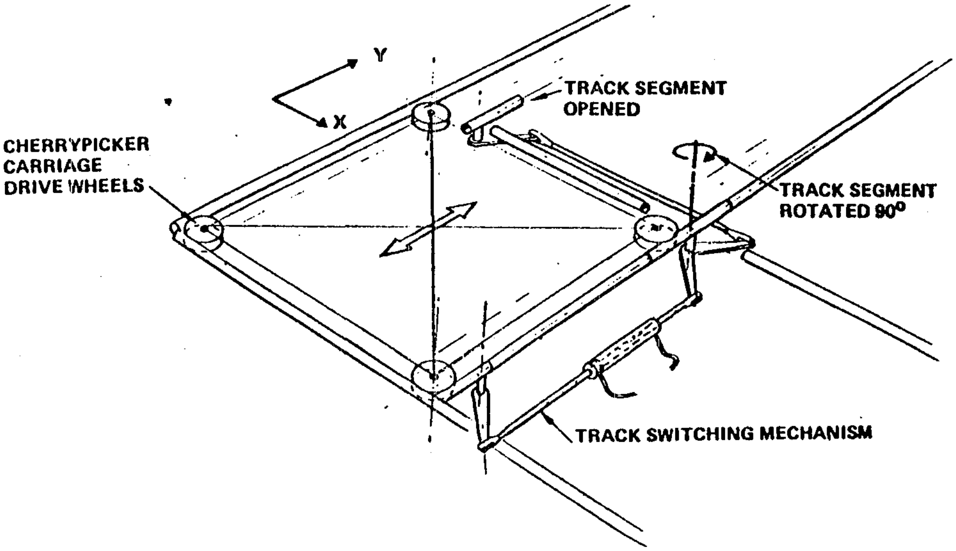

Figure C. Facility Track Intersection Switching Concept—Y Direction Orientation

SOC 334

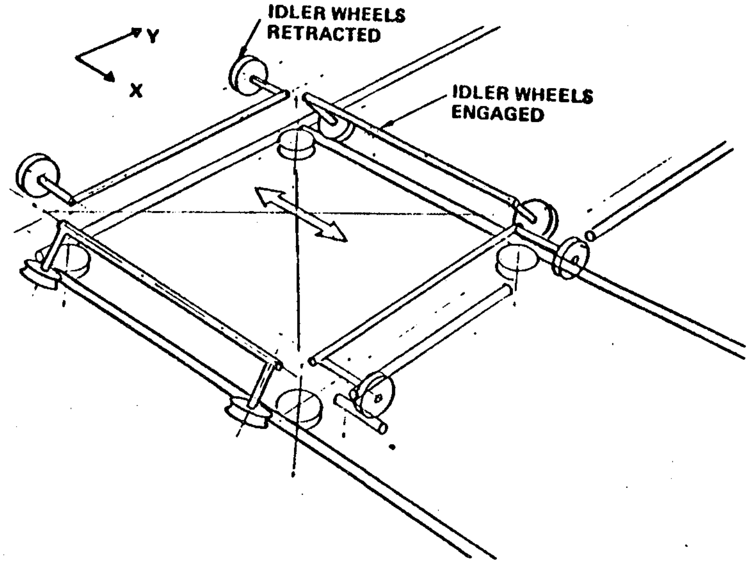

Figure D. Cherrypicker Carriage Idler Wheel Configuration at Track Intersection—X Direction Orientation

SOC-332

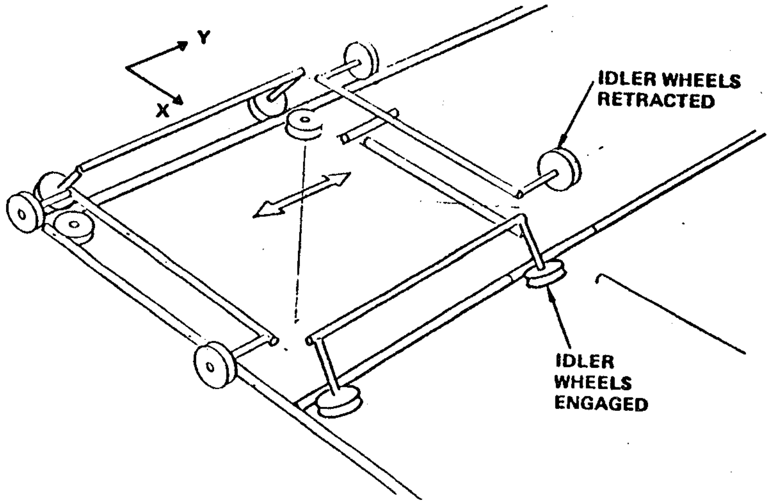

Figure E. Cherrypicker Carriage Idler Wheel Configuration at Track Intersection—Y Direction Orientation

3. Support Structures Requirements

3.1 There are 3 types of track support structures to be considered:

1) Piers that are cantilevered from SOC pressurized modules

2) Secondary structures that support tracks that are mounted on the Docking Tunnel

3) Secondary structures that support the track switch assemblies.

3.2 Piers

3.2.1 There are 2 types of piers:

1) Finger piers which lie alongside the Habitat Modules

2) Construction, flight support and satellite servicing piers that extend from the track switches. A

3.2.2 Finger piers

3.2.2.1 Interfaces - Attach via appropriate bracketry on one end to the Service Modules and on the other end to the track switch assemblies and Docking Module.

3.2.2.2 The piers should be designed to be a deployable structure. However, an assembled structure is not precluded. The structure must be capable of being packaged with the Docking Module in delivery flight no. 2 and with the Logistics Module in delivery flight no. 6.

3.2.3 Construction, Flight Support and Satellite Servicing Piers A

3.2.3.1 Interfaces

3.2.3.1.1 Attach via appropriate bracketry to the Docking Tunnel and track switch assemblies.

3.2.3.1.2 Structure supports the track rails.

3.2.3.2 The piers should provide at least 2 surfaces on which rails can be attached.

3.2.3.3 Piers shall be at least 24m long for construction and 7.5m long for satellite servicing. Exact length is TBD. A

3.2.3.4 A deployable structure is preferrable. This does not preclude an assembled structure.

3.2.3.5 The structure should preferrably be common to the finger pier structure to minimize development.

3.2.3.6 The structure shall provide mountings in the satellite service area for HPA support structures and for propulsion service supplies pallets. A

3.3 Docking Tunnel Track Support Structure

3.3.1 Interfaces

3.3.1.1 Structure attaches to the outside wall of the Docking Tunnel pressure shell.

3.3.1.2 Structure supports the track rails (see 1.5.3).

3.3.2 The structure should be preinstalled on the Docking Tunnel.

3.4 Track Switch Support Structures

3.4.1 Interfaces

3.4.1.1 Structure interfaces between the track switch primary structure (see 2.) and the Docking Tunnel pressure shell.

3.4.1.2 One of the track switch assemblies cannot be preinstalled, therefore, the structural interface should be relatively simple to lend itself to installation via EVA. (see 2.9)

3.5 Maximum static and dynamic loads on the various support structures are TBD.

3.6 Provisions for installing data busses, power busses, and fluid delivery lines should be made.

4. Carriage Remote Control Provisions - provide a track-mounted system that will facilitate the capability for the carriages to be remotely controlled from the Command Center.

3.0 Design Basis

The SOC has been designed to physically separate the various operational areas so that work conducted in one area will not interfere with work being conducted in other areas. This physical separation also minimizes constraints on the size of objects being worked on in the various areas. Also, in the course of normal operations it is necessary to move elements from one area to another. A track and carriage system has been designed to provide this capability. This system was selected over a system that would employ one or more fixed-location cranes for the following reasons:

- The track and carriage system leads to a shorter-reach manipulator/cherrypicker system. A
- The mobile cherrypicker and the mobile platform can move things about with fewer constraints than would be necessary using fixed location cranes.

- The carriage and track scheme lends itself to a simple flight vehicle stage assembly system.
- The track can be used as part of the vehicle launch and capture system.
- This concept lends itself to future growth.
- The track structure is relatively inexpensive.
- The track system is a necessary element in the construction facility for the Growth SOC.

The design of the tracks and the switch mechanism are intimately intertwined with the design of the carriages. Refer to WBS 1.2.3.2.2.1 for detailed discussion of the carriage concepts. This technology is required for both the Operational and the Growth SOC Configurations.

4.0 Mass

Refer to mass statment in WBS 1.2.3.

WBS 1.2.3.2 HANDLING EQUIPMENT

1.0 WBS Dictionary

This element includes the manipulator, mobile cherrypicker, and the payload handling tools that are used to move items from one place to another.

2.0 Description

For the Initial SOC, a remotely controlled manipulator (WBS 1.2.3.2.1) is attached to the Service Module No. 1.

For the Operational and Growth SOC, a mobile cherrypicker (WBS 1.2.3.2.2) is mounted on the track network (WBS 1.2.3.1).

A set of payload handling tools (WBS 1.2.3.2.4) have been identified for use with the Mobile Cherrypicker.

Each of these elements are described in detail in lower-level WBS element descriptions.

3.0 Design Basis

The design basis for these elements are described in the lower-level WBS descriptions.

4.0 Mass

Refer to mass statement in WBS 1.2.3.

WBS 1.2.3.2.1 MANIPULATOR SYSTEM

1.0 WBS Dictionary

This element includes the turntable, articulated arm, and effector, and control system for the manipulator installed on Service Module No. 1 in the Initial SOC Configuration.

2.0 Description

The manipulator system concept is illustrated in Figure A. This manipulator provides a reach of approximately 50 feet. It is attached to SM1 on berthing port number 2. The manipulator meets the requirements listed below:

1.0 General Requirements

1.1 Maximum Load - The largest and heaviest load to be handled by the manipulator is the Habitat Module No. 2 (WBS 1.2.1.2) which is put into place during the SOC build-up operations.

1.2 Maximum Speed - TBD.

1.3 Maximum Reach - Approximately 50 feet. This reach distance is established by the requirements for installing HM2 onto SM2.

1.4 Articulations - The following degrees of freedom are required:

- shoulder yaw ($\pm 360^{o}$)
- shoulder pitch (-2^{o} to $+145^{o}$)
- elbow pitch ($+2^{o}$ to -160^{o})
- wrist pitch ($+120^{o}$ to -120^{o})
- wrist yaw ($+120^{o}$ to -120^{o})
- wrist roll ($\pm 447^{o}$)

2.0 Turntable

2.1 Rotation - $\pm 360^{o}$

2.2 Data and Power - Provided via the standard utility interfaces contained in the standard SOC berthing port.

2.3 Interfaces - Mates to SM1 berthing port No. 2 via a standard berthing fixture and to the boom's shoulder joint.

3.0 Articulated Arm

3.1 Articulators - See item 1.4 above.

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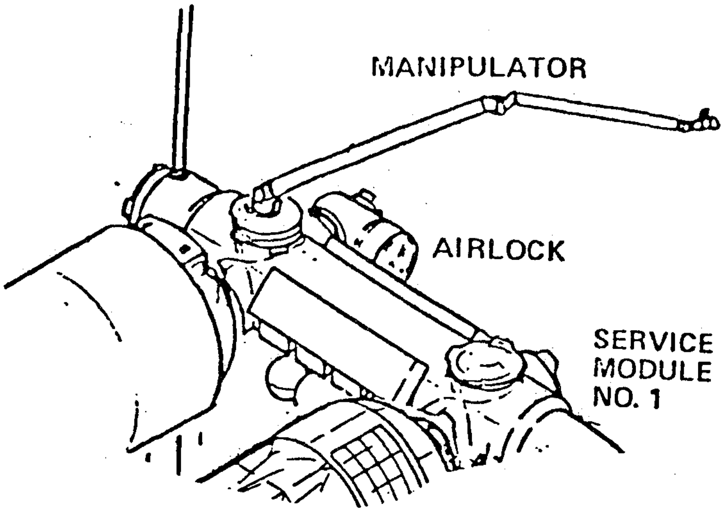


Figure A. Manipulator Concept

3.2 Dimensions - See Figure A.

3.3 Data and Power - Provided via turntable interface.

4.0 End Effector - Use the standard Orbiter RMS end effector.

5.0 Control - This manipulator is remotely controlled from the HM1 Command Center via the Operations control panel.

3.0 Design Basis

This manipulator system is based on the Orbiter RMS configuration.

4.0 Mass

Refer to mass statement in WBS 1.2.3.

WBS 1.2.3.2.2 MOBILE CHERRYPICKER SYSTEM

1.0 WBS Dictionary

This element includes the carriage, articulated arm, and manned workstation that comprises the Mobile Cherrypicker.

2.0 Description

A mobile, articulated arm-type cherrypicker will be required for the SOC operations. Figure A illustrates the mobile cherrypicker concept. It will be used in the flight support, construction, satellite servicing, logistics, maintenance, and SOC build-up operations. This cherrypicker will be used to hold and move loads about the SOC.

The other key elements shown in Figure A, the payload handling tools, are discussed in WBS 1.2.3.2.3. The carriage is related to the facility track system concept discussed in WBS 1.2.3.1. This carriage is identical to the carriages required for the turntable/tilttable (WBS 1.2.3.4), modular construction fixture (WBS 1.2.4.2), and OTV carriage (WBS 1.2.5.2).

The mobile cherrypicker system meets the following requirements:

1.0 General Requirements

1.1 Maximum Load - The largest and the heaviest load to be moved is a fully fueled OTV (approx. 40000 Kg) plus its heaviest payload (approx. 15000 Kg), for a total of 55000 Kg. This requirement comes from the contingency condition where a just-launched OTV malfunctions and must be recaptured.

1.2 Maximum Speed - TBD.

1.3 Reach Envelope - Figure B illustrates the reach envelope defined by the SOC buildup, construction, flight support, satellite servicing, logistics, and base maintenance operations defined to date.

1.4 Maximum Size Payload - 4.2m diameter x TBD m long (depends on spacecraft geometry when attached to an OTV).

1.5 Translation Capability - Provide capability to move along the facility track network. This requirement is based on the fact that the SOC operational

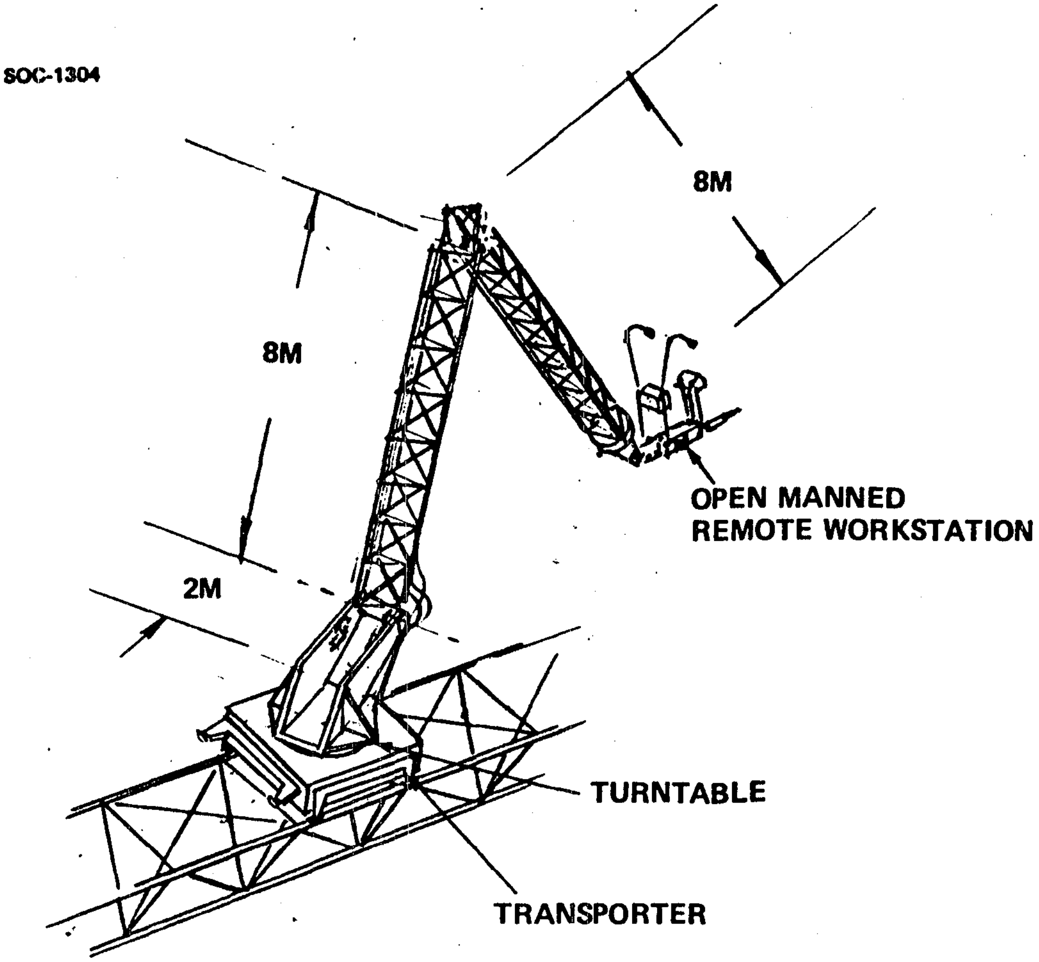
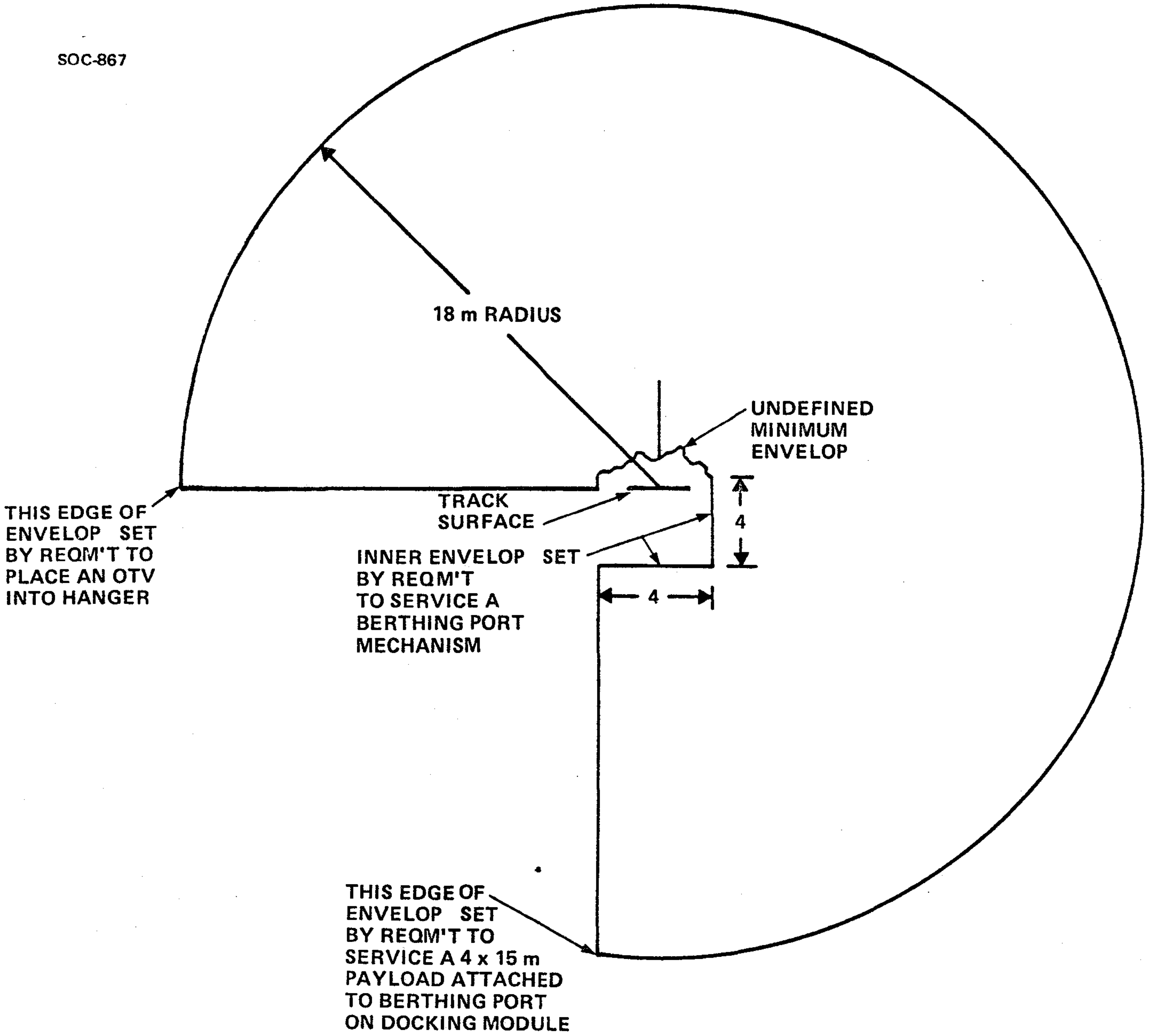


Figure A. Mobile Cherrypicker

SOC-867



NOTE: MOBILE CHERRYPICKER CAN MOVE ALONG TRACK ORTHOGONAL TO THIS VIEW

Figure B. Mobile Cherrypicker Approximate Reach Envelop Requirement areas (construction and flight support) were separated to allow plenty of working room. In addition, providing translation capability provides an additional degree of freedom in moving payloads.

1.6 Manned Remote Work Station - A manned work station to be located on the end of the cherrypicker boom assembly. This work station to provide foot restraints, lighting, and a control console.

1.7 End Effector Grapple System - Provide a grapple system for easily changing the end effectors to be attached to the work station. Two types of end effectors have been defined - a small object handling tool and a large object handling tool.

1.8 Control Modes - The cherrypicker must be controllable from the workstation described in 1.6 and remotely from the habitat module command center. The number and types of control modes have not been defined.

1.9 Man-rated - The mobile cherrypicker must incorporate features which make it a man-rated system.

1.10 Maintainability - Design the cherrypicker to be maintainable via EVA.

1.11 Reliability - The mobile cherrypicker is used in almost all of the SOC operations. It must, therefore, be a highly reliable system so that down time is minimized. The exact reliability requirements are TBD.

1.12 Fail Operational/Fail Safe - The manipulator shall be designed for fail operational/fail safe performance.

1.13 Stopping Distance - The maximum stopping distance of the manipulator, as measured at the wrist to MRWS interface, shall be limited to 2 feet irrespective of its loading conditions (up to 55,000 Kg payload).

1.14 Track and Capture - The manipulator shall have the capability to track and capture incoming spacecraft up to 55,000 Kg mass with spacecraft velocities relative to SOC of up to TBD ft/s and rates of TBD degrees/s.

1.15 Power - Power shall be supplied to the manipulator by rechargeable batteries mounted on the carriage. Voltage and power levels TBD.

1.16 Duty Cycle - The cherrypicker shall be capable of operating for 16 hours in any 24 hour period.

1.17 CCTV's and Lighting - Shall be provided at TBD locations on the manipulator. Video data shall be transmitted to the D&C panels in the habitat module. Provision shall be made for two parallel video channels to the MRWS such that the MRWS operator may select any two camera combinations from those mounted on the manipulator and anywhere else on SOC (such as the OTV hangar).

2.0 Carriage Requirements - (Refer to Figure C)

2.1 Wheelbase - Must be compatible with facility track system (2.5m in reference concept).

2.2 Wheel Arrangement - Must be compatible with track switching system.

2.3 Power Supply - Should be battery powered. Must be capable of running for 16 hours on an 8 hour recharge.

2.4 Control -

4.2.4.1 Operator Controlled - from MRWS.

4.2.4.2 Remote Controlled - via S-band radio from SOC command centers.

2.5 Payload Attachment - This carriage is a standard unit that will be used for 3 payloads (cherrypicker, OTV carriage, and construction fixture).

The payload interface includes structural attach points and a payload umbilical that connects the carriage avionics to the payload.

3.0 Turntable

3.1 Rotation - 360 degrees.

3.2 Data and Power - Provide slip rings for passing data and power across the rotary joint.

3.3 Interfaces - Mates to the carriage payload attach interface and to the boom yoke assembly.

4.0 Boom Assembly

4.1 Articulations - (see 1.5)

4.2 Linear Actuator/Bearing - Provide a mechanism for supporting and linearly indexing the upper arm of the boom. In addition to these functions, provisions for passing the power and data lines across this joint must be made.

3.0 Design Basis

The SOC has been designed to physically separate the various operational areas so that work conducted in one area will not interfere with work being conducted in other areas. This physical separation also minimizes constraints on the size of objects being worked on in the various areas. Also, in the course of normal

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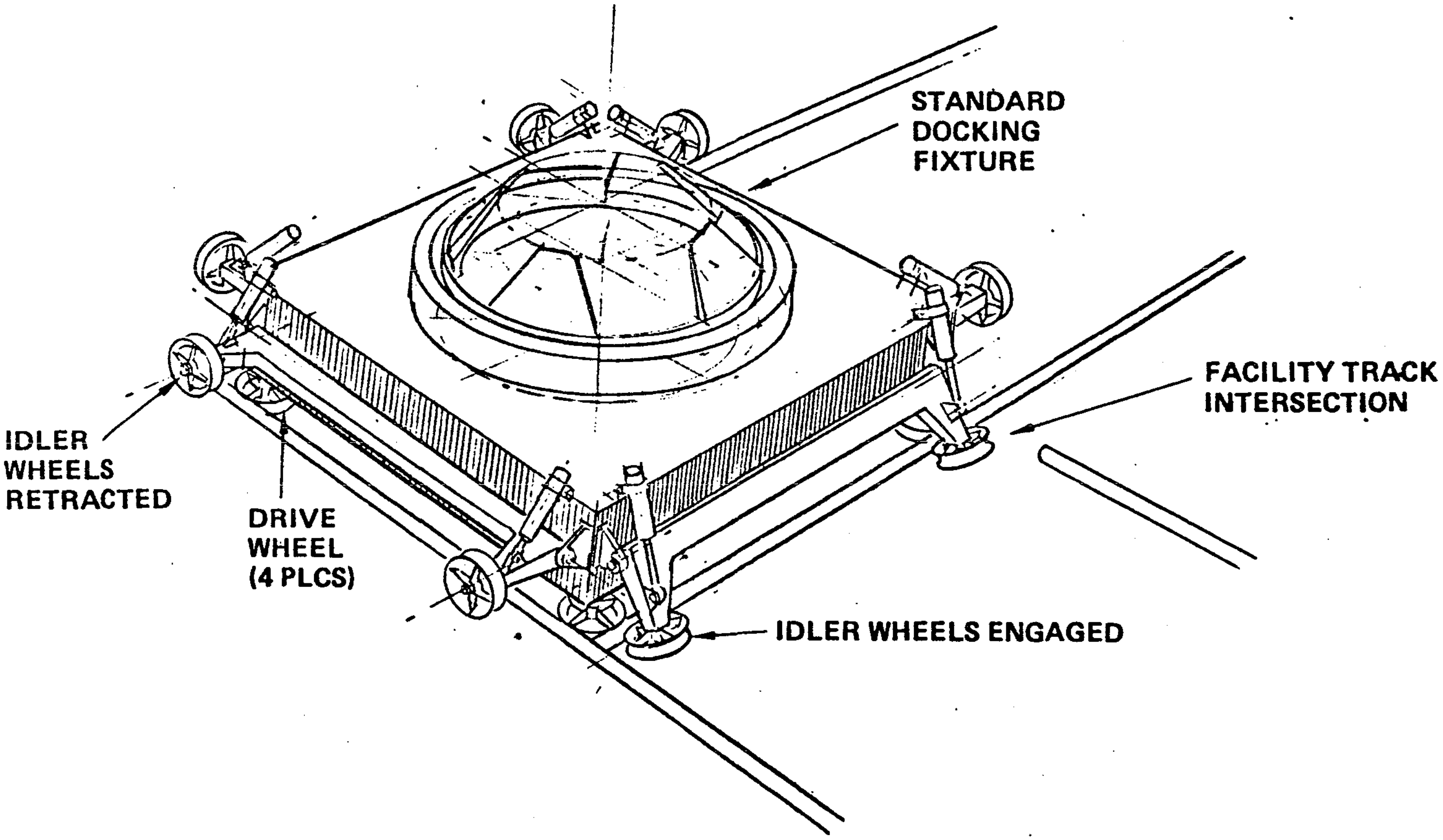

NOTE—
THIS CARRIAGE HAS A RECHARGABLE BATTERY

Figure C. Cherrypicker Carriage Concept

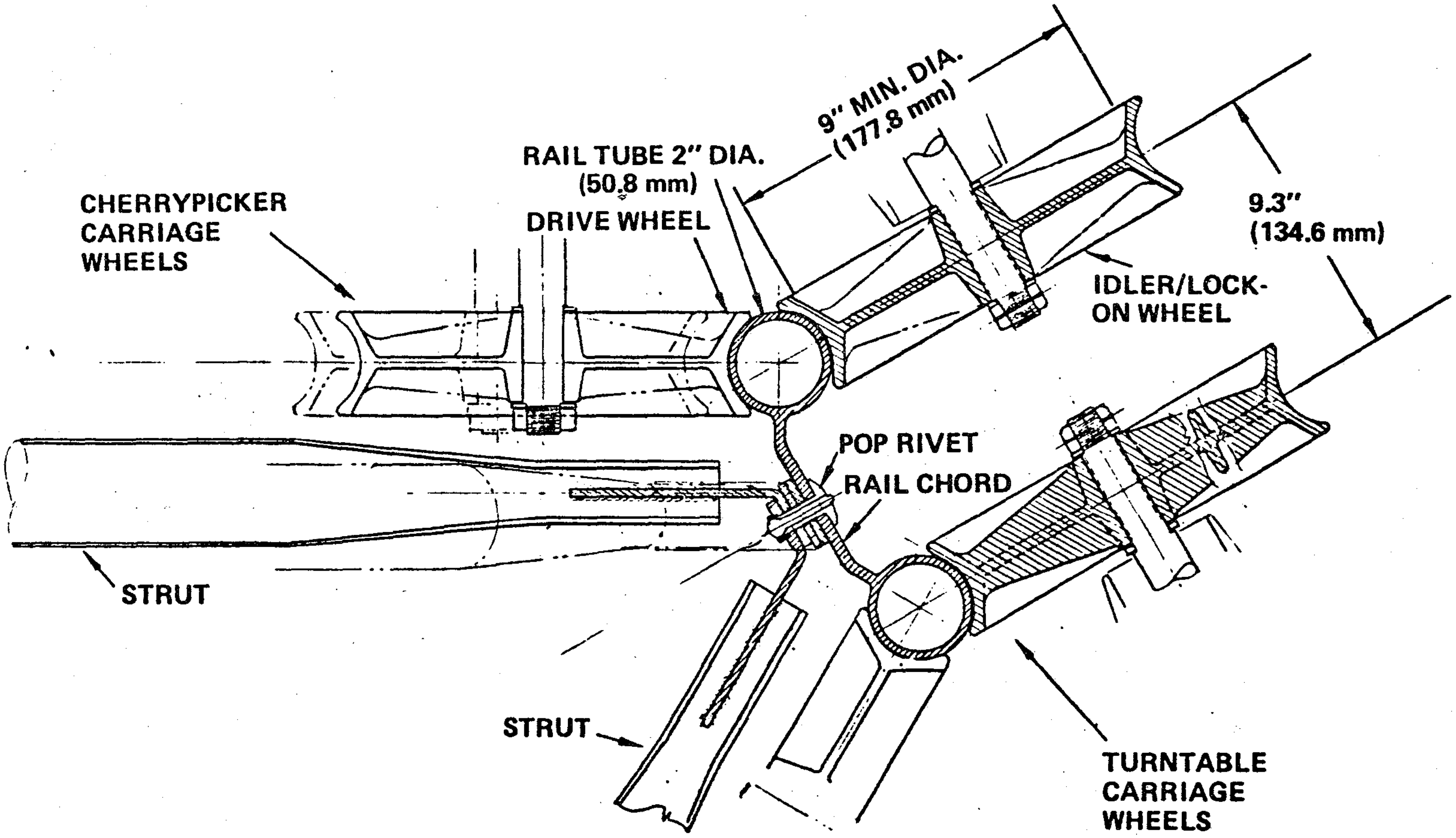

Figure D. Track and Carriage Wheel Details operations it is necessary to move elements from one area to another. A mobile cherrypicker system has been designed to provide this capability. This system was selected over a system that would employ one or more fixed-location cranes for the following reasons:

- The mobile cherrypicker system leads to a shorter-reach cherrypicker.
- The mobile cherrypicker can move things about with fewer constraints than would be necessary using fixed location cranes.
- This concept lends itself to future growth.

4.0 Mass

Refer to mass statement in WBS 1.2.3.

WBS 1.2.3.2.3 PAYLOAD HANDLING TOOLS

1.0 WBS Dictionary

This element includes the small- and large-object handling tools that are attached to the mobile cherrypicker manned workstation end-effector.

2.0 Description

Figure A illustrates a small object handling tool (to be referred to as the Type A Payload Handling Tool). This tool is affixed to the mobile cherrypicker's manned workstation end-effector via a quick-disconnect grapple fitting. This tool is operated from the workstation control panel. The tool has adjustable arms and interchangeable tips so that it can be configured to handle a variety of objects such as shown in Figure A.

Figure B illustrates a large-object handling tool (to be referred to as the Type B Payload Handling Tool). This tool is affixed to the mobile cherrypicker's manned workstation end-effector via a quick-disconnect grapple fitting. This tool is operated from a control stand that is within reach of the operator after the tool is attached to the mobile cherrypicker. The tool has adjustable arms and tips that can be configured to handle a variety of large objects.

3.0 Design Basis

The mobile cherrypicker must transport a wide variety of shapes and sizes of payloads. The mobile cherrypicker must be equipped with payload handling tools that will handle this variety of payloads. In order to minimize the number of types of payload handling tools, a small object handling tool and a large object handling tool have been conceptually configured.

Tool attachment interfaces may be required on the payload. It would be highly desirable not to impose requirements of this sort if suitable handling points can be located on the payload structure. Some payloads may require special purpose "hands" to be attached to the payload handling tool.

4.0 Mass

Refer to mass statement in WBS 1.2.3

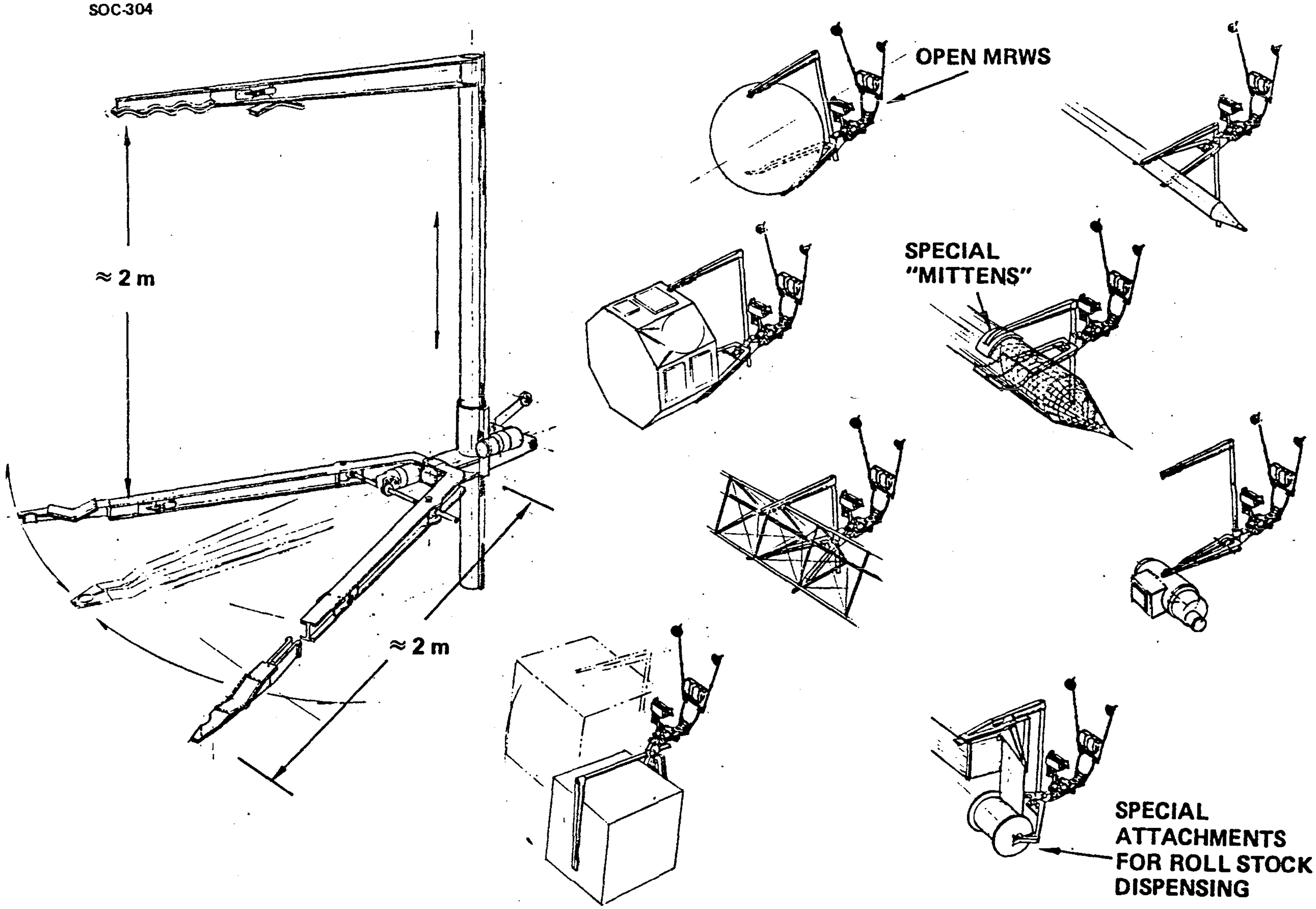

Figure A. Type A Payload Handling Tool

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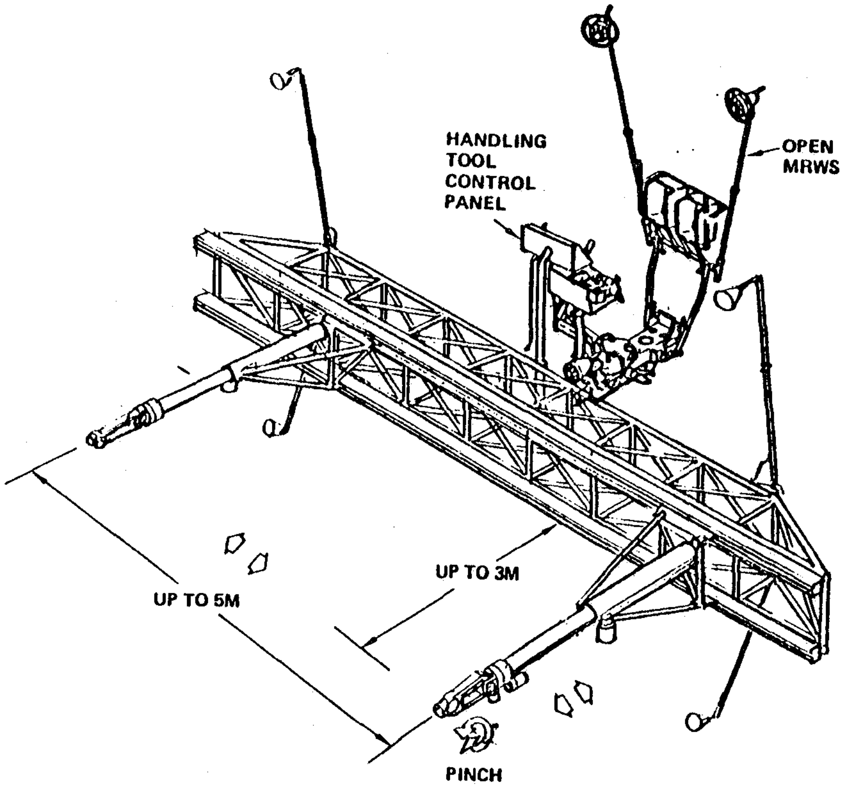


Figure B. Type B Payload Handling Tool

WBS 1.2.3.2.4 MOBILE PLATFORM SYSTEM

1.0 WBS Dictionary

This element includes the carriage, two manipulators, a manned workstation and appropriate end effectors.

2.0 Description

The Manipulator system (WBS 1.2.3.2.1) is used in the initial SOC configuration for operations and build up to operational SOC. This manipulator is based on the Orbiter RMS configuration. The Mobile Platform system is a "next step" development which adds a carriage to provide mobility for handling satellites, equipments, and construction items. Figure A illustrates the platform concept. It employs two of the manipulators used in the manipulator system and mounts them on a carriage to ride the SOC track system. One manipulator mounts an OCP at its tip while the other mounts a suitable payload handling end effector. The system can be used in the flight support, construction, satellite servicing, logistics, maintenance and SOC build up operations.

The Mobile Cherry Picker system, defined in WBS 1.2.3.2.2, also caters to these operations and is viewed as a later development equipment, if the needs for more robust handling capability and greater reach are identified.

Key elements which are shown in Figure A and discussed elsewhere, with their requirements, are:

- Payload handling tools (WBS 1.2.3.2.3)
- Carriage, identical to the carriages defined for turntable/ tilttable (WBS 1.2.3.4), module construction fixture (WBS 1.2.4.2) and OTV carriage (WBS 1.2.5.2).

Requirements for other key elements follow, in general, those defined for the Mobile Cherry Picker system. Manipulator capabilities are those defined for the RMS in document JSC 07700 Vol XIV, latest issue. Main differences between requirements and capability are:

- Maximum load capability to be 55,000 kg. RMS design capability is 29,500 kg, but with software modifications it can handle approximately 90,000 kg to berth an orbiter to SOC.
- The manipulator reach of 15.24 m is considerd to be adequate if an elevator is incorporated into the hangar or if the hangar is relocated, as currently proposed. Thus, the 18-m reach requirement can be reduced.
- The RMS is ground maintained. Two of the options available to cater for the required "maintenance via EVA" are to redesign for space maintenance or to free ride the RMS to ground in the orbiter starboard RMS location.

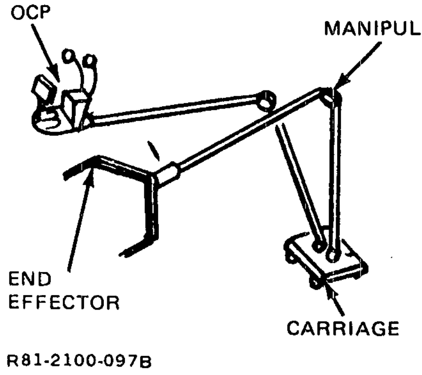
The OCP provides the capabilities call for in the manned remote work station requirements for the Mobile Cherry Picker system.

3.0 Design Basis

Rationale for the design follows that given for the Mobile Cherry Picker (WBS 1.2.3.2.2).

4.0 Mass

Refer to mass statement in WBS 1.2.3.



FEATURES

- USES ORBITER MANIPULATORS
- USES GRUMMAN OCP
- SYSTEM CONTROLLED DIRECTLY BY OCP/EVA CREWMAN OR REMOTELY FROM HABITATION MODULE
- CAN MOUNT TYPES A & B HANDLING TOOLS

Fig. A Mobile Platform Concept

WBS 1.2.3.2.5 HANDLING AND POSITIONING AID

1.0 WBS Dictionary

This element includes the articulated arm, a manned work station, an umbilical interface, services to the workpiece and the appropriate end effector.

2.0 Description

A fixture for handling and positioning satellites and propulsion stages will be required for satellite servicing operations on SOC. It will also be of use for construction missions and in the transfer of logistics and SOC build-up modules. Figure A illustrates the concept.

The fixture utilizes the HPA presently being developed for Orbiter use. Each SOC HPA has a fixed mount to the SOC structure with an articulating arm system which mounts an end effector at its tip. The type of end effector depends upon the mission. An OCP for EVA crewman operation mounts to the arm via a short mast. An Umbilical System, which connects SOC utilities to the workpiece, provides power and data bus. A panel, carrying the utilities, will be located towards the tip of the HPA. Flying leads from the panel to the workpiece will be connected by an EVA crewman. It is considered that direct mating of the workpiece to the umbilical panel will be too restrictive on design.

Provision of utilities at an interface where an HPA is not required for handling operations will be supplied by the Umbilical System defined in WBS 1.2.3.5.

Design requirements follow, in general, those identified for the turntable/tilttable (WBS 1.2.3.4), the articulated construction fixture (WBS 1.2.4.1) and the Umbilical System (WBS 1.2.3.5). HPA capabilities will satisfy these requirements.

The OCP provides the capabilities called for in the manned remote work station requirements for the Mobile Cherry Picker system (WBS 1.2.3.2.2).

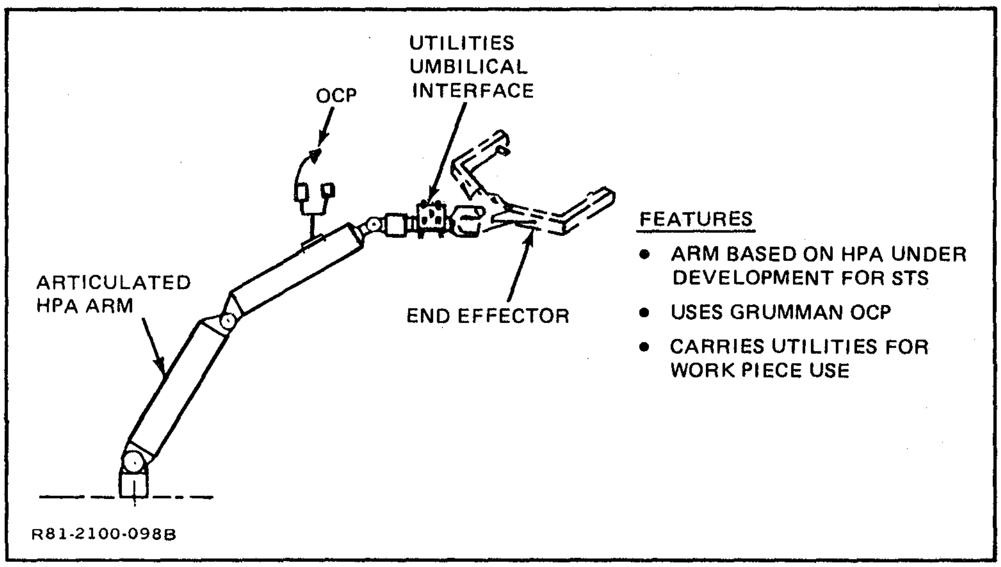
3.0 Design Basis

For satellite servicing operations, a fixture is required to hold, tilt, rotate and locate a satellite being serviced by an EVA crewman occupying the OCP mounted to the mobile platform (WBS 1.2.3.2.5). A similar fixture is also required to perform the same functions for propulsion stages, such as PO[illegible]d VSS, which retrieve and replace the satellites.

The HPA designed for Orbiter use provides these functions.

4.0 Mass

Refer to WBS 1.2.3 mass statement.



FEATURES

- ARM BASED ON HPA UNDER DEVELOPMENT FOR STS
- USES GRUMMAN OCP
- CARRIES UTILITIES FOR WORK PIECE USE

Fig. A Handling and Positioning Aid

WBS 1.2.3.3 EVA WORKSTATION

1.0 WBS Dictionary

This element includes the portable workstation that is used by EVA astronauts that is not attached to the mobile cherrypicker.

2.0 Description

Figure A illustrates a concept for a portable EVA workstation that meets the following requirements:

1. Foot Restraints - foot restraint compatible with EVA suit boots. A tilt and rotation capability would be desirable.
2. Body Restraints - it may be useful to provide a restraint that would attach to the waist of the astronaut (requires further analysis to verify requirement).
3. Lighting - provide one or more adjustable spotlights.
4. Tool Restraints and Storage - provide suitable tool storage and tethers.
5. Power Supply - it would be desirable to make the workstation autonomous from the SOC power supply. This can be provided by a portable power supply system.
6. Attachment System - provide adjustable structural members and clamp brackets that will allow the workstation to be affixed to either the object being worked on or to a nearby SOC structure such that the astronaut is located where he can perform the operations. This attachment system would not interfere with the cherrypicker operations.
7. Grapple Fixtures - provide one or more grapple points where the workstation can be handled by the mobile cherrypicker and its payload handling tools.

3.0 Design Basis

In many of the construction satellite servicing and base maintenance operations, it is necessary to locate an EVA astronaut where he can use handtools to assist in an assembly or maintenance task. To do useful work, the astronaut must be restrained, have lighting, handtools, and tool storage. A portable EVA workstation that can provide these functions would be a very desirable piece of equipment.

4.0 Mass

Refer to mass statement in WBS 1.2.3.

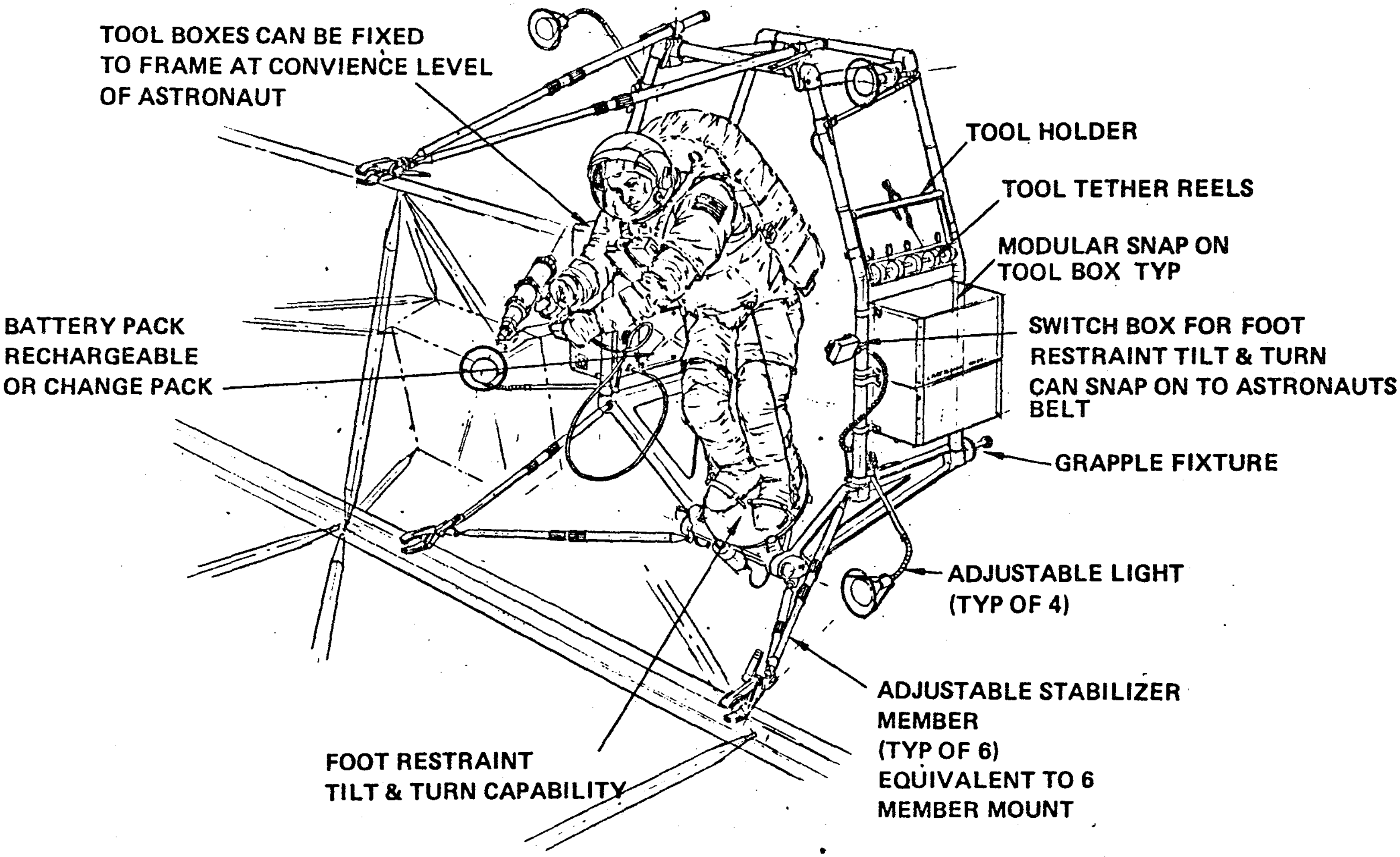


Figure A. EVA Workstation Concept

WBS 1.2.3.4 TURNTABLE/TILTTABLE SYSTEM

1.0 WBS Dictionary

This element includes the carriage, berthing port fixture, turntable, tilttable mechanisms, and extension structure.

2.0 Description

Figure A illustrates a concept for a turntable/tilttable (TT) system that meets the following requirements:

1. Degrees of Freedom - Figure A shows the various degrees of freedom that are required in the Reference and Growth SOC Configurations.
2. Dimensions - The dimensions of the Turntable/Tilttable are TBD.
3. Interfaces -

3.1 Initial and Operational SOC - Berthed to one of the berthing ports. Mechanical electrical power, and control signal interfaces are made through the berthing ring.

3.2 Growth SOC - The TT is mounted on a carriage that is, in turn, mounted on the construction facility pier. Mechanical interface is the wheels and tracks. Electrical power and control signals interfaces are TBD. Note - this carriage should be identical to the carriage used by the mobile cherrypicker (WBS 1.2.3.2.2).

3.3 Turntable Interface - The platen of the turntable should be configured so that a wide variety of mechanical attachments could be made. A pattern of threaded holes should suffice.

4. Control - The various mechanisms should be controllable via the SOC data bus interface.
5. Extension Structure - A separate TBD long extension structure should be provided so that the turntable can be offset from the SOC structures.
6. Mass and Size of Article to be Reoriented - Articles range in size from 1m diameter to 100m diameter; mass range is 1000 kg to 100,000 kg.

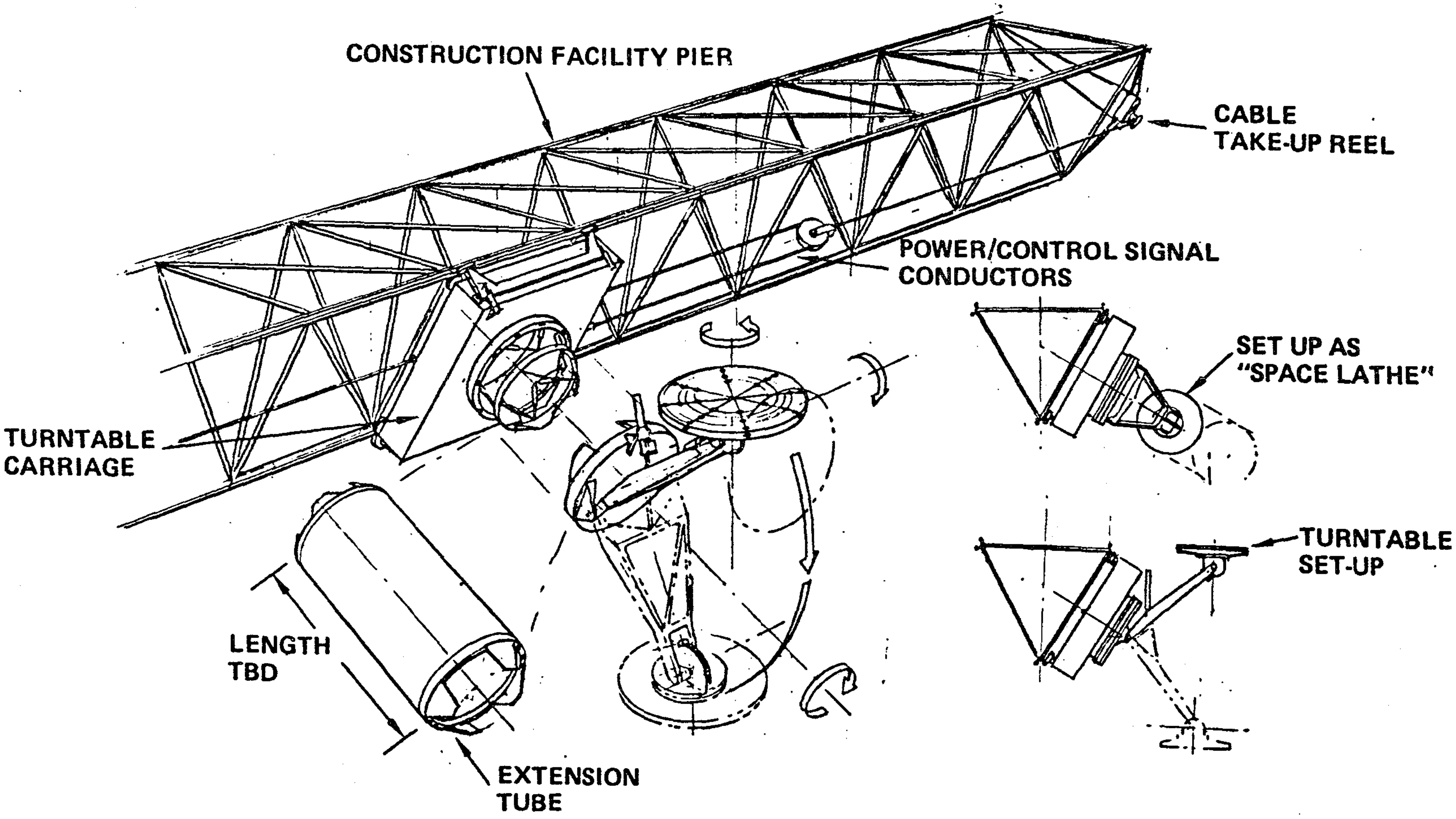


Figure A. Turntable/Tilt-Table System Concept

3.0 Design Basis

SOC construction and satellite servicing operations require a means of reorienting the article being worked on. This reorienting is necessary to make the article more accessible for the cherrypicker or EVA astronauts. In addition, test and checkout of some spacecraft requires that the article be aimed at a target (a star, a ground station, another satellite, etc.) for an extended period of time. This means that the reorienting system must be dynamically controllable so that the spacecraft can track its target while the SOC moves through its orbit. A combination turntable and tilttable system will be required to meet this requirement. For the Initial and Operational SOC Configurations, this Turntable/Tilttable would be berthed to a berthing port. For the Growth SOC Configuration, the TT should be mounted on a carriage.

4.0 Mass

Refer to mass statement in WBS 1.2.3.

WBS 1.2.3.5 UMBILICAL SYSTEM

1.0 WBS Dictionary

This element includes the umbilical-to-spacecraft connection fixture, support arm, umbilical-to-SOC connection station, umbilical utility network, and umbilical control system.

2.0 Description

Figure A illustrates a concept for an umbilical system. Figure B shows the locations where umbilical stations should be located on the Initial, Operational and Growth SOC Configurations.

The umbilical system connects the SOC utilities to the spacecraft. These utilities include power, data bus, and (in the Growth Configuration only) fluids.

The umbilical services should be remotely controlled from the SOC Command Centers via data bus signals to a microprocessor valve/switch controller located on the umbilical station.

3.0 Design Basis

Many of the SOC operations will require SOC-supplied electrical power, data signals, fluids and gasses. These operations include OTV test/checkout/refueling* and satellite test/checkout/propellant loading. This requirement will take some kind of umbilical system to interface the SOC utilities with the spacecraft.

4.0 Mass

Refer to mass statement in WBS 1.2.3.

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*Refueling is a SOC Growth Configuration requirement only

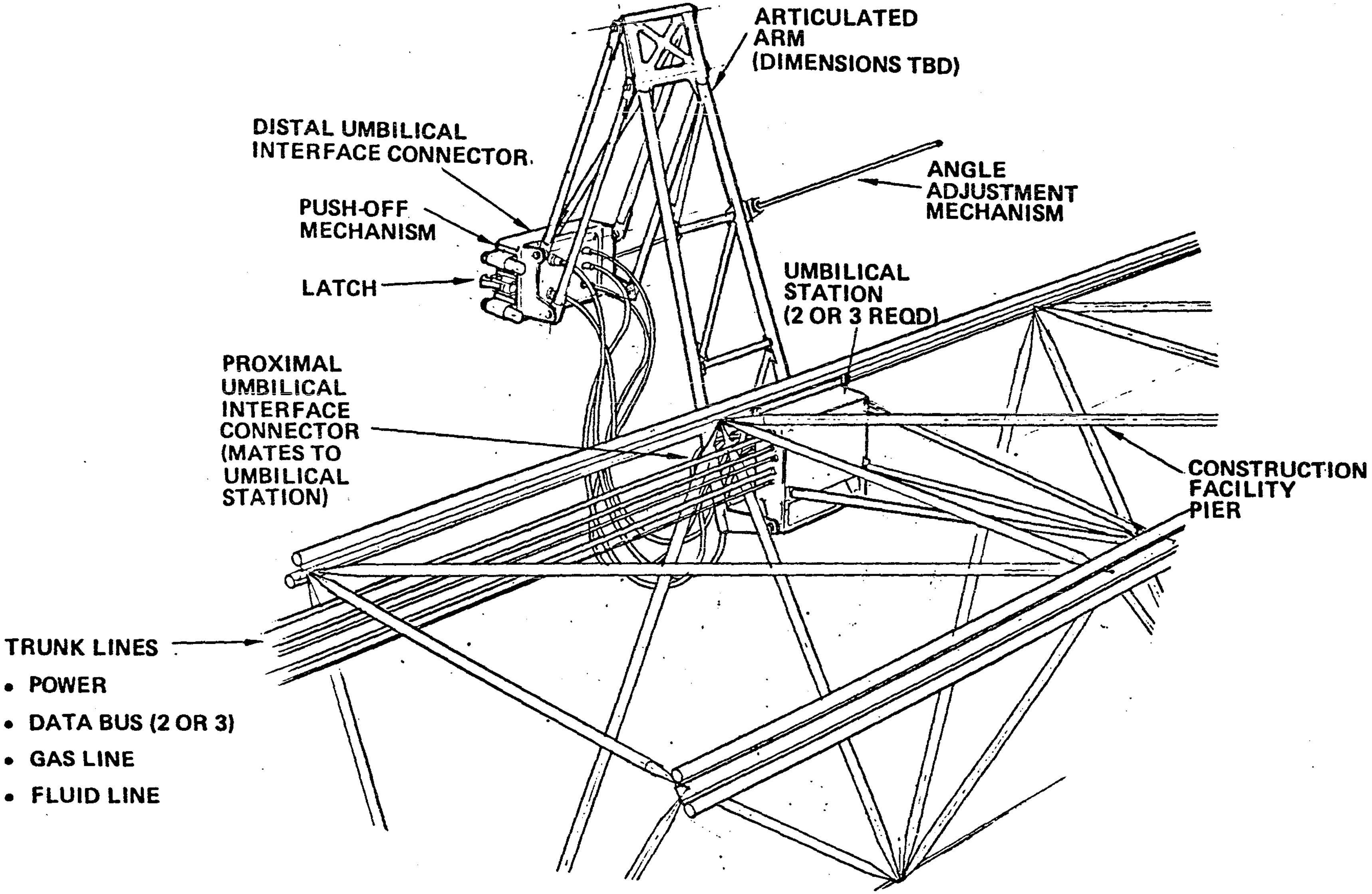
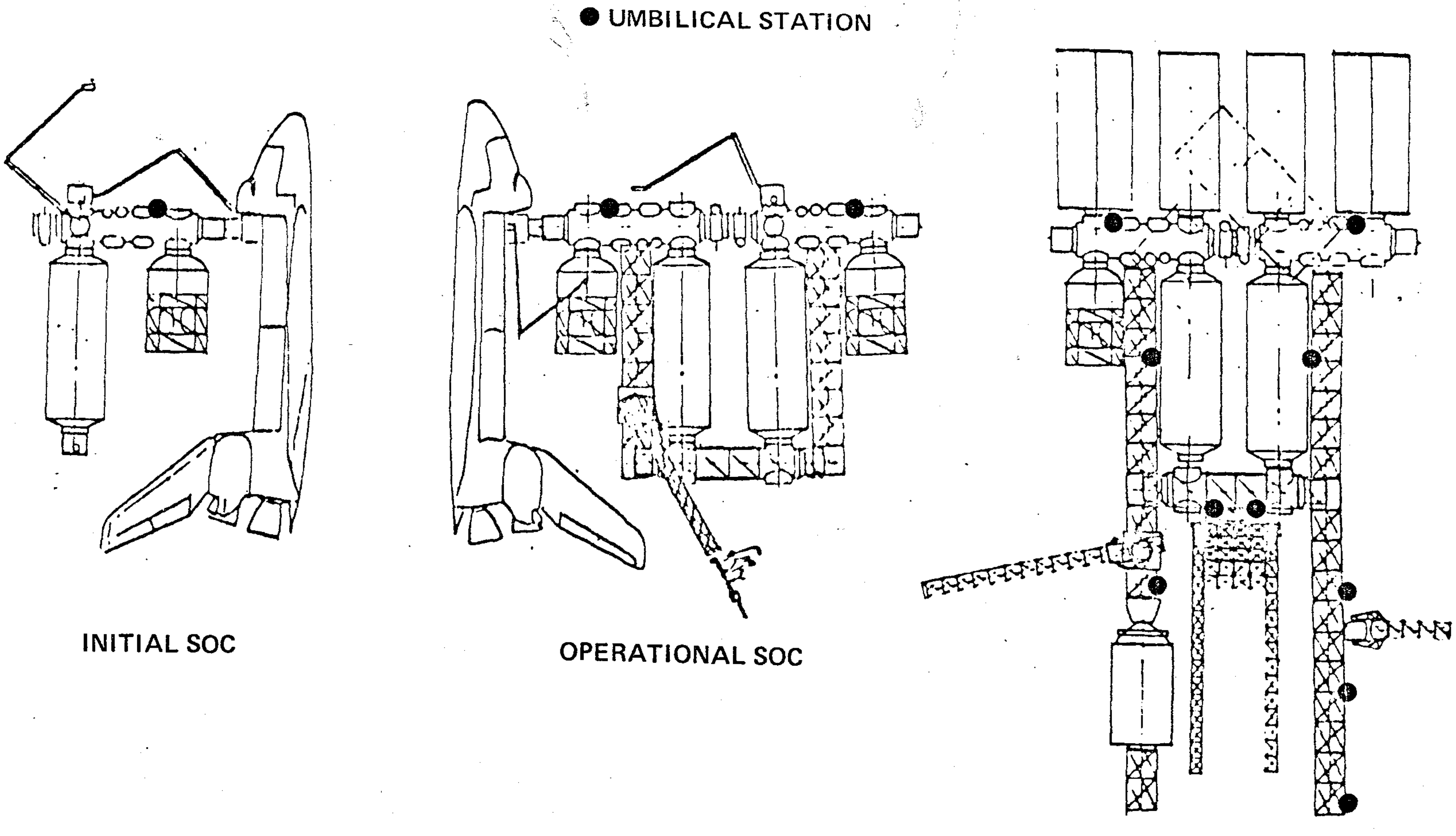


Figure A. Umbilical System Concept



INITIAL SOC

OPERATIONAL SOC

GROWTH SOC

Figure B Umbilical Station Locations

WBS 1.2.3.6 STORAGE SYSTEMS

1.0 WBS Dictionary

This element includes unpressurized storage provisions built into the SOC. This element does not include storage provisions located within the pressurized volume.

2.0 Description

Figure A illustrates a concept for a storage rack that is used in both the Operational and Growth SOC Configurations. Figure B illustrates a concept for a larger storage facility that would be provided for the Growth SOC Configuration. These storage provisions were designed to meet the following requirements:

1.0 Requirements Common to Both the Reference and Growth SOC Configurations

1.1 Payload Handling Tool Storage Provisions

1.1.1 Provide retention system for storing the Type A Payload Handling Tool.

1.1.2 Provide retention system for storing the Type B Payload Handling Tool.

1.1.3 The retention system must allow the tools to be stowed/unstowed without the operator actuating any retention device (these tools will be changed out by the mobile cherrypicker. The operator will not be able to actuate any retention system actuators as he will not be within reach).

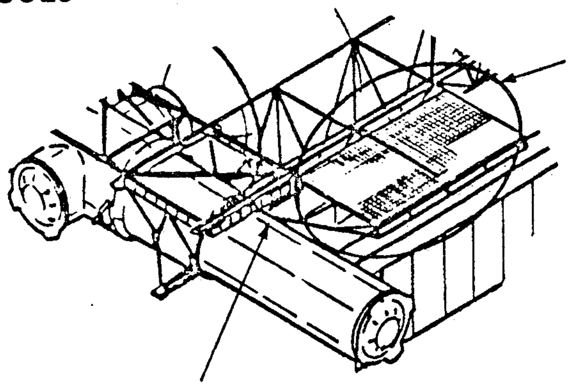
1.1.4 Environmental protection for the tools should not be required (needs further investigation).

1.1.5 The tool storage area must be located such that the mobile cherrypicker can easily access the tools.

1.2 (Other common storage requirements are TBD).

2.0 Storage System Requirements Applicable to Only the Reference SOC Configuration

2.1 The storage system shall be delivered along with other elements on the first Logistics Module delivery flight.



EQUIPMENT STORED
ON STORAGE RACK

- PAYLOAD HANDLING TOOLS
- MISC. TOOLS
- SMALL PAYLOAD COMPONENTS

STORAGE RACK (2.5 x 5 m)

- UPPER SURFACE EQUIPPED WITH RELOCATABLE RETENSION LATCHES

ATTACHES TO PIER

Figure A Storage Rack Concept

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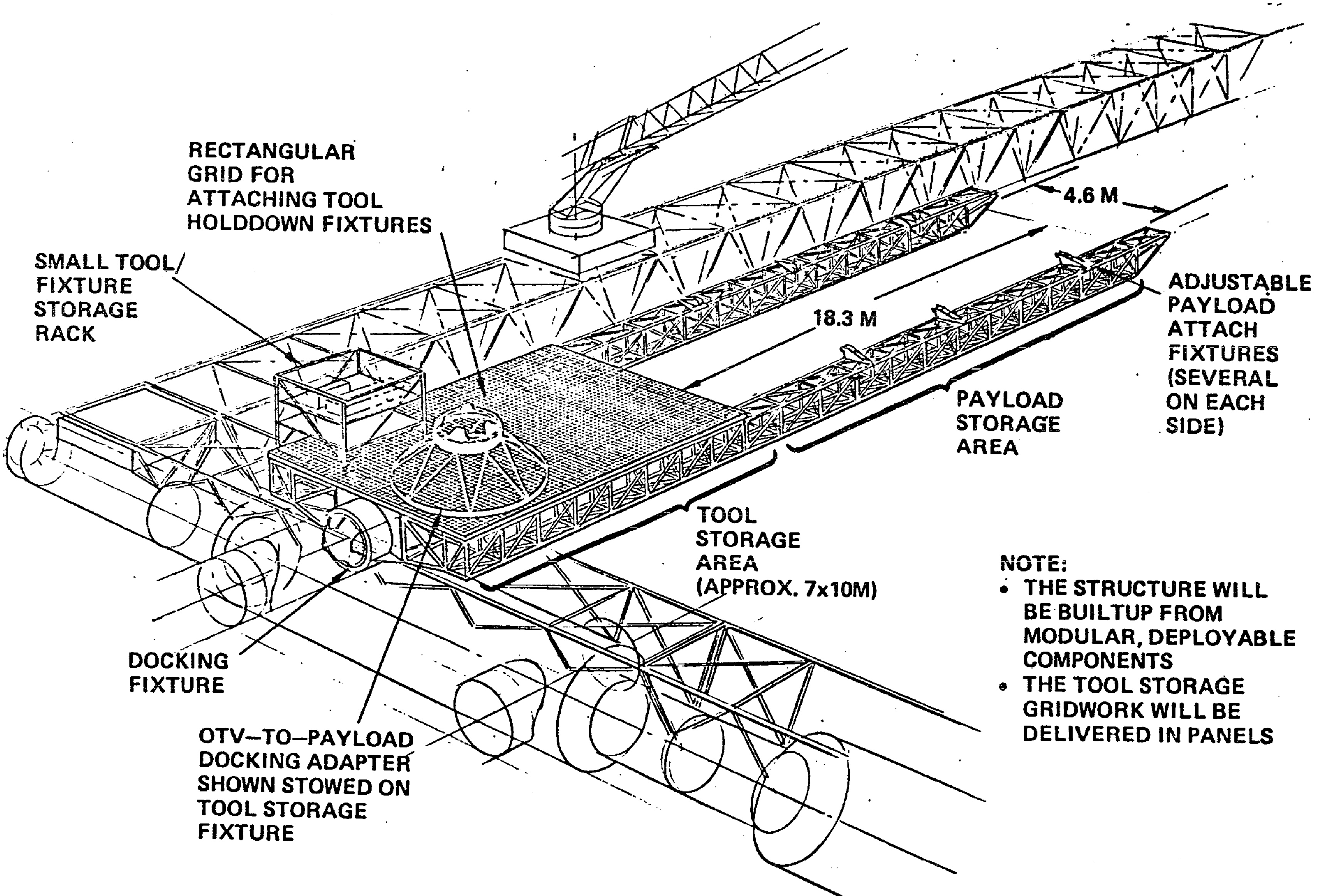

NOTE:
- THE STRUCTURE WILL BE BUILTUP FROM MODULAR, DEPLOYABLE COMPONENTS
- THE TOOL STORAGE GRIDWORK WILL BE DELIVERED IN PANELS

Figure B. Storage Facility Concept for Growth SOC

2.2 The preferred location for the storage system is on one of the finger piers in a location that does not interfere with the Logistics Module changeout or Orbiter docking to the Docking Tunnel.

2.3 (Other requirements TBD)

3.0 Storage System Requirements Applicable to Only the Growth SOC Configuration

3.1 Tool Storage Provisions

3.1.1 In addition to the requirements of 4.1, provide storage for the following equipment items:

- o Modular Construction Fixture Elements
- o Structural building blocks
- o Turntable/tilttable extension structure
- o Fixture attachment modules
- o Mission-dedicated modules
- o Articulated Construction Fixture
- o Beam Builder System
- o Beam builder
- o Unattached BB attachment modules

3.1.2 Requirements 1.1.3, 1.1.4, and 1.1.5 are applicable to these tools.

3.2 Component Storage Provisions

3.2.1 Provide a storage location large enough to store the largest orbiter payload (15 ft. diameter x 60 ft. long).

3.2.2 Utilize the same payload retention fittings as are used on the longitudinal sills of the Orbiter cargo bay.

3.2.3 Provide at least 10 fittings on each side.

3.2.4 These retention fittings can be remotely actuated from the SOC Command Centers.

3.3 General Requirements

3.3.1 Provide fixed lighting system that will adequately illuminate all storage locations. These lights can be controlled from the SOC Command Centers.

3.3.2 The storage system's preferred location is between the construction and flight support facility piers attached to the Docking Module.

3.3.3 The structural elements of this storage system should preferably be deployables.

3.3.4 Structural static and dynamic loads are TBD.

3.3.5 The storage system should make provision for the subassembly area discussed in another technology assessment writeup.

3.3.6 (Other requirements are TBD).

3.0 Design Basis

The requirements for the storage rack and storage facility were defined by the operations analysis of the construction, flight support, satellite servicing, and base buildup missions.

4.0 Mass

Refer to mass statement in WBS 1.2.3.

WBS 1.2.4 CONSTRUCTION SUPPORT EQUIPMENT

1.0 WBS Dictionary

This element includes equipment items that are dedicated to construction operations.

2.0 Description

At this time, the equipment items, that have been identified to be specifically used for construction operations include the following:

- Construction fixture
- Modular construction fixture
- Beam Builder
- Contour Measuring System

Each of these elements are described in lower level WBS descriptions.

3.0 Design Basis

Refer to lower level WBS descriptions.

4.0 Mass

The mass statement for the manipulator is given in Table A. The other equipment mass estimates were not required at this time.

					OFFSETS,M			
IN-DEX #	IN-DENT #	WBS #	TITLE	MASS KG	X	Y	Z	RATIONALE FOR ESTIMATE
26	1	1.2.4	CONSTR SUP EQUIP	582	0	0	0	SUM
27	2	1.2.4.1	POSITIONING ARM	582	0	0	0	1.5 X SHUTTLE RMS

(Note: This mass statement includes only those items pertinent to the Operational SOC Configuration. The mass of the items to be used in the Growth SOC are TBD.)

Table A. Construction Support Equipment Mass Statement

WBS 1.2.4.1 ARTICULATED CONSTRUCTION FIXTURE

1.0 WBS Dictionary

This element is the construction fixture to be used in the Operational SOC Configuration.

2.0 Description

A concept for an articulated construction fixture is depicted in Figure A.

Note: This construction fixture has been named the "Articulated Construction Fixture" to differentiate it from the "Modular Construction Fixture" (WBS 1.2.4.2) that will be required for the Growth SOC Configuration. There are many common requirements for these 2 types of fixtures.

This fixture was configured to meet the following requirements:

1. The fixture shall be designed primarily for the potential "constructable" spacecraft of the 1988 to 1993 time span. This does not preclude its being used for post-1993 spacecraft.
2. The fixture provides the support and positioning interface between the spacecraft and the SOC.
3. The fixture should attach to the turntable/tilttable.
4. The fixture must be capable of aligning the centerline of the spacecraft with the centerline of the OTV to facilitate mating of the vehicle to the spacecraft.
5. The fixture must be configured so that it can be retracted out of the way after the spacecraft and OTV are mated (i.e., after the spacecraft is supported by the OTV).
6. The fixture design should impose a minimal design impact on the spacecraft.
7. Wherever feasible, fixture attachment devices on the spacecraft should serve multiple purposes (e.g., the hardpoints used to attach the spacecraft to the transportation pallet should also be used as the hardpoints for attaching the fixture, if feasible).

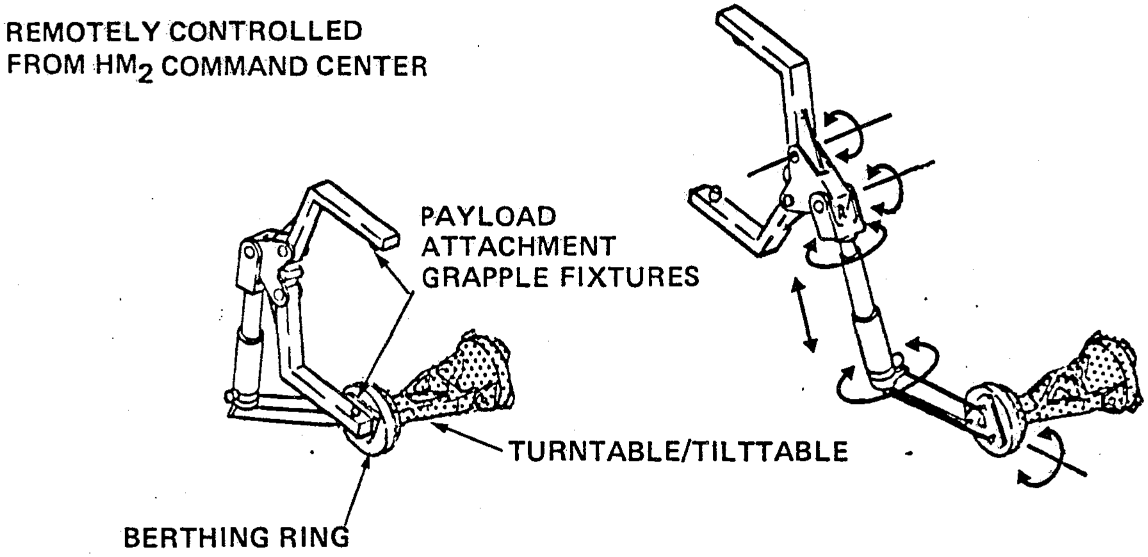

Figure A Articulated Construction Fixture

8. The dimensions of the fixture are TBD.
9. The degrees of freedom provided by the fixture are TBD.

3.0 Design Basis

For the Operational SOC Configuration, the construction projects will not be too complex. The construction work will generally entail deployment of appendages, assembly of a couple of large modules, test and checkout, and mating of an upper stage vehicle to the spacecraft. These operations will require some kind of construction fixture to provide the support and positioning interface between the spacecraft and the SOC. (The mobile cherrypicker is not an option as it will be employed in performing the deployment, joining, etc. - i.e., it cannot hold the spacecraft and do other tasks too.)

The primary design challenge will be the identification and design of a fixture that will be "universally" adaptable to many spacecraft sizes and shapes - many of which will not be defined at the time of the design of the fixture. The particular concept shown here was based on the Experimental GEO Communications Platform construction requirements analysis (Boeing -10, Boeing -15).

4.0 Mass

Refer to WBS 1.2.4 mass statement.

WBS 1.2.4.2 MODULAR CONSTRUCTION FIXTURE

1.0 WBS Dictionary

This element is the construction fixture used in the SOC Growth Configuration.

2.0 Description

Figure A illustrates a concept for a modular construction fixture system. The major elements of the system are the modular structural building blocks and some accessory modules.

Note: This construction fixture has been named the "Modular Construction Fixture System" to differentiate it from the "Articulated Construction Fixture" (WBS 1.2.4.1) that will be required for the Operational SOC Configuration.

The modular construction fixture was configured to meet the requirements listed below:

1. This fixture system shall be designed for the potential "constructable" spacecraft of the post-1993 era.
2. The fixture system, in conjunction with the Turntable/Tilttable system, provides the support and positioning interface between the spacecraft and the SOC.
3. The fixture system will also be used to position construction equipment relative to the spacecraft during the construction operations.
4. The fixture must be capable of aligning the centerline of the spacecraft with the centerline of the OTV to facilitate mating of the vehicle to the spacecraft.
5. The fixture must be configured so that it can be retracted out of the way after the spacecraft and OTV are mated (spacecraft supported by the OTV).
6. The fixture design should impose a minimal design impact on the spacecraft.
7. Wherever feasible, fixture attachment devices on the spacecraft should serve multiple purposes (e.g., the handpoints used to attach the spacecraft to the transportation pallet should also be used as the handpoints for attaching the fixture, if feasible).

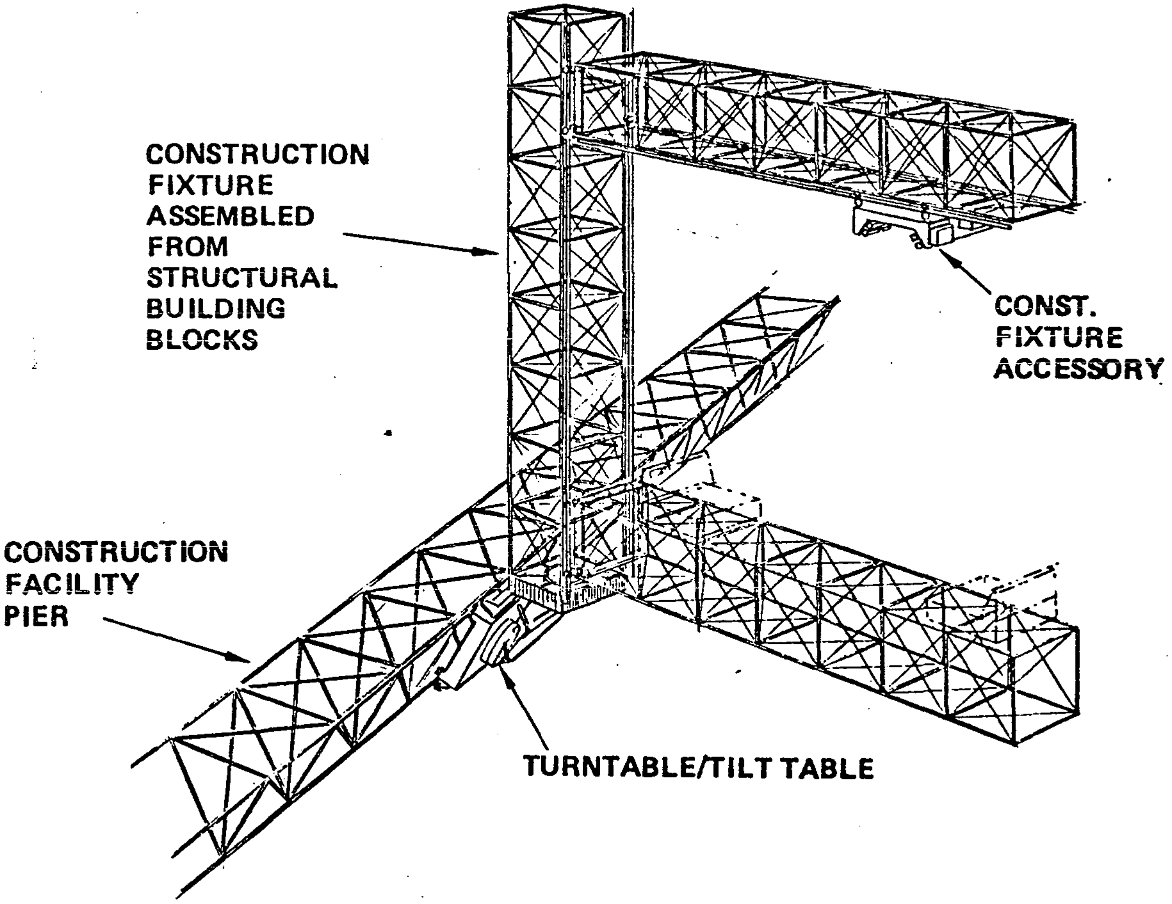

Figure A. Modular Construction Fixture Concept

8. Structural Building Block Module Requirements (see Figures B and C)

8.1 Provide a system of structural cubes that can be joined together on any face of the cubes.

8.2 The cube-to-cube attachment interface must be configured such that an EVA astronaut can assemble the cubes by hand and make the connections either by hand or by using a simple zero-g handtool (wrench or screwdriver).

8.3 The structural cubes must be collapsible for stowage.

8.4 The collapsed structural cubes must be designed so that an EVA astronaut can fold/unfold and lock the collapsible members either by hand or by using a simple zero-g handtool.

8.5 The structural cubes should incorporate wiring and junction boxes for electrical power and control signal circuits that will be connected to attached modules (see 9., 10., . . .)

8.6 A 2m cube has been defined for the reference concept, however, an analysis should be conducted to confirm this sizing.

8.7 Dynamic and static loads are TBD.

8.8 The quantity of cubes to be available at SOC is TBD (at least 20 cubes).

8.9 Provide a set of rail attachments that can be used to attach cubes one-to-another at non-incremental locations.

9. Accessory Modules - Analysis of 3 construction projects have exposed requirements for the accessory modules discussed in this section.

9.1 Linear Actuator Module

9.1.1 This module attaches to the structural cubes.

9.1.2 This module provides the capability to slide one section of the fixture relative to another section in one degree of freedom.

9.1.3 The movable section of the fixture interfaces to the Linear Actuator Module via the attachment rails (see 8.9).

9.1.4 Provide a means to pass the electrical power and control signal circuits across the sliding joint in order to supply active modules attached to the movable portion of the fixture.

9.1.5 The electrical power and control signals for the module are taken from the circuits provided in the structural cubes.

9.2 Beam Holder/Indexer Module (see Figures D and E)

9.2.1 This module attaches to the structural cubes.

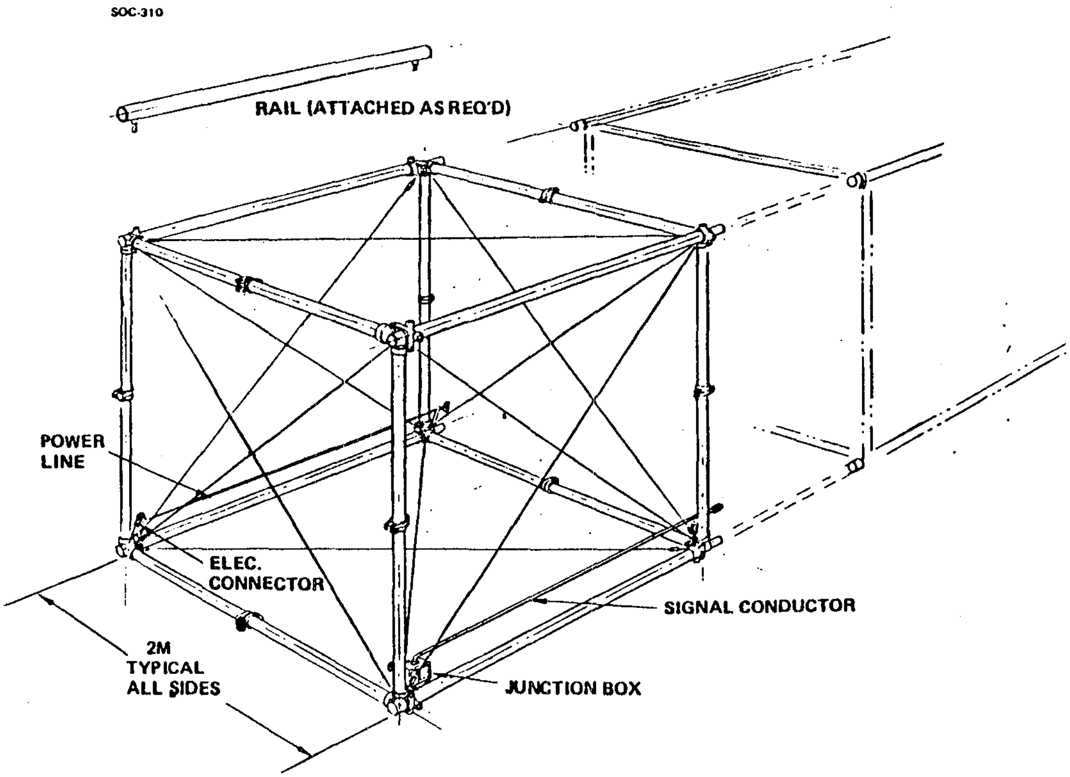

Figure B. Modular Construction Fixture Structural Building Block Deployed Configuration

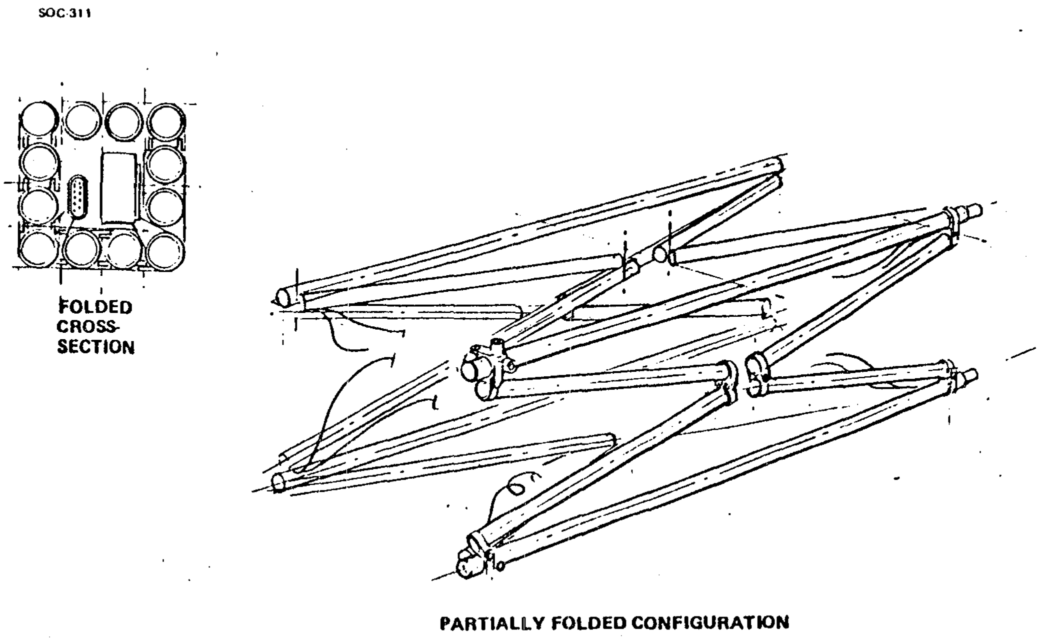

Figure C. Modular Construction Fixture Structural Building Block Collapsed Configuration

SOC-308

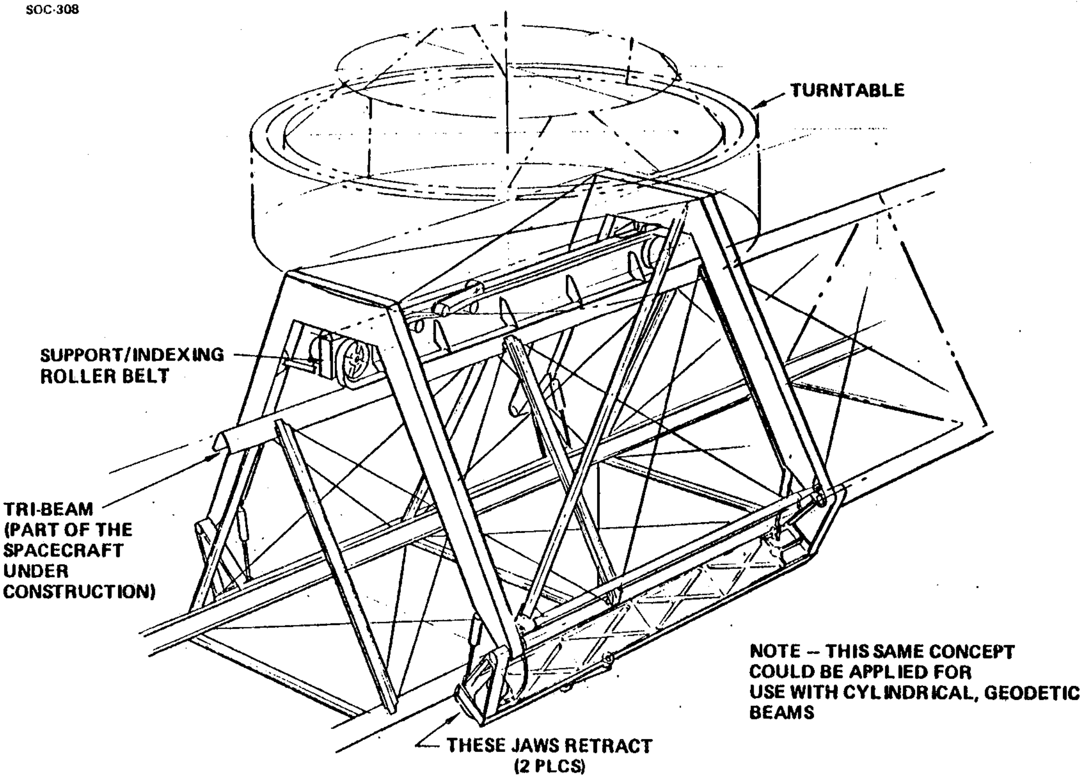

Figure D. Construction Fixture Accessory—Tri-Beam Support/Indexing Module

SOC-309

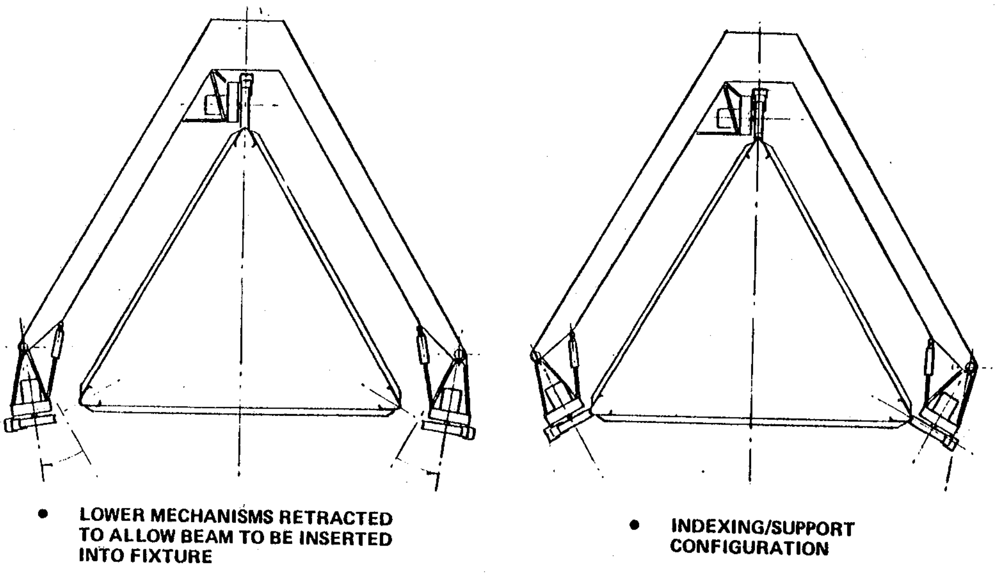

Figure E. Beam Indexing/Support Fixture—End View

9.2.2 This module provides the capability for holding and indexing the beams fabricated by the beam builder.

9.2.3 This device must be configured so that a beam can be inserted either in the longitudinal direction or in a lateral direction.

9.2.4 Must be configured so that the module can be removed from the beam after the beams have been attached to other spacecraft elements such that the holder/indexer is no longer required.

9.2.5 The electrical power and control signals for the module are taken from the circuits provided in the structural cubes.

9.3 Platform Modules

9.3.1 This module attaches to the structural cubes.

9.3.2 These modules provide a mounting surface for attaching instrumentation, other construction equipment (e.g., the beam builder), or other TBD elements.

9.3.3 The electrical power and control signals for this module are taken from the circuits provided in the structural cubes.

9.4 Other Modules - there have been 2 other types of modules (a Cross Brace Cord Reel Module and an Electrical Line Installer Module) that have been defined for one of the reference construction projects. However, their general utility on other projects has not been ascertained so they are not listed here as primary accessory modules.

3.0 Design Basis

For the Growth SOC Configuration, the construction projects will generally be very large and very complex. The construction operations will entail various combinations of deployment, assembly, and fabrication operations in addition to test/checkout and mating of the spacecraft to OTV's. These operations will require varying levels of complexity of the holding and positioning fixtures that will provide the interface between the spacecraft and the SOC.

The objective of the modular construction fixture system concept was to create a system that will be adaptable to the wide variety of spacecraft sizes, shapes, and complexity. The goal is to minimize the need for mission-dedicated fixtures.

This modular construction fixture concept evolved from the construction analyses of the Orbiting Deep Space Relay Station, Large Ambient IR Telescope, and the Rockwell Engineering Verification Test Article (Boeing -8, -10, -13, -14).

4.0 Mass

It was not required to make a mass estimate on these elements at this time.

WBS 1.2.4.3 BEAM BUILDER

1.0 WBS Dictionary

This element is the automated tri-beam fabrication machine.

2.0 Description

The beam builder is under development by General Dynamics Convair Division. Information on the beam builder can be found in the "Space Construction Automated Fabrication Experiment Definition Study (SCAFEDS)" final report, Volume II, Study Results, CASD-ASP77-017, dated 5-26-78.

The SCAFE beam builder is an automatic machine process which fabricates beam assemblies from non-metallic materials stored within the machine. The materials are preconsolidated thermoplastic graphite/fiberglass composites which are manufactured in a convenient form for small volume storage. The thermoplastic composite materials not only provide excellent properties for space structures, but lend themselves to automatic fabrication techniques because they are heat formable and can be joined by efficient spot welding techniques.

3.0 Design Basis

A beam builder will be required for constructing large space platforms. This SCAFE beam builder was specifically identified in the construction analysis for the Rockwell Engineering Verification Test Article mission (see Boeing -20 and -21).

4.0 Mass

It was not required to make a mass estimate for this element at this time.

WBS 1.2.4.4 CONTOUR MEASURING SYSTEM

1.0 WBS Dictionary

This element includes the sensor and controls/displays for a system used to measure the geometry of parabolic reflectors.

2.0 Description

A contour measuring system is required which will meet the requirements listed below:

1. Interfaces - Attaches to the modular construction fixture instrument mounting module. This module provides the structural attachment, power, and data bus interfaces.
2. The controls and deploys for this system shall be implemented through the SOC Command Center's operations control multifunction control/display system.
3. Should be able to measure the parabolic surface contour dimensions for reflectors up to 100m in diameter.
4. The required accuracy of the measurement is TBD.

3.0 Design Basis

Many of the spacecraft to be assembled at SOC will incorporate deployable or erectable parabolic antenna reflectors. It is essential that for the antennas to perform up to their specifications, the antenna reflective surface be within very tight dimensional tolerances of the optimal design geometry. It is prudent to provide a single, multi-use contour measuring system at the SOC because it alleviates having to build a contour measuring system into each satellite.

This is a system required for the Growth SOC Configuration.

4.0 Mass

It was not required to make a mass estimate on this element at this time.

WBS 1.2.5 TRANSPORTATION SUPPORT EQUIPMENT

1.0 WBS Dictionary

This element includes all equipment items dedicated to transportation support operations.

2.0 Description

At this time, the equipment items that have been identified to be specifically used for transportation support operations include the following:

Hangar
Dolly
Propellant Storage/Delivery System

Each of these elements are described in lower level WBS descriptions.

3.0 Design Basis

Refer to lower level WBS descriptions.

4.0 Mass

The mass estimate for these elements is given in Table A.

IN-DEX #	IN-DENT #	WBS #	TITLE	MASS KG	OFFSETS,M X	Y	Z	RATIONALE FOR ESTIMATE
28	1	1.2.5	FLIGHT SUP EQUIP	2954	0	0	0	SUM
29	2	1.2.5.1	HANGAR	2954	0	0	0	SUM
30	3	1.2.5.1.1	STRUCTURES	832	0	0	0	SUM
31	4	1.2.5.1.1.1	WALL PANELS	581	0	0	0	- SIX PANELS - 15 M X 4.2 M X 0.46MM - ALUMINUM - 20% FOR STIFFENERS AND ATTACHMENT PROVISIONS
32	4	1.2.5.1.1.2	END PANELS	141	0	0	0	- TWO HEXAGONAL PANELS - 4.2 M HEX SIDE - 0.46 MM THICK - ALUMINUM - 20% FOR STIFFENERS AND ATTACH PROVISIONS

Table A Flight Support Equipment Mass Statement

IN-DEX #	IN-DENT #	WBS #	TITLE	MASS KG	OFFSETS, M X	Y	Z	RATIONALE FOR ESTIMATE
33	4	1.2.5.1.1.3	END FRAMES	110	0	0	0	- FRAME AT EACH END - ROUGH ESTIMATE
34	3	1.2.5.1.2	MECHANISMS	560	0	0	0	SUM
35	4	1.2.5.1.2.1	SIDE DOOR ACTUAT	60	0	0	0	SIX ACTUATORS AT 10 KG EACH
36	4	1.2.5.1.2.2	END DOOR ACTUATO	40	0	0	0	FOUR ACTUATORS AT 10 KG EACH
37	4	1.2.5.1.2.3	PLATFORM DRIVE	60	0	0	0	- BALLSCREW DRIVE FOR MOVABLE WORK PLATFORM - 2 DRIVES 15M LENGTH EACH - 2 KG/M AVERAGE MASS
38	4	1.2.5.1.2.4	RETRACTION DRIVE	250	0	0	0	- THIS DRIVE RETRACTS ENTIRE HANGAR - ROUGH ESTIMATE
39	4	1.2.5.1.2.5	BERTHING FIXTURE	150	0	0	0	ESTIMATE
40	3	1.2.5.1.3	THERMAL CONTROL	25	0	0	0	SUM
41	4	1.2.5.1.3.1	THERMAL COATING	25	0	0	0	THERMAL CONTROL COATING ON HANGAR EXTERIOR

Table A (Con't)

IN-DEX #	IN-DENT #	WBS #	TITLE	MASS KG	OFFSETS, M X	Y	Z	RATIONALE FOR ESTIMATE
42	3	1.2.5.1.4	PRIMARY PROPULSI	0	0	0	0	(NO PRIMARY PROPULSION)
43	3	1.2.5.1.5	AUX PROPULSION	0	0	0	0	(NO AUXILIARY PROPULSION)
44	3	1.2.5.1.6	ORDNANCE	0	0	0	0	(NO ORDNANCE)
45	3	1.2.5.1.7	ELECTRICAL POWER	155	0	0	0	SUM
46	4	1.2.5.1.7.1	HARNESS	50	0	0	0	- POWER THRU BERTHING INTERFACE - SERVES LIGHTS & COM - ESTIMATE
47	4	1.2.5.1.7.2	INTERIOR LIGHTIN	80	0	0	0	- TWICE HAB MODULE - MORE VOLUME TO ILLUMINATE
48	4	1.2.5.1.7.3	EMERGENCY BATTER	25	0	0	0	SERVES EMERGENCY LIGHTS & COM
49	3	1.2.5.1.8	GN & C	0	0	0	0	(NO GN & C)
50	3	1.2.5.1.9	TRACKING & COMM	25	0	0	0	SUM
51	4	1.2.5.1.9.1	EVA REPEATER	20	0	0	0	REQUIRED FOR VOICE COM WITH EVA CREW INSIDE HANGAR

Table A (Con't)

```
IN- IN-  WBS                 TITLE              MASS    OFFSETS,M      RATIONALE
DEX DENT  #                                      KG    X      Y      Z    FOR ESTIMATE
 #   #

  52  4 1.2.5.1.9.2      EVA ANTENNA              5    0      0      0       ESTIMATE

  53  3 1.2.5.1.10       DATA MGMT               10    0      0      0       SUM

  54  4 1.2.5.1.10.1     DATA BUS                10    0      0      0       DATA BUS FOR
                                                                             INSTRUMENTATION

  55  3 1.2.5.1.11       INSTRUMENTATION         50    0      0      0       ALLOWANCE FOR
                                                                             NON-DEDICATED
                                                                             INSTRUMENTATION

  56  3 1.2.5.1.12       CREW ACCOMM.           312    0      0      0       SUM

  57  4 1.2.5.1.12.1     HANDHOLDS               20    0      0      0       40 HANDHOLDS @ 0.5 KG
                                                                             EACH

  58  4 1.2.5.1.12.2     MOVABLE PLATFORM       292    0      0      0       29.2 M2 @ 10 KG/M2
                                                                             AVERAGE UNIT MASS

  59  3 1.2.5.1.13       EC/LSS                   0    0      0      0       (NO EC/LSS)

  60  3 1.2.5.1.17       MISSION EQUIPMEN         0    0      0      0       (NO MISSION
                                                                             EQUIPMENT)

  61  3 1.2.5.1.18       GROWTH                 985    0      0      0     - 50% OF IDENTIFIED MASS
                                                                           - HANGAR IS LESS WELL
                                                                             DEFINED THAN OTHER
                                                                             ELEMENTS

Ready
```

Table A. (Con't)

WBS 1.2.5.1 HANGAR

1.0 WBS Dictionary A

This element is the environmental protective enclosure and maintenance facility to be used with OTV's, satellites, crew modules, and other spacecraft.

2.0 Description A

Figure A shows the locations of the hangars in the Growth SOC Configuration. This hangar provides an unpressurized protective enclosure for OTV's, satellites and other spacecraft that require some shielding from the man-made orbital debris (see Section 3.0). One of these hangars will be required for each OTV and MOTV Crew Module stored and maintained at SOC.

The primary elements of this hangar are the primary structure, the skin, the pier, door opening/closing mechanisms, and interior lighting. The equivalent of 18 mils of aluminum is the desired wall thickness to provide this shielding. In the Growth SOC Configuration, maintenance access scaffolding, spare parts storage, and propellant loading provisions would also be included. Figure B shows an OTV in a hangar and Figure C shows an MOTV Crew Module located in the hangar.

3.0 Design Basis

The requirement for an environmental protective enclosure were based on an analysis of the man-made orbital debris hazard (see Boeing -7, -8, and -13). The hangar was sized to house a space-based OTV (see Boeing -14), although, other mission elements could also be housed. Other design features were derived by an analysis of the flight support operations (see Boeing -15).

4.0 Mass

The mass of this element is given in the WBS 1.2.5 mass statement.

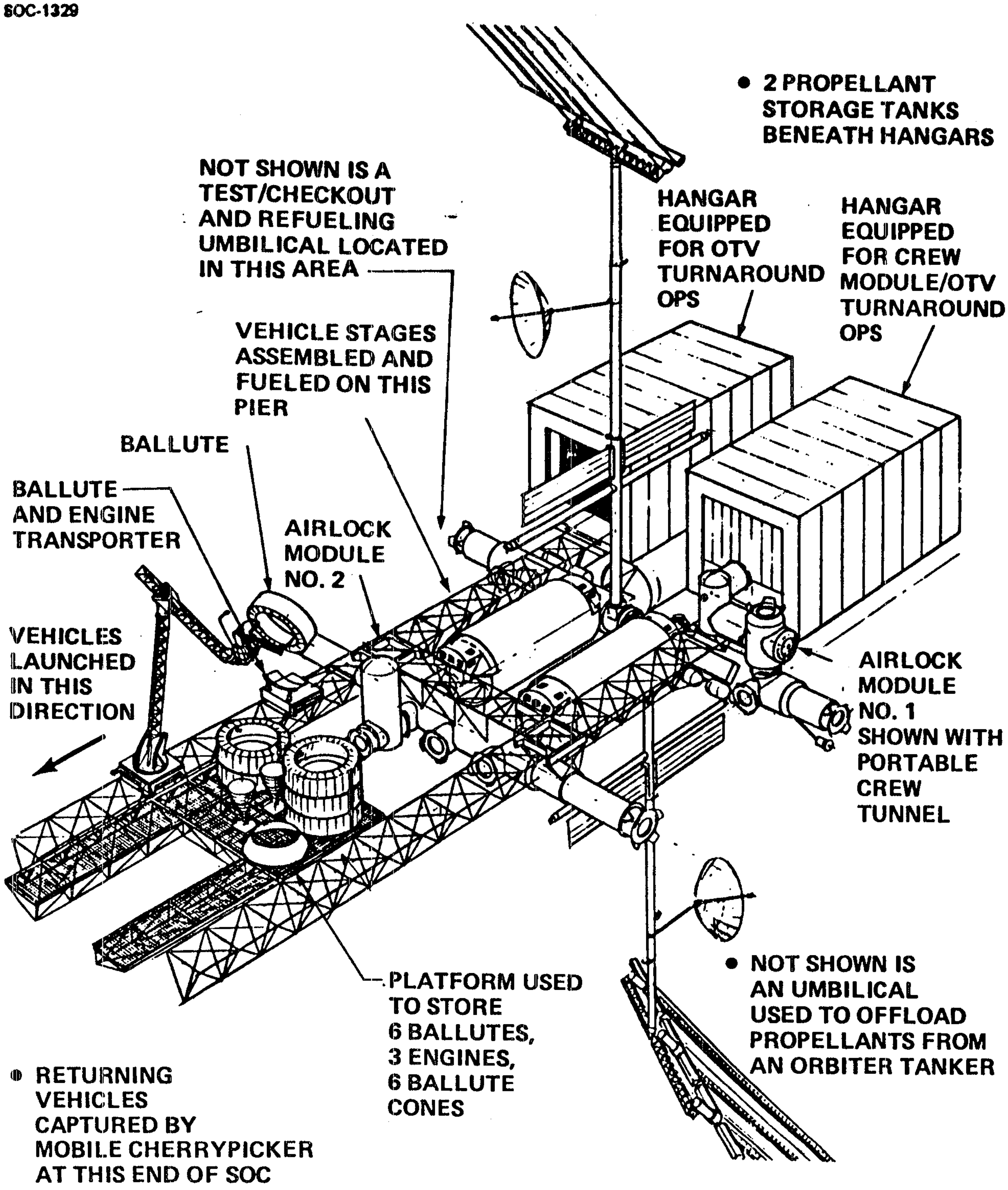

Figure A. Location of Hangars

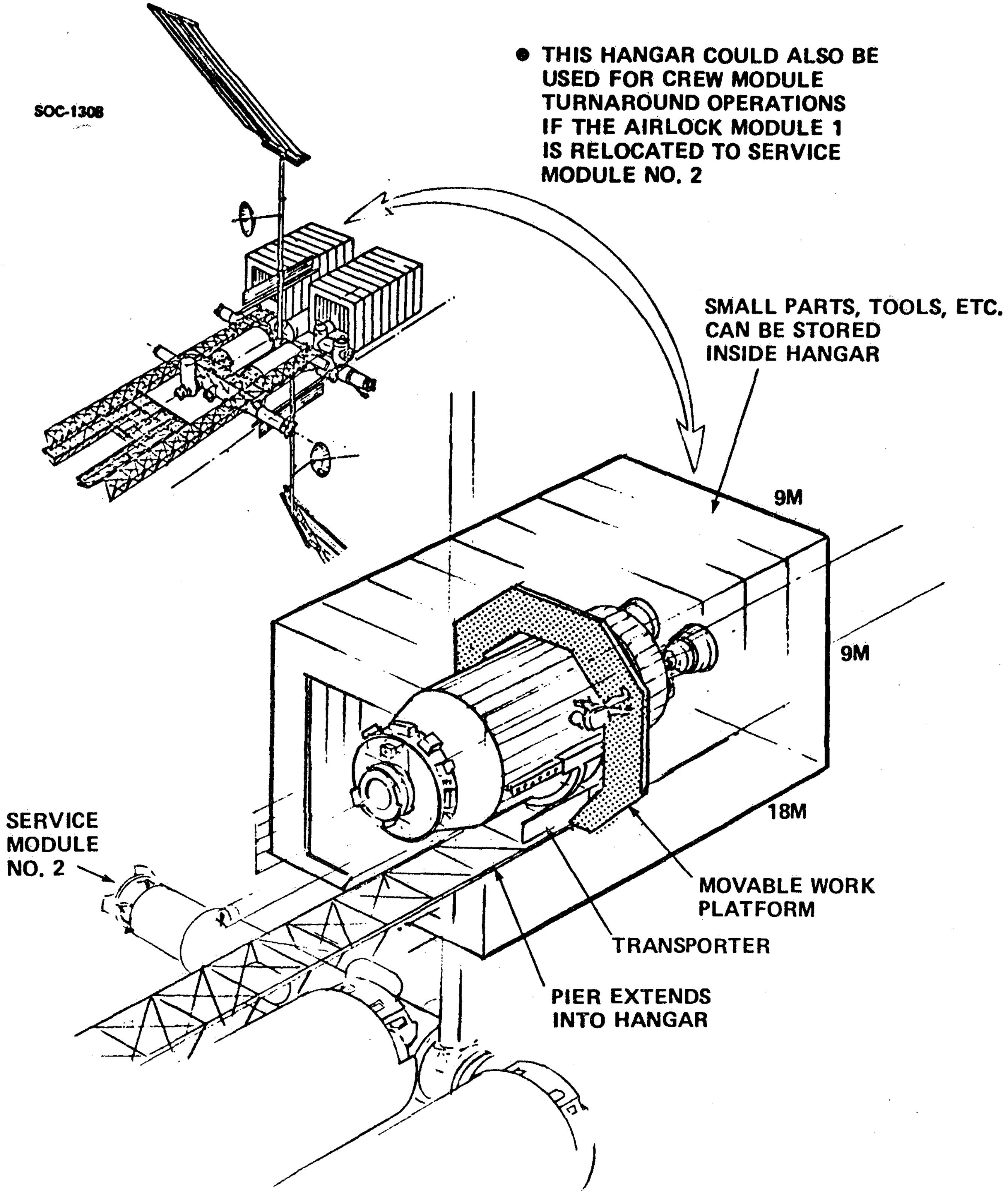

Figure B. Hangar Equipped for OTV Turnaround Operations

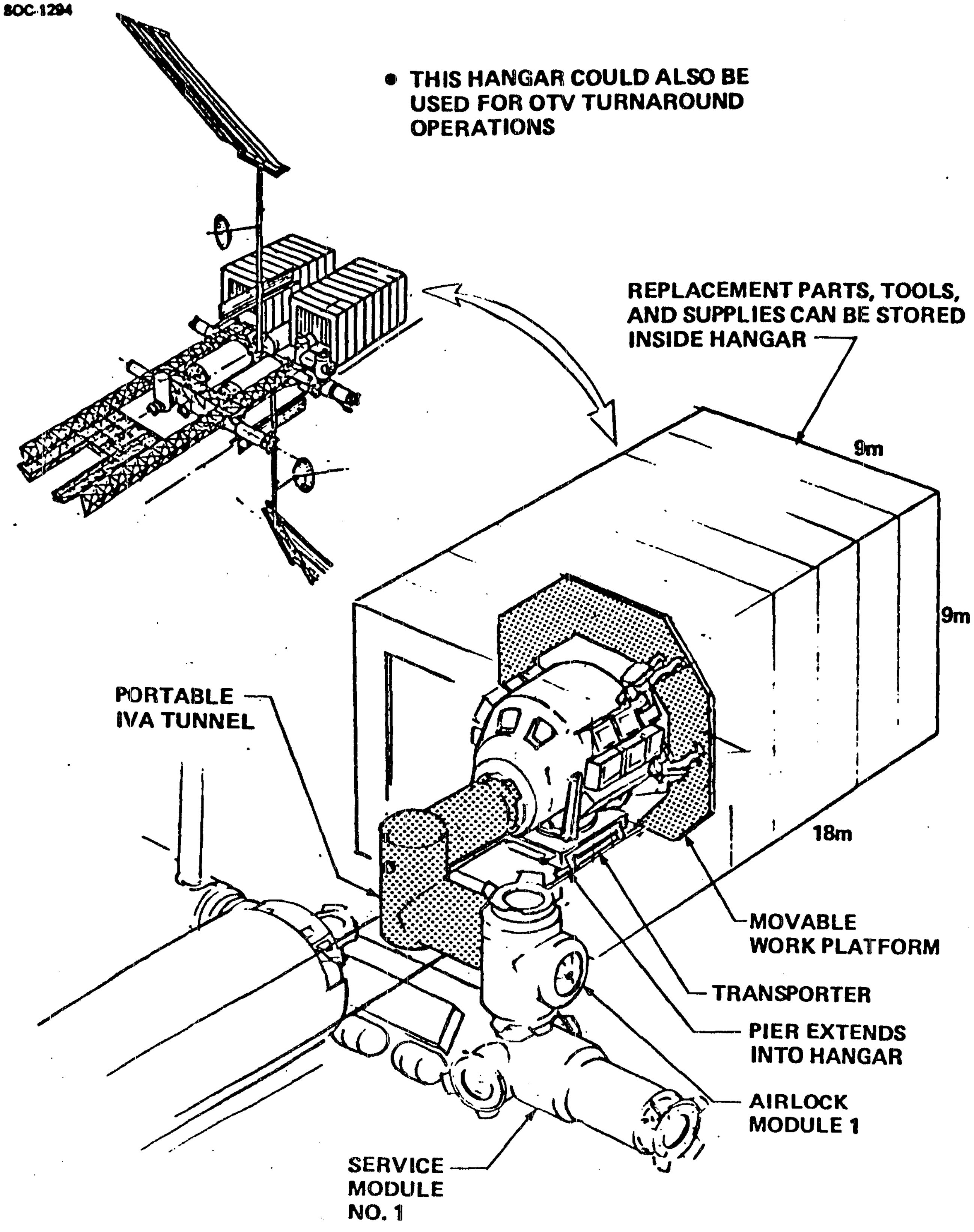

Figure C. Hangar Equipped for Crew Module Turnaround Operations

WBS 1.2.5.2 DOLLY

1.0 WBS Dictionary

This element is the carriage used to transport OTV's on the SOC track network.

2.0 Description

Figure A illustrates a concept for an OTV dolly.

The dolly carriage is identical to the carriage used on the mobile cherrypicker (WBS 1.2.3.2.2) and the modular construction fixture (WBS 1.2.4.2).

The OTV support fixture attaches to 4 handling fixtures on the OTV. The support fixture-to-OTV interface can be remotely latched/unlatched.

3.0 Design Basis

The requirements for this dolly were defined by an analysis of the flight support operations (see Boeing -15) and construction operation, (see Boeing -10 and -15).

4.0 Mass

The mass of this element is estimated to be 454 kg (the same as the mobile cherrypicker carriage).

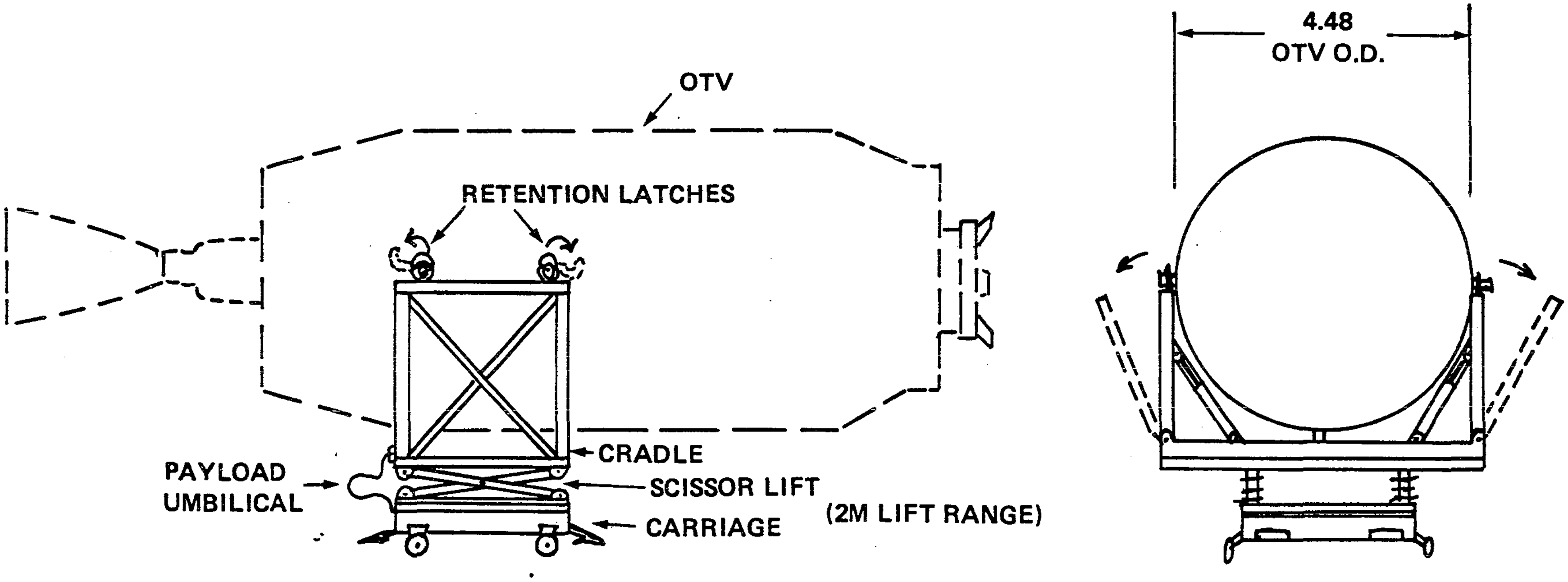

Figure A. OTV Carriage Concept

WBS 1.2.5.3 PROPELLANT STORAGE AND DELIVERY SYSTEM

1.0 WBS Dictionary

This element includes the OTV propellant storage tank, pumps, delivery lines, and other propellant delivery system elements.

2.0 Description

This system has been defined as a part of the Growth SOC Configuration. It is intended to serve space-based OTV operations. Its function is to receive propellant from the launch system (shuttle or HLLV tanker), store it until needed for transfer to an OTV, and to transfer the propellants to a space-based OTV. Figure A shows the propellant storage and delivery system schematic.

Tankage—The propellant storage tanks will have a capacity of roughly 120,000 kg equally divided between two tanks. These tanks will be high-quality insulated dewars employing multilayer insulation and an external collision and plume shield to protect the MLI. The external shield need not be vacuum-tight as the vacuum of low Earth orbit is adequate for insulation performance and the performance of the insulation during launch is not an issue. If the tanks are launched loaded, a helium purge will be applied to the insulation space to prevent water or air condensation.

Each tank will include separate containers for liquid oxygen and hydrogen. The volumes of these containers will be set by the storage mixture ratio of six kg of oxygen per kg of hydrogen. The tanks will be configured for launch (presumably empty) by space shuttle. Each tank will include a berthing fixture for attachment to the SOC.

Boiloff will be routed through cooling coils in the outlet region to provide subcooling of the tank structure and equipment in this region, in order to ensure liquid delivery. The tanks will be oriented such that the residual gravity gradient in the tanks (about 10^{-6} g) will aid propellant settling; in addition, surface-tension acquisition and retention devices will be used in the outlet area.

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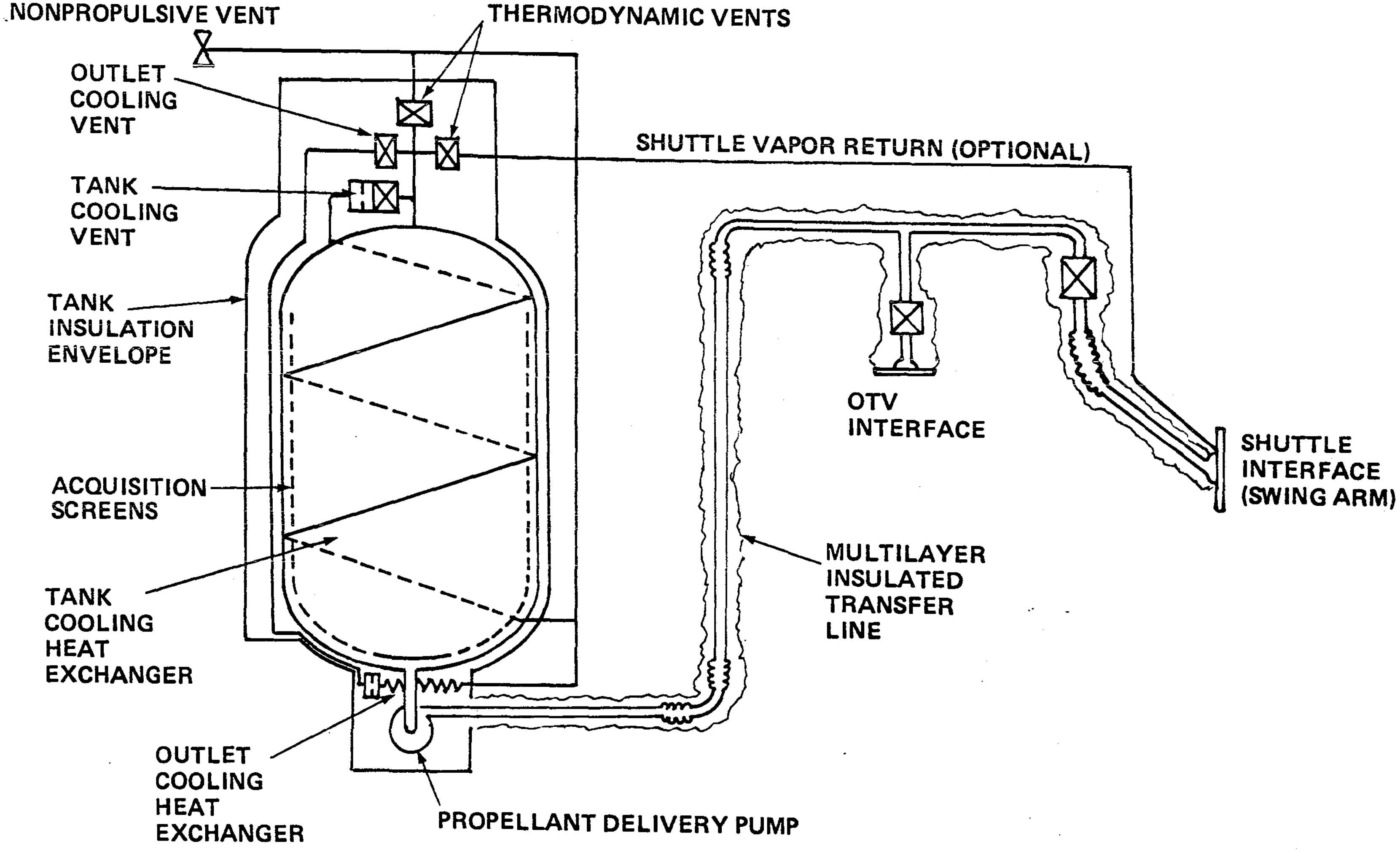


Figure A. Propellant Storage/Delivery System Concept

Propellant delivery will be accomplished by zero-NPSH electrically-driven pumps mounted external to the tank outlet. The pumps will be thoroughly insulated to minimize boiloff and mounted in such a way as to minimize heat leak into the tanks.

Several options are available for propellant gaging, none particularly attractive. Acoustic devices offer good accuracy when the tanks are nearly full. Flowmeter integration can improve accuracy when the tanks are nearly empty. Normal operational procedure for these tanks will be to retain them at a half-filled or greater level. The flowmeters will be installed at the pump outlets to minimize two-phase flow, which can cause large flow indication errors.

Delivery lines will be insulated with multilayer insulation and protected by an external metal shield. Delivery lines will be fixed to the SOC except for swing-arm ends that mate to umbilical plates on the OTV for refueling or on the shuttle or HLLV tanker for SOC storage replenishment. The pumping system for delivery from the launch tanker may be a part of the SOC propellant system or may be installed on the launch tanker.

3.0 Design Basis

The propellant storage and delivery system concept was developed based on available information and concepts for zero-g propellant management. The feasibility of these concepts is presently ill-defined and needs confirmation by flight tests with cryogenic fluids.

Studies of Shuttle-upper stage-SOC interrelationships indicated that efficiency of propellant transfer and storage with a minimum of loss is of paramount importance in establishing a cost-effective space-based upper stage operation. Accordingly, the concept presented here uses storage and transfer means intended to minimize losses.

4.0 Mass

Refer to WBS 1.2.5 mass statement.

WBS 1.2.5.4 ENGINE/BALLUTE TRANSPORTER

A

1.0 WBS Dictionary

This element is a transporter equipped for transporting and positioning OTV engines and ballutes.

2.0 Description

The engine/ballute transporter is shown in Figure A. This transporter is used during the space-based OTV turnaround operations.

After every aerobraked OTV flight, the ballute mounting cone must be removed and a new ballute installed. This transporter is used to move the ballute from the ballute storage area in the Storage Facility to the hangar where the OTV will be worked on. This transporter is used to slip the ballute past the engine bells into its mating position.

This transporter is also used during engine changeouts to transport and install the engines on the OTV.

3.0 Design Basis

This machine was conceived of during the OTV operations analysis (Boeing -28). There is very little clearance between the ballute and the engine bells. This requires that the ballutes be very carefully slipped past the engines to avoid accidental contact. The transporter fulfills this requirement.

The engine changeout operations will also require very careful and positive positioning of the engines.

4.0 Mass

No mass estimate has been made for this element.

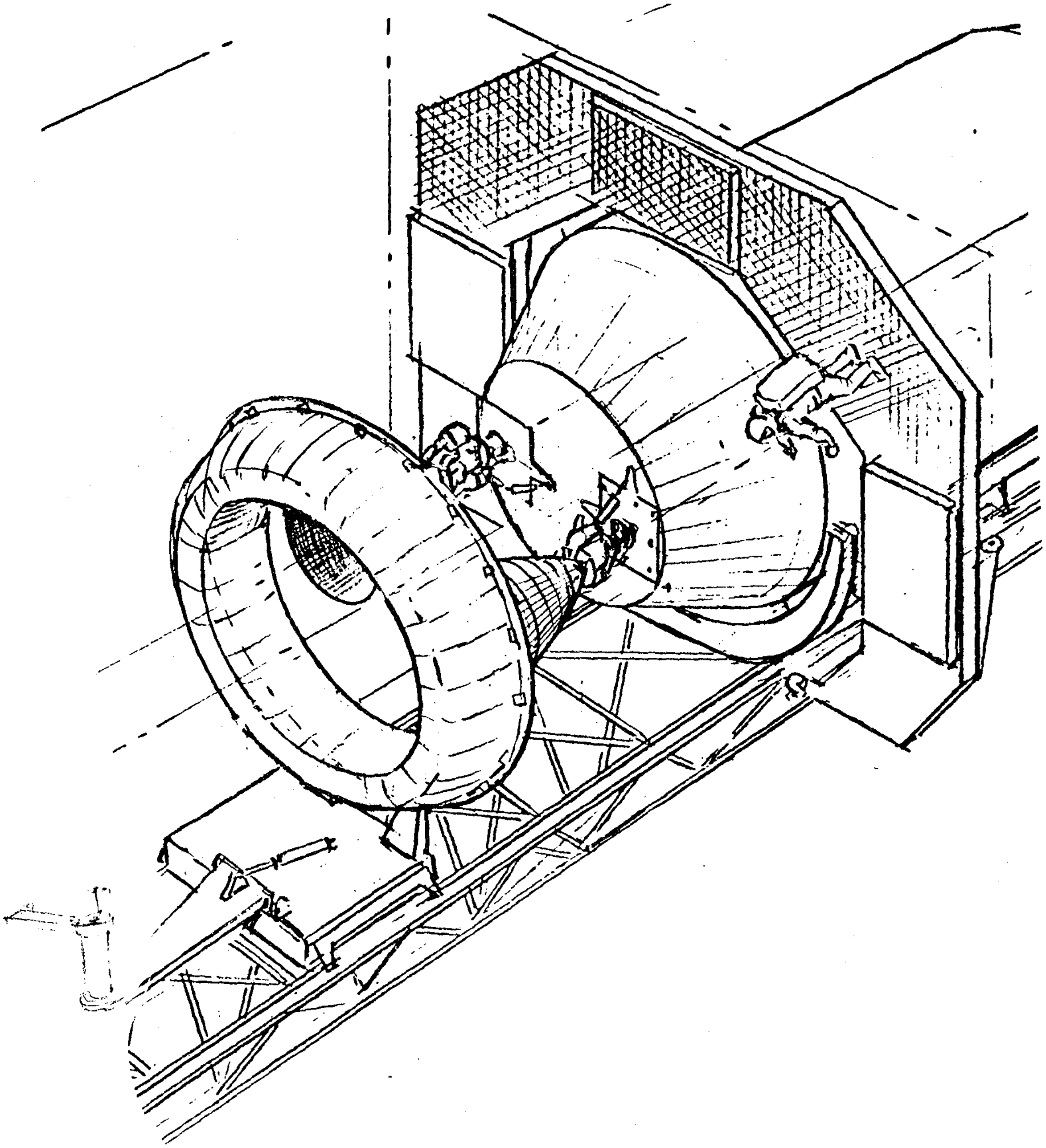


Figure A. Ballute and Engine Transporter

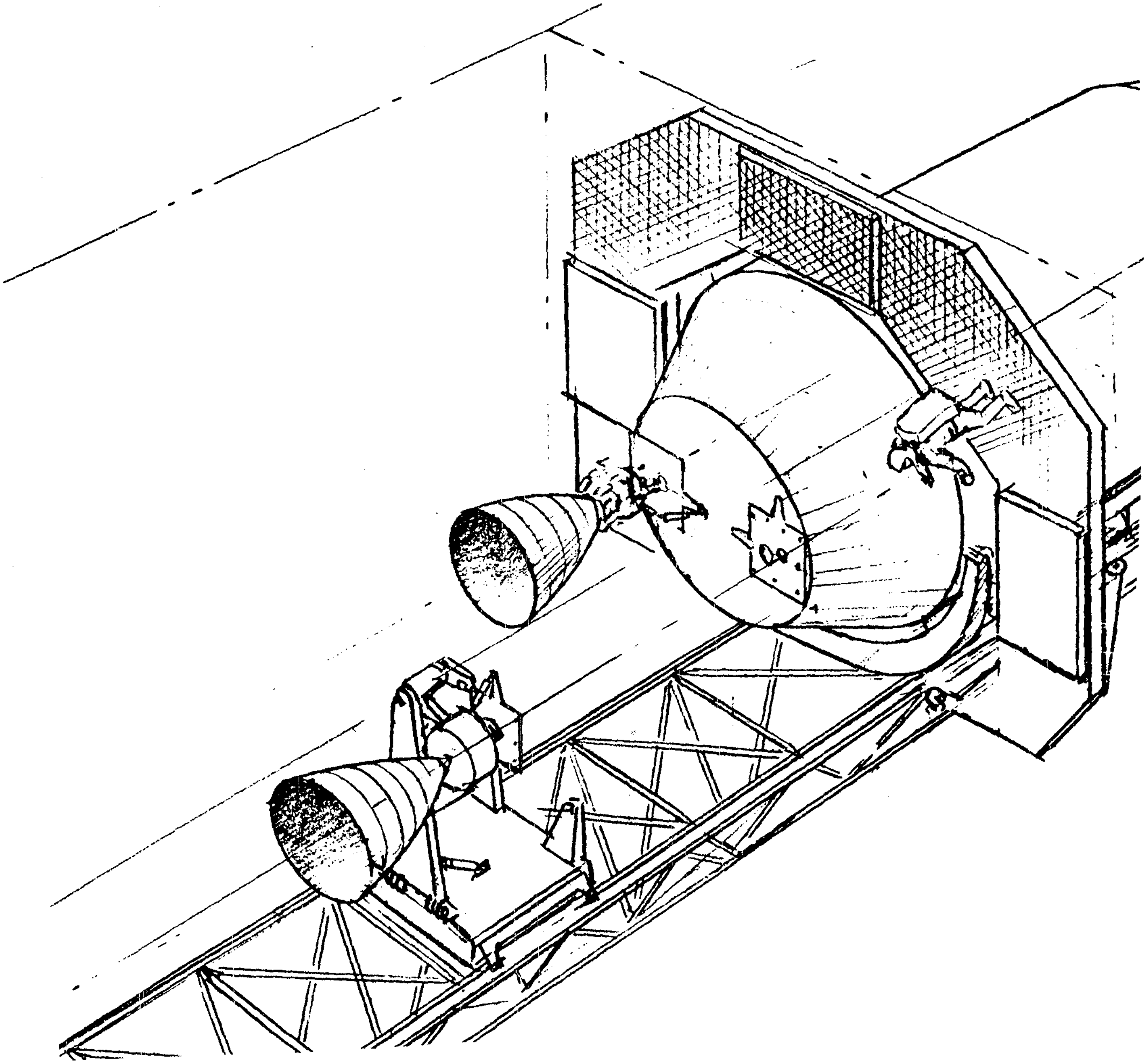


Figure A. Ballute and Engine Transporter (Continued)

WBS 1.2.6 RESUPPLY AND LOGISTICS SUPPORT SYSTEMS

1.0 WBS Dictionary

This element includes the Logistics Module, OTV Propellant Transport Module, and any other module devoted to resupply.

2.0 Description

Refer to subelement descriptions.

3.0 Design Basis

The 90 day resupply cycle for the SOC operations will require dedicated resupply modules as the quantity of items to be delivered exceed the volume available in the Shuttle Orbiter middeck. Also, there are no other resupply modules in development.

4.0 Mass

Refer to subelement descriptions.

WBS 1.2.6.1 LOGISTICS MODULE

1.0 WBS Dictionary

This element is the module used to deliver crew supplies, spare parts, hydrazine, and water.

2.0 Description

Figures A and B illustrate a concept for a Logistics Module (LM). There will be at least 3 LM's in the resupply cycle-one at the SOC, one on the ground being reloaded, and one spare. A

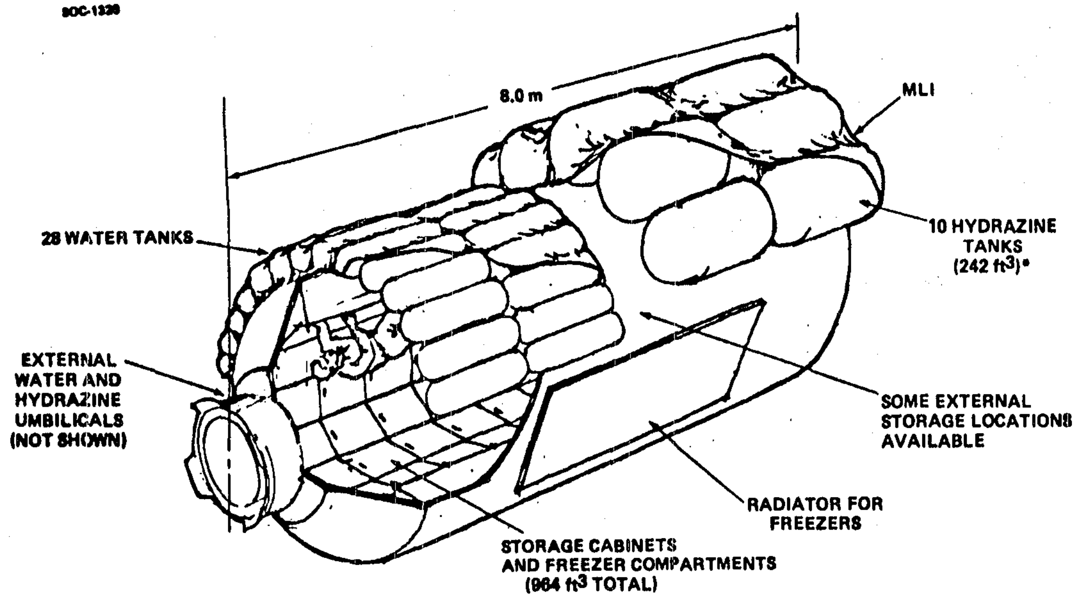
Table A lists the elements to be delivered and their volume. Note—For the Initial SOC the LM is only partially loaded as it is supplying a 4-man crew instead of the 8-man crew for which the LM is sized.

The LM is berthed to either SM-1 or SM-2. Once it is berthed, the hatch is opened so that the SOC crew can transport goods in and out of the LM via IVA. An external umbilical connection is made upon berthing the LM. This connects the water and hydrazine lines to the SOC plumbing.

Compacted waste products are stowed in the LM storage lockers for return to Earth.

3.0 Design Basis

The LM design evolved as the resupply requirements were defined (see Boeing -5, -9, -10, -13, -14, and -15). A pressurized and an unpressurized storage area were obvious requirements. The LM had to be sized to fit into the Orbiter cargo bay. It was desirable to keep the length to less than 8 meters - this was determined by an analysis of the mission model that showed that many of the mission payloads could be delivered with the LM if the length were less than 8m (see Boeing -7, -9, and -14).



* INCLUDES BLOW-DOWN PROVISIONS

Figure A. New Logistics Module Concept

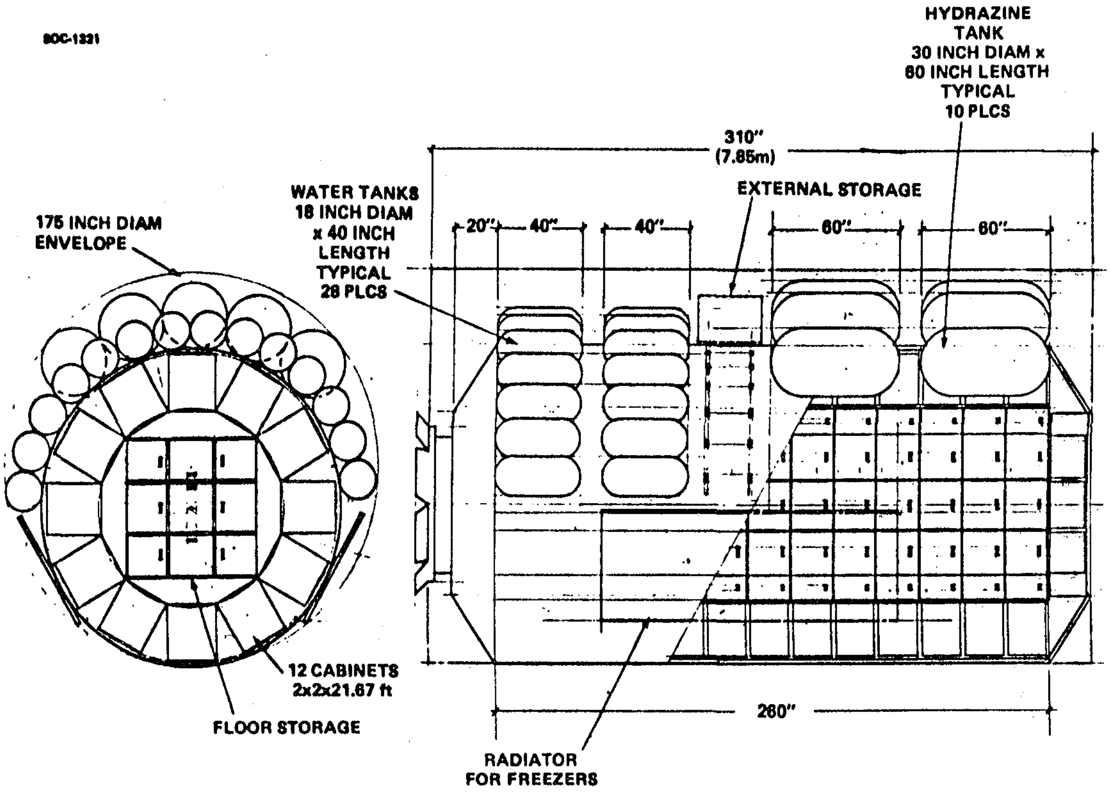


Figure B. New Logistics Module Details

Table A. Resupply Requirements (For Crew of 8 for 90 Days)

REV C 3-16-81

	VOLUME, FT^3
FOOD	
• SHELF STABLE	192
• FROZEN FOOD + FREEZER	40
WATER	148.5
PERSONAL SUPPLIES	104
SHIP STORES	6.8
HOUSEKEEPING/HYGIENE	56
MAINTENANCE EQUIPMENT	5.6
EVA SUPPLIES	105.2
ECLS FILTERS, CHEMICALS, SPARES, ETC	122.6
COMMODE LINERS	52
HYDRAZINE (PROPELLANT + ECLS)	242*
SOC SPARES (EXCLUDING ECLS)	TBD
OTV SPARES	
• BALLUTES	(3.5mOx1.87mL)
• MAIN ENGINES	(1.87mOx3.55mL)
• THRUSTER MODULE	1.3
• FUEL CELL	1
• AVIONICS	< 2 (VARIES)

*TANK VOLUME INCLUDING BLOW-DOWN PROVISIONS

4.0 Mass

Table B lists the mass estimate for a Logistics Module loaded with 90 days of supplies for 8 people. The total mass is 17448 kg. The mass of a Logistics Module loaded with 90 days of supplies for 4 people is 12365 kg.

Table B — Logistics Module Mass Statement

IN-DEX #	IN-DENT #	WBS #	TITLE	MASS KG(LB)	OFFSETS,M(FT) X	Y	Z	RATIONALE FOR ESTIMATE
1	1	1.2.6.1	LOGISTICS MODULE	17980	4.2	0	0	SUM
				(40090	13.9	0	0)	
2	2	1.2.6.1.1	STRUCTURES	4751	3.2	0	0	SUM
				(10474	10.5	0	0)	
3	3	1.2.6.1.1.1	PRESSURE MEMBRAN	3627	3	0	0	- D=4.47M - L-CYL=6.60M - T=1 CM - .707 ELLIPT DOMES 1CUTOUT @ 1 M DIA - A-CYL=81.68M2 - A-DOMES=50.88M2 - A-CUT=-.79M2 - NET=133.35M2 - 2219 ALUM - 1% FOR WELDS,WELD LANDS, AND SKIN THICKNESS TOLERANCES
				(7996	9.8	0	0)	
4	3	1.2.6.1.1.2	MAIN SUPT RINGS	290	3	0	0	- DEPTH=0.25M - X-SEC-AREA=38.7 CM2 - 2219 ALUM
				(639	9.8	0	0)	
5	3	1.2.6.1.1.3	MAIN SUP LONGERO	60	3	0	0	- LENGTH=2.08M - X-SEC-AREA=51.5CM2 - 2219 ALUM
				(132	9.8	0	0)	
6	3	1.2.6.1.1.4	MAIN SUP TRUNNIO	45	3	0	0	- 2 SIDE FTGS - 1 KEEL FTG - FWD YZ LOADS & TORSION - TITANIUM
				(99	9.8	0	0)	

Table B — Logistics Module Mass Statement (Continued)

IN-DEX #	ID-DENT #	WBS #	TITLE	MASS KG(LB)	OFFSETS,M(FT) X	Y	Z	RATIONALE FOR ESTIMATE
7	3	1.2.6.1.1.5	MAIN SUP TRUNNIO	91 (201	3 9.8	0 0	0 0)	- AFT TRUNNIONS - 2 SIDE FTGS - X LOADS & AFT YZ LOADS - TITANIUM
8	3	1.2.6.1.1.6	ENTRY HATCH & ME	57 (126	.5 1.6	0 0	0 0)	BASED ON ORBITER AIRLOCK HATCH & MECH
9	3	1.2.6.1.1.7	ENTRY HATCH FRAM	41 (90	.5 1.6	0 0	0 0)	ESTIMATE
10	3	1.2.6.1.1.8	STORES SUP STRUC	408 (899	5.5 18	0 0	0 0)	CONSISTS OF THE FOLLOWING: - STUB ADAPTER 8.9M2 - CONICAL SECTION 17.6M2 - CYLINDER 10.4M2 - TOTAL 36.9M2 - T-BAR 0.4 CM - ALUMINUM
11	3	1.2.6.1.1.9	WATER TANK SUP	54 (119	6 19.6	0 0	0 0)	ESTIMATE
12	3	1.2.6.1.1.10	N2 TANK SUPPORT	18 (40	7 22.9	0 0	0 0)	ESTIMATE
13	3	1.2.6.1.1.11	EC/LSS DUCTING	15 (33	3 9.8	0 0	0 0)	ESTIMATE
14	3	1.2.6.1.1.12	MISC. SEC STRUCT	45 (99	4 13.1	0 0	0 0)	ESTIMATE
15	2	1.2.6.1.2	MECHANISMS	113 (249	.5 1.6	0 0	0 0)	SUM
16	3	1.2.6.1.2.1	UNIVERSAL DOCKIN	113 (249	.5 1.6	0 0	0 0)	ESTIMATE

Table B — Logistics Module Mass Statement (Continued)

IN-DEX #	IN-DENT #	WBS #	TITLE	MASS KG(LB)	OFFSETS,M(FT) X	Y	Z	RATIONALE FOR ESTIMATE
17	2	1.2.6.1.3	THERMAL CONTROL	85	3.4	0	0	SUM
				(187	11.1	0	0)	
18	3	1.2.6.1.3.1	RADIATOR PANEL	25	3	0	0	RADIATOR FOR REFRIGERATOR AND FREEZER. SCALED FROM SM RADIATOR.
				(55	9.8	0	0)	
19	3	1.2.6.1.3.2	MULTILAYER INS	35	4	0	0	SCALED FROM HAB MODULE
				(77	13.1	0	0)	
20	3	1.2.6.1.3.3	PUMP PACKS	0	3	0	0	BASED ON HAMILTON STANDARD ESTIMATE
				(0	9.8	0	0)	
21	3	1.2.6.1.3.4	MISC. COMPONENTS	25	3	0	0	ESTIMATE
				(55	9.8	0	0)	
22	2	1.2.6.1.4	PRIMARY PROPULSI	0	0	0	0	(NO PRIMARY PROPULSION)
				(0	0	0	0)	
23	2	1.2.6.1.5	AUX PROPULSION	0	0	0	0	(NO AUX PROPULSION)
				(0	0	0	0)	
24	2	1.2.6.1.6	ORDNANCE	0	0	0	0	(NO ORDNANCE)
				(0	0	0	0)	
25	2	1.2.6.1.7	ELECTRICAL POWER	170	3	0	0	SUM
				(375	9.8	0	0)	
26	3	1.2.6.1.7.1	HARNESSES	100	3	0	0	ESTIMATE
				(220	9.8	0	0)	
27	3	1.2.6.1.7.2	INTERIOR LIGHTIN	20	3	0	0	HALF OF HAB MODULE
				(44	9.8	0	0)	
28	3	1.2.6.1.7.3	MISC. EQUIPMENT	25	3	0	0	HALF OF HAB MODULE
				(55	9.8	0	0)	
29	3	1.2.6.1.7.4	EMERGENCY BATTER	25	3	0	0	EMERGENCY LIGHTS AND VOICE COM POWER
				(55	9.8	0	0)	

Table B — Logistics Module Mass Statement (Continued)

IN-DEX #	IN-DENT #	WBS #	TITLE	MASS KG(LB)	OFFSETS,M(FT) X	Y	Z	RATIONALE FOR ESTIMATE
30	2	1.2.6.1.8	GN & C	0	0	0	0	(NO GN & C)
				(0	0	0	0)	
31	2	1.2.6.1.9	TRACKING & COMMU	28	3	0	0	SUM
				(62	9.8	0	0)	
32	3	1.2.6.1.9.1	RF EQUIPMENT	0	0	0	0	(NO RF EQUIPMENT)
				(0	0	0	0)	
33	3	1.2.6.1.9.2	INTRA-SOC VOICE	10	3	0	0	SUM
				(22	9.8	0	0)	
34	4	1.2.6.1.9.2.1	VOICE TERMINALS	10	3	0	0	ESTIMATE
				(22	9.8	0	0)	
35	3	1.2.6.1.9.3	C & T SUPPORT	18	3	0	0	SUM
				(40	9.8	0	0)	
36	4	1.2.6.1.9.3.1	CABLE HARNESSES	18	3	0	0	HALF OF HAB MODULE
				(40	9.8	0	0)	
37	2	1.2.6.1.10	DATA MGMT	0	0	0	0	(NO DATA MGMT)
				(0	0	0	0)	
38	2	1.2.6.1.11	INSTRUMENTATION	50	4	0	0	ALLOWANCE FOR NON-DEDICATED INSTRUMENTATION - HALF OF HAB MODULE
				(110	13.1	0	0)	
39	2	1.2.6.1.12	CREW ACCOMMODATI	0	0	0	0	(NO CREW ACCOMMODATIONS)
				(0	0	0	0)	
40	2	1.2.6.1.13	EC/LSS	82	3	0	0	SUM
				(280	9.8	0	0)	
41	3	1.2.6.1.13.1	REFRIGERATOR	0	3	0	0	PER HAB MODULE
				(99	9.8	0	0)	
42	3	1.2.6.1.13.2	FOOD FREEZER	82	3	0	0	PER HAB MODULE
				(181	9.8	0	0)	
43	2	1.2.6.1.17	MISSION EQUIPMEN	10749	4.8	0	0	SUM
				(24049	15.8	0	0)	

Table B — Logistics Module Mass Statement (Continued)

IN-DEX #	IN-DENT #	WBS #	TITLE	MASS KG(LB)	OFFSETS,M(FT) X	Y	Z	RATIONALE FOR ESTIMATE
44	3	1.2.6.1.17.1	STORAGE & TRANSF	1040 (2645	5.9 19.4	0 0	0 0)	SUM
45	4	1.2.6.1.17.1.1	N2H4 TANK	176 (388	6.9 22.6	0 0	0 0)	- 1.85 M SPHERICAL TANK - P-NOM=2760 KPA (400 PSI) - P-ULT=2900 KPA (420 PSI) - TITANIUM - T=.244 CM - UFS=2 - AREA=10.75M2 - 50% FACTOR FOR WELDS,WELD LANDS,THICKNESS TOLERANCES, GIRTH RING, STANDPIPE, & BLADDER
46	4	1.2.6.1.17.1.2	H2O TANKS (20)	455 (1003	6 19.6	0 0	0 0)	- 0.72M SPHERICAL TANK - P-NOM = 1380 KPA (200 PSI) - P-MAX = 1520 KPA(220 PSI) - 2219 ALUM - UFS=2 - T=.156 CM - AREA=1.63 M2 PER TANK - 50% FACTOR FOR WELDS, WELD LANDS, THICKNESS TOLERANCES, SUPPORT LUGS, STANDPIPE, & BLADDER

Table B — Logistics Module Mass Statement (Continued)

IN-DEX #	IN-DENT #	WBS #	TITLE	MASS KG(LB)	OFFSETS,M(FT) X	Y	Z	RATIONALE FOR ESTIMATE
47	4	1.2.6.1.17.1.3	N2 BOTTLES (4)	0 (353	6 19.6	0 0	0 0)	- 0.686M SPHERICAL BOTTLE - P-MAX=24,150 KPA (3500 PSI) - P-VENT=24,840 KPA (3600 PSI) - KEVLAR OVERWRAPPED BOTTLES - UFS=2 - BOTTLE WT/N2 WT=0.7
48	4	1.2.6.1.17.1.4	PLUMBING SYSTEMS	91 (201	5 16.4	0 0	0 0)	ESTIMATE
49	4	1.2.6.1.17.1.5	TRAPPED N2H4	96 (212	5 16.4	0 0	0 0)	- 2% IN TANKS - 1% IN PLUMBING
50	4	1.2.6.1.17.1.6	TRAPPED WATER	50 (110	5 16.4	0 0	0 0)	- 2% IN TANKS - 1% IN PLUMBING
51	4	1.2.6.1.17.1.7	N2	172 (379	6 19.6	0 0	0 0)	DISTRIBUTION AT END OF TRANSFER: - IN EMPTY N2H4 TANKS: 59.7% - IN EMPTY H20 TANKS: 21.6% - IN DEPLETED N2 BOTTLES: 18.7%

Table B — Logistics Module Mass Statement (Continued)

IN-DEX #	IN-DENT #	WBS #	TITLE	MASS KG(LB)	OFFSETS,M(FT) X	Y	Z	RATIONALE FOR ESTIMATE
52	3	1.2.6.1.17.2	CONSUMABLES	6398	5.5	0	0	SUM
				(14104	18.3	0	0)	
53	4	1.2.6.1.17.2.1	USABLE N2H4 - AC	2200	6.9	0	0	BASED ON RESUPPLY REQUIREMENTS FOR WORST-CASE ATMOSPHERE DRAG
				(4850	22.6	0	0)	
54	4	1.2.6.1.17.2.2	USABLE N2H4 - EC	354	6.9	0	0	BASED ON MAXIMUM ESTIMATE FOR EVA ACTIVITY
				(780	22.6	0	0)	
55	4	1.2.6.1.17.2.3	USABLE H20	1620	6	0	0	BASED ON MAXIMUM ESTIMATE FOR EVA ACTIVITY
				(3571	19.6	0	0)	
56	4	1.2.6.1.17.2.4	ATMOSPHERE	585	6	0	0	BASED ON RESUPPLY OF EMERGENCY REPRESSURIZATION
				(1290	19.6	0	0)	
57	4	1.2.6.1.17.2.5	SPARES	136	3	0	0	ESTIMATE
				(300	9.8	0	0)	
58	4	1.2.6.1.17.2.6	SHELF STABLE FOO	1176	3	0	0	JSC ESTIMATE
				(2593	9.8	0	0)	
59	4	1.2.6.1.17.2.7	FROZEN FOOD	327	3	0	0	JSC ESTIMATE
				(721	9.8	0	0)	
60	3	1.2.6.1.17.3	SUPPLIES	2812	3	0	0	SUM
				(6200	9.8	0	0)	
61	4	1.2.6.1.17.3.1	PERSONAL EQUIPME	602	3	0	0	JSC ESTIMATE
				(1327	9.8	0	0)	
62	4	1.2.6.1.17.3.2	SHIP STORES	47	3	0	0	JSC ESTIMATE
				(104	9.8	0	0)	

Table B — Logistics Module Mass Statement (Continued)

IN- DEX #	IN- DENT #	WBS #	TITLE	MASS KG(LB)	OFFSETS,M(FT) X	Y	Z	RATIONALE FOR ESTIMATE
63	4	1.2.6.1.17.3.3	HOUSEKEEPING/HYG	321	3	0	0	JSC ESTIMATE
				(708	9.8	0	0)	
64	4	1.2.6.1.17.3.4	ECLS RESUPPLY	429	3	0	0	HAMILTON STANDARD
				(946	9.8	0	0)	ESTIMATE
65	4	1.2.6.1.17.3.5	EVA RESUPPLY	1366	3	0	0	BASED ON MAXIMUM EVA
				(3011	9.8	0	0)	ACTIVITY LEVEL - MAINLY LIOH CANNISTERS
66	4	1.2.6.1.17.3.6	MAINTENANCE	47	3	0	0	JSC ESTIMATE
				(104	9.8	0	0)	
67	3	1.2.6.1.17.4	STORAGE CABINETS	499	3	0	0	- 11 CABINETS
				(1100	9.8	0	0)	- 0.76M X 0.76M X 2.08M EACH
68	2	1.2.6.1.18	GROWTH	1952	4	0	0	33% EXCLUSIVE OF
				(4303	13.1	0	0)	PRESSURE MEMBRANE AND CONSUMABLES

WBS 1.2.6.2 OTV PROPELLANT TRANSPORT MODULE

1.0 WBS Dictionary

This element includes the propellant storage tanks and attached propellant delivery hardware to be installed in the Orbiter cargo bay for transporting OTV propellants to the SOC.

2.0 Description

(This system was not studied during this contract so no data is available.)

INTRODUCTION

In the following subsection, the crew jobs and scheduling concepts will be discussed. This will be followed by high-level descriptions of the basic SOC operations shown in Figure II-1 (except for the Ground Support Operations which were not studied during this contract).

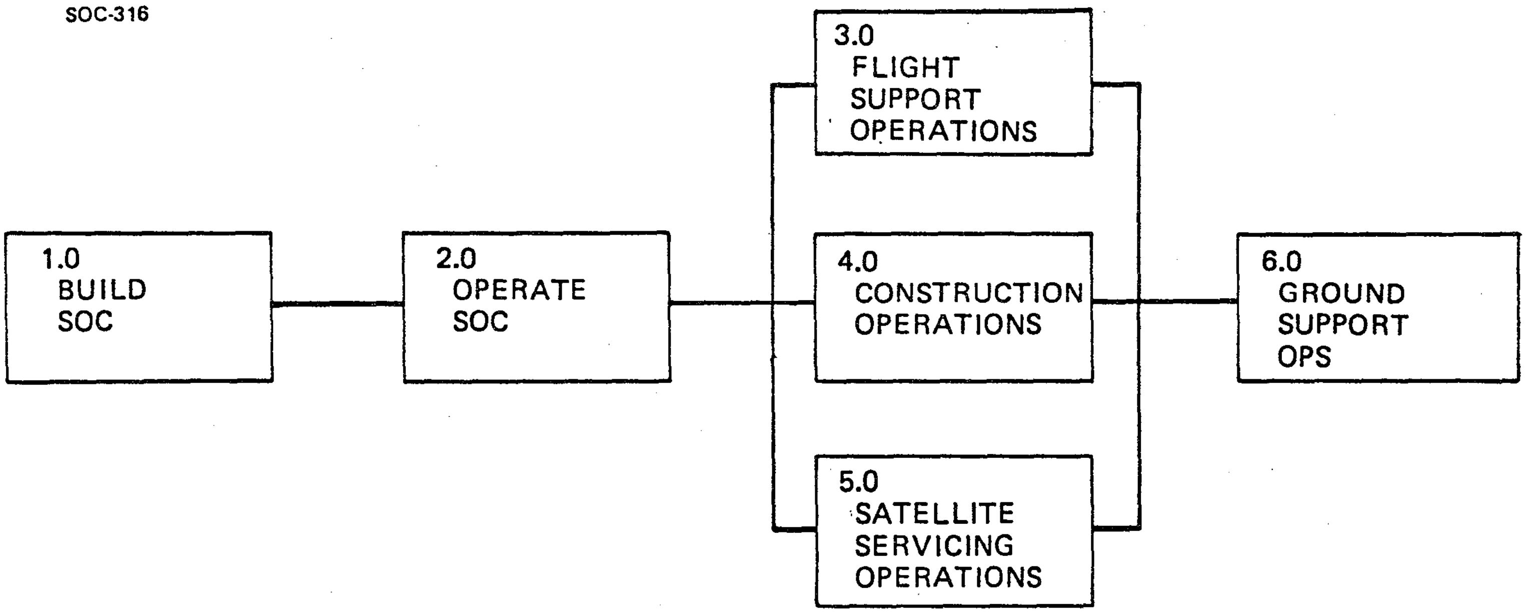


Figure II-1. Top-Level SOC Operations

CREW JOBS AND SCHEDULING CONCEPTS

Table II-1 describes the crew jobs required to perform the SOC missions. There is not a one-to-one relationship between the crew jobs and the number of crewmen. Each crewman will be cross-trained to perform one or more crew jobs. As the SOC transitions from one configuration to another to accommodate growing mission requirements, the SOC crew size will vary. There will be times where a 4, 5, 6, 7, 8, 9, 10, 11, or 12 person SOC crew will be apppropriate for the missions to be performed. When the crew size required exceeds 12 people, it is probably appropriate to put up another SOC. A A

The assumptions related to crew assignments and skills that were used to define the crew jobs are listed in Table II-2.

The guidelines and assumptions used to create a crew daily schedule are listed in Table II-3. The nominal work schedule selected for the SOC crew is as follows:

- 90 days tour of duty on-orbit
- 7 day work week
- 6 days of work
  - 1 day off
- 8 hour workshift
- 2 shifts per day (when required)

Figure II-2 shows a typical daily schedule for an 8-person crew working 2 shifts.

TABLE II-1 - CREW JOBS

A

Job Title	Work Location
IVA OPERATOR	IVA in Habitat Module Command Center

Basic Tasks

- Operate/control the mobile cherrypicker remotely from the Habitat Module Command Center
- Operate the tilttable/turntable
- Operate the construction fixture mechanisms
- Support EVA MCP and EVA workstation operators as required
- Maintain visual and voice contact with all EVA crewman and will participate in rescue operations as required.
- Support satellite repair, refurbishment and servicing work performed on-board SOC as required.
- Support satellite repair, refurbishment and servicing work performed on-board SOC as required
- Operate umbilical system
- Operate storage facility retension latches
- Operate airlock subsystems
- Operate transporters
- Operate track switches
- Operate hanger doors, access platforms, lighting, etc.
- Support OTV and payload mating and prelaunch activity as required
- Serve as back up mobile cherrypicker remote control operator

Requirements

- Aptitude for precise remote control operations

TABLE II-1 (continued)

Job Title	Work Location
EVA Operator (Mobile Cherrypicker Operator)	EVA, Manned Remote Work-Station (MRWS) on MCP

Basic Tasks

- Operate/control the Mobile Cherrypicker (MCP) locally from the manned remote Workstation located on the end of the cherrypicker boom assembly.
- Maintain voice and visual contact with other EVA or IVA crewman as required.
- Support work performed by EVA workstation operator
- Provide hands-on assistance to accomplish refurbishment tasks, i.e., replace equipment externally located on the spacecraft or module being services.
- Participate in OTV payload prelaunch activities.
- Remotely control the mobile cherrypicker during OTV capture and berthing operations.

Requirements

- Aptitude for precise control operation
- EVA qualified
- Mechanical aptitude
- Skilled in use of handtools

TABLE II-1 (continued)

Job Title	Work Location
EVA Operator (EVA Workstation)	EVA - Selected Workstations Locations

Basic Tasks

- Perform hands-on mechanical assembly, disassembly, repair and maintenance tasks as required
- Maintain voice and visual contact with other EVA and IVA crewmen as required
- Serve as an observer of other EVA activities and participate in rescue operations if required
- Perform external inspections of spacecraft which dock with SOC and co-orbit with SOC
- This crewman will perform servicing tasks on spacecraft located in a hanger.
- Perform work during OTV preparation, OTV and payload mating and prelaunch activities as required

Requirements

- Mechanical aptitude
- EVA qualified
- Skilled in use of handtools

TABLE II-1 (continued)

A

Job Title	Work Location
Test/Checkout (T&CO) Engineer	SOC Command Center

Basic Tasks

- Initiate perform and coordinate all spacecraft test and checkout procedures required for specific spacecraft during construction missions

- Establish and maintain voice and interactive data links between earth ground station and spacecraft during test and checkout

- Provide support in in-situ and on-board repair, refurbishment and servicing operations, i.e.:

  1. Repair - obtain diagnostic data from nonfunctioning or disabled spacecraft and isolate fault conditions in coordination with ground control

  2. Refurbishment - perform test and checkout of newly installed sensors, antennas, solar array, etc.

  3. Servicing - coordinate test and checkout performed during inspace servicing of equipment installed, removed or transferred on a scheduled basis.

- Initiate, perform and coordinate all test/checkout procedures required to support Flight Support Operations.

- Perform T&CO required during OTV preparation and prelaunch checkouts of OTV and payload

- Supervise and perform safing, checkout and maintenance operations on returning OTV's. Includes refueling operations

Requirements

- Basic electronic engineering skills

- High level diagnostic and trouble-shooting skills

- Aptitude for precise remote control operations

- EVA qualified (for back-up operations only)

- Mechanical aptitude

TABLE II-1 (continued)

Job Title	Work Location
Propellent/Fuel Specialist	IVA and EVA

Basic Tasks

- Perform IVA and EVA propellant/fuel handling, transfer, and associated activities
- Service/refuel spacecraft engines and on-board subsystems as required
- Responsible for maintaining/performing "by the book" refueling safety precautions
- Coordinate/directs emergency operations involving fuel spillage, mop-up operations, fuel storage, etc.
- Maintain all records and data concerning fuel requirements of spacecraft and subsystems

Requirements

- Basic electronic and mechanical aptitude
- Extensive propellant training

TABLE II-1 (continued)

Job Title	**Work Location**
Flight Controller, Systems Engineer	IVA - Habitat Module Command Center

Basic Tasks

- Primary function is to provide tracking and mission control for incoming OTV's
- Control rendezvous and docking of unmanned OTV and assist operations by RF if OTV is manned
- Following OTV launch, activate OTV attitude control propulsion and later OTV main propulsion system
- Control OTV flight to orbit via SOC mission control or hand off to ground control authority
- Maintain data management control for all SOC flight support missions
- Maintain all communications links and direction/coordination with ground stations

Requirements

- Aptitude for precise control operation and OTV launch, control and return and dock operations scheduling

TABLE II-1 (continued)

Job Title	Work Location
Electro/Mechnical Engineer	IVA - SOC Locations

Basic Tasks

- Perform all IVA repair and refurbishment tasks
- Primary function is to repair, perform maintenance and replace LRU's, install mechanical and electrical equipment units for in-situ and on-board satellite servicing and construction and operations.
- Secondary function is to provide management control of servicing equipment, spares, MOD equipment and maintain maintenance schedules

Requirements

- Basic electronic and mechnical skills are required
- Must be EVA trained for emergency and contingency conditions

TABLE II-1 (continued)

A

Job Title	Work Location
PILOT	MOTV Crew Module

Basic Tasks

- Perform all on-board piloting functions for the MOTV

Requirements

- Basic pilot astronaut training

TABLE II-1 (continued)

Job Title	**Work Location**
MATERIALS RESEARCHER	Materials Research Module

Basic Tasks

- The skills called out in the Materials Research Blue Book included biochemist, physicist, photographic technician, optical technician, optical scientist, metallurgist, physical chemist and materials scientist. As the specific types of materials processing experiments to be conducted on the SOC are not defined, it was elected to create this one skill title to cover all of the above.

Requirements

TBD

TABLE II-1 (continued)

Job Title	Work Location
Customer Materials Processing Development Specialist	Materials Process Development Module

Basic Tasks

- This crewman would be hired and trained by commercial customers who have designed and paid for a custom materials process development module to be stationed on the SOC. This crewman would work full-time on the specific process development work.

Requirements

TBD

TABLE II-1 (continued)

A

Job Title	**Work Location**
Life Sciences Researcher	o Health Maintenance Facility o Space Available Experiment Locations o Life Sciences Research Module o CELSS Research Module

Basic Tasks

- The skills called out in the Life Sciences Blue Books include biological technician, biochemist, physiologist, medical doctor, behavioral scientist, biological technician, microbiological technician, chemical technician, and electro-mechanical technician. As the specific life sciences research to be conducted at the SOC has been defined at a high-level, it was elected to create this one skill type to cover all of these skills.

Requirement

TBD

TABLE II-2

ASSUMPTIONS RELATED TO CREW ASSIGNMENTS AND SKILLS

- The SOC crew rotation schedule and the SOC mission schedule will be known far enough in advance so that the primary and backup SOC crews can be specifically trained for each mission to be performed during a crew on-orbit tour of duty.
- Nominal on-orbit stay time will be 90 days.
- Nominal on-ground time between tours of duty will be at least 6 months.
- In concept, the total SOC crew could be changed out at one time. However, it is more likely that there will be fractional crew changeouts.
- IVA crew members are cross-trained to perform all required IVA crew functions and EVA rescue operations for the mission.
- EVA crew members are cross-trained to perform all EVA functions required for the various SOC missions.
- All crew members are trained to perform routine SOC housekeeping and maintenance functions.

A

TABLE II-3
GUIDELINES AND ASSUMPTIONS FOR CREW WORK/REST CYCLES

- The crew will follow a 16-hr awake/8-hr sleep cycle.
- The crew workday is nominally 8 hours.
- There will be 3/4-hour per day schedule for pre-sleep and post-sleep activities (1-1/2 hours total).
- The crew meal periods will be scheduled for one hour at least twice per day.
- Crewmen will sleep and work in shifts as required.
- Private sleeping quarters for each crewmember is provided. These sleeping areas are located away from the operational areas so that off-duty crewmen will not be disturbed.
- A 50% margin is added to all computed tasks times to account for set-up, conversation, interruptions, and other hard-to-define time delays.
- EVA crew will have an average of at least 10 minutes rest per hour, preferably after 50 minutes work, and 20 minutes for a lunch (candy bar).
- Cabin crew works when EVA crew is outside and coordinates breaks with EVA schedule.
- EVA by a single crew member shall be permitted. However, an IVA crewmember shall be available at all times to engage in rescue operations.
- No prebreathing will be required for EVA.
- EVA suit donning and doffing, airlock transition, moving to/from worksite, and setting up/shutting down, are allotted 45 minutes before and after each shift.
- EVA periods of 9 hours are permitted by using 4.5-psi pressure suits.
- No assembly activities or EVA activities are performed during flight vehicle approach and departure operations.

SOC-315

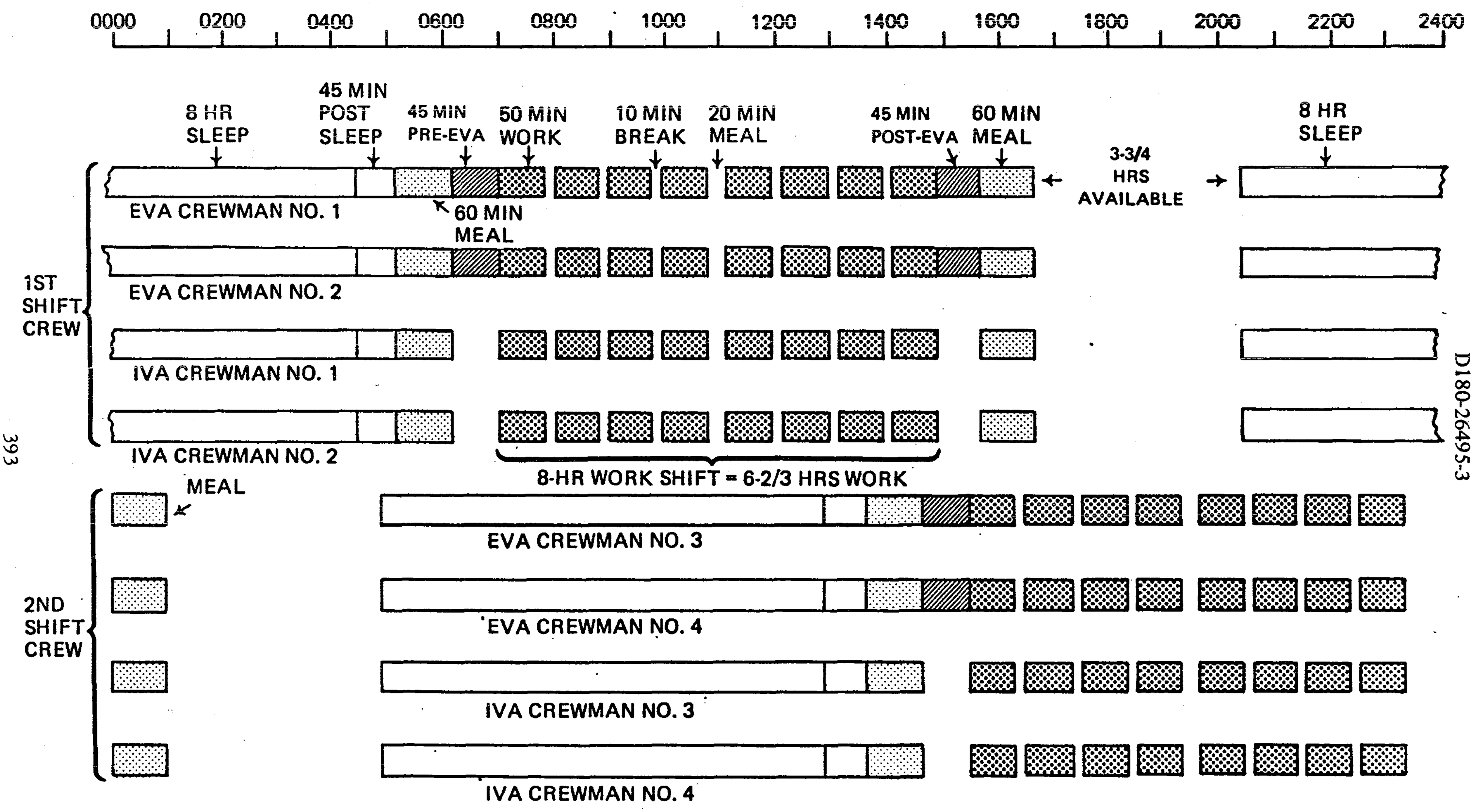


Figure II-2. Crew Schedule Concept (Crew of 8)

BLOCK NO. 1 - BUILDUP SOC

INITIAL SOC BUILDUP OPERATIONS

The Initial SOC Configuration, shown in Figure 2 of the Introduction, will be built up in the 3 module delivery flights described below.

Delivery Flight No. 1 - Service Module No. 1

Figure II-3 illustrates the flight operations sequence discussed below:

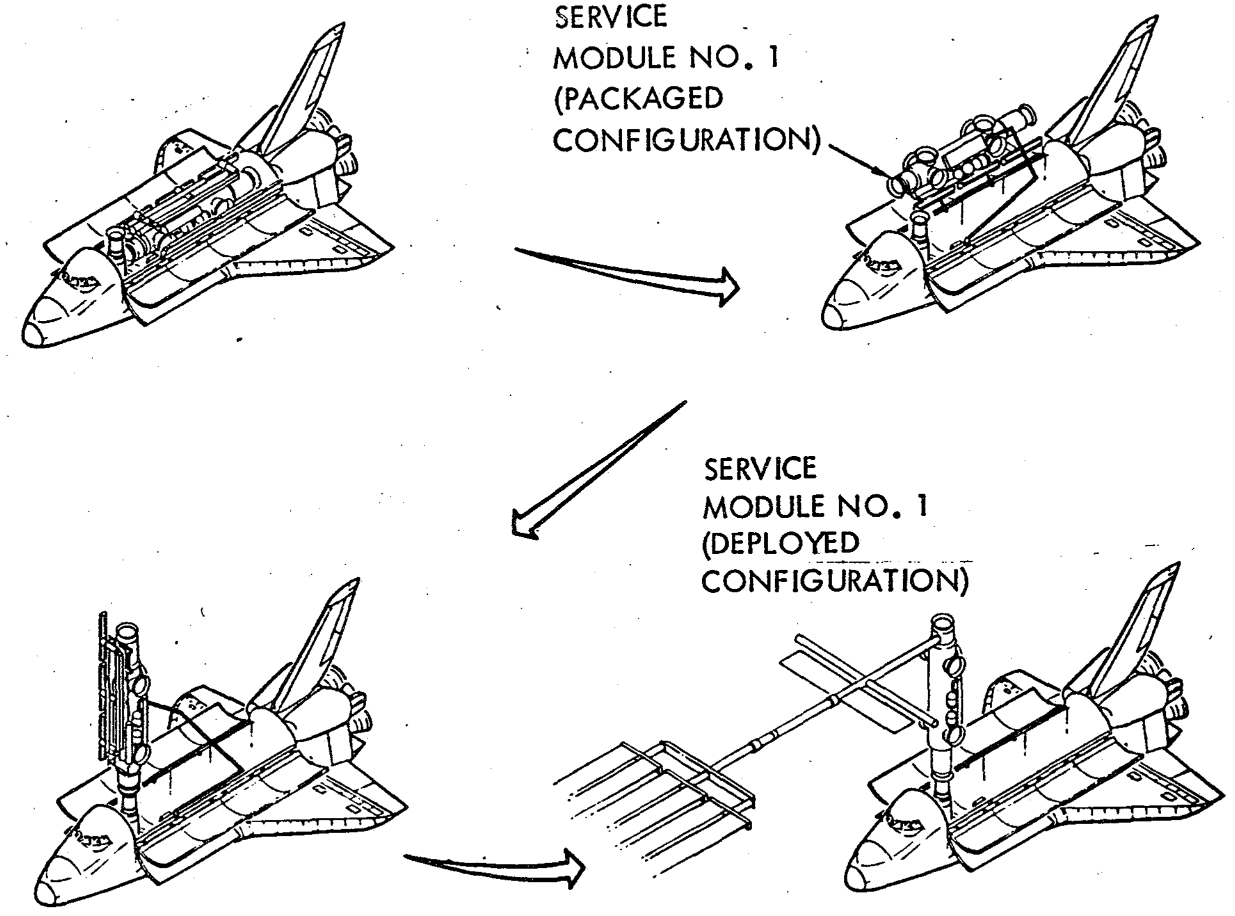
1. The Orbiter arrives at the SOC orbital location and the cargo bay doors are opened.

2. The Service Module (SM) is rolled out of the cargo bay using the Payload Installation and Deployment Aid (PIDA). The RMS end effector is maneuvered into attachment with a grapple fixture on the SM.

3. The RMS is locked and the PIDA is retracted leaving the SM supported by the RMS. The RMS is then used to maneuver the SM into a berthed position on the docking tunnel. The RMS is then detached and moved into a standby position.

4. The solar array boom and appendages are then unfolded under remote control from the Orbiter crewstation. (The control signals are hard-wired between the control panel and the SM via umbilicals in the docking tunnel.) The radiator heat pipe panels are taken from their delivery rack in the cargo bay and are individually installed on the mast using the RMS.

5. The SM systems are remotely activated and checked out. Orbiter crewmen could enter the SM IVA via the docking tunnel as required. This test and checkout could be conducted directly from the Orbiter and/or by remote control from a SOC ground station. After the SM is declared operational, the subsystems would be configured in a quiescent mode. The RMS is then used to deberth the SM and move it away from the Orbiter. The Orbiter then



(Illustrations courtesy of Rockwell)

Figure II-3. SOC Assembly — Delivery Flight 1 returns to Earth. The SM is remotely controlled/monitored from the SOC ground station.

Delivery Flight No. 2 - Habitat Module No. 1

Figure II-4 illustrates the flight operations sequence discussed below.

1. Prior to the Orbiter arrival, the SM-1 is partially reactivated. A homing beacon is activated to assist in the rendezvous.

2. The Orbiter arrives in the vicinity of the SM-1 and the cargo bay doors are opened.

3. The Orbiter approaches the SM-1 so that the SM is within the optimal reach envelope of the RMS. The RMS grapples the SM and maneuvers the SM into a soft berthing with the docking tunnel. The SM could be entered IVA if necessary at this point.

4. The Handling and Positioning Aid (HPA) is deployed.

5. The RMS deberths the SM and berths it to the HPA.

6. The Habitat Module (HM) is rolled out of the cargo bay using the PIDA.

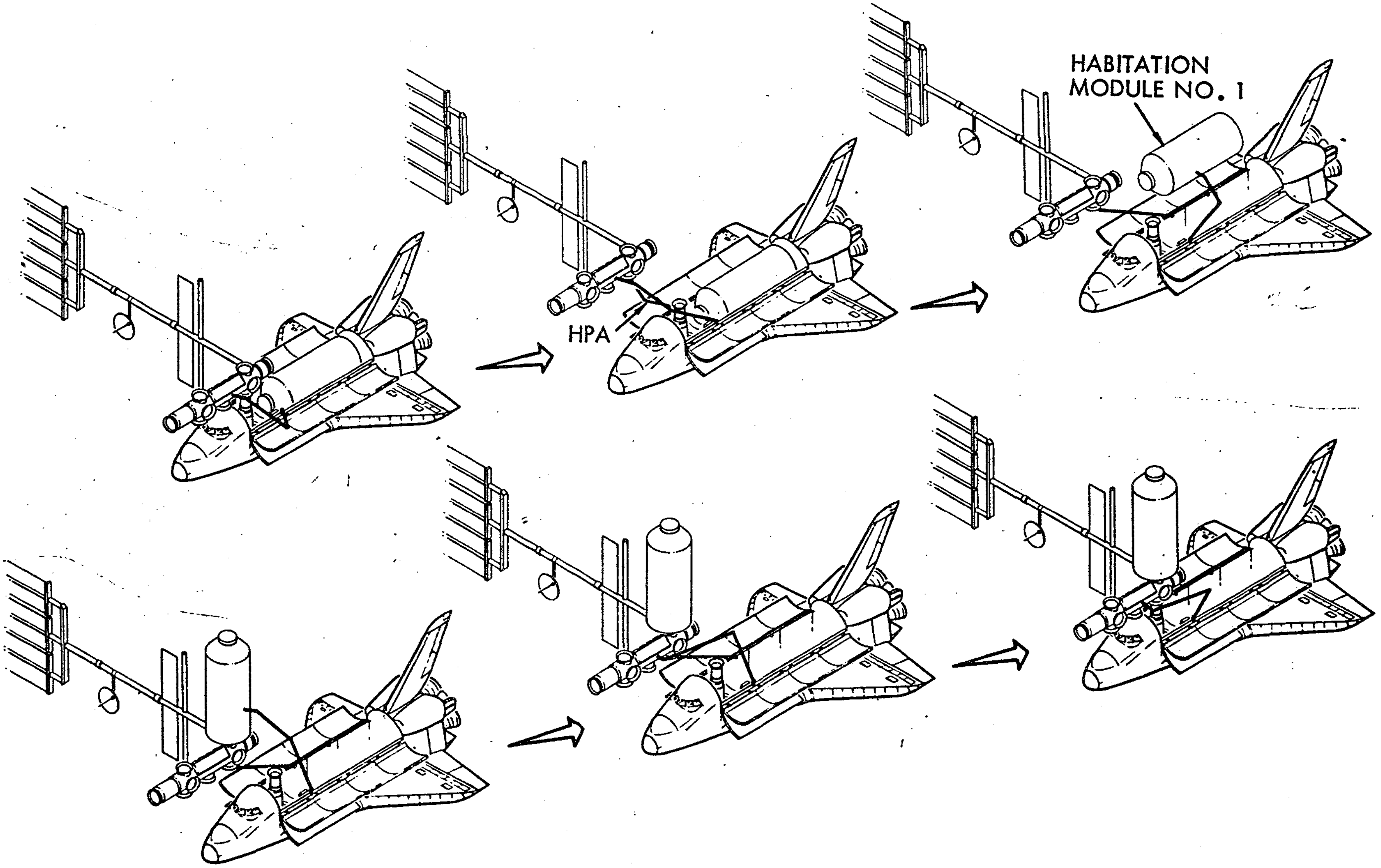
7. The RMS grapples that HM and the PIDA is retracted.

8. The RMS moves the HM into a soft berthing with the appropriate SM berthing port.

9. The RMS is then detached and repositioned to grapple the SM.

10. The RMS support the SM/HM as the HPA is detached.

11. The RMS moves the SM/HM into a soft berthing with the docking tunnel.



(Illustrations courtesy of Rockwell)

Figure II-4. SOC Assembly – Delivery Flight 2

12. The HM subsystems can now be activated either by control from the Orbiter crew station or via remote control from the SOC ground station.

13. The HM could be entered via IVA by the Orbiter crew to conduct tests and checkouts.

14. When the SM/HM checkout is completed, the subsystems would then be reconfigured into a quiescent mode.

15. The RMS is then used to deberth and deploy the SM/HM.

16. The Orbiter can then depart. The partially assembled SOC is then remotely controlled/monitored from the SOC ground station.

Delivery Flight No. 3 - Logistics Module and Airlock Modules

Figure II-5 illustrates the flight operations sequence discussed below.

1. Prior to the arrival of the Orbiter, the SM/HM is partially reactivated. A homing beacon is activated to assist in the rendezvous.

2. The Orbiter arrives in the vicinity of the SM/HM and the cargo bay doors are opened.

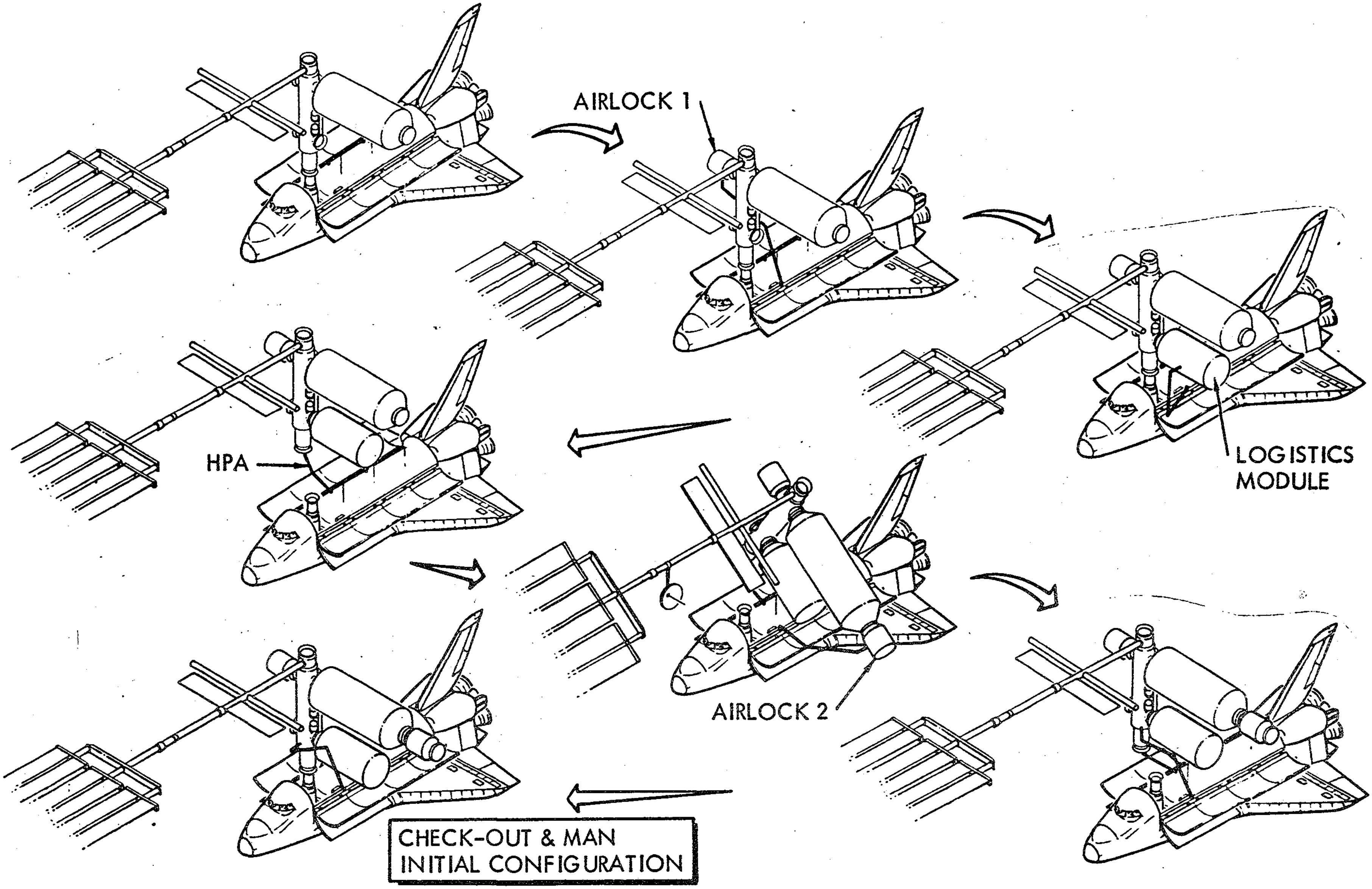
3. The Orbiter is maneuvered into a hard docking with the SM.

4. The SM/HM could be fully activated at this point if necessary. Crewmen could enter the SM/HM via IVA if required.

5. The RMS grapples one of the Airlock Modules (AM) and berths it to a SM berthing port.

6. The Logistics Module (LM) is then rolled out of the cargo bay using the PIDA.

7. The RMS grapples the LM and the PIDA is retracted.



(Illustrations courtesy of Rockwell)

Figure II-5. SOC Assembly – Delivery Flight 3

8. The LM is then berthed to the SM.

9. The HPA is then deployed.

10. The RMS grapples the SM, deberths it from the docking tunnel, and moves the SOC assembly over to the HPA.

11. The HPA is used to tilt the SOC as shown in the illustration.

12. The second Airlock Module is then picked out of the cargo bay and is berthed to the HM using the RMS.

13. The SOC is then tilted back to the orientation shown.

14. The RMS then detaches the SOC from the HPA and berths it to the docking tunnel.

15. The SOC can now be manned by the first crew of 4.

16. The SOC is checked out to confirm its operational readiness.

17. The Orbiter can then depart.

OPERATIONAL SOC BUILDUP OPERATIONS

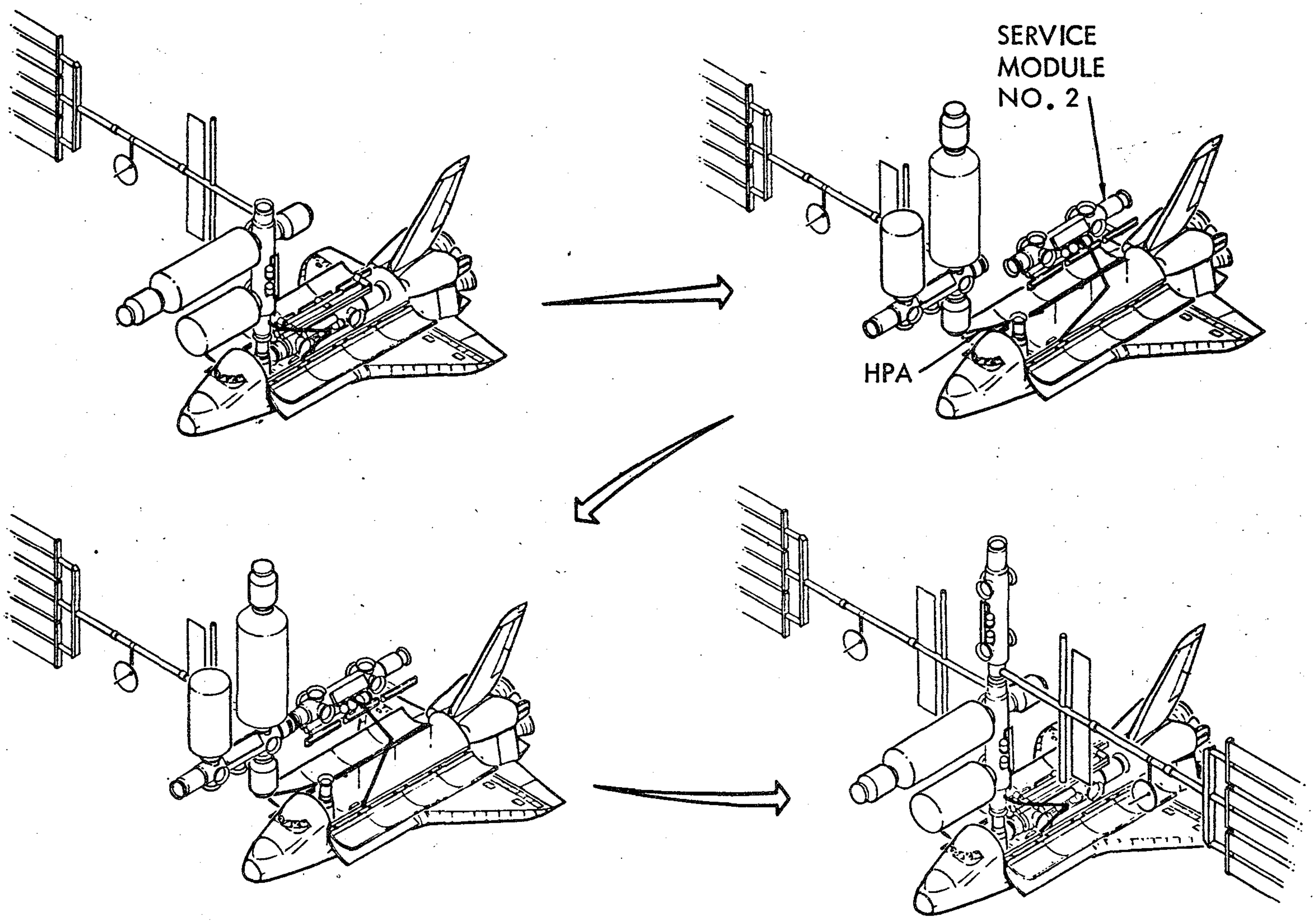
The Operational SOC Configuration, shown in Figure 3 of the Introduction, will be built up from the Initial SOC Configuration in 3 more delivery flights described below.

Delivery Flight No. 4 - Service Module No. 2

Figure II-6 illustrates the flight operations sequence discussed below.

1. The Orbiter arrives at the SOC and docks to SM1.

2. The HPA is deployed.



(Illustrations courtesy of Rockwell)

Figure II-6. SOC Assembly – Delivery Flight 4

3. The RMS moves the SOC over to the HPA and berths the SM1 Airlock Module to the HPA.

4. The PIDA rolls the SM2 out of the cargo bay.

5. The RMS grapples SM2 and the PIDA is retracted.

6. The RMS berths SM2 to SM1.

7. The SM2 mast and appendages are then deployed.

8. The SM2 radiator panels are then installed by the RMS.

9. The SM2 subsystems are then activated and checked out.

10. The Orbiter can depart at any time during the test period.

Delivery Flight No. 5 - Habitat Module No. 2

Figure II-7 illustrates the flight operations sequence discussed below.

1. The Orbiter docks to SM2.

2. The HPA is deployed.

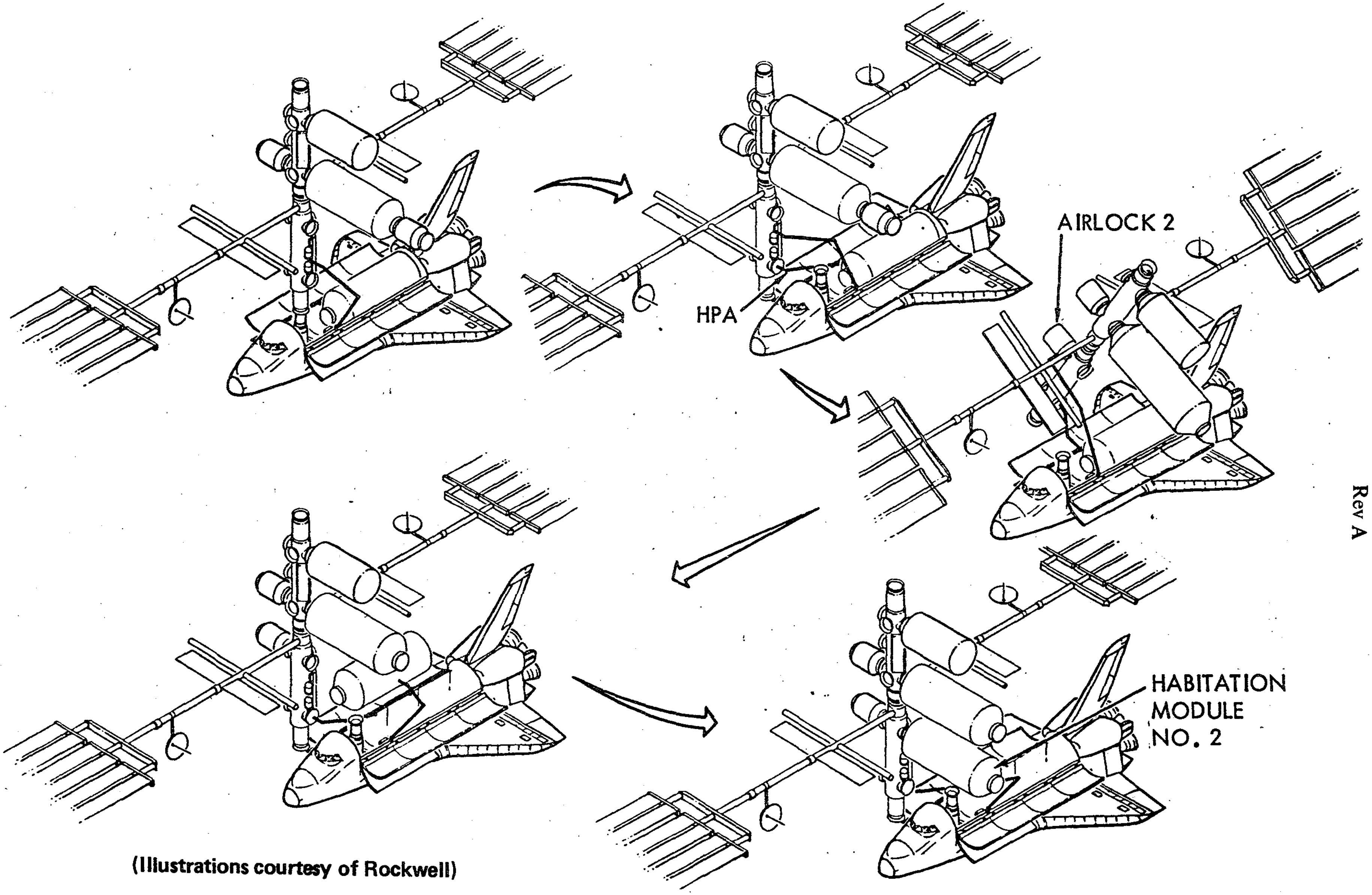
3. The RMS moves the SOC over to the HPA.

4. The HPA tilts the SOC as shown in the illustration.

5. The HM Airlock Module is detached from HM1 and moved over to a SM1 berthing port by the RMS.

6. The SOC is tilted back to its original position by the HPA.

7. The HM2 is rolled out of the cargo bay by the PIDA.



(Illustrations courtesy of Rockwell)

Figure II-7. SOC Assembly – Delivery Flight 5

8. The RMS grapples the HM2 and moves it into its berthed location on SM2.

9. The Orbiter can now depart.

10. The HM2 is activated and checked out by the SOC crew with assistance from the SOC ground station.

Delivery Flight No. 6 - Docking Tunnel and Miscellaneous Equipment

Figure II-8 illustrates the flight operations sequence discussed below.

1. The Orbiter docks to SM2.

2. The HPA is deployed.

3. The RMS moves the SOC over to the HPA.

4. The Docking Tunnel (DT) is removed from the cargo bay by the RMS.

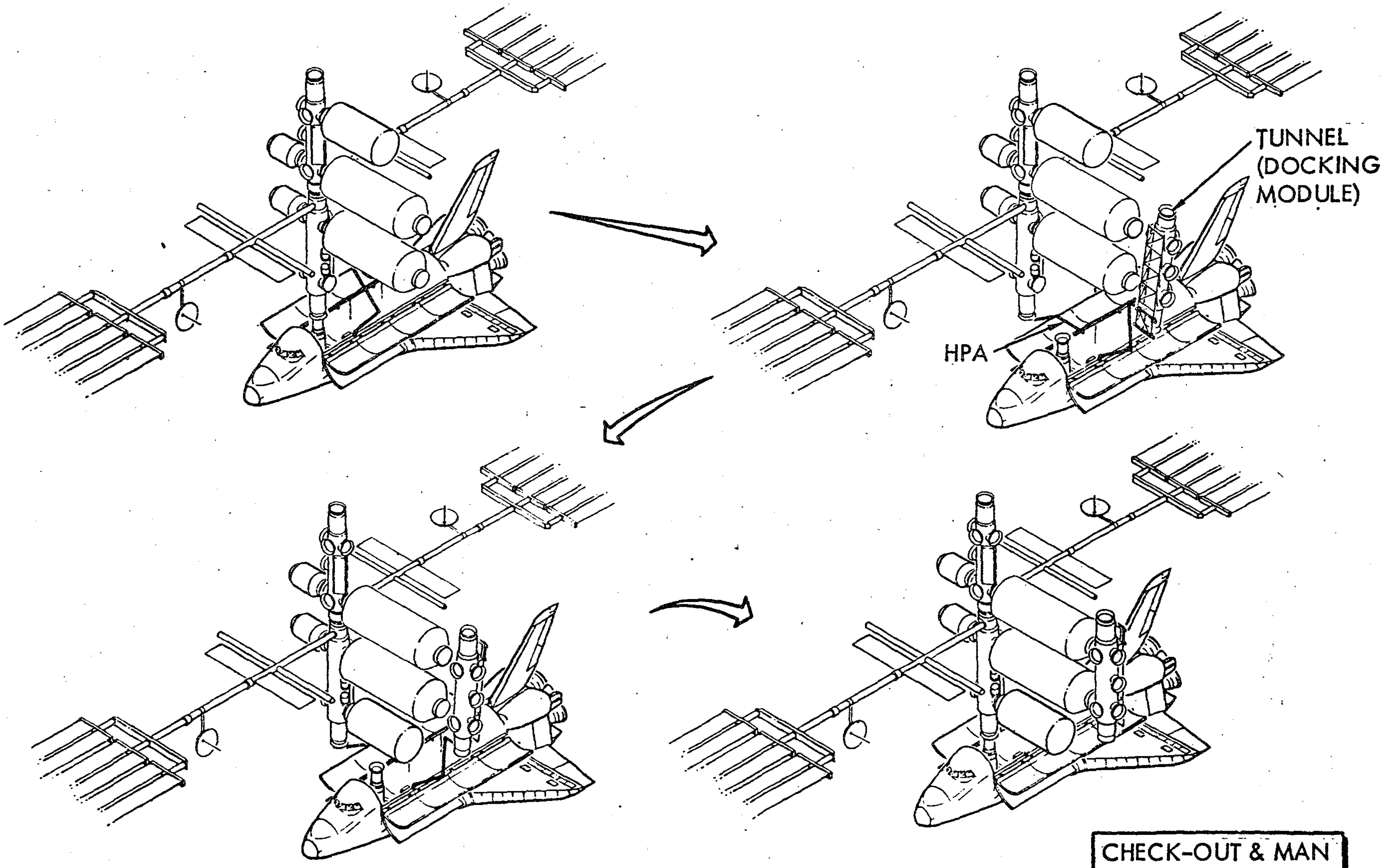
5. The DT is berthed to HM1 and HM2.

6. The Module Cherrypicker would be delivered to the SOC in 2 pieces (a transporter and the arm assembly) stowed on the DT. These 2 elements would be assembled on the DT track using the RMS.

7. The Orbiter can now depart.

8. The DT and Mobile Cherrypicker would then be activated and checked out by the SOC crew.

9. The Mobile Cherrypicker would then be used to deploy finger pieces that extend between the DT and the two SM's. These pieces would be deployable structures stowed on the DT.



(Illustrations courtesy of Rockwell)

Figure II-8. SOC Assembly – Delivery Flight 6

Hangars, umbilicals, storage platforms and other miscellaneous SOC elements would be delivered on the next SOC crew rotation/resupply flight. These elements would be installed and assembled using the SOC cherrypicker and crew.

GROWTH SOC BUILDUP OPERATIONS - When the next level of SOC capability is required, i.e., space basing of OTV's and large platform construction, the SOC will be enlarged to the Growth SOC Configuration shown in Figure 4 of Section I. It will take 3 more delivery flights. The sequence of deliveries is not critical. The sequence described below is arbitrary.

Delivery Flights No. 8 and 9 - Propellant Tanks

The Orbiter will dock to the SM on which the propellant storage tanks (PT) will be installed. The tank is removed from the Orbiter by the SOC's mobile cherrypicker. The PT is installed onto a SM berthing port. Propellant delivery lines and connectors will be attached to the SM and plumbed into the hangars as required.

Delivery Flight No. 10 - Storage Facility, Piers, and Miscellaneous Equipment

The Orbiter docks to the Docking Tunnel. The storage facility components are removed from the cargo bay and installed as shown in Figure II-5A.

The piers are then installed.

The modular construction fixture elements are placed into the storage facility. The carriage for the turntable/tilttable is installed on the construction pier.

The Growth SOC Configuration is now fully established.

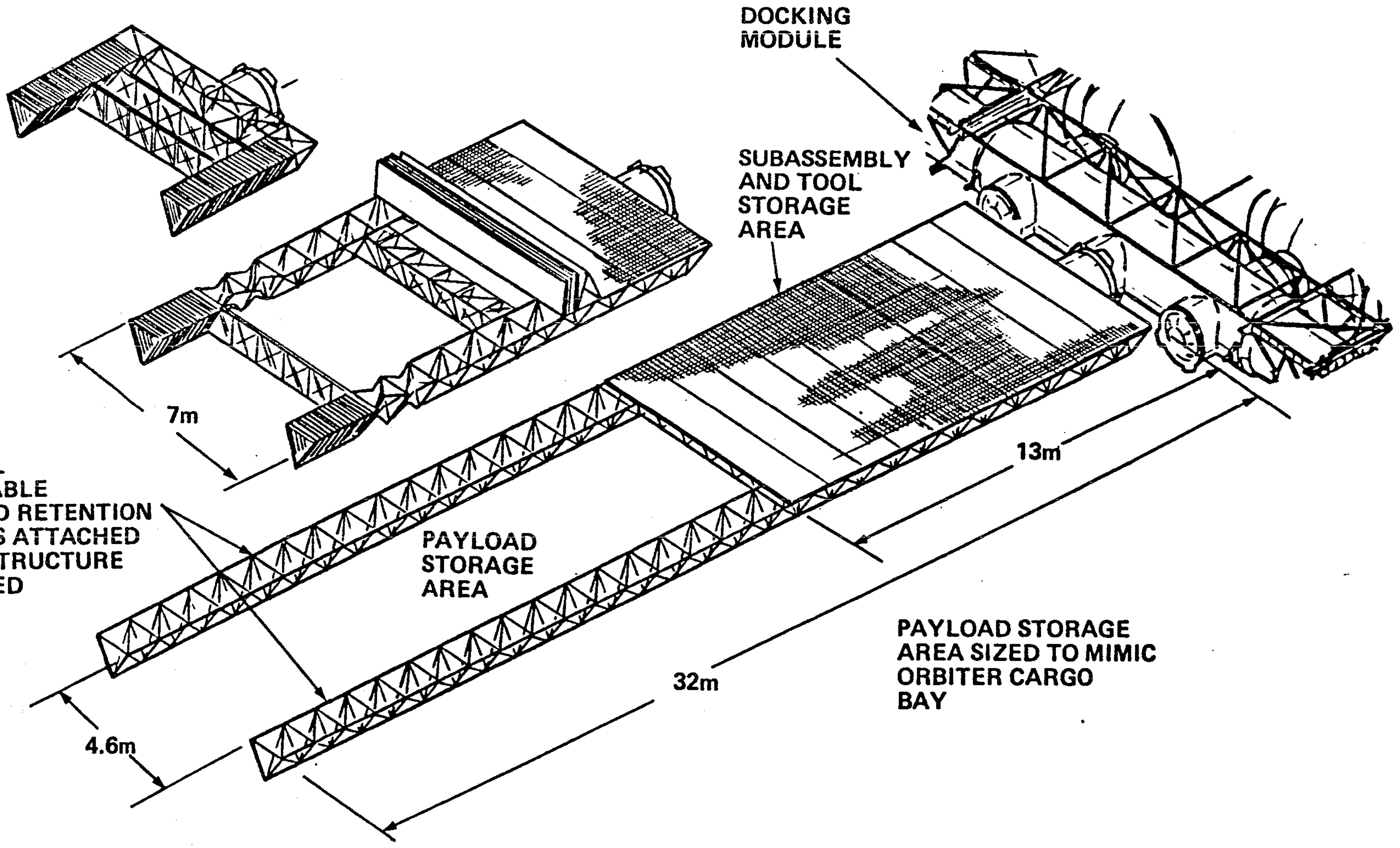


Figure II-5A Storage Facility Installation Concept

BLOCK NO. 2.0 - BASE OPERATIONS SCENARIOS

The descriptions that follow represent initial concepts on how the various base operations will be conducted. Figure II-6 shows the third-level functions included here. These scenarios have been synthesized from the subsystem and SOC element reference design concepts, the SOC requirements document, informal discussions with NASA-JSC SOC study team members, and collaboration with Boeing/Ham Standard SOC study team members.

Block 2.1 BASE SUBSYSTEMS OPERATIONS

This section describes the operations of the various SOC "utilities", i.e., the power, communications, ECLS, etc.

The subsystems will be controlled from the Command Centers in each of the Habitat Modules. There are 2 workstations in each Command Center. Each workstation will be able to control any subsystem.

The operators will have access to the various subsystems control functions, via multifunction control and display panels. There will also be some dedicated controls and displays for safety-critical backup functions. The subsystems are, in general, operating in automatic modes where operator intervention is required only to change modes or to respond to anomalies.

The crew also uses the multifunction controls and displays to operate the external SOC equipment (track switches, carriages, turntables, hangars, etc.). These panels can also be programmed to interface with attached mission hardware (OTV's, satellites, experiment modules) so that test and checkout can be controlled.

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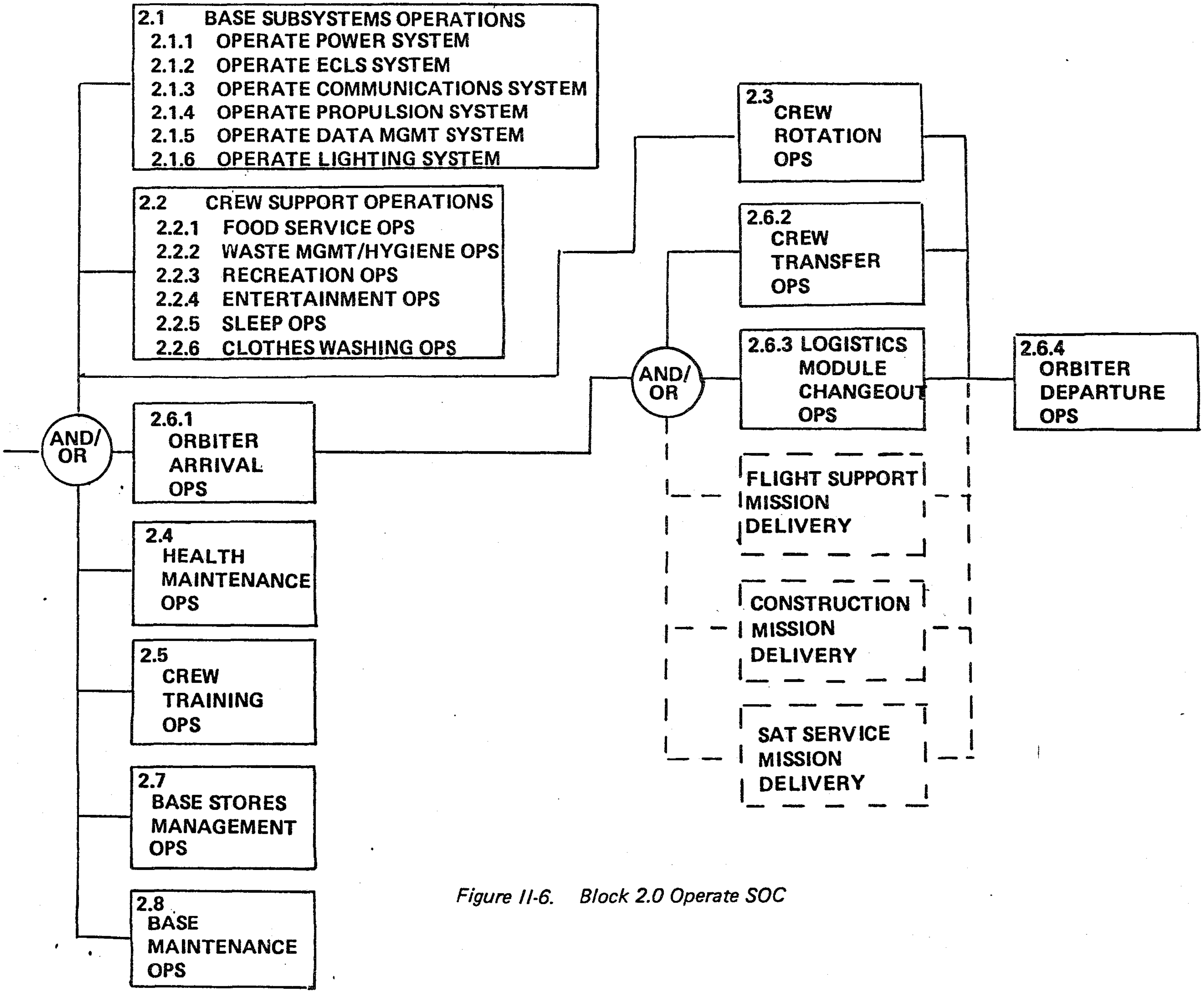

Figure II-6. Block 2.0 Operate SOC

Block 2.2 CREW SUPPORT OPERATIONS

This section describes the operation of the various crew support systems, i.e., the food service, waste management, hygiene, recreation, etc. The food service operations will be discussed in detail and the others will only be briefly described.

Block 2.2.1 Food Service Operations - Refer to Figure II-7 for the 4th-level functional flow.

The primary galley will be in Habitat Module No. 1. A backup, but fully equipped galley will be Habitat Module No. 2.

The person assigned to food service (IVA Crewman No. 2) will go to the adjacent medical area and will use its multi-function control/display console to call up the daily menu options. He will select an optional menu for each meal. The software will note his selection and will then display and print a hard copy of where the food is located (the software automatically updates the food inventory and storage location database when the operator selects a menu). This hard copy will also provide food preparation instructions (cooking time, temperature, etc.).

If the food locater list tells him that some items must be transferred from the Logistics Module storage, then the crewman will find these items and will transport them (hand carry) to the galley where they will be stowed either in the refrigerator, freezer, or shelf storage locker.

The food system will consist of frozen precooked portions, supplemented with flexible retort packages and rehydratable foods. These items will be packaged in bulk, i.e., multiple units per pack. It is planned that some in-space baking of bread, cakes, and pastries will be feasible. Milk-based beverages and ice cream should be available. The capability of growing fresh salad greens will be considered. The objective is to provide a highly palatable, flexible, and satisfying food system so that there will be a high level of crew module.

At the appropriate time, food packages that require cooking will be taken from the storage, reconstituted with water (if necessary), and then will be placed into the

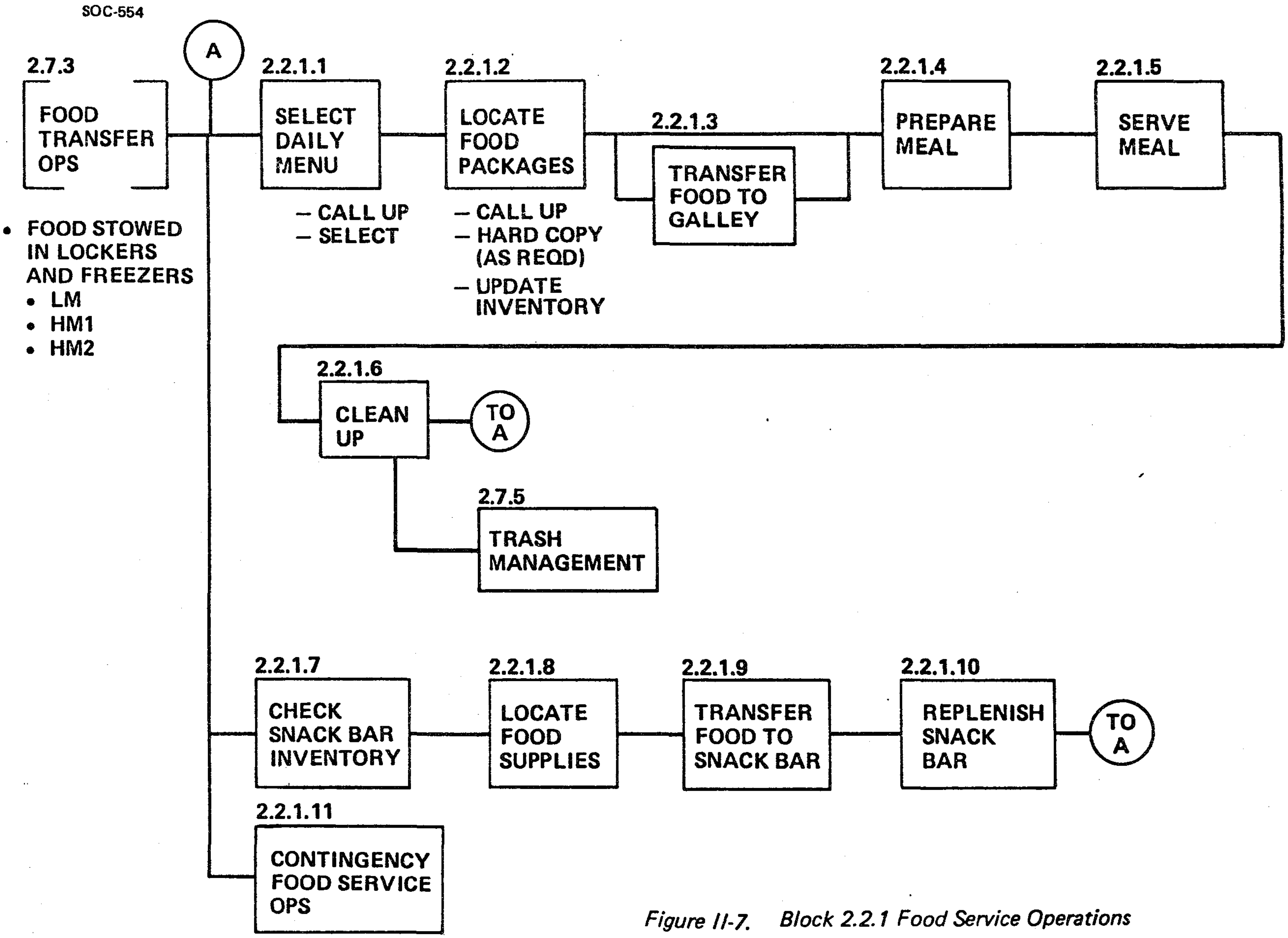

Figure II-7. Block 2.2.1 Food Service Operations oven. After the hot food is ready, the containers will be placed on the food service counter along with cold food from the refrigerator and room temperature food.

The crew will serve themselves cafeteria style. They will draw their own utensils and trays. They will select their food and beverages. They will go to the dining table to consume their meal.

After eating, the crewmen will place the waste food and throwaway containers into the trash compactor. Utensils and food trays will be placed into the dishwasher. The food service crewmen will be responsible for restowing the clean utensils, etc., disposing of the compacted trash (see Block 2.7.5), tidying up the galley, and updating the food inventory data.

One of the crewmen will also be in charge of keeping the galley in Habitat Module No. 2, stocked with food and supplies. This galley could be used to serve up sandwiches, french fries, hot and cold beverages, and other fast food items.

If Habitat Module No. 1 has to be evacuated, the crew will get their meals in Habitat Module No. 2. In this contingency mode, there will still be available the food stored in the Logistics Module (both frozen and shelf stable food) and the food stowed in Habitat Module No. 2. The contingency food management strategy will be to cut back on the total amount of food per day for each crewman, provide the full water ration, and stretch out the use of the available normal food supplies.

Block 2.2.2 Waste Management/Hygiene Operations - In each of the habitat modules, there will be a john and a handwasher. There will be a shower in HM1.

The dry john is very similar to that used in the Orbiter. The primary operational difference is that for SOC, the john will be configured so that the commode liners can be easily replaced. These commode liners are like a tub. About every 3 weeks, a loaded commode (dry, compacted, disinfected waste lines the walls of the tub) will be removed from the john and placed in double sealed plastic bags. This container will then be hand carried to the Logistics Module where empty commode liners are stowed in a locker. The loaded liner is placed into the locker (for return to Earth) and a clean one is taken to the john where it is installed.

In a contingency mode, the handwasher would be used for sponge bathing.

The handwasher is also used for tooth brushing, shaving, and cleaning of small articles. The personal grooming supplies are stowed in personal storage drawers above the handcleaner. General purpose items (tissues, wet wipes, etc.) are also stowed in this area for ready access.

A zero-G, whole body shower will be located in HM-1. A dressing area is provided. Towels, washclothes, soap and shampoo will be stowed in the dressing area.

Blocks 2.2.3 and 2.2.4 Recreation and Exercise Operations - The nature of the exercise and recreation provisions is fairly ill-defined at this time. A treadmill or exercise cycle will be available. There will be TV (perhaps live TV from Earth, videotapes, video games), stereo tape decks, and games for entertainment. Another primary source of entertainment will be the observation windows for watching the Earth and stars go by. There will also be a closed circuit TV set-up where the outside construction and flight support facility operations could be observed. Private quarters will be equipped with stereo headsets and, perhaps, TV.

Block 2.2.5 Sleep Operations - Each crewmember will have private sleeping quarters. This compartment will have storage, a desk, reading lights, and a sleep restraint. During crew rotation or contingency operations, sleep restraints will be taken from storage and mounted on the walls to provide sleeping space for the additional people.

Block 2.2.6 Clothes Washing Operations - Habitat Module No. 1 will be equipped with a clothes washer. Crewmen will take turns doing the laundry. The laundry will include dirty towels, washclothes, and sleep restraint liners, in addition to clothing.

Block 2.3 CREW ROTATION OPERATIONS

Each crewmember will have a 90 day staytime at SOC. Conceptually, the entire crew of 8 could be changed out at one time (there is a way to configure the orbiter to transport 8 people). However, this total changeout of the crew would not be operationally desirable nor would it be necessary. The preferred crew rotation mode would be a combination of changing groups of 3 or 4 people at a time along with rotating individual crewmembers as mission requirements dictate.

The orbiter will be docked to a SOC docking fixture. This fixture provides for shirtsleeve egress/ingress between the Orbiter and SOC. Arriving crewmembers will have been assigned to a specific sleeping quarters. They will double up with the current occupant during the day or two allowed for crew overlap. The new crew's personal gear will have to remain in the Orbiter's mid-deck storage lockers (if a Logistics Module is not delivered during this crew delivery flight) or in the Logistics Module until the current crew vacates their quarters (the current occupant could pack up some of his gear before the new crew arrives in order to provide some storage space for his replacement).

There will have to be at least one shift allowed for the new crew to be briefed by the departing crew in order to make a smooth transition in the mission and base operations.

Block 2.4 HEALTH MAINTENANCE OPERATIONS

As presently visualized, there will be a "doctor's-office-like" medical treatment compartment in Habitat Module No. 1 and an "emergency-room-like" medical facility in Habitat Module No. 2.

The crew for SOC will require at least one crewman to have extensive medical training, equivalent to a physician's assistant or actually to be a physician. At least a second crewman will have 100 hours of training such as the Emergency Medical Technicians.

The Health Maintenance Facility will have a programmed medical diagnosis logic scheme which could be used by a crewman with a medical problem. The interface would be accomplished on a CRT display and the program will include a broad spectrum of the most common medical conditions. A computer will provide immediate accessability of medical records on each of the crewmen. In addition, it will serve as input by the medical crewman of all significant physiological data obtained on the crewmen on a daily basis. This computer will also receive and analyze data obtained from any biomedical experimentation being carried out during the mission.

SOC will have a program treatment logic scheme which will follow the diagnosis. These treatment modalities will cover the broad spectrum of the most common treatment approaches. Drugs and medications will be similar to the Space Shuttle Medical Systems, (SOMS-B) but with increased quantities and some additions. A shelf life of 6 months to a year will be specified for drug supplies.

The dental treatment capability will be the same as was used in Skylab. That capability was all inclusive for dental problems. The prime medical crewman will need training in extractions, temporary fillings, and dental analgesia.

The facilities for carrying out surgical procedures will include capabilities to treat fractures, lacerations and minor trauma. In addition, surgery on SOC will include incision and drainage of a wound and other procedures which do not require general analgesia or an elaborate sterile field. A method, and the equipment to sterilize surgical instruments, will be provided.

The SOC will contain the equipment to treat life threatening conditions such as cardiac arrest, major trauma, etc.

A crewman who becomes ill or injured may have to be transferred back to Earth for final treatment. While he waits for transportation, he may require medical monitoring and stabilization with a variety of life support systems.

The SOC will have equipment to monitor vital signs, will receive telemetry of cardiac rhythm from crewmen during EVA, and will have the capability to transmit cardiac rhythm to the ground as needed.

A down-link system of communications will include image transmission so that the onboard medical crewman may show images of an injured crewman, microscope slides, or X-ray films while he is in consultation with the ground physician.

During the course of an extended mission such as SOC, there will undoubtedly be equipment failures and instances where it becomes desirable to change or add to the equipment onboard. It is expected that a crewman will be trained in making necessary repairs and maintenance on medical equipment.

Block 2.5 CREW TRAINING OPERATIONS

This is an operational category that has not received any attention to date. There will undoubtedly be a requirement for some kind of in-space training.

Block 2.6 ORBITER-RELATED OPERATIONS

Block 2.6.1 Orbiter Arrival Operations - (See Figure II-8 for operations flow.) Many days in advance of an Orbiter flight, the SOC crew will be given a verbal flight plan. The base commander will then review the projected crew activity schedule to: 1) ensure that there will be the necessary people on-duty during the Orbiter arrival, and 2) to suspend all EVA operations while the Orbiter approaches and docks.

Several hours before the orbiter launch time, the SOC tracking radar, navigational aides, and docking system will be activated and checked out. The SOC status will be given to ground control.

After the Orbiter is launched, the SOC will be verbally informed of the vehicles status. The EVA operations will be terminated. The SOC tracking radar will be aimed to acquire and track the approaching vehicle.

The docking maneuvers will be controlled by the Orbiter pilot. The maneuver will be monitored by a SOC crewman who is voice contact with the pilot. If, for any reason, the SOC crewman determines that it is not safe to dock, he can call out a "Break Away" command to terminate the maneuver. If the maneuver is proceeding properly, then nothing is said until soft docking and then hard docking is achieved. The SOC crewman monitors the docking system status indicators and reports "all systems go". He then turns off the nav aides and saves the docking system.

Block 2.6.2 Crew Transfer Operations - Most of the crew transfer operations will be under the control of the Orbiter crew. The only operation for the SOC crew is to monitor the activity to ensure safety.

After docking, one of the orbiter crewmembers will activate the Orbiter's airlock pressurization sequence (if not already pressurized). He will proceed through the

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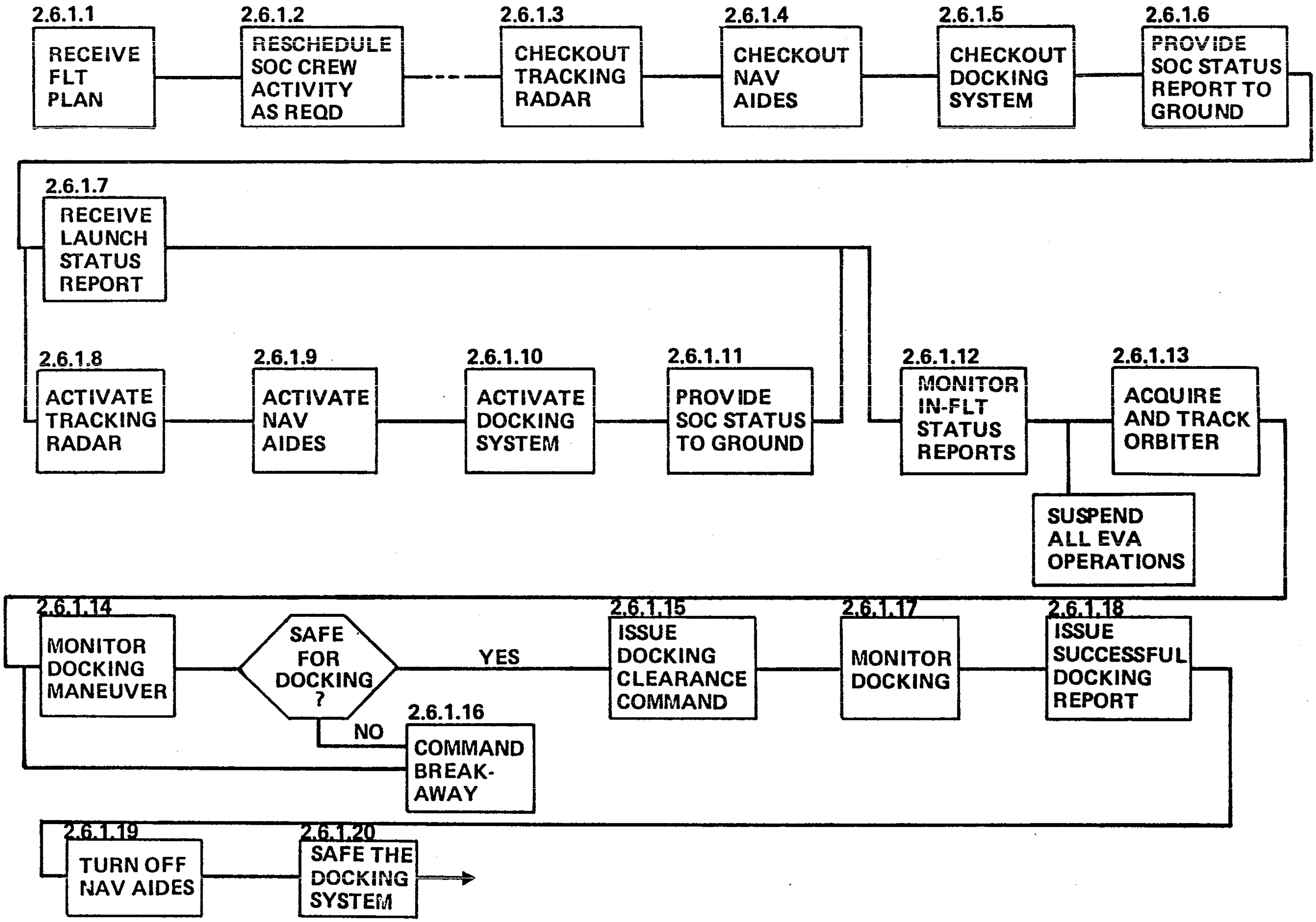


Figure II-8. Block 2.6.1 Orbiter Arrival Operations airlock to open the Orbiter's and SOC's hatches. When all clear, he will give the go ahead for the SOC crew egress.

These steps will be retraced when preparing for departure.

Block 2.6.3 Logistics Module Changeout Operations - The operational flow sequence is shown in Figure II-9. The LM changeout operations will require at least 3 people: 1) an EVA Crewman No. 1, to operate the cherrypicker, 2) an IVA Crewman No. 1, to monitor the EVA crewman, activate the berthing systems, activate track switch mechanism, and activate the SOC-to-LM umbilical actuators, and 3) an Orbiter crewman, to activate the payload retention mechanisms and to monitor the LM handling operations at the Orbiter.

EVA operator No. 1 will board the mobile cherrypicker (CP) and will proceed to the tool storage area. He will attach the Type B payload handling tool to the CP and will check it out. He then drives over to the Orbiter. In conjunction with the Orbiter crewman, the CP operator extracts the incoming LM from the cargo bay. It is transported to its assigned berthing port.

In conjunction with IVA crewman No. 1, the CP operator berths the LM. The CP then moves over to the returning LM. In preparation for return, this LM has been checked out to ensure that all down cargo has been secured properly, the hatch closed, and the LM systems deactivated. The SOC-to-LM umbilicals have been disconnected by remote control. The CP operator and IVA crewmen work together to deberth the LM. The LM is then transported to the Orbiter, placed into the cargo bay, and secured in place (latches controlled by the Orbiter crewman). The CP then moves away and the procedure is terminated.

*Changeout of the LM using only the orbiter's RMS will not be precluded. However, the cherrypicker will not be tied up during the Orbiter's arrival (as all outside work is suspended during this time), so it can be put to use. In addition, the Type B Payload Handling Tool is ideally suited for handling large, bulky payloads so it is the preferred handling system for this operation.

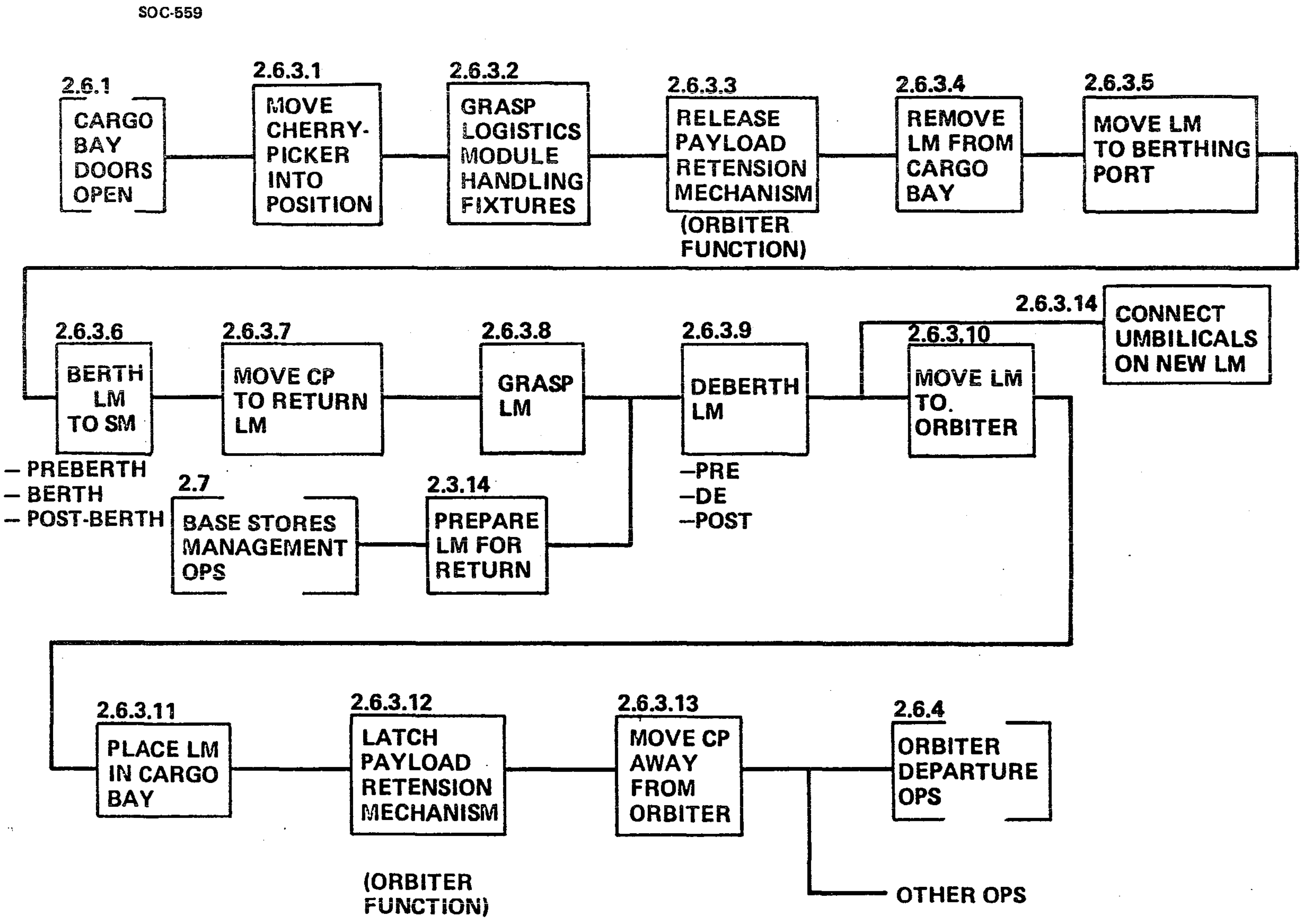


Figure II-9. Block 2.6.3 Logistics Module Changeout Operations

Block 2.7 BASE STORES MANAGEMENT

The operations conducted under this title can be found in Figure II-10.

The stores management concept is driven by several requirements: 1) move items to as close to the user as possible, 2) disperse the elements in several locations to minimize the risk of loss due to a single anomaly, and 3) control the SOC's center of gravity location envelope to minimize the impact on the base attitude control system. These factors will be taken into account in the design of the SOC elements. We will concern ourselves here with the operations involved in moving the consummables around the base.

One or two of the crewmen will be assigned the duty of managing the inventory control system. The inventory records will be maintained in computer memory. Via the multifunction control/display consoles, the inventory records can be called up, modified, and a hard copy be produced. These records contain the name of the items, the locations where stowed, and the quantity in each location. As items are consumed or are moved to new locations, the person who causes these things to happen will write down the appropriate information. This data will be collected and entered into the inventory control records on a daily basis.

Block 2.7.2 Miscellaneous Supplies Transfer Operations - The hand-carrying of the various supplies between the Logistics Module and the Habitat Modules will be a shared responsibility for all crewmen. Soon after the LM is berthed, the crewmen will start transferring the new supplies to the various storage locations to restock depleted supplies. At least 1/3 of the supplies will be left on-board the LM as a precaution. These remaining items will be drawn from LM storage as late in the resupply cycle as possible.

The supplies will all be contained in packages small enough for hand-carrying. The storage shelves in the LM will be identical to those used in the habitat modules so that the supplies will not have to be repacked.

Block 2.7.3 Trash Management Operations - The trash that is collected over a 90-day period will be collected and stowed in the Logistics Module for return to Earth. The waste products will include the following items:

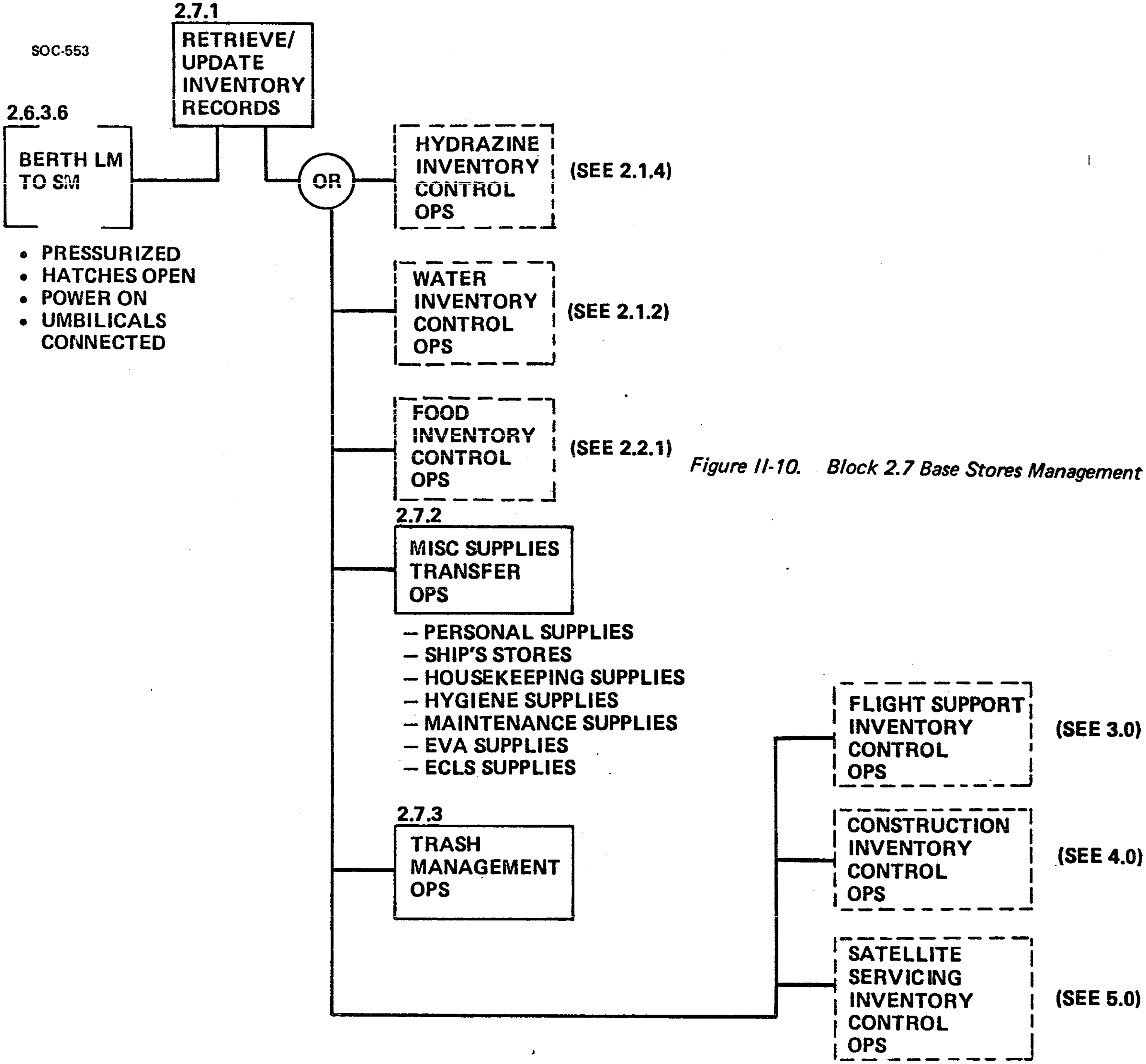


Figure II-10. Block 2.7 Base Stores Management Operations

- food containers, waste food, tissues, paper, etc. (compacted bales)
- ECLS filter beds, chemical containers, etc.
- commode liners (tubs sealed in plastic bags)
- construction article rejects
- defective components

The collection and packaging of these waste products will be a shared responsibility for all of the crew. At least one of the crewmembers will be charged with the responsibility of recording the collections so that mass calculations can be made and transmitted to ground control. This individual should also be responsible to ensure that all down cargo is properly stowed in the LM.

Block 2.8 BASE MAINTENANCE OPERATIONS

It is a fundamental design requirement that all subsystems shall be maintainable. The general intent will be to make replacements at the "black box" level, although, replacement of components should not be precluded.

Many of the subsystems will incorporate build-in-test equipment (BITE) that will monitor the health of the subsystem, detect and annunciate fault conditions, and switch over to redundant or backup systems. There will be some kinds of fault conditions that will not be annunciated. These faults will be detected by visual inspection or by observation of secondary effects.

Maintenance manuals will be available on-board stored on video disks. Some of the fault isolation checklists, schematic diagrams, and repair/checkout procedures shall be stored in the computer memory for operator callup and review. Hard copy of the displayed data will be available. The SOC crew will also be able to consult with experts on the ground.

There will be several portable tool kits stowed in the habitat modules that will contain a variety of screw drivers, wrenches, pliers, wire cutters, tape, etc. suitable for tackling most maintenance jobs. There will also be a similar set of EVA tools for use in repairing external components. If special tools are required, they would be shipped along with the replacement parts.

BLOCK NO. 3.0 - FLIGHT SUPPORT OPERATION

A

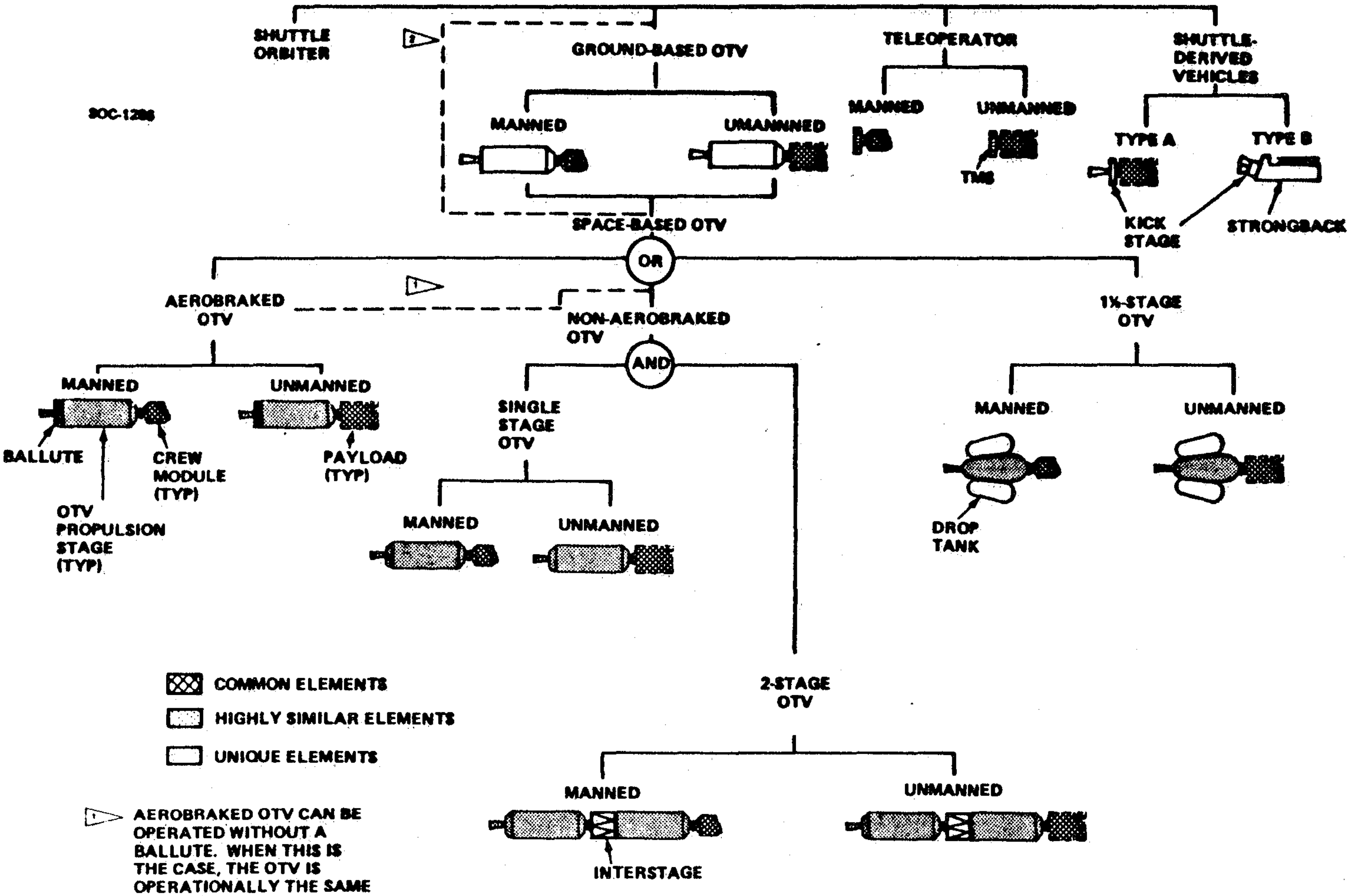
Figure II-11 shows the variety of space vehicles that may interface with the SOC. There will be three primary vehicle types - the Shuttle Orbiter, Orbital Transfer Vehicles (OTV's), and a Teleoperator (TMS). A fourth class, Shuttle Derived Vehicles (SDV's) is also a distinct possibility.

As the figure illustrates, there are 2 basic classes of OTV concepts: ground-based OTV's or space-based OTV's. It is unclear, at this point in time, as to whether or not a ground-based OTV would precede the space-based OTV. There are 3 mutually exclusive OTV concepts that have been studied: aerobraked OTV's, non-aerobraked OTV's, and 1½ stage OTV's. Which, if any, of these OTV's will eventually be used is still an open question. The aerobraked OTV appears to be the most promising concept.

All of the space vehicle types shown in the figure have had operations analysis performed on them to derive the facility, support equipment, and crew requirements. Figure II-12 shows a generally applicable functional flow chart of the space vehicles handling operations at the SOC.

The SOC configurations and sub-elements described in Section I of this document reflect the results of these operations analyses. As Table II-4 shows, various combinations of these sub-elements can be adapted to any of the OTV concepts. In only one case has it been found necessary to significantly alter the SOC flight support facility configuration to adapt to the OTV configuration - the 1½-stage OTV using 3 or 4 drop tanks requires an additional Docking Tunnel.

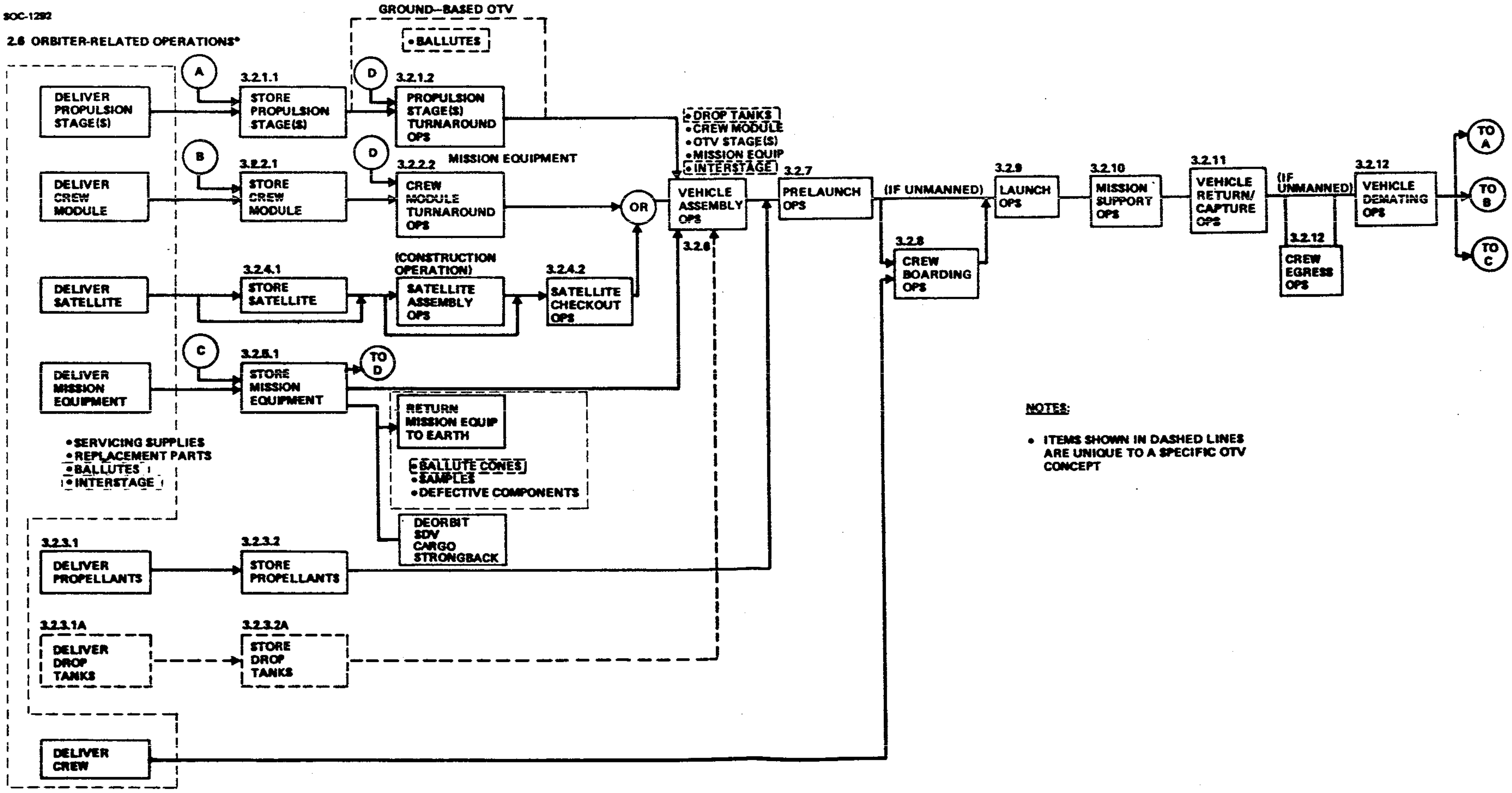
Each of the vehicle types and their SOC-related operations are described in following subsections. Figure II-13 shows the flight support elements in the Growth SOC configuration that were defined for the aerobraked space-based OTV. As it includes most of the elements, this illustration will be used as a reference for the following operational descriptions.



1 AEROBRAKED OTV CAN BE OPERATED WITHOUT A BALLUTE. WHEN THIS IS THE CASE, THE OTV IS OPERATIONALLY THE SAME AS AN OTV NEVER DESIGNED FOR AEROBRAKING.

2 MAY GO DIRECTLY TO SPACE-BASED OTV's

Figure II-11. Potential Types of Vehicles to be Operationally Interfaced with SOC



NOTES:

- ITEMS SHOWN IN DASHED LINES ARE UNIQUE TO A SPECIFIC OTV CONCEPT

*REFER TO BASE OPERATIONS SECTION IN THE SOC SYSTEM DEFINITION REPORT, D180-26495-3, FOR DETAILS

** COULD ALSO BE A SHUTTLE—DERIVED VEHICLE OPERATION

Figure II-12 Flight Support Operations Functional Flow

Table II-4. Flight Support Facility, Support Equipment, and Modules Applicable to the Various Space Vehicles

FACILITIES/MODULES/ SUPPORT EQUIP. REQ'D / VEHICLE		SERVICE MODULE DOCKING PORTS	DOCKING TUNNEL DOCKING PORTS	HANGAR		TRACK NETWORK OPERATIONAL SOC	GROWTH SOC CONFIGURATION	GROWTH SOC CONFIGURATION WITH ADDITIONS	GROWTH SOC CONFIGURATION PLUS ANOTHER DOCKING TUNNEL	VEHICLE/MODULE TRANSPORTERS	UMBILICAL SYSTEM		STORAGE FACILITY			PROPELLANT STORAGE/TRANSFER SYSTEM	AIRLOCK MODULES		PORTABLE IVA TUNNEL	MOBILE CHERRYPICKER AND HANDLING TOOLS	BALLUTE/ENGINE TRANSPORTER	CREW MODULE
				NO MAINT PROVISIONS	MAINT PROVISIONS						IN HANGAR	ON PIER	PLATFORM AREA	EXPANDED PLATFORM AREA	PAYLOAD STORAGE AREA		AM-1	AM-2				
ORBITER		●	●			●	●								●					●		
TELEOPERATOR	– UNMANNED					●	●			●		●			●					●		
	– MANNED						●			●		●			●					●		●
GROUND-BASED OTV	– UNMANNED			●		●				●		●			●					●		
	– MANNED			●			●			●		●			●		●	●	●	●		●
AEROBRAKED OTV	– UNMANNED				●	●	●			●	●	●	●		●	●				●	●	
	– MANNED				●		●			●	●	●	●		●	●	●	●	●	●	●	●
SINGLE STAGE OTV	– UNMANNED				●	●	●			●	●	●	●		●	●				●	[2] ●	
	– MANNED				●		●			●	●	●	●		●	●	●	●	●	●	[2] ●	●
2-STAGE OTV	– UNMANNED				●	●	●			●	●	●	●		●	●				●	[2] ●	
	– MANNED				●		●			●	●	●	●		●	●	●	●	●	●	[2] ●	●
1½-STAGE OTV	– UNMANNED				●	●	●		● [1]	●	●	●	●		●	●				●	[2] ●	
	– MANNED				●		●		● [1]	●	●	●	●		●	●	●	●	●	●	[2] ●	●
SHUTTLE DERIVED VEHICLE	– TYPE A							●						●	●					●		
	– TYPE B							●						●	●					●		

[1] REQ'D FOR 3 AND 4 DROP TANK VERSIONS ONLY

[2] TRANSPORTER CONFIGURED FOR ENGINE HANDLING ONLY

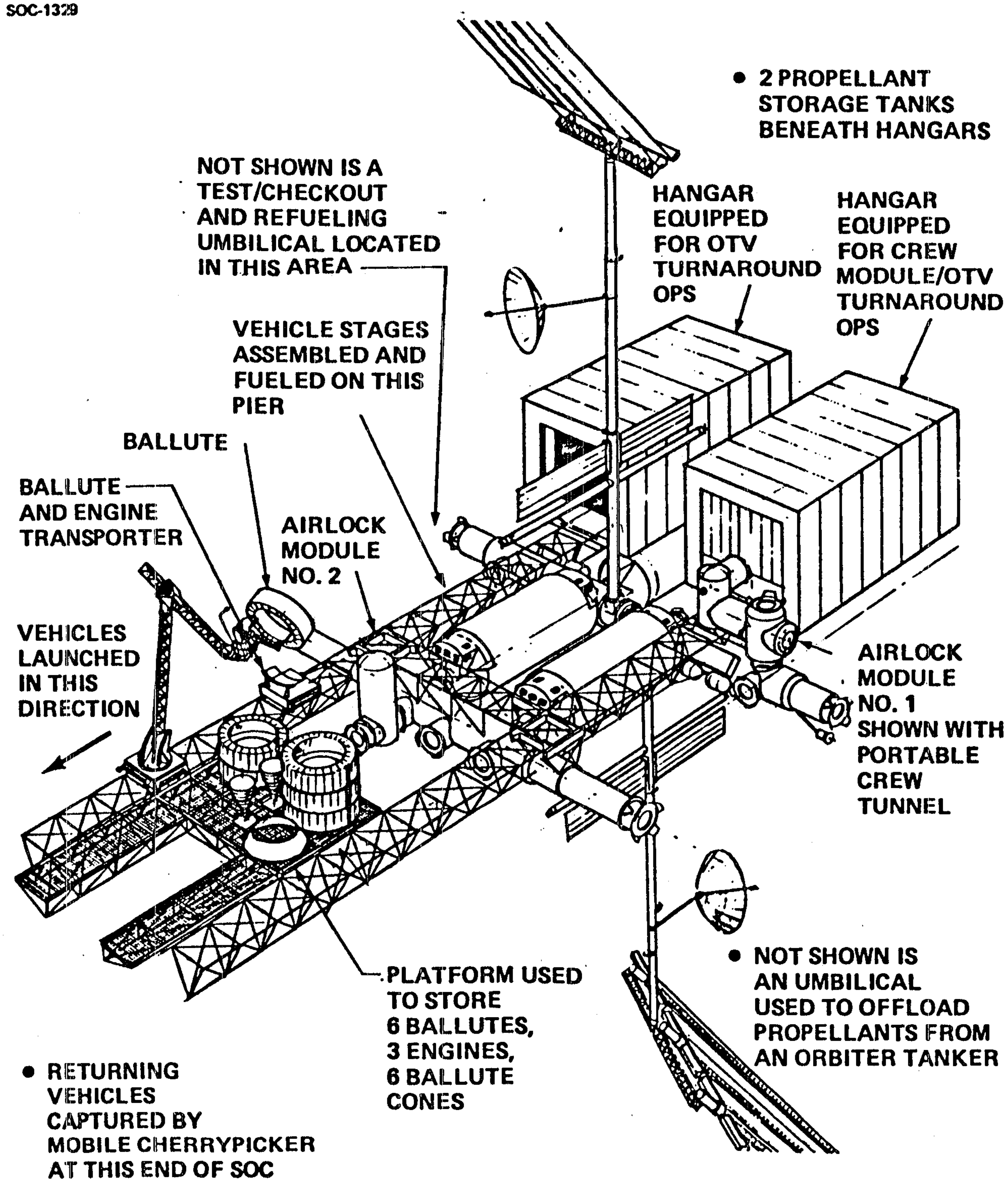


Figure II-13. Integrated Flight Support Facility Concept

ORBITER FLIGHT SUPPORT OPERATIONS A

The Orbiter-related operations were discussed in Block 2.6 in the previous subsection.

TELEOPERATOR FLIGHT SUPPORT OPERATIONS A

The teleoperator maneuvering system (TMS), such as shown in Figure II-14, is used in both manned and unmanned modes of operation. It is used 1) to place, retrieve, and service co-orbiting satellites located within the TMS performance envelope, and 2) as a vehicle tug - see the Shuttle-Derived Vehicle operations discussion. The TMS operations have not been analyzed in detail. The concepts given below are preliminary in nature.

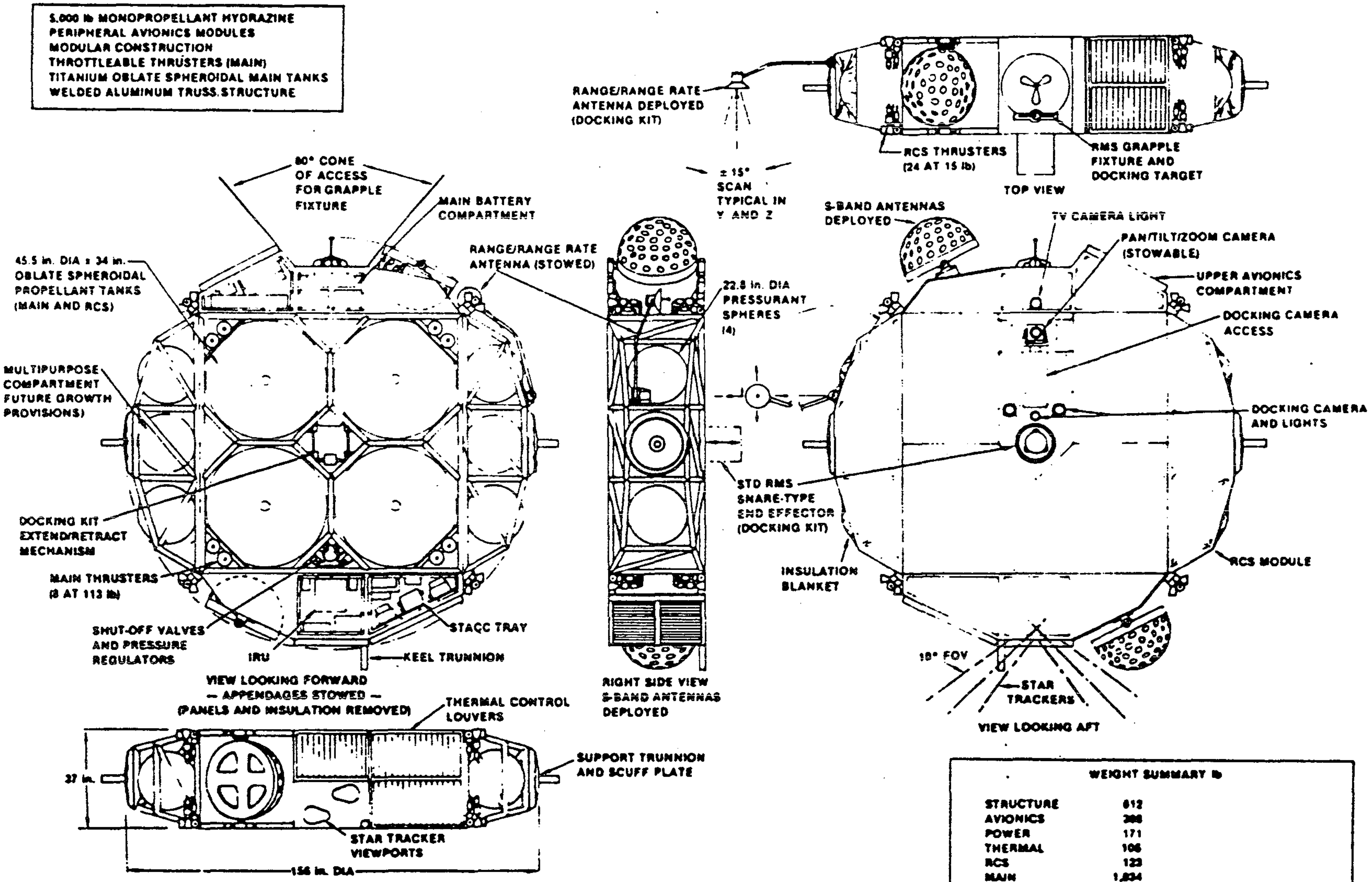
The TMS will be delivered to the SOC by the Orbiter. It is mounted in a TMS Cradle, see Figure II-15, in the Orbiter cargo bay. The TMS and cradle are removed from the Orbiter and stowed in the Storage Facility payload storage area.

When a payload is to be attached to the TMS, the TMS is removed from its cradle and placed onto a transporter. It is then moved to the payload mating area. The TMS is connected to the servicing umbilical for test and checkout and refueling. The payload (either a Crew Module or an unmanned satellite) is then mated to the TMS as is done with OTV payloads.

The TMS/payload is then launched as is described for the space-based OTV's, i.e., the transporter is used as a "catapult" to launch the vehicle off the pier. The TMS recovery, demating, etc., are similar to the operations described for the OTV's.

GROUND-BASED OTV FLIGHT OPERATIONS

The ground-based OTV's may be the first class of OTV's to be handled at the SOC. These vehicles would be delivered to the SOC fully fueled. They are mated to their payload at the SOC and launched. The following discussion describes the operational flow shown in Figure II-16.



5,000 lb MONOPROPELLANT HYDRAZINE
PERIPHERAL AVIONICS MODULES
MODULAR CONSTRUCTION
THROTTLEABLE THRUSTERS (MAIN)
TITANIUM OBLATE SPHEROIDAL MAIN TANKS
WELDED ALUMINUM TRUSS STRUCTURE

WEIGHT SUMMARY lb

STRUCTURE	612
AVIONICS	388
POWER	171
THERMAL	106
RCS	123
MAIN	1,034
CONTINGENCY	112
PROPELLANT (MAIN AND RCS)	5,000
SUBTOTAL	7,546 (PLACEMENT)
DOCKING KIT	281
TOTAL	7,826 (PLACEMENT AND RETRIEVAL)

Figure II-14. TMS General Arrangement

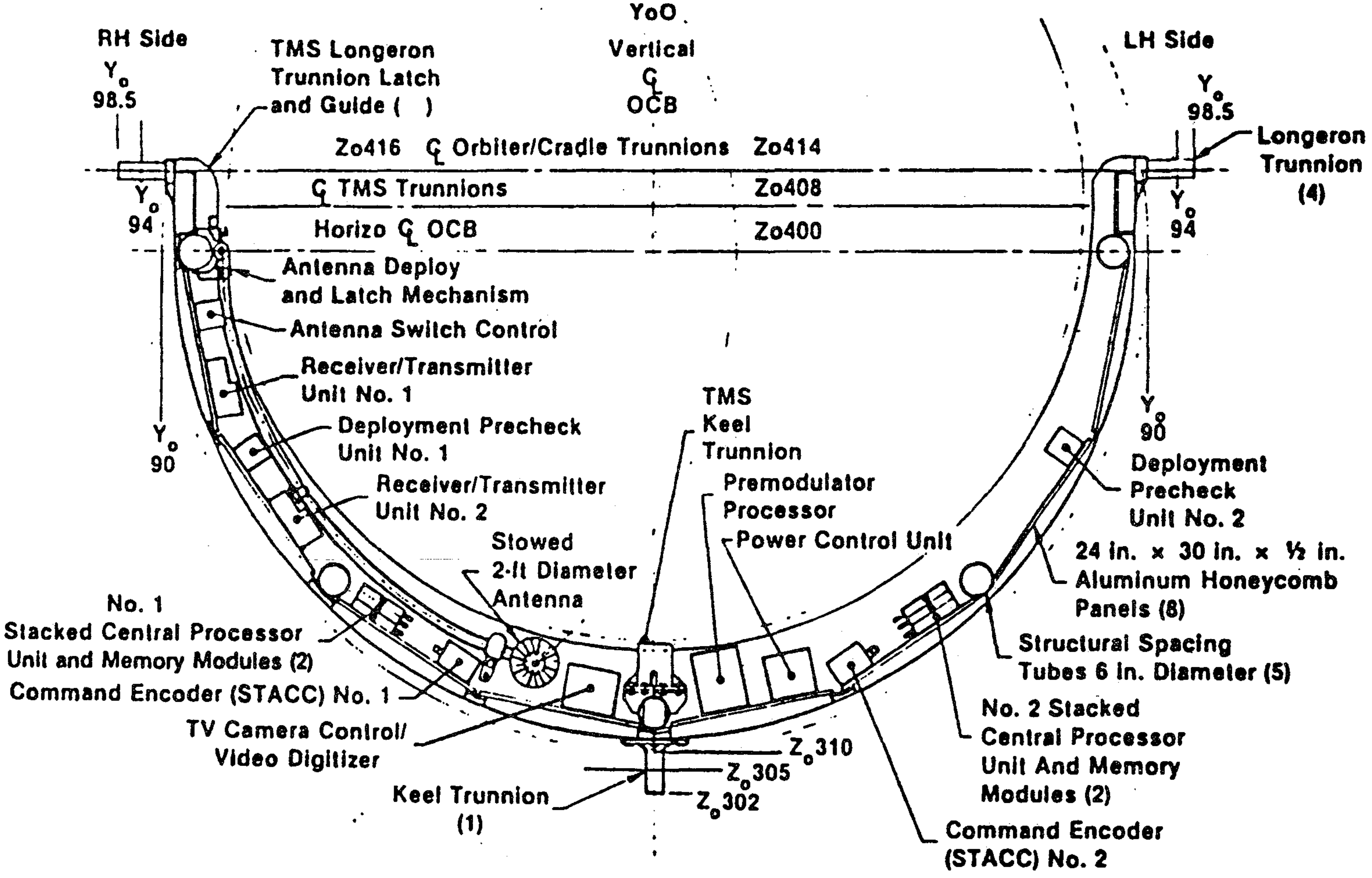


Figure II-15. TMS Cradle Assembly

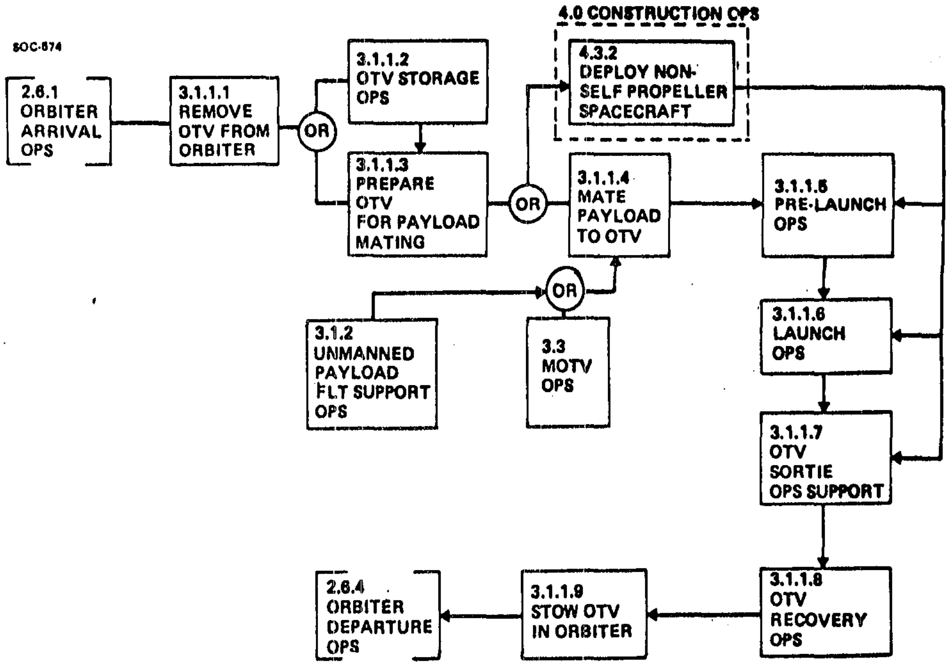


Figure II-16. Block 3.1.1.1 OTV Flight Support OPS 4th-Level Functional Flow

Block 3.1.1.1 - Remove OTV From Orbiter - Figure II-17 shows the fifth-level functional flow for this activity.

Figure II-18 shows an OTV being off-loaded from the Shuttle Orbiter. (Note - This also illustrates how an OTV would be loaded into the Orbiter for return to Earth. - Block 3.1.1.9.) The vehicle would be attached to the Orbiter cargo bay payload retention latches. The vehicle would have PIDA interfaces so that the PIDA could be used to roll the OTV out of the cargo bay into the position shown here. The mobile cherrypicker, equipped with the Type B Payload Handling Tool, would grasp the OTV, the PIDA's would be disconnected, and the OTV could then be moved away from the Orbiter and lowered onto an OTV transporter.

Block 3.1.1.2 - OTV Storage Operations - The OTV is then driven into the hangar. The hangar doors would have been previously opened and the interior lights turned on. The vehicle is stowed in the hangar if it is expected to be at the SOC for more than a few days as the hangar provides debris protection and thermal protection.

Block 3.1.1.3 - Prepare OTV for Payload Mating - The OTV is driven out of the hangar and moved to a location alongside the Habitat Module. An umbilical is attached to the OTV so that the OTV can be checked out.

Block 3.1.1.4 - Mate OTV to Payload - Figure II-19 illustrates how the OTV is moved into position behind the payload by remotely driving the OTV carriage. The OTV is then berthed to the aft end of the payload. Table II-5 lists the requirements imposed on the spacecraft to be SOC compatible.

Block 3.1.1.5 Pre-Launch Operations - The OTV and payload are then put through their prelaunch checkouts. These are conducted by remote control from the SOC Command Center via radio links. During this time, the mobile cherrypicker is moved out of the way. The EVA crew retreats to the SOC interior. The articulated fixture is disconnected from the spacecraft and retracted, leaving the spacecraft supported by the OTV and carriage.

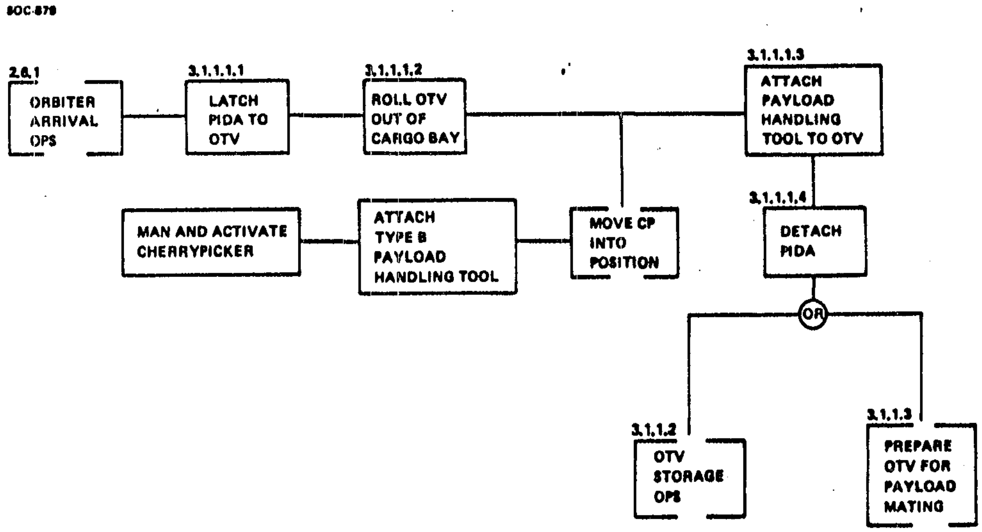


Figure 11-17. Block 3.1.1.1 Remove OTV From Orbiter

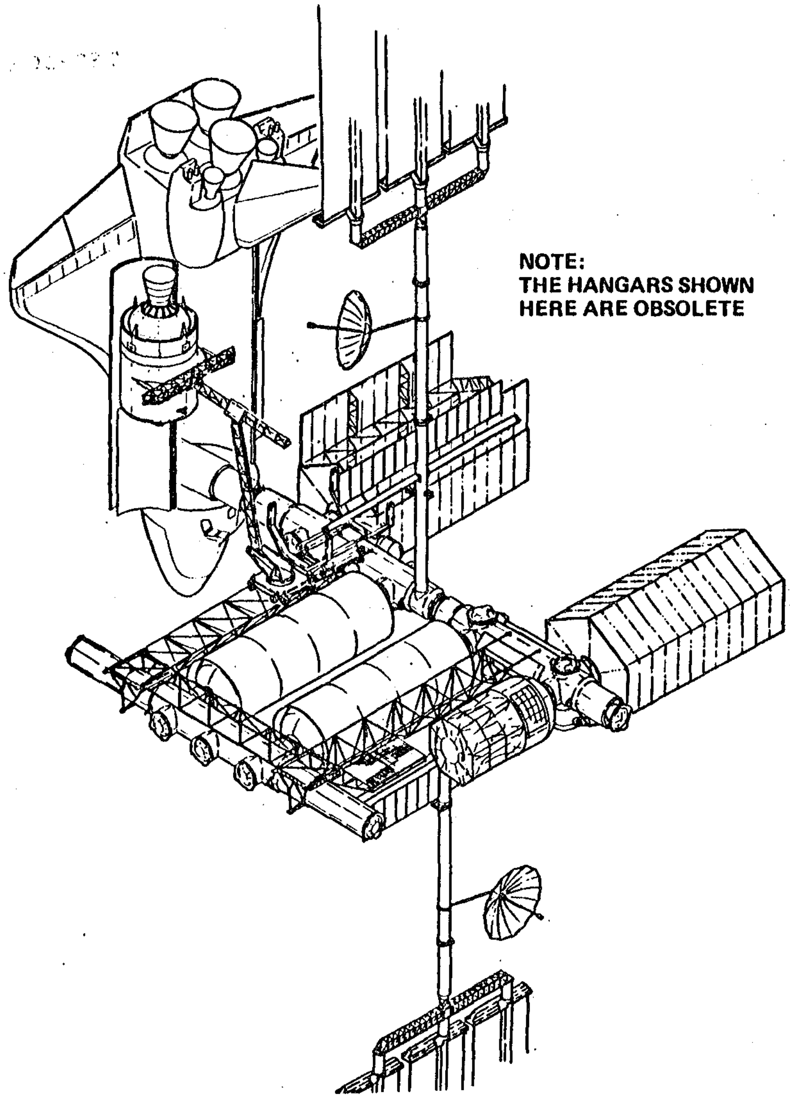
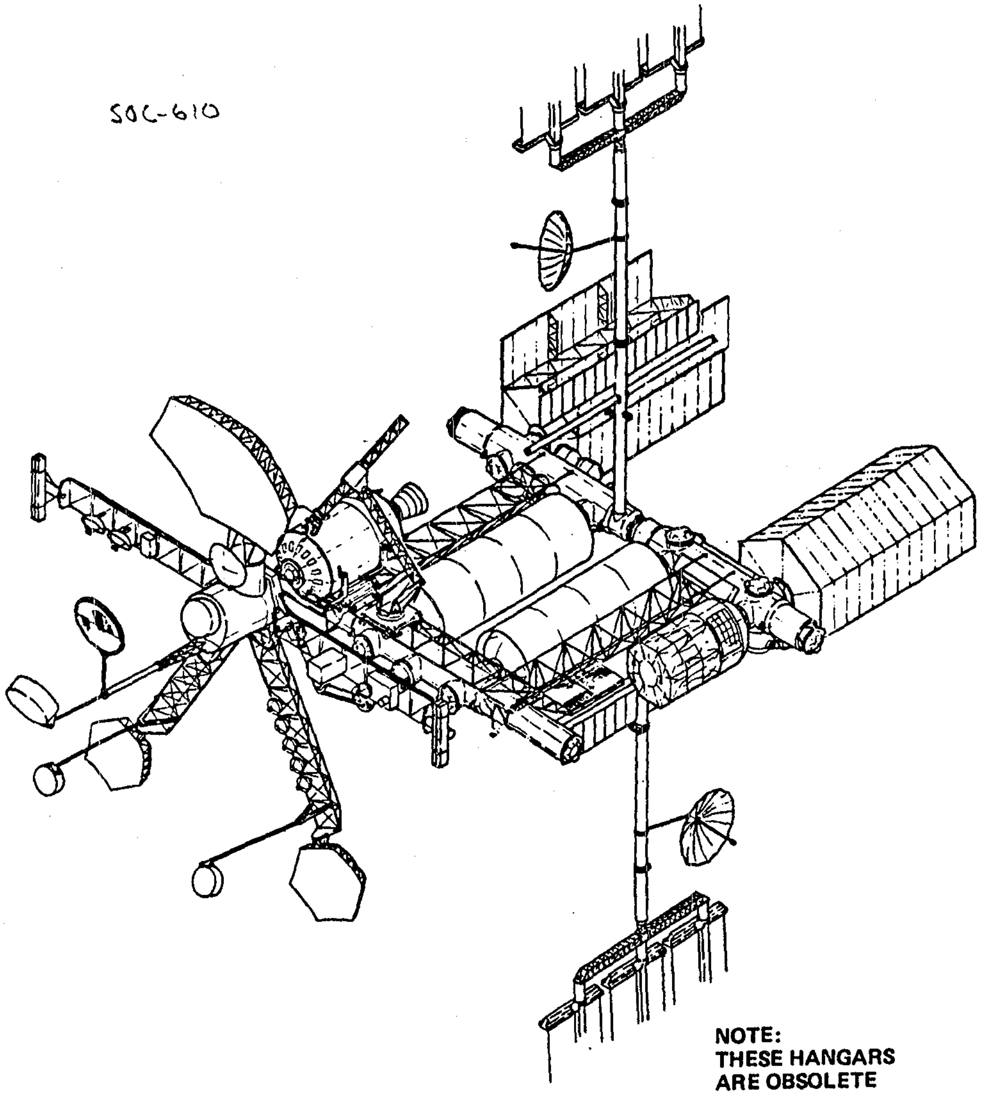


Figure II-18. OTV Being Offloaded from the Orbiter (Also Represents Loading of OTV into Orbiter)

SOC-610



NOTE:
THESE HANGARS
ARE OBSOLETE

Figure II-19. The OTV is Moved into Position for Mating to the Satellite

SOC-886

Table 11-5. Requirements Imposed on Spacecraft to be SOC Compatible

ALL SPACECRAFT

- PROVIDE AN UMBILICAL PANEL COMPATIBLE WITH THE SOC UMBILICAL END–EFFECTED
- PROVIDE CHERRYPICKER HANDLING POINTS (COULD BE SAME AS THOSE USED FOR GROUND HANDLING)
- APPENDAGES THAT WILL NOT REQUIRE REMOTELY CONTROLLED DEPLOYMENT COULD BE DEPLOYED MANUALLY. THIS WOULD REQUIRE ON APPENDAGE DEPLOYMENT TOOL INTERFACE AND MECHANISM
- SOME SPACECRAFT MAY REQUIRE EVA INTERFACE PROVISIONS (EVA WORKSTATION ATTACH POINTS, FOOT RESTRAINT ATTACH POINTS, HANDLING HANDHOLDS, ETC.)

SELF–PROPELLED SPACECRAFT

- PROVIDE ASSEMBLY FIXTURE ATTACH POINTS

OTV–PROPELLED SPACECRAFT

- PROVIDE A STANDARD DOCKING FIXTURE FOR OTV MATING/DEMATING –THIS FIXTURE TO INCORPORATE ASSEMBLY FIXTURE ATTACH POINTS

Block 3.1.1.6 - Launch Operations - The OTV/Payload launch is controlled from the SOC command center in HM2. The launch is achieved by releasing the carriage-to-OTV retention latches and firing the aft-firing RCS thrusters. The OTV/Payload is thus flown slowly away from the SOC as shown in Figure II-20. The OTV is flown to a stationkeeping position a few hundred meters away from the SOC. Pre-transfer checkouts are conducted. When everything is ready, the OTV is maneuvered into the transfer attitude and the main engines fired.

Block 3.1.1.7 OTV Sortie Operations Support - The OTV/payload sortie is controlled from the Earth. The SOC crew is periodically notified of mission status.

Block 3.1.1.8 OTV Recovery Operations - After the OTV has made its round trip to deliver its payload, it approaches the SOC as shown in Figure II-21.

In the reference technique, the OTV approaches the SOC from below and behind (Earth is toward the lower left and the SOC is moving to the right). This places the vehicle in a fail-safe approach path for if it cannot be captured by the cherrypicker as it drifts by the SOC, the OTV will pass harmlessly past the SOC. (Other OTV capture techniques are described in Boeing -15.)

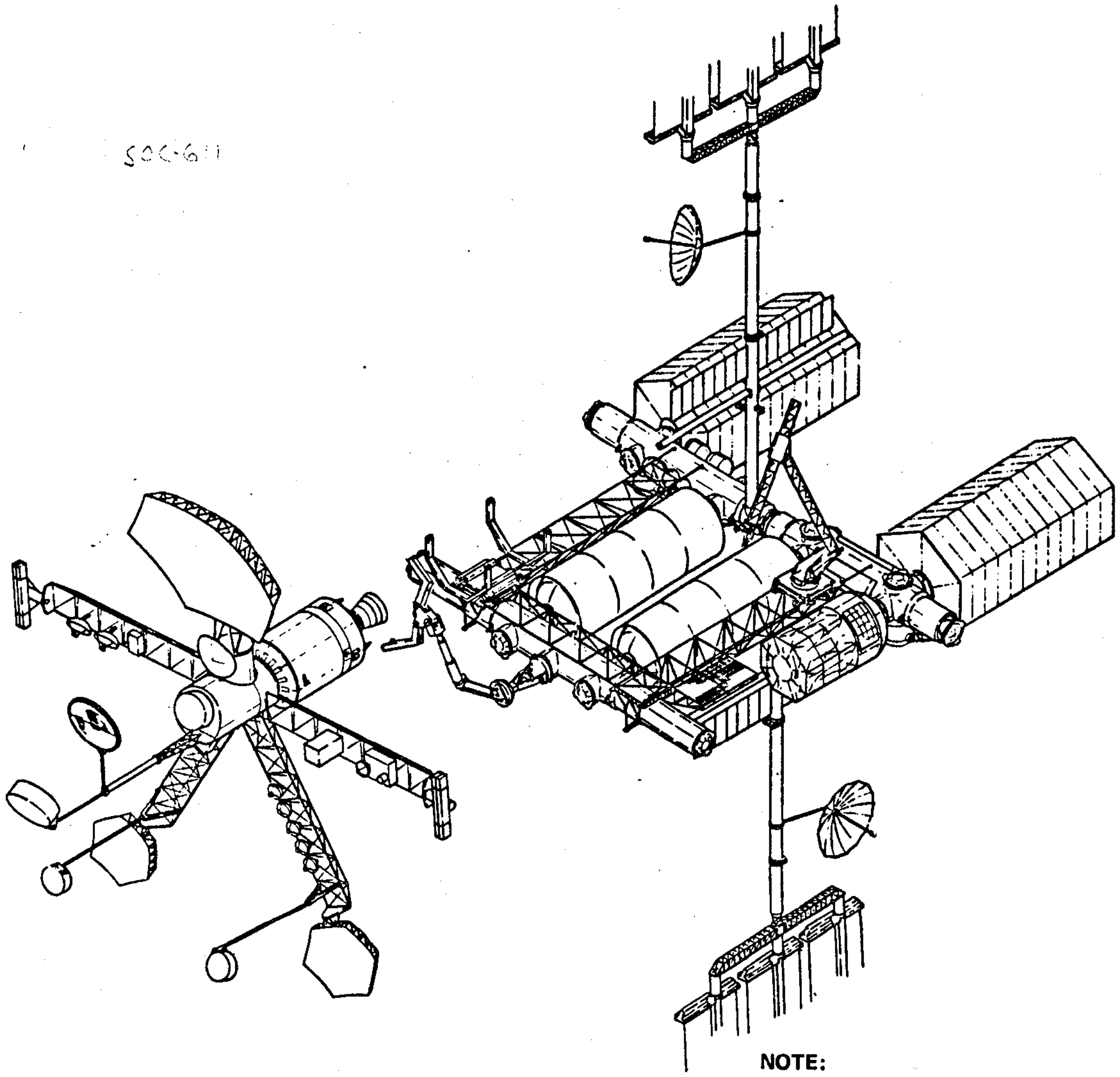
The mobile cherrypicker is equipped with the Type B Payload Handling tool which has a docking aide attachment. This attachment would have a docking target and active homing device. The cherrypicker is unmanned during this operation. It is under remote control from the Habitat Module No. 2 Command Center.

Figure II-22 shows the OTV in the captured position.

After the OTV is captured, it is placed into the OTV carriage, as shown in Figure II-23. The carriage would then be moved to the hangar for storage awaiting an orbiter that will have space available on the Return-to-Earth trip.

Block 3.1.1.9 Stow OTV in Orbiter - This operation is the reverse of that described in Blocks 3.1.1.1 and 3.1.1.2.

SOC-611



**NOTE:
HANGARS SHOWN
ARE OBSOLETE**

Figure II-20. The OTV Flies the Satellite Away from the SOC and Moves into a Temporary Stationkeeping Position Several Hundred Meters Away

SOC-739

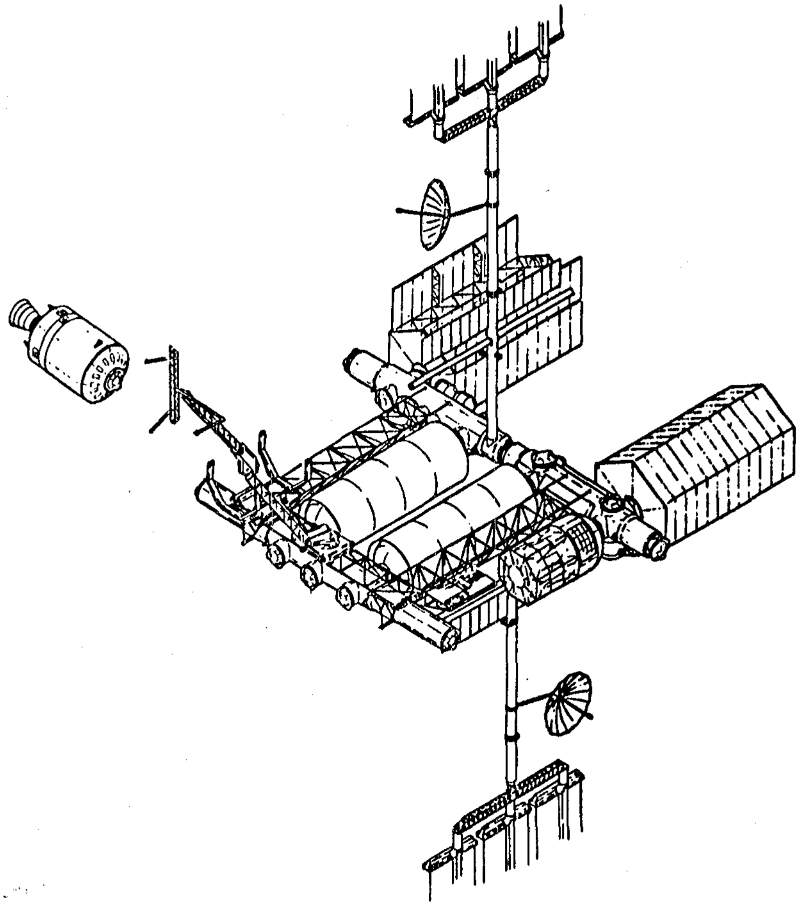


Figure 11-1: The OTV Approaches The SOC From Below And Behind. The Mobile Cherrypicker Is Equipped With An OTV Capture Fixture.

SOC-742

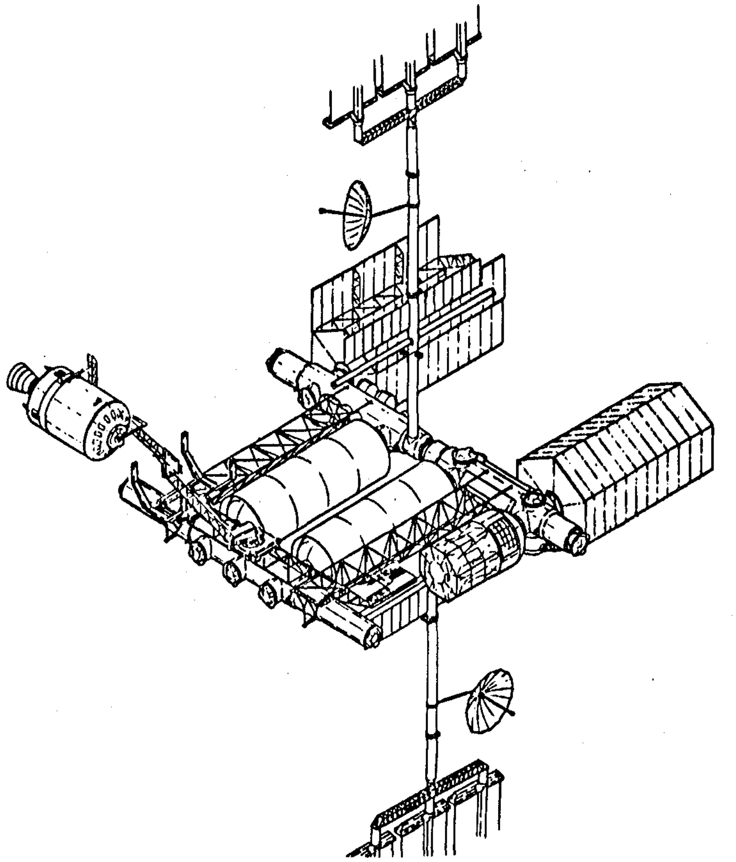
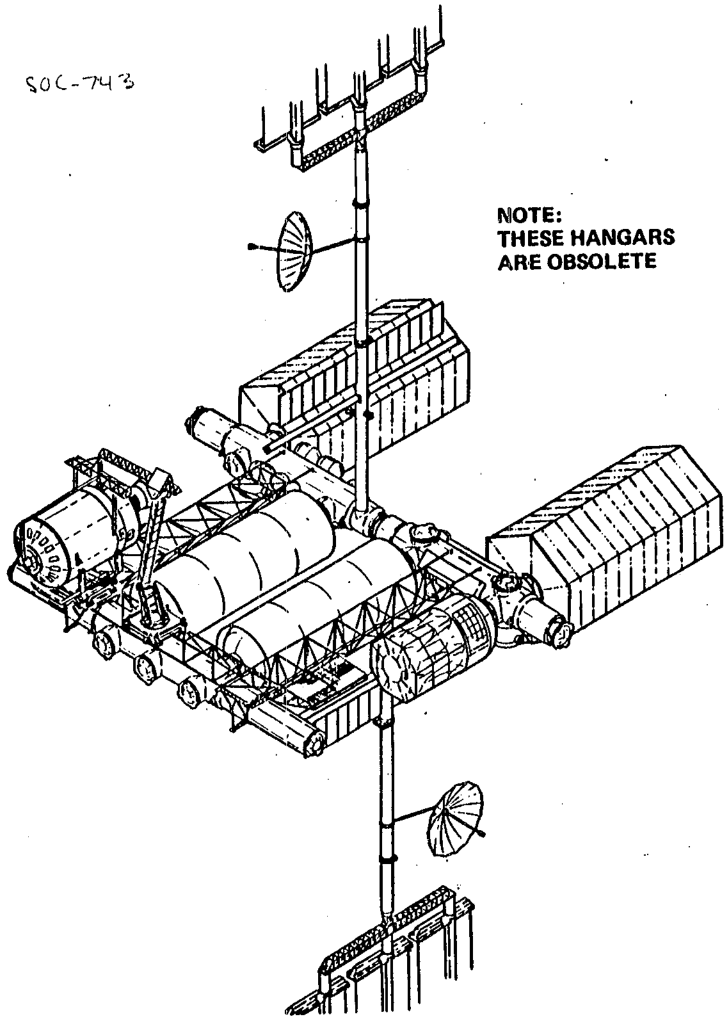


Figure 11-22. The OTV Is Captured By The Mobile Cherrypicker. This Operation Is Remotely Controlled From The HM2 Command Center Facing This Direction.

SOC-743



NOTE:
THESE HANGARS
ARE OBSOLETE

Figure II-23. The OTV is Placed into the OTV Dolly

SPACE-BASED OTV FLIGHT SUPPORT OPERATIONS

A

Figure II-12 showed a high-level functional flow diagram for space-based flight support operations. Note that most of the functions are independent of the specific type of OTV (aerobraked, 1½-stage, etc.). The operations and elements that are unique to one of the specific OTV configurations are shown enclosed in dashed lines.

The facility and support equipment concepts described on the worksheets mentioned above have been synthesized into the integrated flight support facility concept shown earlier in Figure II-13.

Figure II-24 illustrates the configuration of a "drive-in" hangar which is equipped for space-based maintenance of an OTV.

Figure II-25 illustrates the hangar being used for Crew Module maintenance. Figure II-26 shows the crew module/OTV in its mating position on the track.

These facility concepts will be referred to as the "baseline flight support facility" in following sections where the specific OTV concepts are addressed.

AEROBRAKED OTV OPERATIONS

A

Aerobraked OTV Concept

Considerable cost savings can be achieved by the development of an OTV which offers increased payload delivery capability when operated in the reusable space-based mode. The aerobraking option provides approximately twice the payload delivery capability as an all-propulsive OTV operating in this mode.

The aerobraking option is developed by the installation of the ballute deceleration subsystem on the OTV. The ballute subsystem consists of the ballute, ballute inflation system, installation provisions, and pyrotechnic devices for the deployment prior to and release of the ballute after re-entry. In addition, a Global Positioning System (GPS) receiver/processor subsystem is added to the vehicle avionics to provide the more precise position determination required for the aerobraking maneuver.

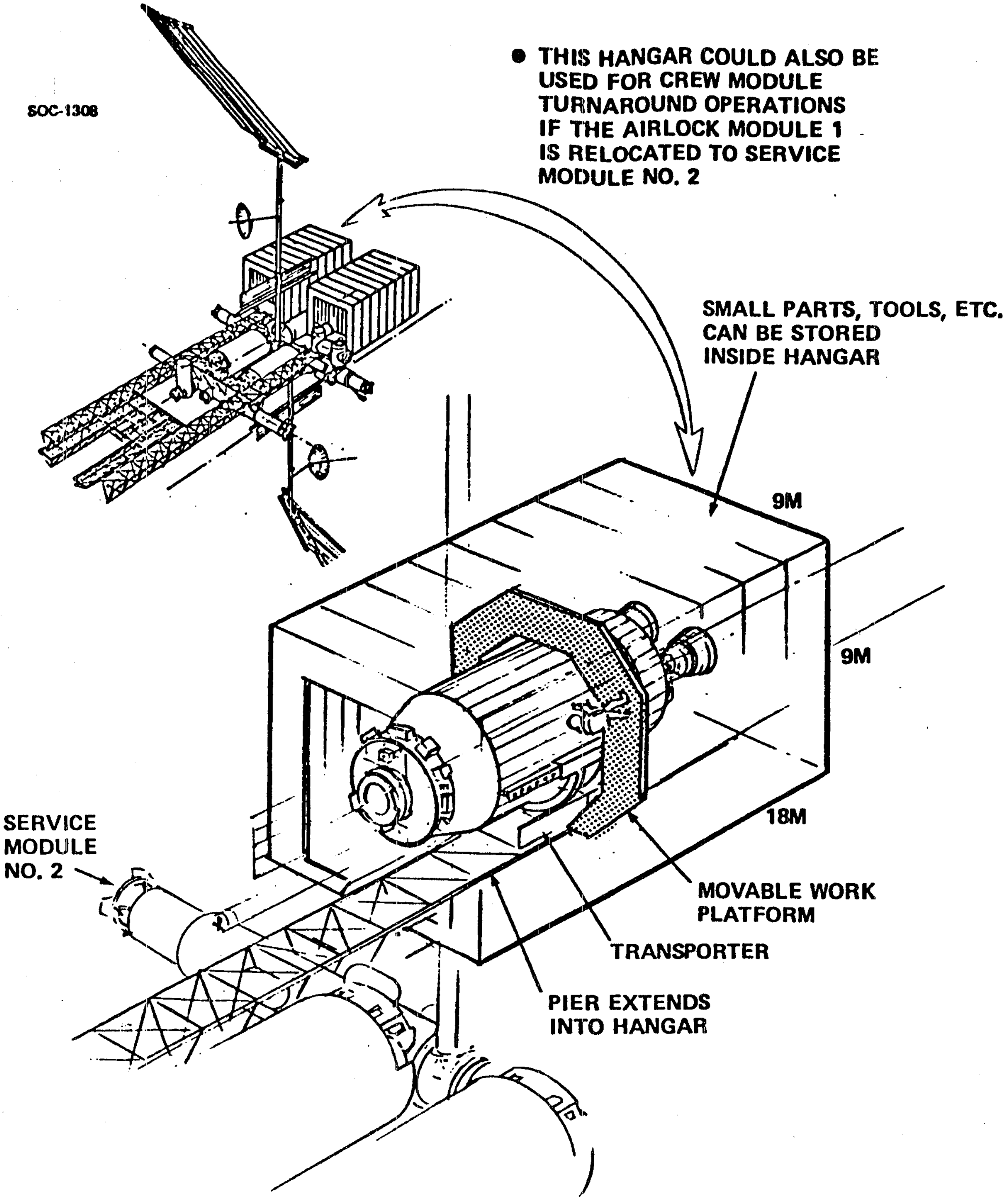
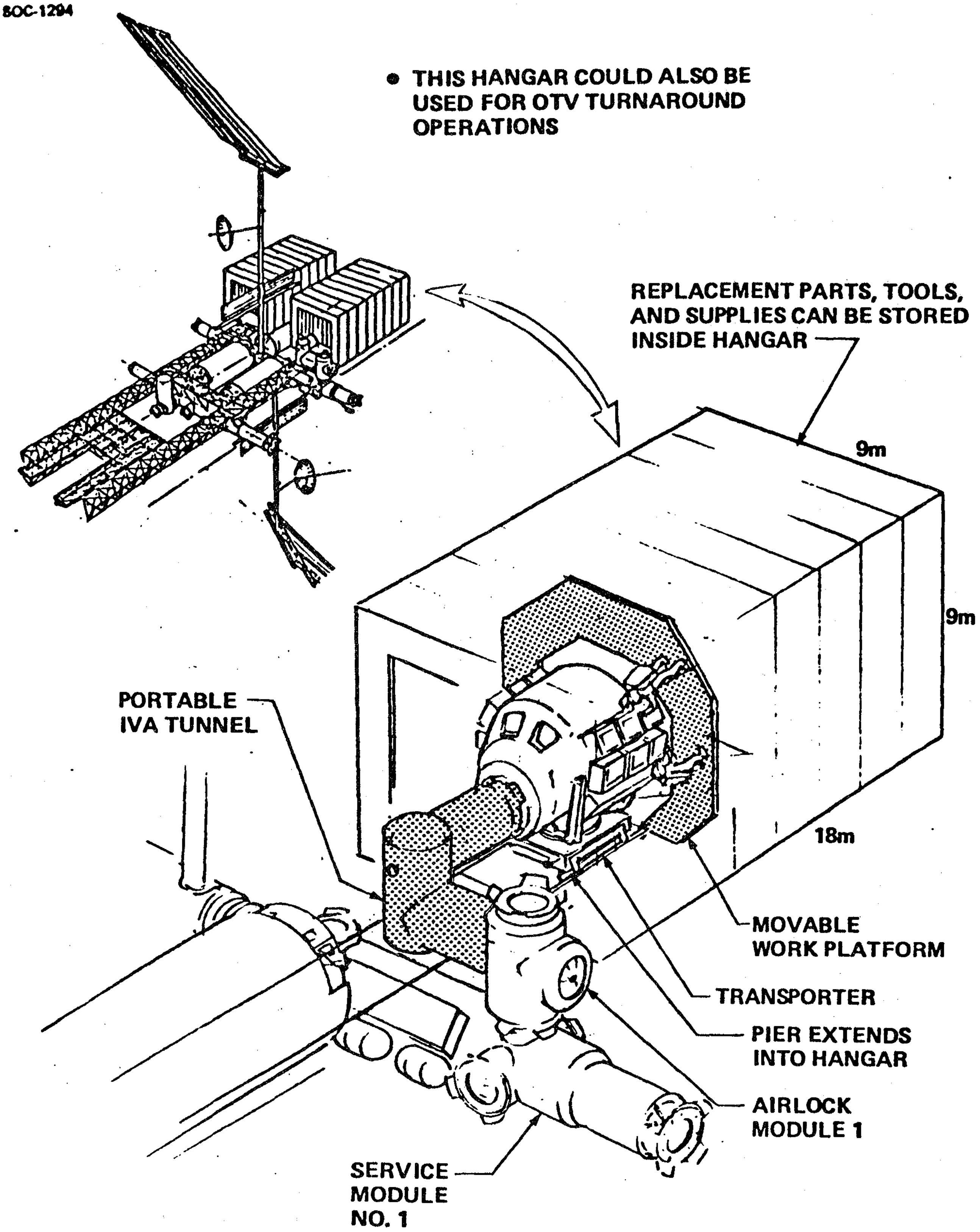


Figure II-24. Hangar Equipped for OTV Turnaround Operations

SOC-1294



- THIS HANGAR COULD ALSO BE USED FOR OTV TURNAROUND OPERATIONS

Figure II-25. Hangar Equipped for Crew Module Turn-Around Operations

- PORTABLE CREW TUNNEL REMOVED FROM AIRLOCK MODULE NO. 1 AND IS TEMPORARILY STORED OUT OF WAY
- CREW MODULE MOVED OVER TO AND BERTHED TO OTV USING TRANSPORTER
- PORTABLE CREW TUNNEL ATTACHED TO AIRLOCK MODULE NO. 2

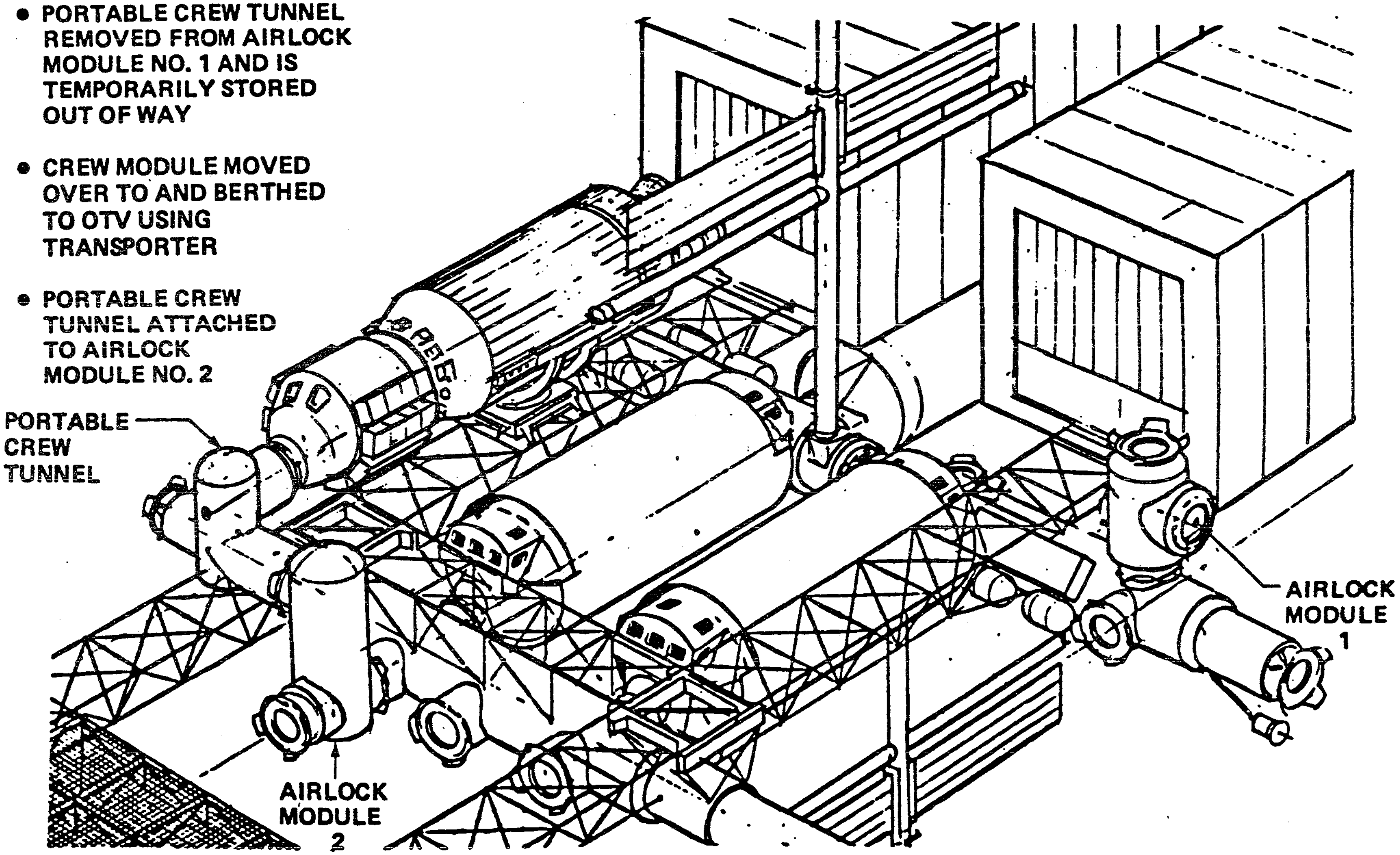


Figure II-26. Crew Module IVA Access Provisions when MOTV is on the Track

A

The baseline control mode used is drag variation using engine thrust to vary the flow field characteristics. In this mode vehicle drag can be varied by approximately an order of magnitude by switching between tank head idle and low pumped idle engine thrust levels.

The basic operating scenario for a worst case trajectory (highest density) is shown in Figure II-27.

At t=0 the LH_2 engine valves are opened and the engine is started, running in the tank head idle mode. During this period vehicle deceleration is measured using accelerometers and compared with the decelerations associated with the nominal trajectory. Discrepancies are noted and input into an algorithm which determines when and for how long the engine thrust should be raised to pump idle to correct for density variation. For a 3 sigma high trajectory the engine will stay at tank head idle; for the 3 sigma low trajectory shown the engine will be at pumped idle for approximately 40 seconds through perigee.

After engine shutdown and completion of the aero-assist maneuver, the ballute is gradually allowed to cool and deflate until the vehicle has left the sensible atmosphere at which time the forward restraint straps are released. This clears the RCS for use and enables the vehicle to orient itself for the apogee burn. The ballute is discarded during the burn and reenters on its next pass.

Aerobraked OTV Configuration

The aerobraked OTV configuration is shown in Figure II-28 in the configuration prior to installation of the ballute. The ballute is assembled on the ground in the configuration shown here. The ballute is packaged onto a structural cone (see Figure II-29) which is then shipped to SOC in sets of six units every 90 days (the requirement for supporting one of the mission models).

Ballute Installation Operations

The unique operations associated with the aerobraked OTV concept are those associated with the ballute installation.

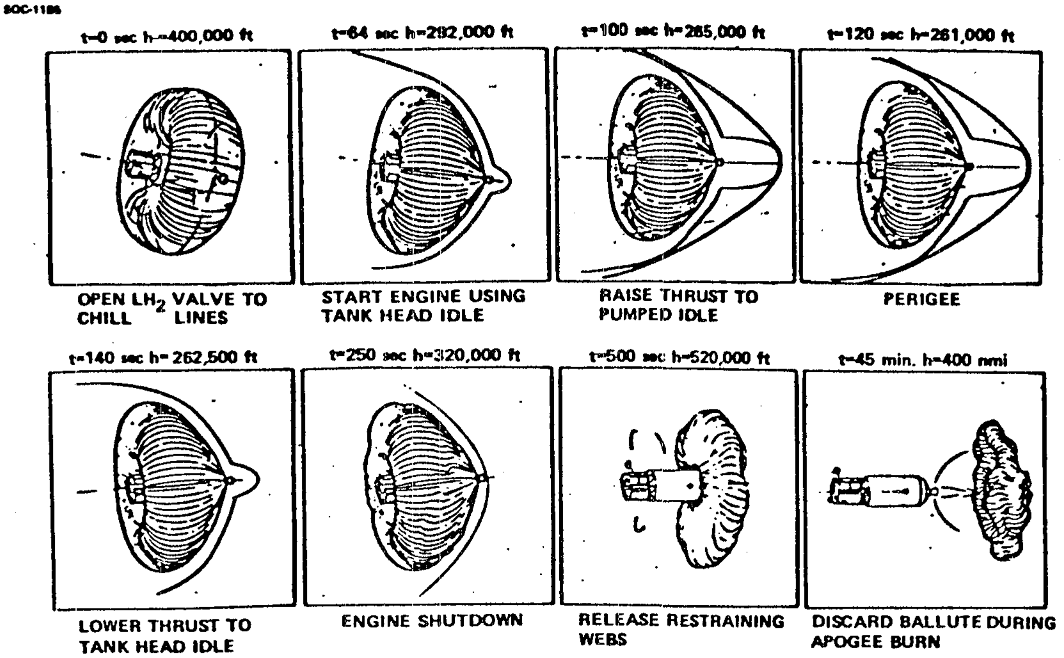


Figure II-27. Aerobraking Operating Scenario

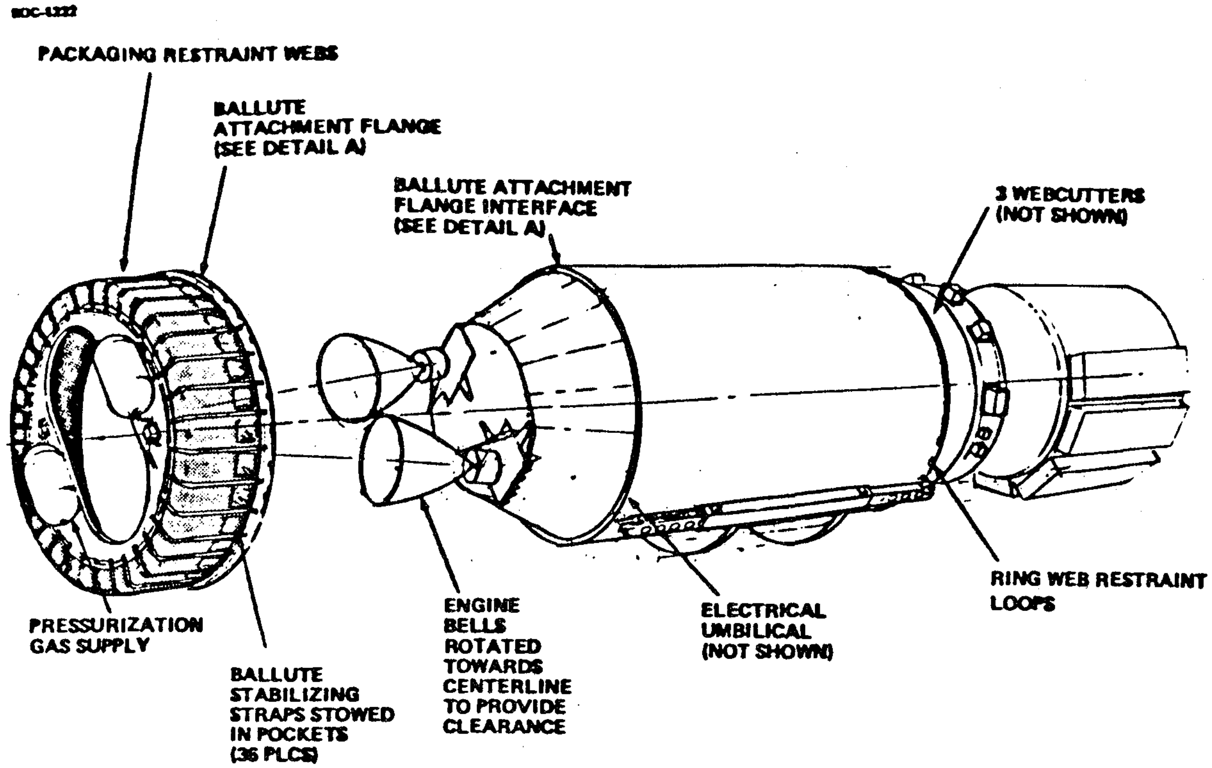


Figure II-28. Ballute and OTV Interfaces Configurations

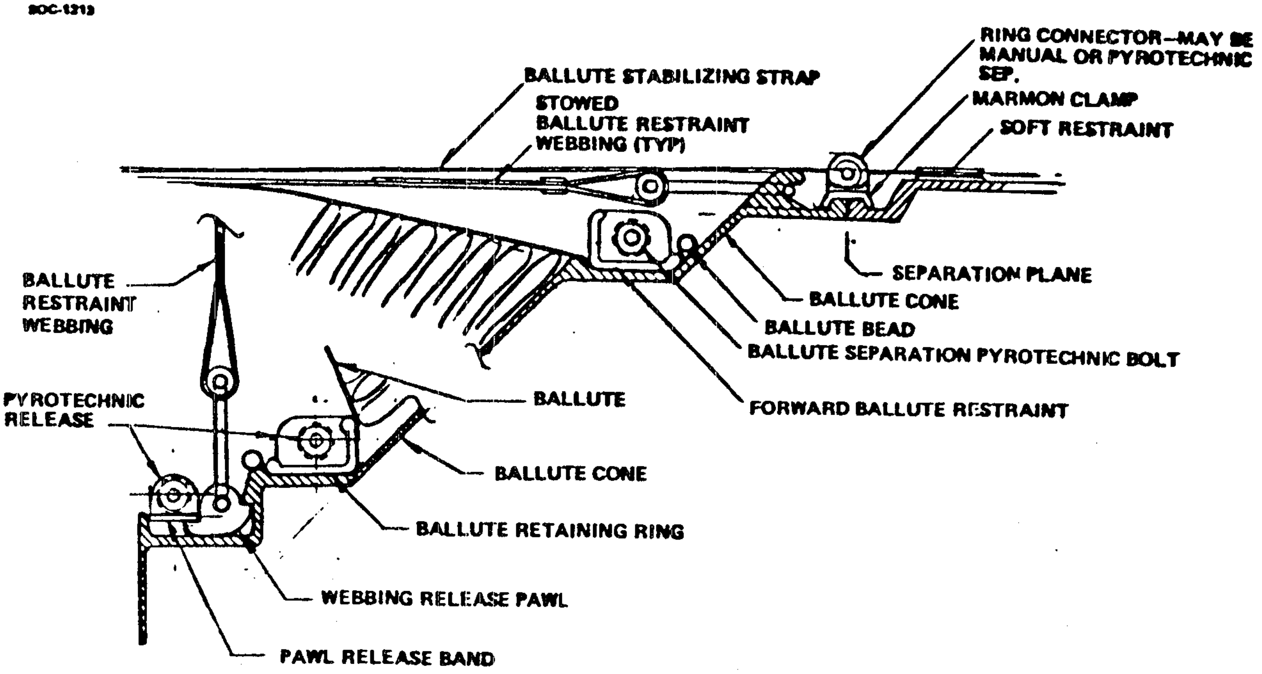


Figure II-29. Ballute Retention and Separation Concept

Figure II-30 illustrates the operations required to install the ballute. The turnaround scenario would proceed as described below (refer to Figure II-12 functional flow diagram for reference):

1. The returning OTV has its ballute cone removed in the vehicle assembly/demate area (refer to function 3.2.12). The cone is stored on the storage platform for eventual return to the ground (refer to function 3.2.5.1).

2. The OTV is backed into the hangar for the turnaround operations (refer to function 3.3.1.1 and 3.3.1.2).

    a. Prior to the return of the OTV, a ballute is taken from storage and placed on a transporter (refer to Figure II-13) and then moved inside the hanger (refer to function 3.2.5.1 and 3.2.1.2).

3. The EVA access platforms are moved into position so that crewmen can remove remnants of webs and umbilicals and to remove bolt catchers (this would be a part of the normal OTV inspection and refurbishment procedures).

4. At some point in the turnaround cycle, the new ballute will be installed. This procedure will require that the engine bells be tilted toward the centerline so that the ballute structure can slip over the bells. The ballute is then carefully maneuvered into its attachment position via remote control of the ballute transporter and/or by EVA crewman rolling the transporter along the track. The ballute structure will attach to the OTV structure using a Marmon clamp (see Figure II-29).

5. At the forward end of the OTV, a ballute restraining "ring web" is installed by threading a web through some guide eyelets on the perimeter of the tank wall. This installation also requires installing three web cutters and hooking up the electrical umbilicals from these web cutters to connectors on the OTV.

6. There are 36 longitudinal stabilizing straps that are then individually deployed from pockets on the ballute. These webs are restrained in several

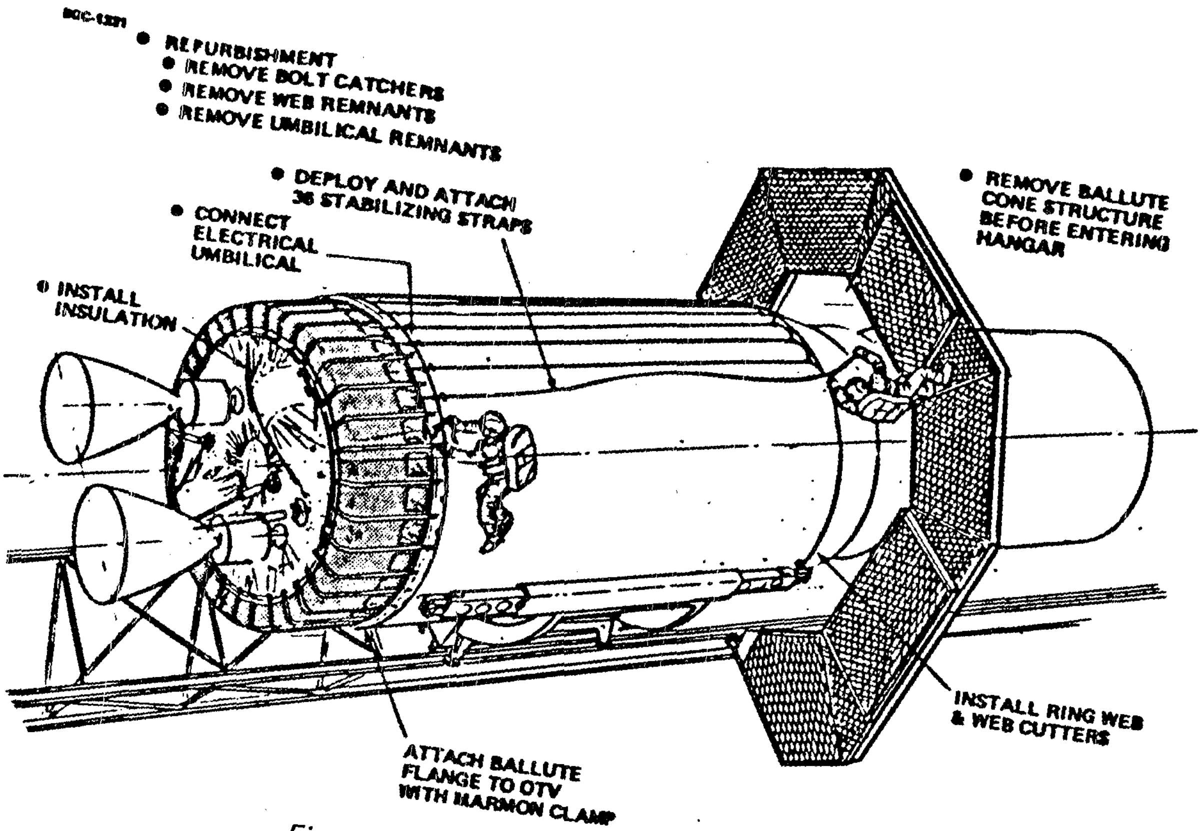


Figure II-30. Ballute Installation Operations places with breakaway restraints (see Figure II-29). The distal end of each strap is then snapped onto the ring web installed in Step 5.

7. An electrical umbilical is connected between the ballute and the aft end of the OTV.

The timeline and crew required for these operations are shown in Figure II-31.

Table II-6 summarizes the support equipment required for the ballute handling operations.

1½-STAGE OTV OPERATIONS ANALYSIS

1½-Stage OTV Configuration

Figure II-32 shows the 1½-stage OTV configured as a manned orbital transfer vehicle (MOTV). The system is comprised of a propulsion core module, a crew module, and drop tanks. The various 1½-stage OTV configurations require from one to four drop tanks.

The propulsion core is common for all missions; it has two RL 10 CAT 11B engines and a cryogenic propellant capacity of 17,500 Kg.

The drop tanks are standard for all missions and each has a cryogenic propellant capacity of 27,270 Kg. When fully loaded, the drop tank absorbs the launch capability of a standard shuttle. Useful propellant loading of each tank is mission dependent, but the launch capacity diminishes with boil-off as the tank remains at the SOC, waiting for the assembly of the drop tanks to propulsion core. When empty, the tank is disposed of by a motor mounted to the LO_2 tank, which de-orbits it to burn up in the Earth's atmosphere.

**NOTE: This crew module concept was chosen to represent a typical crew module concept for all of the OTV concepts. It could, perhaps, also be used as a TMS crew module.

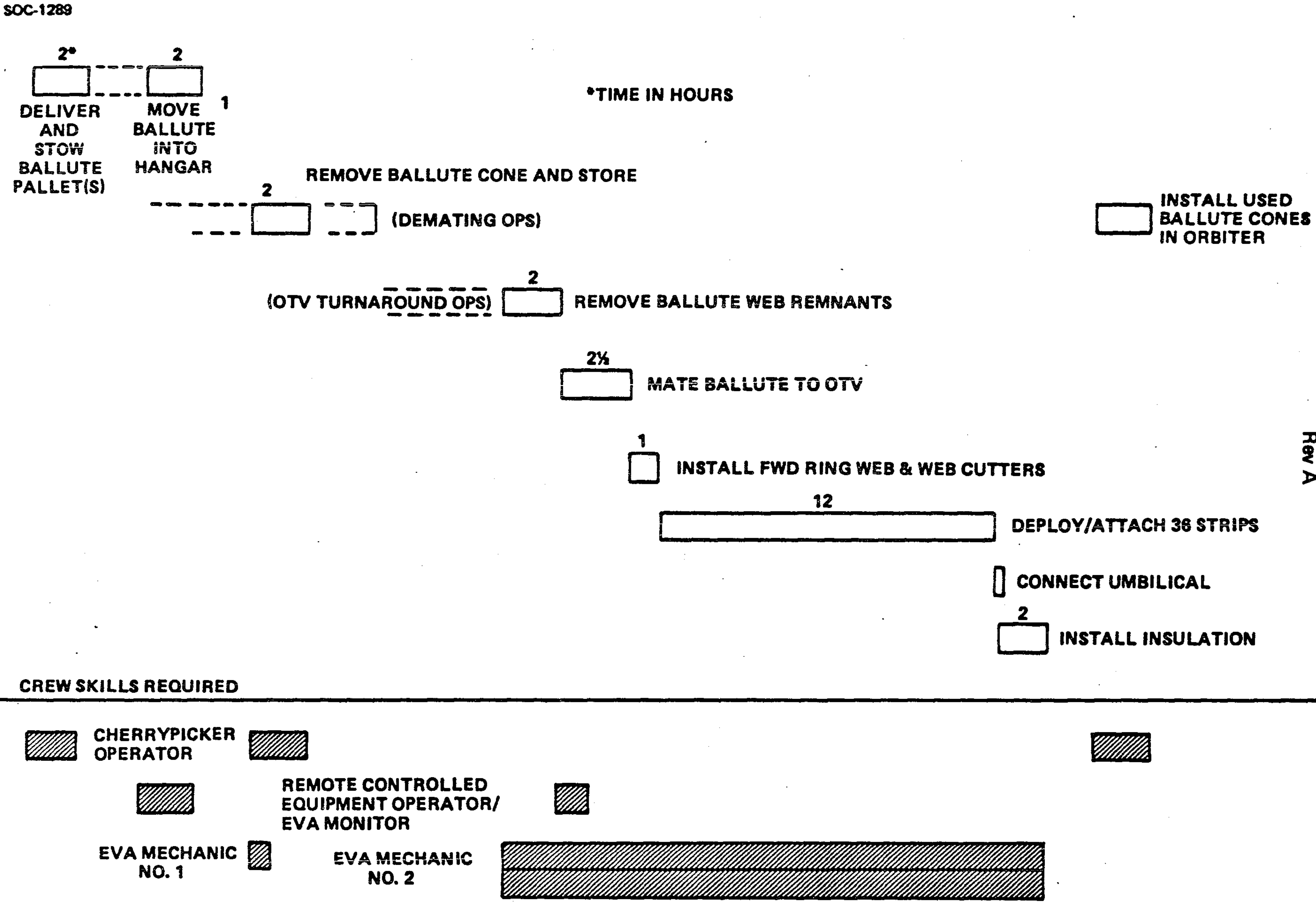


Figure II-31. Ballute Handling Operations Timeline and Crew Skills Requirements

TABLE II-6

BALLUTE OPERATIONS SUPPORT EQUIPMENT

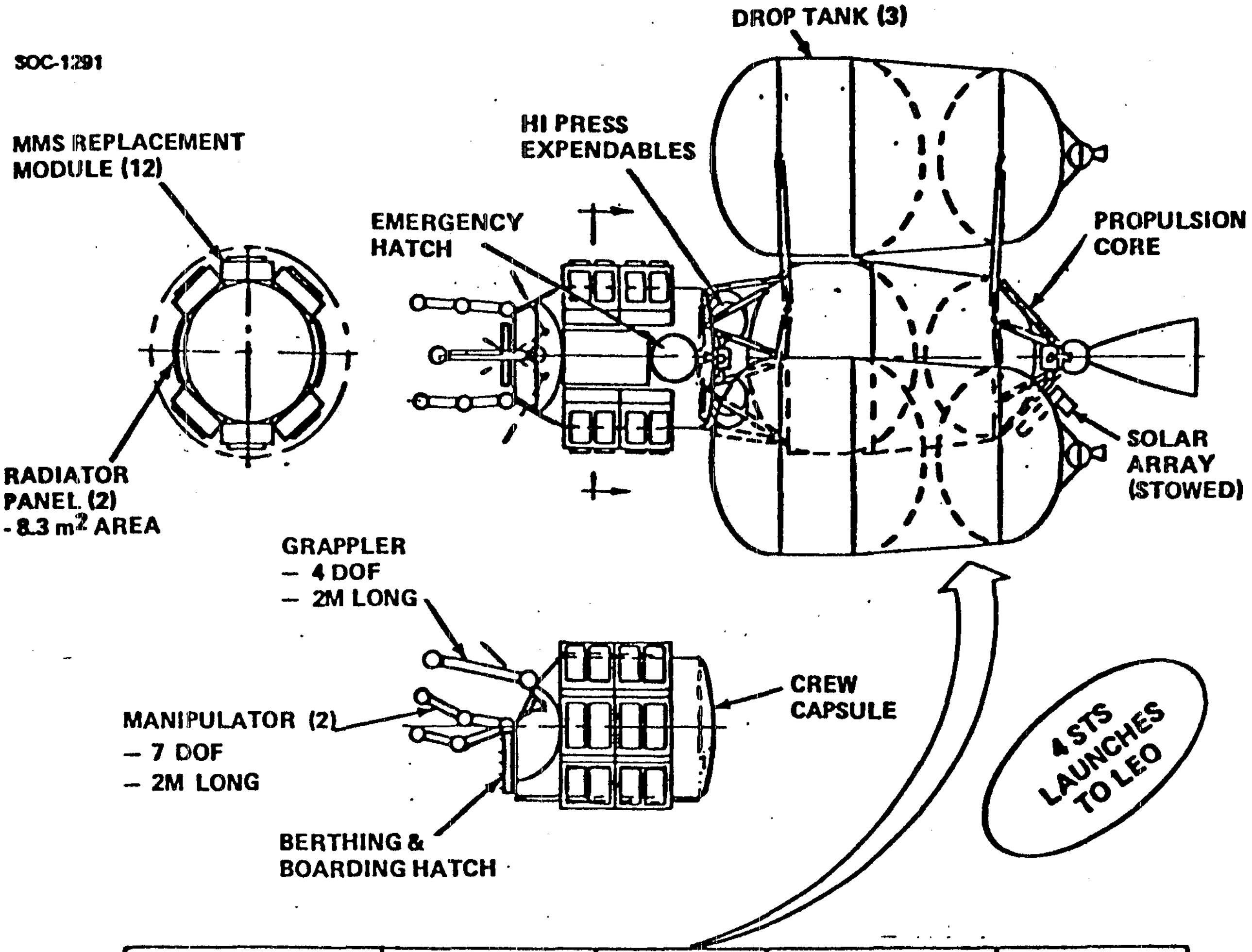
A

Dedicated Equipment

- Ballute Storage/shipping pallets
- Ballute transporter (also used for engine support)
- Ballute web fragment and bolt catcher disposal containers (to be used to return debris to the ground).

Multiple Use Equipment

- Mobile cherrypicker
- Type B payload handling tool
- Portable EVA workstation
- EVA handtools
- Movable EVA workstands
- Portable EVA lights
- Transporter remote control system
- Engine bell tilt remote control



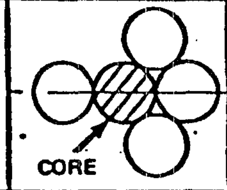
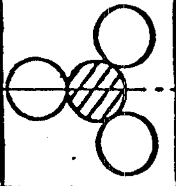
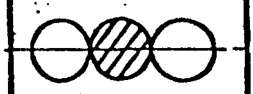
MULTIPLE CLUSTER TANKS				
NO. TANKS:	4	3	2	1
ENGINE MAX GIMBAL:	±10°	0°	0°	±20°

Figure II-32. 1½-Stage MOTV Configuration Concept

Figure II-33 shows the capsule layout.** The crew capsule is sized for the basic crew of three who may be male and/or female. The total internal volume is 25 cubic meters: this provides 13 cubic meters of unrestricted free volume - a little more generous than the requirements demand - plus room for subsystems, lines runs, and internal structure.

Dedicated mission equipment (cargo) is located external to the capsule. In one example, the cargo is Multi-Mission Subsystem modules carried on standard mounting rails on the cylindrical shell as shown in Fig. II-33. Also shown in that figure is General Purpose Mission Equipments. An external grappler to berth the MOTV to the workpiece satellite is mounted to the forward end of the capsule. This grappler can also move the MOTV relative to the satellite to improve the operator's view and to locate the satellite in the work envelope of the pair of manipulators. These dexterous manipulators have 7 degrees of freedom and are a bilateral force relecting type that are presently being investigated in MRWS studies. The manipulators are operated from within the crew capsule by a master/slave system.

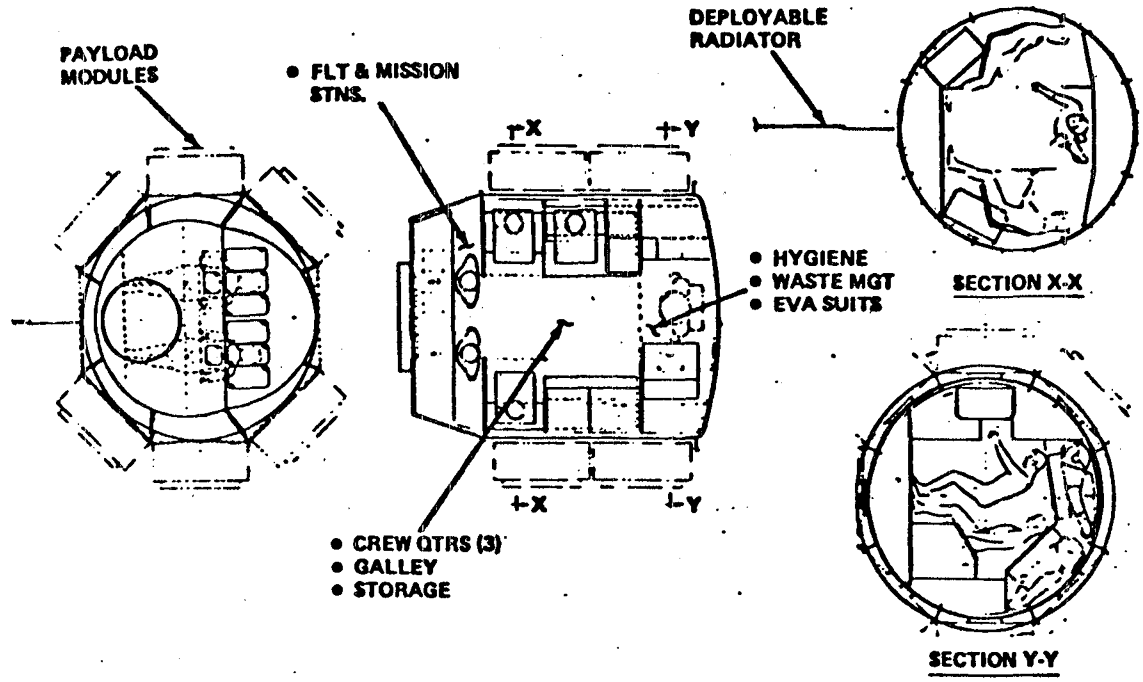
Drop-Tank Handling Operations

The unique operations associated with the 1½-stage OTV concept are those associated with the assembly of the drop tanks to the core propulsion stage/crew module.

The 0, 1, and 2 drop tank configurations could be assembled on the track system as is baselined for the other OTV concepts (refer to function 3.2.6).

For the 1½-stage OTV concept where three or four drop tanks were required, it was found that there was no practical way of assembling the vehicle while the core propulsion stage/crew module were mounted on a transporter on the track system. If these OTV configurations were required, then it will be necessary to add another

SOC-1290



1776-198W

Figure II-33. Crew Module Configuration Concept

A

Docking Tunnel (WBS 1.2.2.3) to the SOC configuration, as shown in Figure II-34, in order that these vehicle configurations can be assembled. The mobile cherrypicker will easily be able to maneuver all three or four drop tanks into their mating locations on the propulsion stage.

The drop tank handling operations scenario would proceed as described below (refer to Figure II-12 for the overall functional flow):

1. The drop tank(s) will be delivered to the SOC either loaded with propellants (per the Grumman concept) or they would be empty (function 3.2.3.1A). It will be assumed that the tanks will not be stored at the SOC for very long thus alleviating the need to place them in a protective hangar. The one to four drop tanks could be stored on cradles in the Storage Facility or they would be parked on cradles or transporters located on the pier (function 3.2.3.2A).

2A. <u>0, 1, or 2 Drop Tank Vehicle</u> - The crew module and the propulsion core stage are driven out of the hangars onto the pier where they are mated. The drop tank(s) will then be mated to the propulsion core stage using the mobile cherrypicker (function 3.2.6).

2B. <u>3 or 4 Drop Tank Vehicle</u> - The crew module and propulsion core stage are driven out of their hangars and are mated as described for function 3.2.6. The combined crew module/propulsion core is then picked up by the mobile cherrypicker and berthed to the new Docking Tunnel. The 3 or 4 drop tanks are then mated to the propulsion core as shown in Figure II-34.

3. The OTV propulsion stage (and the drop tanks, in one option) would be fueled after the vehicle stages are assembled (function 3.2.7).

Figure II-35 shows the timeline for these operations and the applicable crew skills.

Table II-7 lists the drop tank handling equipment.

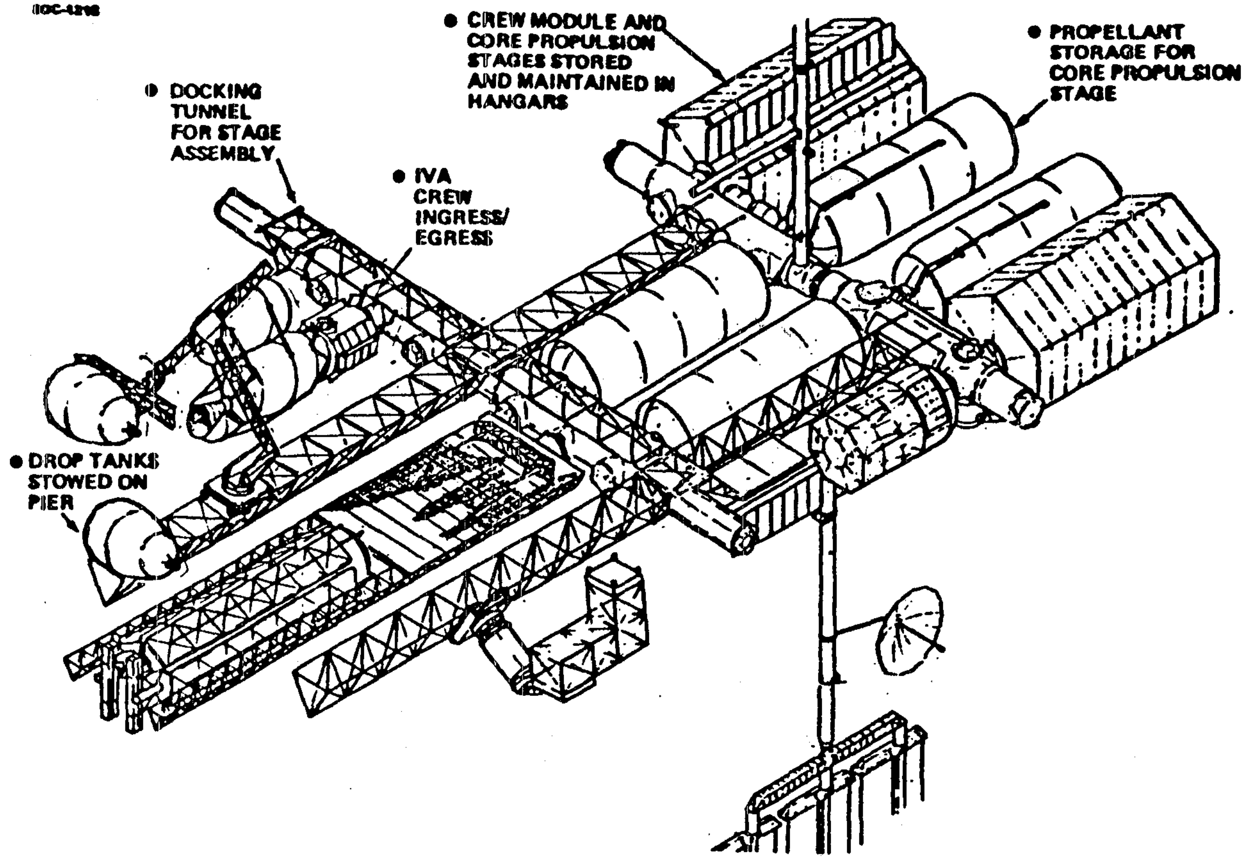


Figure II-34. 1½-Stage MOTV Facilities

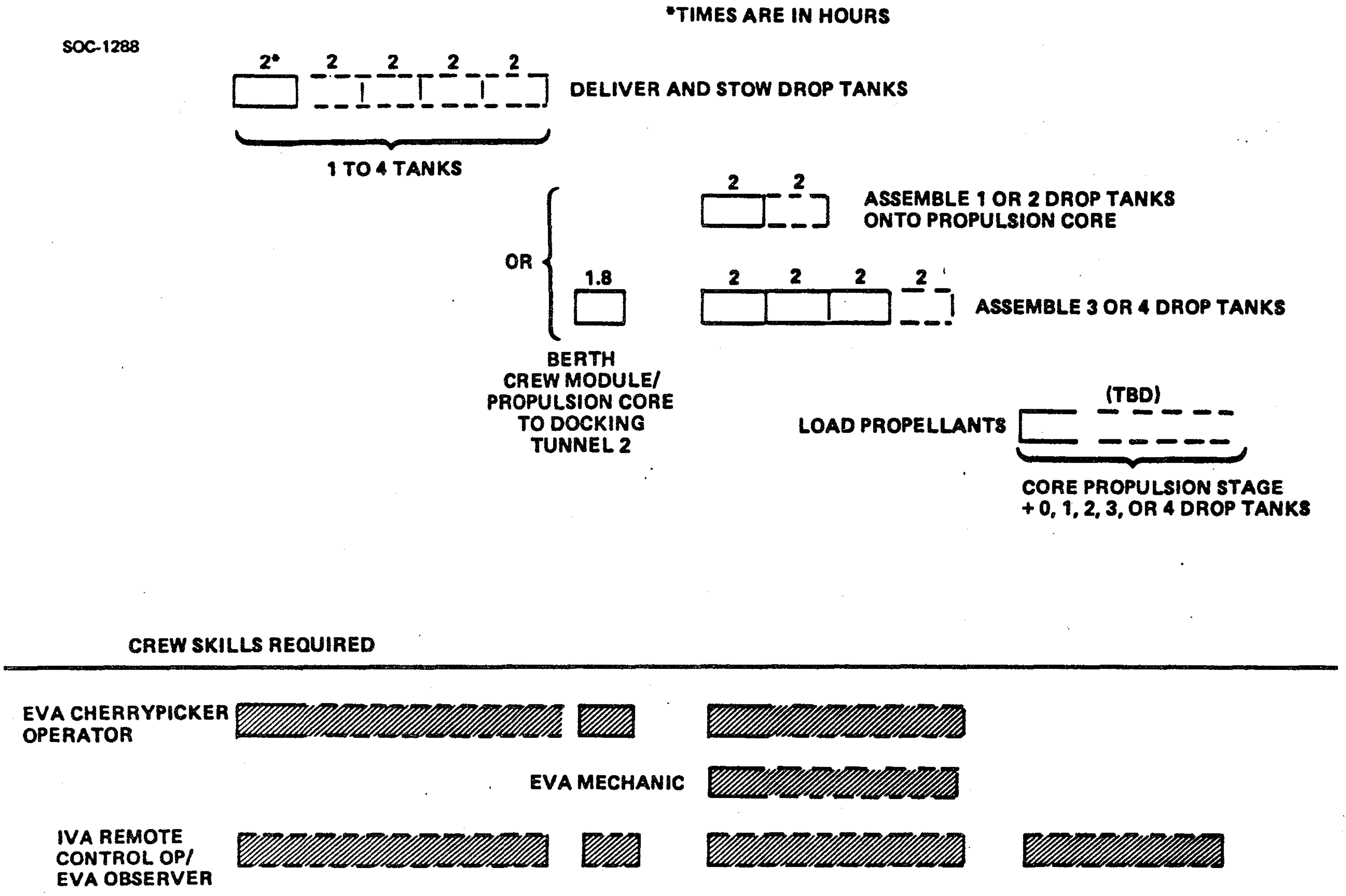


Figure II-35. Drop-Tank Handling Operations Timeline and Crew Skills Requirements

TABLE II-7

DROP TANK OPERATIONS SUPPORT EQUIPMENT

A

Dedicated Equipment

- Propellant delivery umbilical on Docking Tunnel 2

Multiple Use Equipment

- Storage facility or drop tank cradles on pier
- Mobile cherrypicker
- Type B payload handling tool
- Portable EVA workstation
- EVA handtools

2-STAGE OTV OPERATIONS ANALYSIS

A

2-Stage OTV Configuration

The 2-stage OTV configuration concept is shown in Figure II-36. The interstage configuration was created by SOC designers as there was no published concept.

Interstage Handling Operations

The unique operations associated with the 2-stage OTV concept are those associated with mating the interstage to the two OTV stages. Figure II-37 illustrates the mating concept.

The interstage handling operations scenario would proceed as described below (refer to Figure II-12 for the overall functional flow):

1. The OTV interstage is stored on its transporter on the track network (function 3.2.5.1). Between missions, the interstage would probably have to be occasionally moved around to keep it out of the way of other operations.

2. After the second-stage OTV is mated to its payload, the interstage is transported into its mating position at the aft end of the OTV (function 3.2.6). This is done by remote control from the SOC command center.

3. The forward end of the interstage is connected to the aft end of the OTV via explosive bolts. The cherrypicker operator (and/or an EVA mechanic on a portable workstand) would make the attachments.

4. The first-stage OTV is then transported into position behind the interstage and is then driven into a soft berthing with the interstage (function 3.2.6). These operations are remote controlled from the command center and are under close observation by the cherrypicker operator.

5. The interstage remains attached to the first-stage OTV after the inflight first-stage separation (the separation plane being the forward end of the interstage). After the first-stage OTV returns to the SOC and is captured

SOC-1288

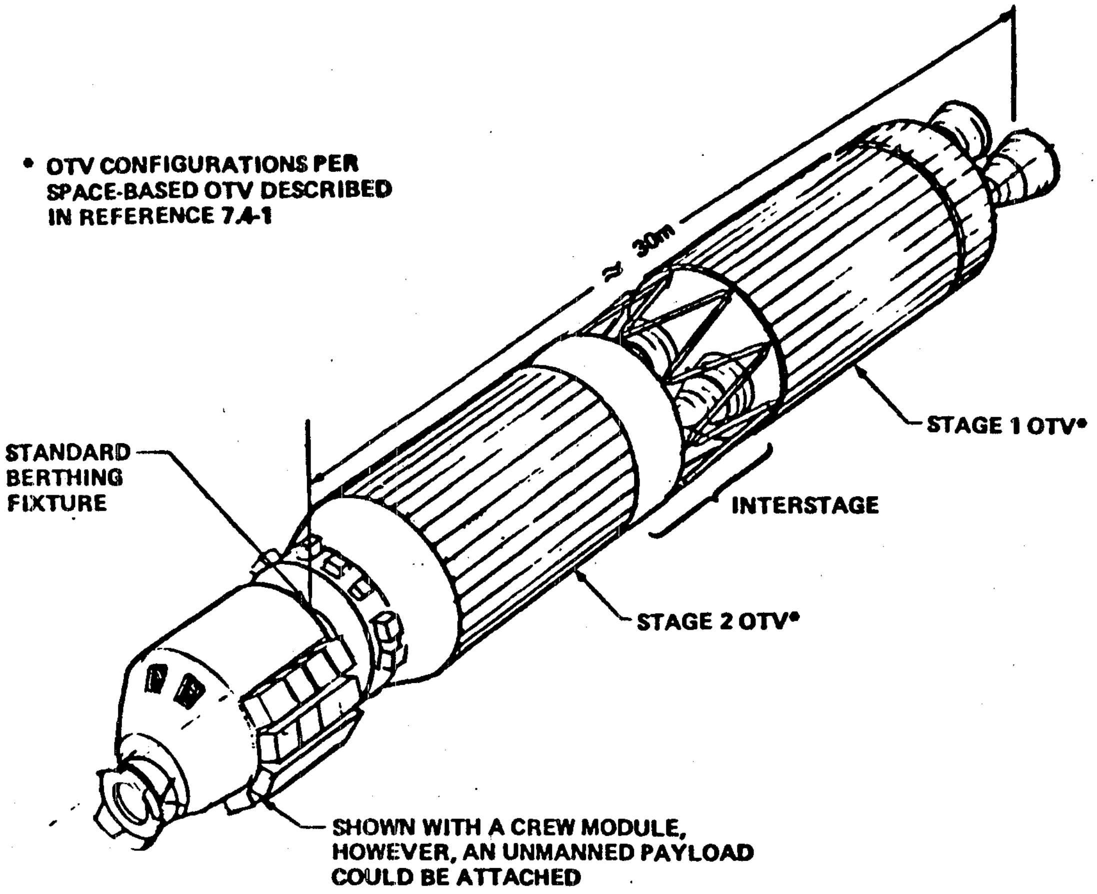
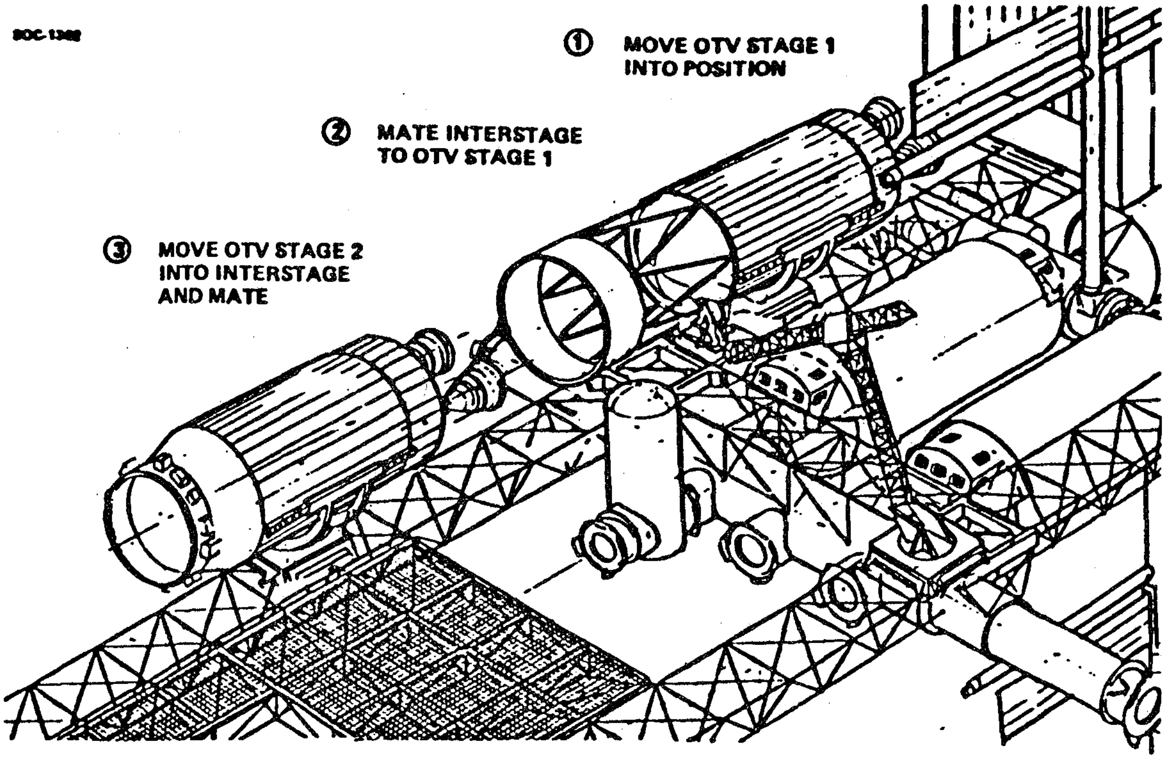


Figure II-36. 2-Stage OTV



① MOVE OTV STAGE 1 INTO POSITION

② MATE INTERSTAGE TO OTV STAGE 1

③ MOVE OTV STAGE 2 INTO INTERSTAGE AND MATE

Figure II-37. 2-Stage OTV Assembly

and placed on a transporter (function 3.2.11), the interstage can be deberthed (function 3.2.12) and placed onto its transporter using the cherrypicker.

The timeline for these operations is shown in Figure II-38 along with the crew skills requirements.

The support equipment list is given in Table II-8.

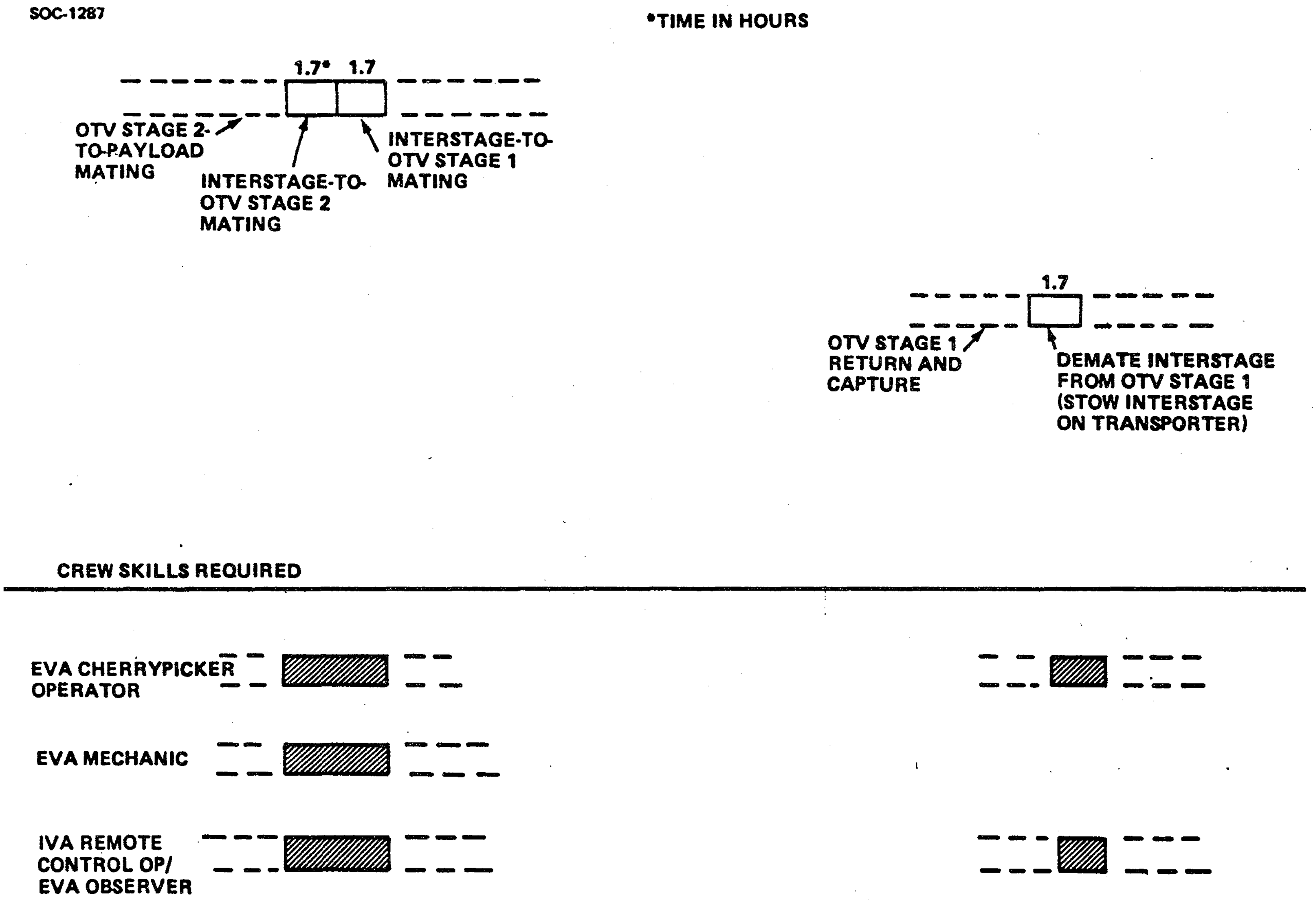


Figure II-38. Interstage Handling Operations Timeline and Crew Skills Requirements

TABLE II-8

INTERSTAGE OPERATIONS SUPPORT EQUIPMENT A

Dedicated Equipment

(None)

Multiple Use Equipment

- Mobile cherrypicker
- Type B payload handling tool
- Portable EVA workstation
- EVA handtools

SOC/SDV OPERATIONAL INTERFACES

A

Shroud Configurations

The basic configurations for the Boeing and Martin SDV's are shown in Figures II-39 and II-40 respectively. The Boeing design has the shroud split apart and fall away from the SDV at an altitude of approximately 57 miles. The Martin design has a single piece shroud which separates from the strongback at approximately the same place in the launch sequence as the Boeing design.

In both cases the shroud does not achieve orbital velocity and therefore is not a consideration in SOC operations.

Payload Configurations

There are several payload stowing configurations. The Martin design appears to use shuttle-type side attach points to stow payloads on the strongback, see Figure II-41. The Boeing design primarily uses aft attach points to stow the payload on the kickstage. Multiple payloads would be mounted side-by-side in a larger diameter shroud. However, a truss can be attached to the kickstage to provide a strongback for shuttle-type payload attaching, see Figure II-42.

Propulsion/Avionics (P/A) Module Configurations

Both designs incorporate P/A modules which should be returned to Earth. The Martin design shows a P/A module which can return to Earth on its own power — retrofire, enter the atmosphere, and deploy its own parachutes to softland.

The Boeing design employs a "kickstage" which can only be returned in the Orbiter payload bay.

Launch Sequence

The flight events for each design are shown in Figures II-41 and II-42. It can be seen from these figures that no operational interface will be required with SOC for separation and disposal of the SRB's, the shroud, or the external tank/core stage.

SOC-1368

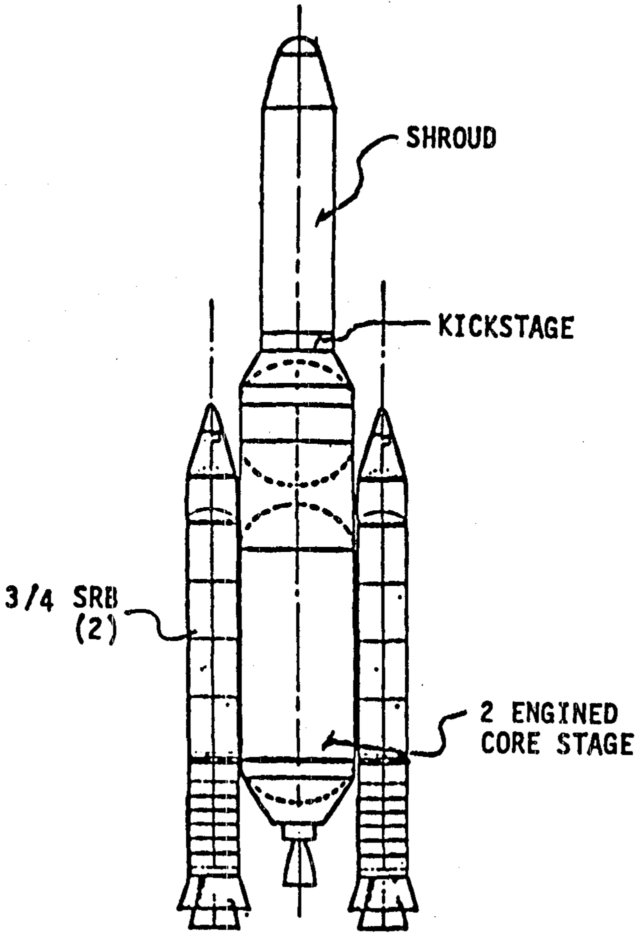


Figure II-39. Boeing SDV Concept

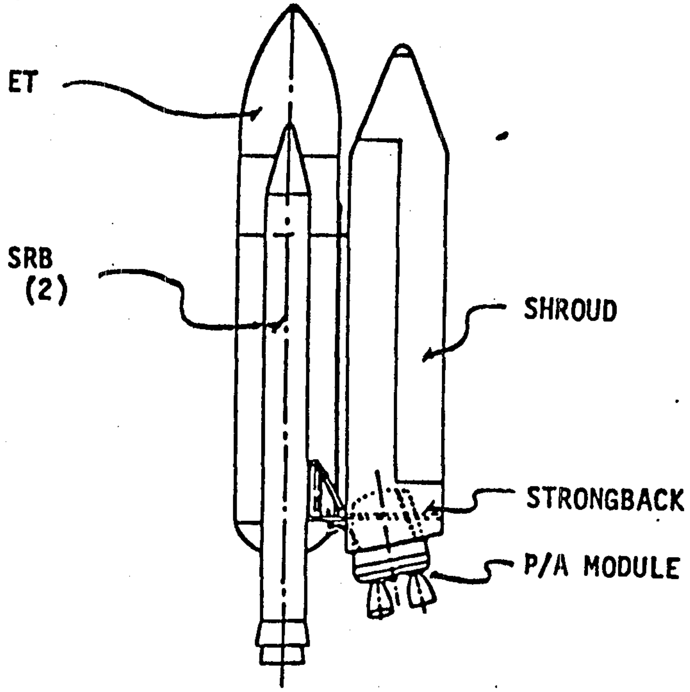


Figure II-40. Martin SDV Concept

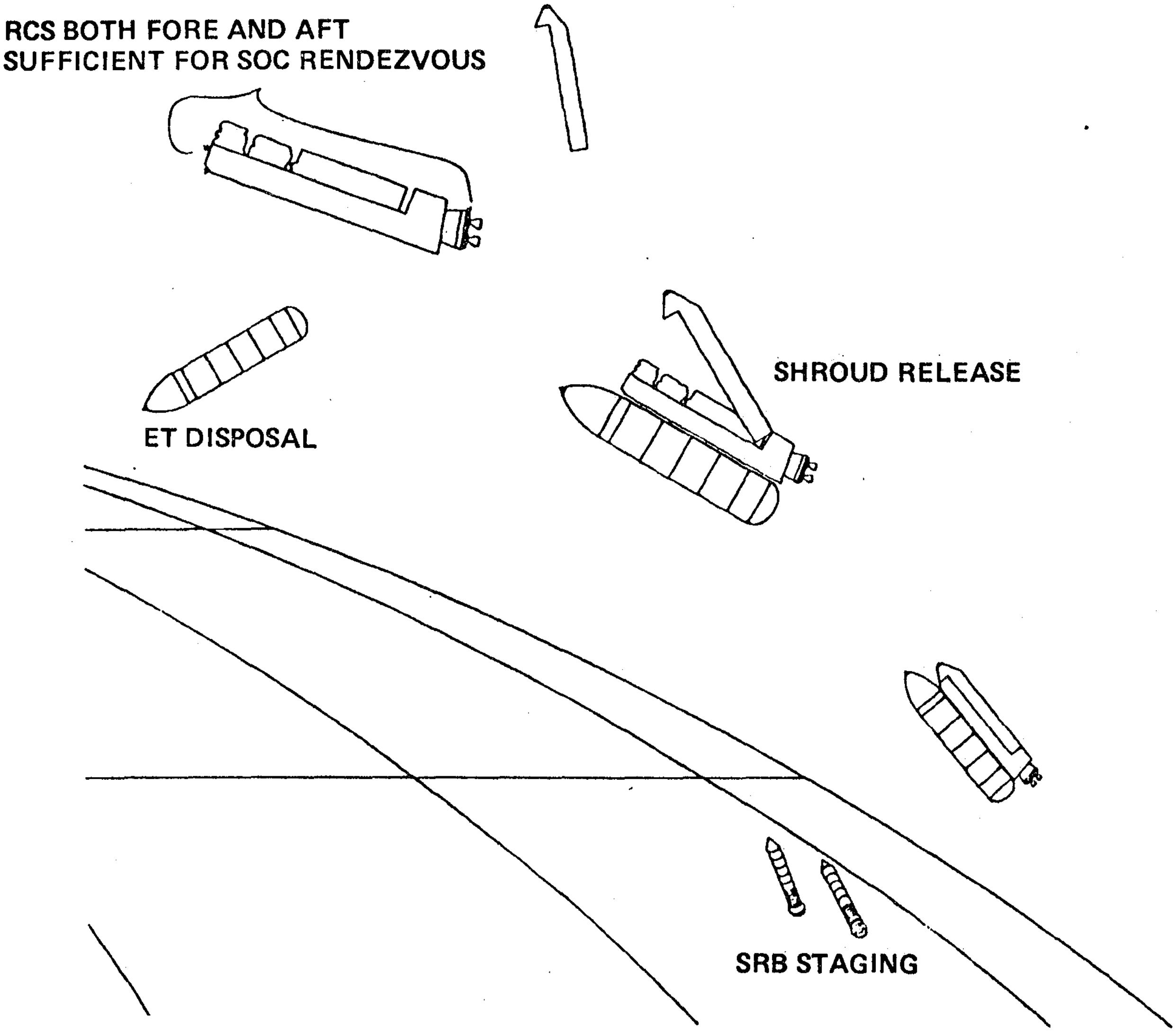


Figure II-41
SDV Flight Events
Martin SDV Concept

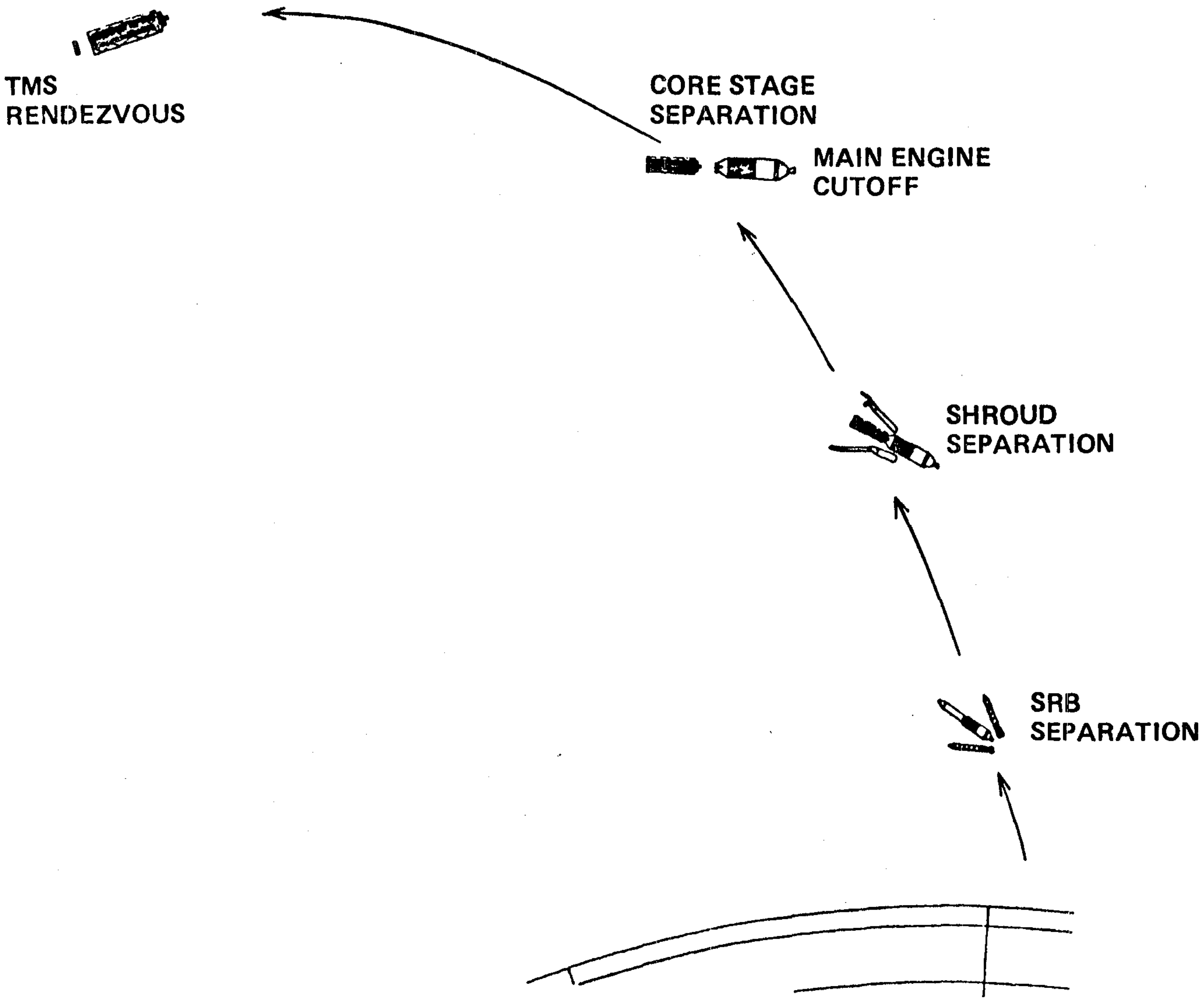


Figure II-42
SDV Flight Events
Boeing SDV Concept

After the SDV achieves orbit it must stationkeep some distance from the SOC. At this point SOC crewmembers will take over operational control for rendezvous and berthing.

SOC Rendezvous and Berthing

The Martin SDV appears to have an adequate reaction control system to enable it to directly rendezvous with the SOC within reach of the mobile cherrypicker. Provision has been made to locate RCS engines both fore and aft of the payload which would give it sufficient control authority to safely rendezvous.

The Boeing SDV has reaction control only in the aft-located "kickstage" P/A module. In order to provide sufficient control authority a TMS must be attached to the front of the payload or supporting truss as shown in Figure II-~~42~~43. This assembly would then rendezvous with the SOC within reach of the mobile cherrypicker.

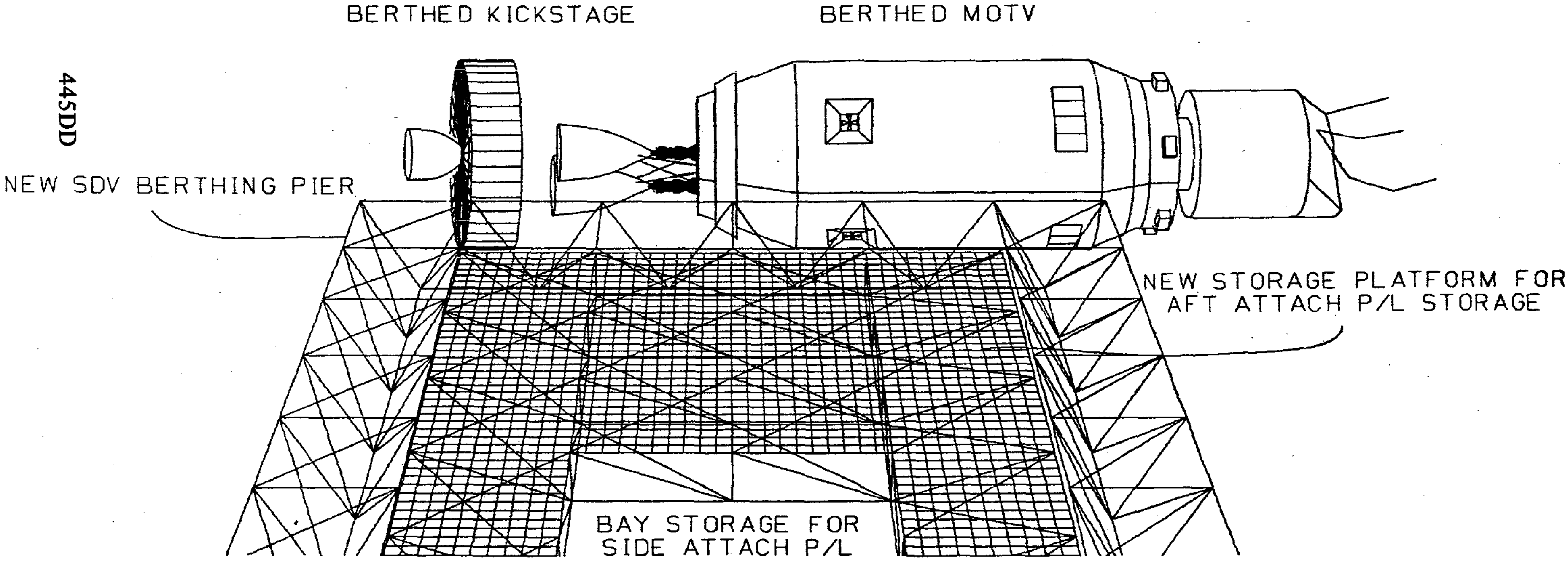
Berthing operations will be accomplished using the mobile cherrypicker. For assemblies where the payload is attached to a strongback or truss the entire truss will be secured to the berthing pier along with the P/A module. For assemblies where the payload is fastened to the "kickstage" only through its aft attach points, only the "kickstage" will be secured to the berthing pier as shown in Figure II-42.

Payload Handling & Storage

The payload handling operations for assemblies with a strongback or supporting truss will not require any special equipment or considerations, and will not be markedly different from the payload handling operations used with the Orbiter. Operations involving payloads with only aft attach points may require special considerations to avoid damaging sensitive surfaces. These considerations vary greatly depending on the specific payload.

The side attach payloads may be stored in the present storage area used for shuttle payloads. The aft-attach payloads may be stored and secured on a new grid platform erected adjacent to the new berthing pier as shown in Figure II-42.

FIGURE II-43



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Propulsion/Avionics Module Operations

The Martin design incorporates a P/A module which can control its descent from orbit. The SOC crewmembers must position the module some distance from the SOC so it may retrofire without concern of plume damage. This positioning operation is the only action the crew members need perform.

The Boeing design incorporates a "kickstage" which must be loaded into the Orbiter cargo bay in similar fashion to any returning payload.

7.3.3.5 Strongback/Structural Truss Operations

After removing payloads from the supporting structure, the strongback or truss may be disposed of by attaching a TMS to it, and injecting the structure into a rapidly decaying orbital track. It may be determined that some elements of the structure are worth the effort needed to "scaven" and store them at SOC.

Facility and Support Equipment Requirements

A new berthing pier would be needed for SDV operations as shown in Figure II-42. This pier position minimizes collision risk with the standard V-bar approach trajectory. The pier is located at the end of the flight support area, and includes cherrypicker access for SDV payload handling operations. This berthing facility must accommodate one or the other of the two types of SDV's studied; the one shown in Figure II-42 without a strongback whose only hard attach point is on the kickstage or an SDV with a strongback and hard attach points which span the length.

A separate storage area must be erected in order to accommodate payloads which have aft attach points (instead of shuttle-type side points). This truss and grid construction can be seen in Figure II-42 adjacent to the SDV berthing pier.

BLOCK NO. 4.0 - CONDUCT CONSTRUCTION OPERATIONS

A spacecraft construction mission encompasses the following major activities: 1) spacecraft design/mission planning, 2) spacecraft element fabrication/testing, 3) construction support equipment design/fabrication/testing, 4) construction crew training, 5) transportation operations, 6) SOC pre-construction preparation, 7) spacecraft construction, 8) spacecraft deployment, and 9) post-construction operations. Each of these activities are briefly described below.

(1) Spacecraft Design/Mission Planning

The SOC Program Office shall prepare, maintain, and distribute appropriate SOC user's documentation. In the earliest stages of spacecraft mission planning, it will be imperative that the SOC Program Office be included in the discussions to ascertain if and how the SOC should be used for construction, flight support, or satellite servicing. If a construction role is defined, then a SOC specialist would be assigned to the spacecraft design and mission plannning team. The SOC specialist will be responsible for reviewing all of the SOC-related operations and will participate in the spacecraft design reviews. This SOC specialist will analyze, define, or monitor the other 8 major activities to be discussed below.

(2) Spacecraft Element Fabrication/Testing

The supervision of these activities will be the responsibility of the spacecraft program office. SOC specialists will be assigned to monitor these activities to provide feedback to the other SOC planning functions.

(3) Construction Support Equipment Design/Fabrication/Testing

Each spacecraft construction project will require the use of general purpose SOC construction support equipment (manipulators, tools, test equipment, etc.). The SOC specialists responsibile for SOC construction support equipment will be responsible for planning the use of this equipment. If the general purpose equipment cannot provide all of the necessary functions, then the spacecraft design group will draw up the specifications for dedicated support equipment. The SOC specialists will then monitor the design, fabrication, and testing of these new items and will arrange for transporting the equipment to SOC, installing the equipment, and training the crew in its use.

(4) Construction Crew Training

As the spacecraft fabrication and testing nears completion, SOC crew planners will define the scheduling of the construction operations. The specific SOC crewmembers who will be scheduled for a tour of duty during the construction operations will be identified. These crewmembers, and their backups, will be trained for the construction operations involved for the spacecraft. A SOC ground training facility will be equipped with the new, dedicated support equipment as well as the general purpose equipment. The construction operation will be simulated and the crew trained.

(5) Transportation Operations

Transportation of spacecraft elements and construction support equipment will be planned and executed by the Shuttle Transportation System Office in conjunction with the spacecraft program office. SOC specialists will be included in the planning to coordinate SOC-related interfaces.

(6) SOC Pre-Construction Preparation

Prior to spacecraft construction, it will be necessary to configure the SOC construction facility for the new project. New, dedicated support equipment will be installed and checked out. The dedicated support equipment may be delivered prior to the spacecraft elements, or may be included in the delivery of these elements. The general purpose support equipment will be made ready.

(7) Spacecraft Construction

Spacecraft elements will either be transferred directly from the orbiter cargo bay to the construction facility or the elements may be offloaded to a temporary storage area. IVA crewmen will operate some of the support equipment from the Command Center. EVA crewmen will perform hands-on construction tasks. The construction tasks will generally involve the use of the remote manipulator system with an open cherrypicker. Jigs, indexing fixtures, beam machine, hand tools, alignment instruments, electrical test equipment, fluid/gas transfer systems, etc., may be employed. In some cases, the orbiter's RMS may also be used to assist the construction. Construction will continue on a multishift schedule until the operations are completed. Spacecraft specialists on the ground will be in continuous contact during the assembly to monitor the operations and to give consultation. The spacecraft will be incrementally tested and inspected culminating in integrated systems tests after final assembly is completed. Figures II-25 thru II-28 illustrate some of the typical construction operations conducted from the Operational SOC Configuration. Additional construction concepts are found in Boeing -8, -10, -13, -14, -15, -20, and -21.

(8) Spacecraft Deployment

After final test and checkout, the spacecraft is either attached to a transfer vehicle (an OTV or teleoperator) or it is lifted off of the construction facility and separated from the SOC using the SOC's RMS. The spacecraft is then moved away from the SOC and placed into its operational orbit. This transfer maneuver would either be controlled from the ground or from SOC.

(9) Post-Construction Operations

The dedicated support equipment is then dismantled and stored. This equipment may be returned to Earth or it may be retained at the SOC for reuse in some other construction mission. The general purpose support equipment will be repaired/maintained/refurbished and then stored.

SOC-605

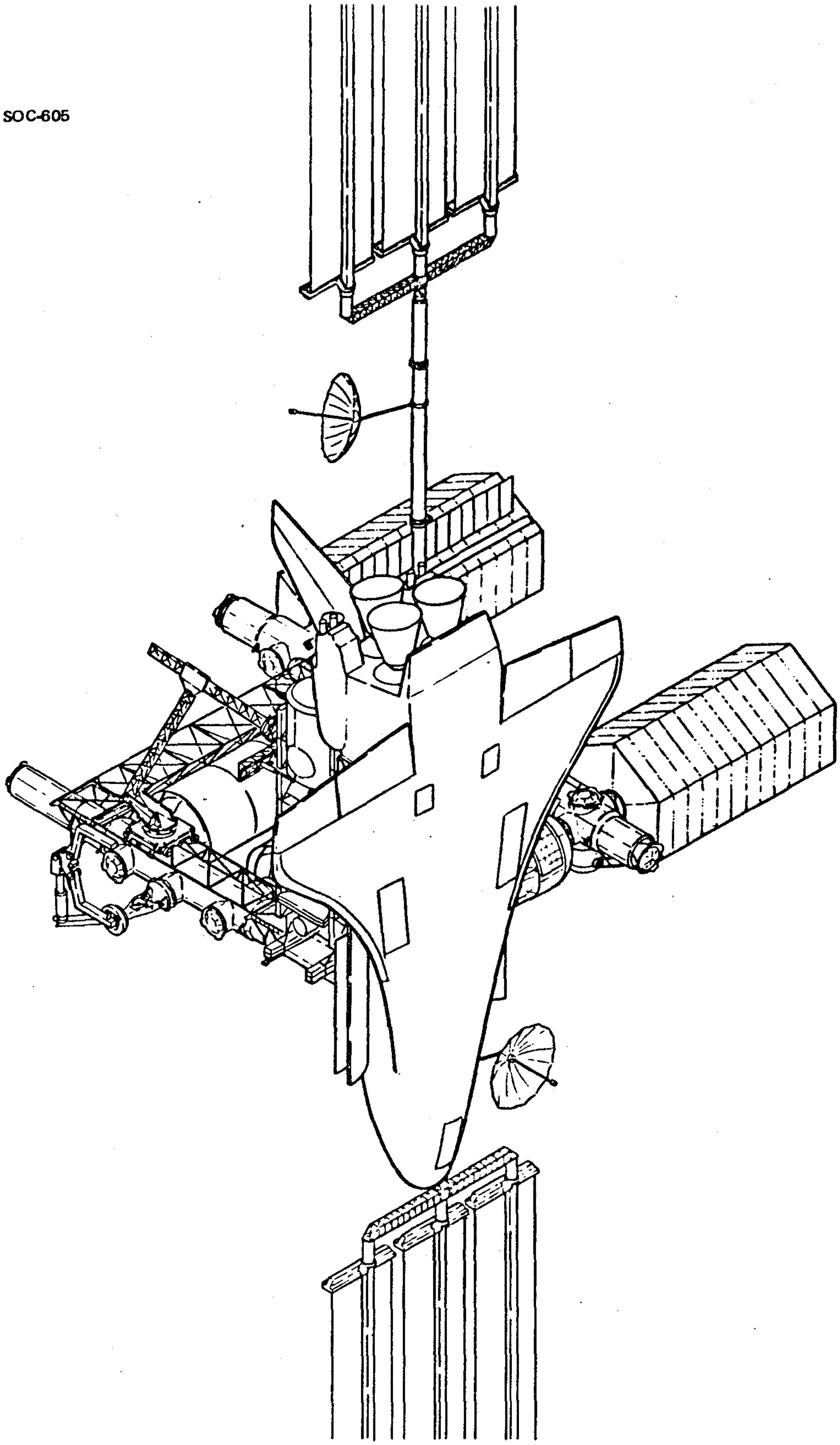


Figure II-25. The Spacecraft is Being Removed from the Orbiter Cargo Bay by the Mobile Cherrypicker. The Articulated Construction Fixture is Configured for Accepting this Spacecraft.

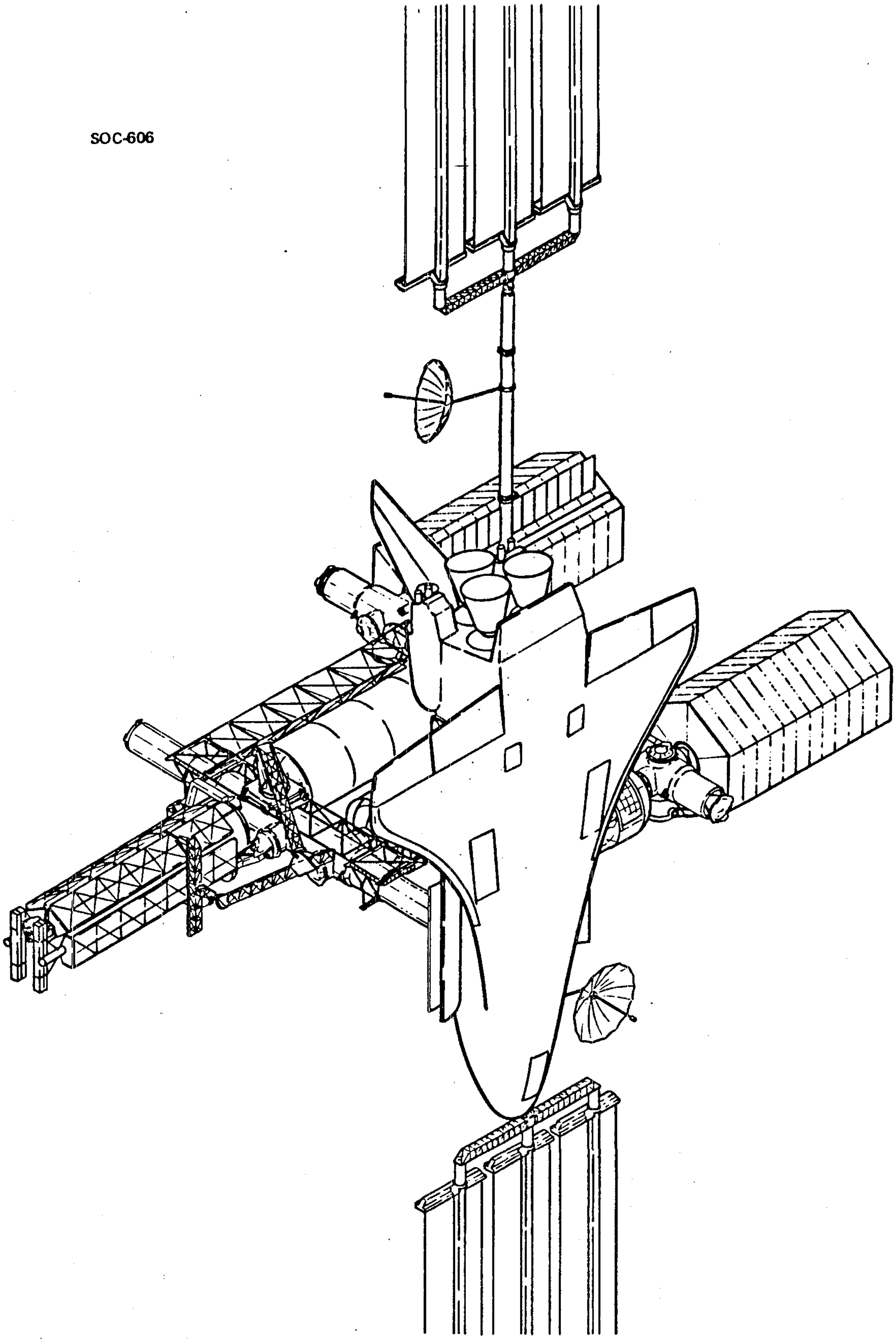


Figure II-26. The Spacecraft is Placed into the Articulated Construction Fixture.

SOC-607

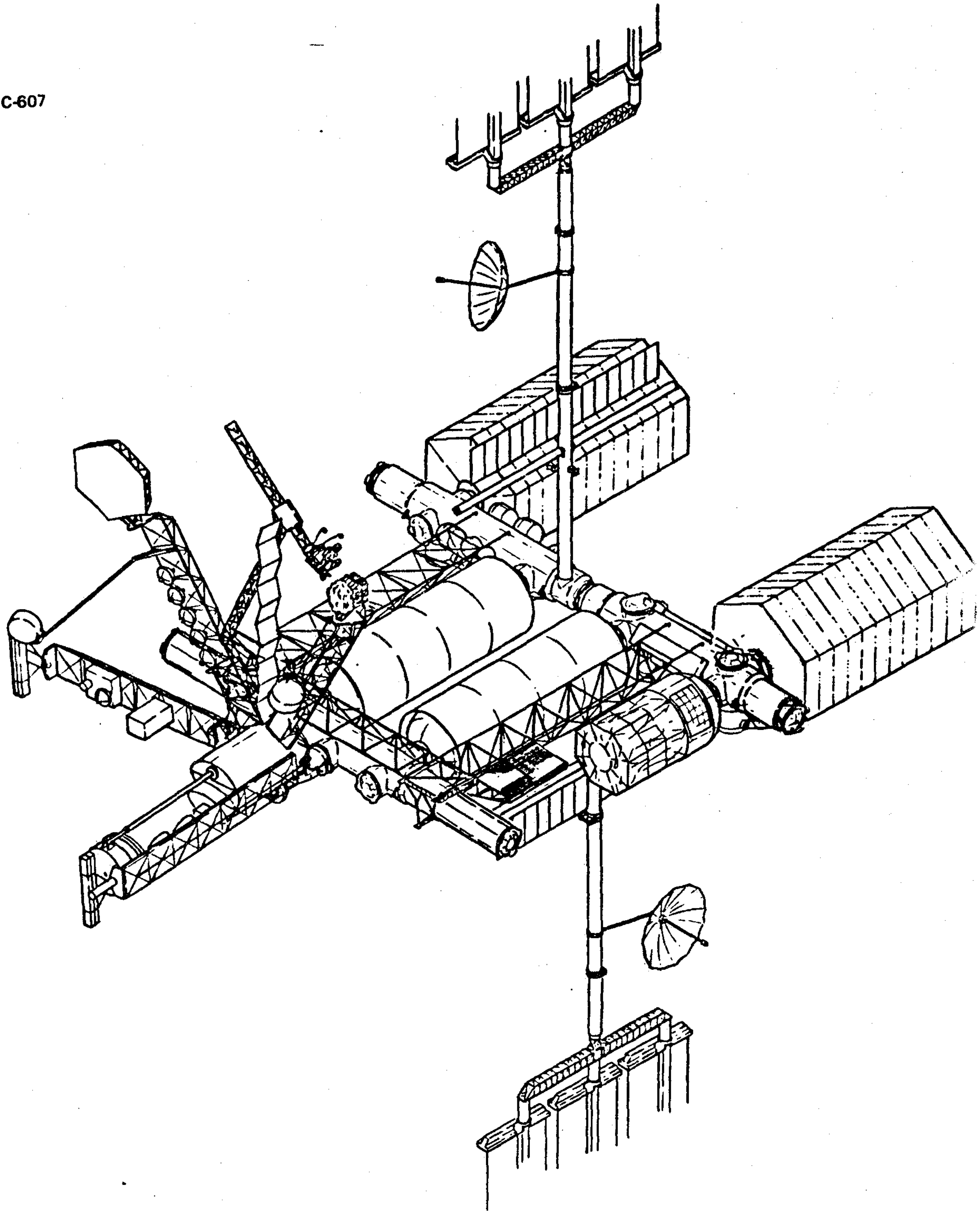
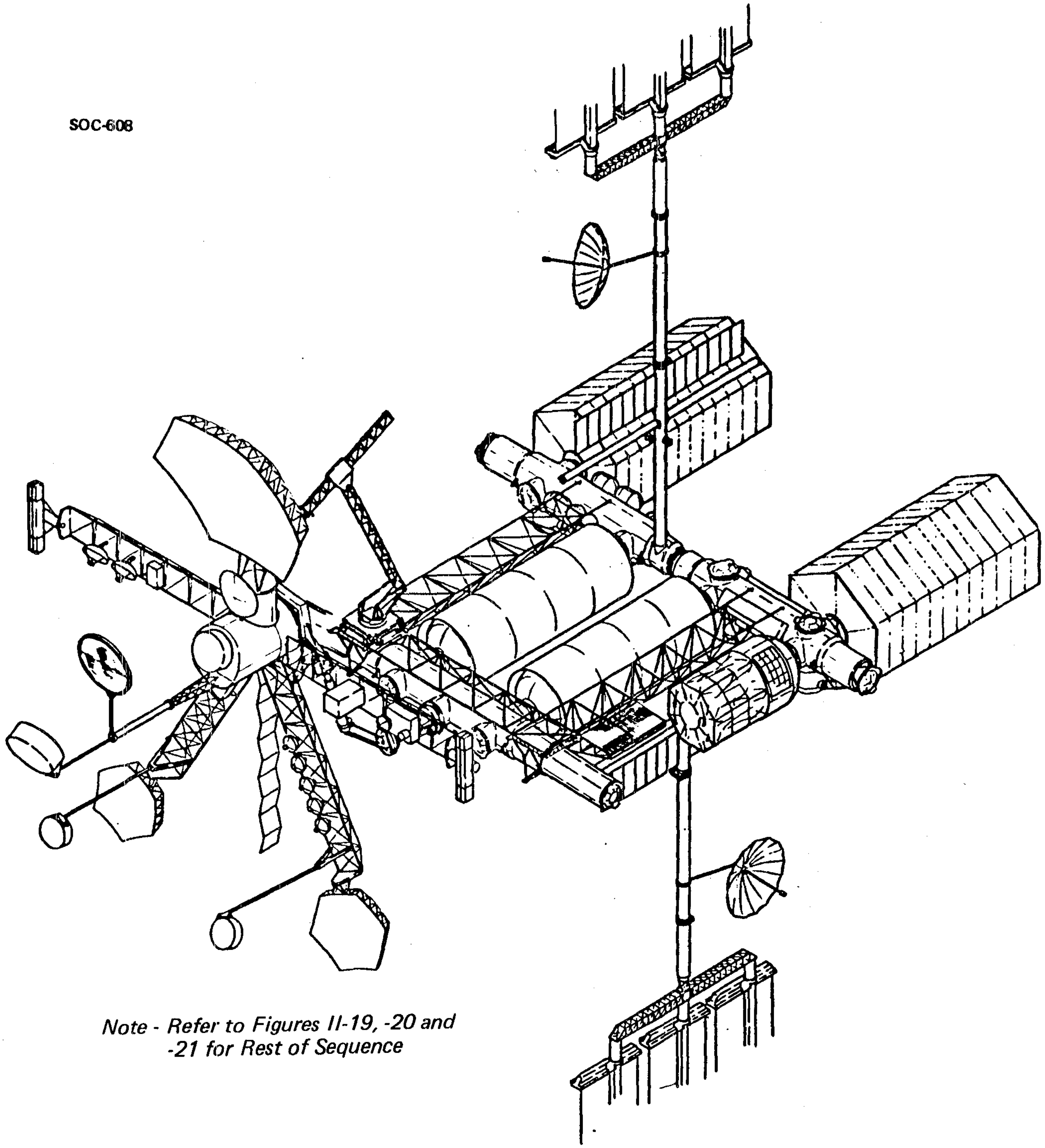


Figure II-27. The Mobile Cherrypicker Operator Deploys the Appendages.

SOC-608



Note - Refer to Figures II-19, -20 and -21 for Rest of Sequence

Figure II-28. The Articulated Construction Fixture Has Rolled The Spacecraft 180° To Orient The Spacecraft So That The Last Appendage Can Be Deployed. This Also Brings The Spacecraft Centerline Into Alignment Where The OTV Can Be Mated To The Aft End.

BLOCK NO. 5 SATELLITE SERVICING OPERATIONS

Satellite servicing covers the full mission cycle from initial check out and orbital deployment to subsequent in-orbit support and finally, removal of the spacecraft from orbit. In-orbit support includes examination, maintenance/repair of basic subsystems and mission peculiar equipment, resupply of consumables, and reconfiguration of experiments. End of mission retrieval and temporary on-orbit storage of satellites awaiting repair, earth return, or controlled re-entry disposal are also part of satellite servicing.

Satellite servicing operations are subdivided into two main categories, those that are accomplished on SOC and those that are conducted remotely from SOC, see Figure II-43. Modes of payload/satellite services at SOC are illustrated by Figure II-44. Most servicing operations will be performed at SOC. Remote in situ operations would be performed on LEO satellites that are too large to be brought to SOC or would impose prohibitive propulsion requirements to transport them to SOC. GEO satellites would also be serviced in situ. Remote satellites are serviced in the same way as those serviced on SOC.

5.1 SERVICING AT SOC

Figure II-43 shows the following modes of SOC satellite servicing at SOC:

- Payloads that are attached and operated on SOC
- On-orbit satellites without propulsion
- On-orbit satellites with propulsion
- Satellites that are prepared/assembled at SOC and launched for co-orbiting flight or transfer to another operating orbit.

5.1.1 SOC Attached Payloads

The item to be serviced is attached to the SOC. This would be the case for Spacelab-derived missions or instruments. The SOC would provide services such as power and communications in addition to crew

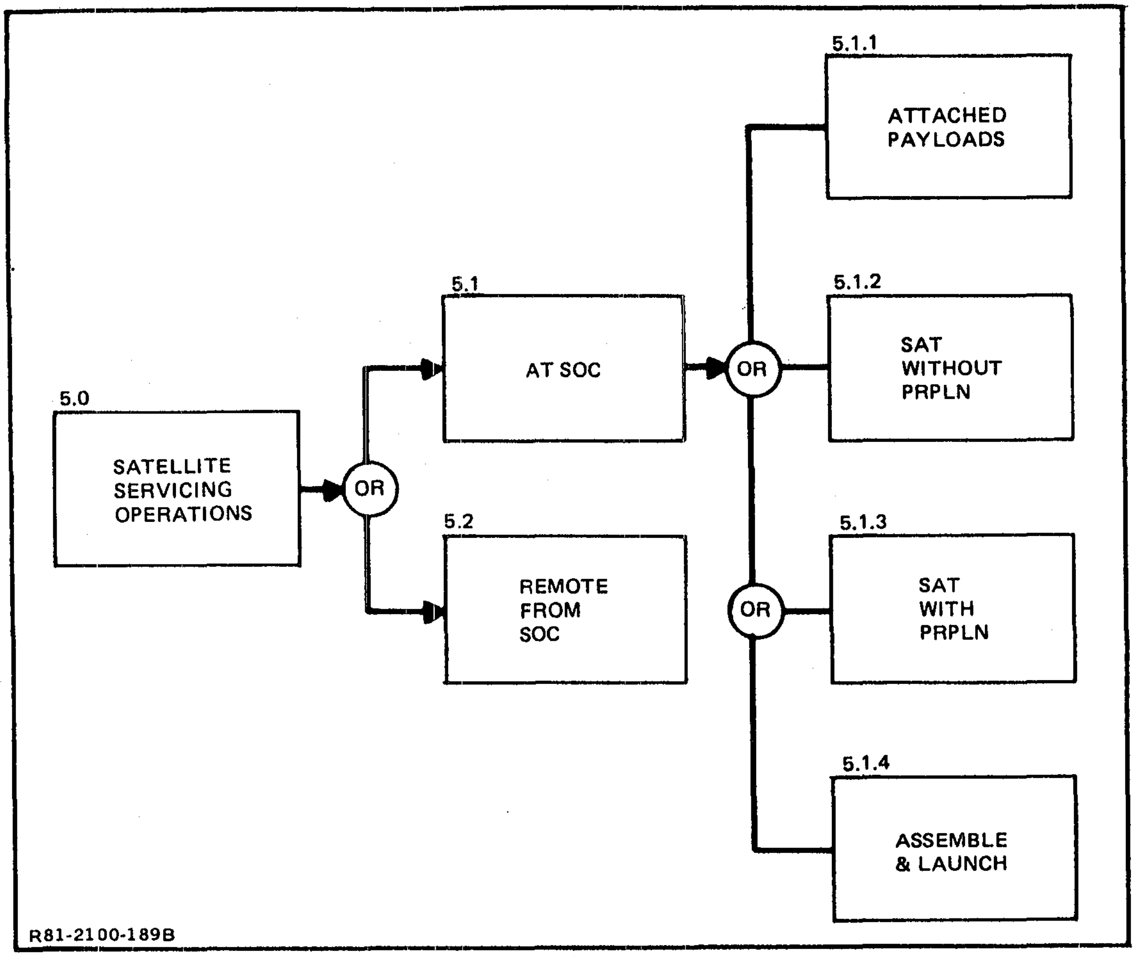


Fig. II-43 Satellite Servicing Operations

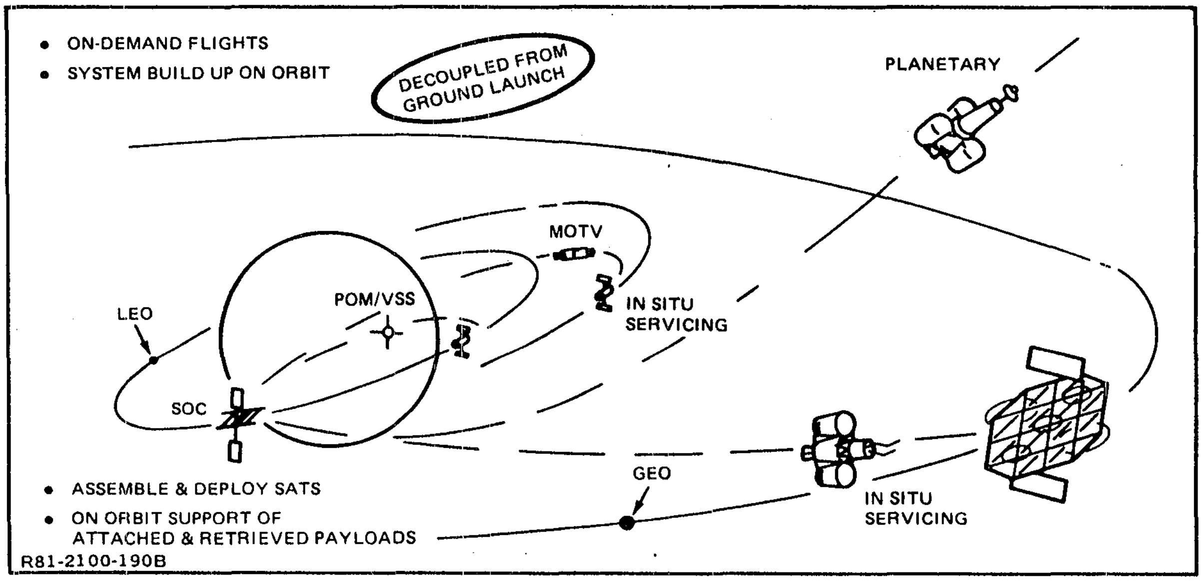


Fig. II-44 Satellite Service Modes

attention for maintenance or instrument changes. This mode of operations would "extend" certain Spacelab missions to arbitrarily long duration and could be quite beneficial in improving Shuttle fleet utilization by performing long-duration missions to avoid long on-orbit stay times by Shuttle.

SOC-based science missions will include life sciences and materials processing research. Materials processing research, as opposed to process development and prototyping, should be carried out onboard SOC because of the relatively short duration of most experiments, the need for crew involvement to avoid high automation costs for one-of-a-kind tests, and the benefits of crew participation in a research-oriented activity where dealing with the unexpected is much more likely than in development and prototyping.

These experiment programs will initially be carried out on a time and equipment available basis, but to reach full potential will probably require a dedicated mission module.

5.1.2 Satellites Without Propulsion

SOC Proximity Operated Satellites - Proximity operated spacecraft could be intentionally station-kept with the SOC. This would allow convenient access at frequent intervals. It could be the preferred operational mode for missions that require frequent service but are separated from the SOC to avoid contamination of the mission environment. A good example is a space processing facility that needs a high-purity zero-g environment. Certain optical instrument missions will also be best flow in this mode because of outgassing and similar contamination problems.

Satellite servicing missions in the early SOC years will deal with science and applications satellites in orbits easily accessed from SOC. In this period, a manned OTV for reaching more distant satellites will almost certainly not be available.

Remotely Operated Satellites - Satellites that are operated remotely from SOC and do not have orbit transfer capability, either due to propulsion fuel depletion or have no propulsion system, must be transported to SOC for service. In this case, the SOC will dispatch a vehicle such as the Proximity Operations Module, Versatile Service Stage, or Orbit Transfer Vehicle, depending on propulsion needs, to fetch the satellite. Figure II-45 contains the primary servicing functions. After the satellite is berthed to SOC, the propulsion stage requires servicing in addition to SOC meeting the needs of the satellite. The satellite could be repaired, resupplied, and reconfigured then checked out and returned to operational orbit.

Scientific satellites such as the Space Telescope, Long Duration Exposure Facility, Advanced X-Ray Astrophysics Facility, and materials processing free flyers are likely candidates.

For example, the AXAF will be deployed by Orbiter into a low earth orbit at low inclination. The scenario illustrated in Figure II-46 shows its retrieval by a Versatile Service Stage (VSS), which originates from SOC, rendezvous with AXAF and brings it to SOC for service. After service and check out, a VSS returns the satellite to its operational orbit.

The operations for servicing an AXAF at SOC starts with delivery of supplies by an Orbiter. These supplies are mounted on pallets which are transferred from a docked Orbiter, as shown in Fig. II-47. A Mobile Platform Manipulator berths the supplies pallet to a berthing port on the SOC docking module. The pallets for servicing and refueling the VSS and the POM are transferred to mountings on the extension pier. Both operations are controlled by an EVA crewman on the OCP.

AXAF is a free flyer with no transfer propulsion of its own. A SOC based propulsion stage is sent to dock to the satellite to bring it back for rendezvous with SOC. The propulsion stage in this scenario is a Versatile Service Stage (VSS) which is used for extended range retrieval. First, the Mobile Platform is moved along the tracks to the tip of the extension pier. Next, the Platform Manipulator is maneuvered to capture the VSS/AXAF. The manipulator then transfers

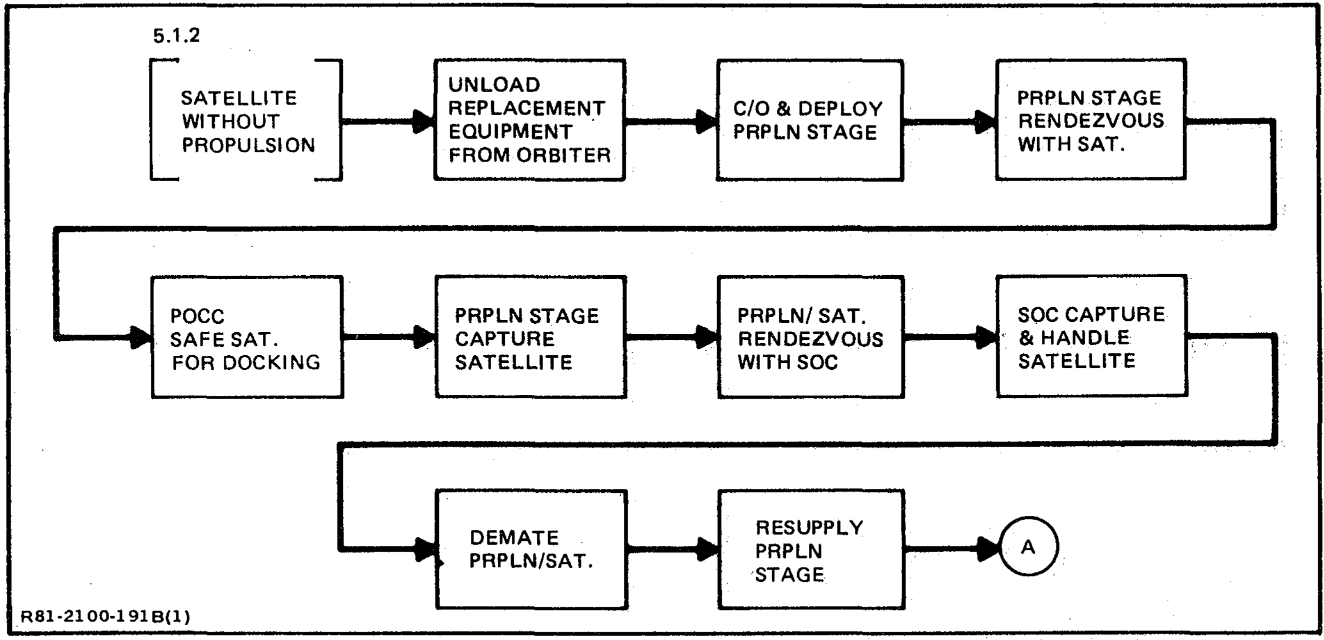


Fig. II-45 Satellites Without Propulsion (Sheet 1 of 2)

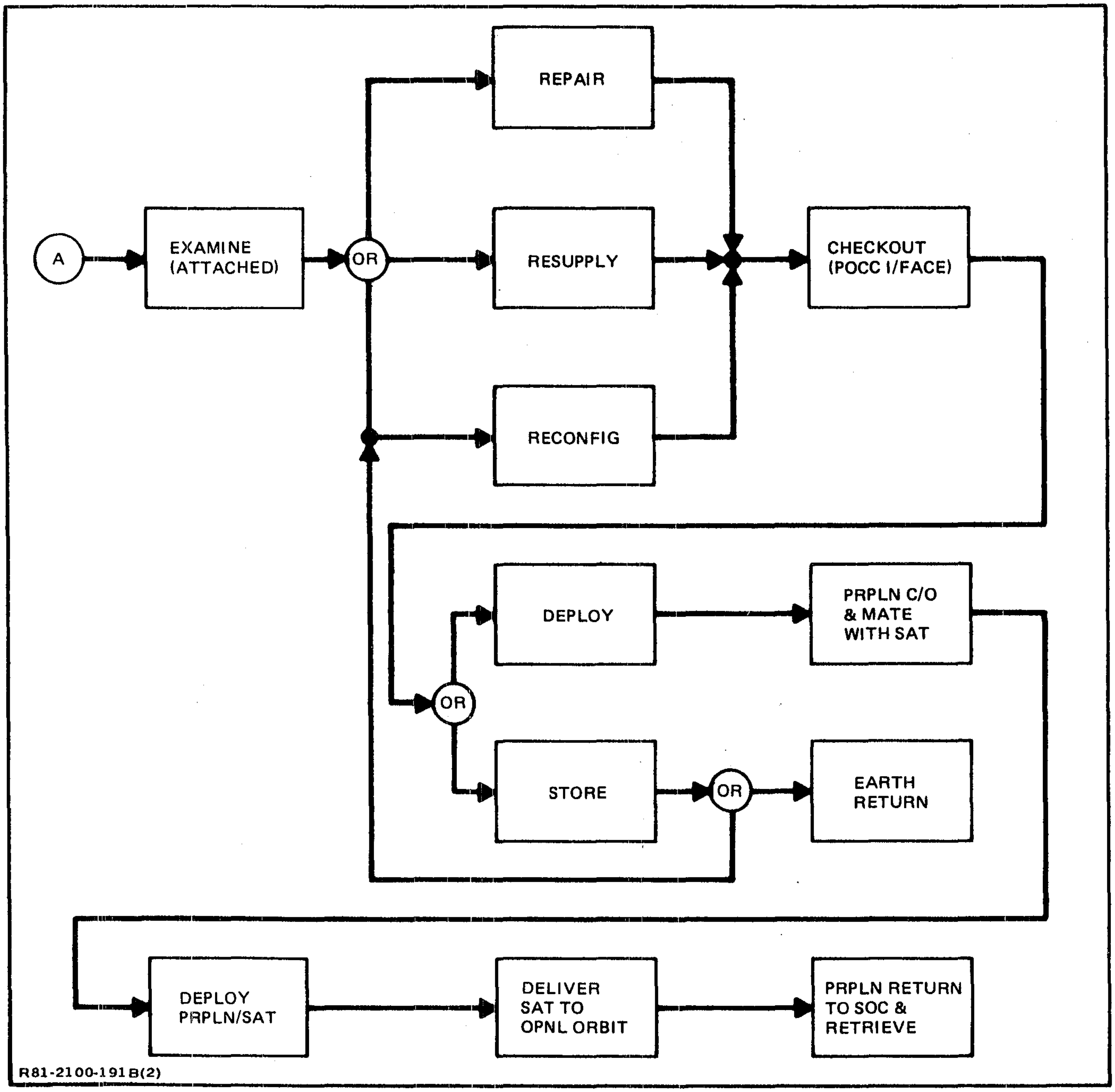


Fig. II-45 Satellites Without Propulsion (Sheet 2 of 2)

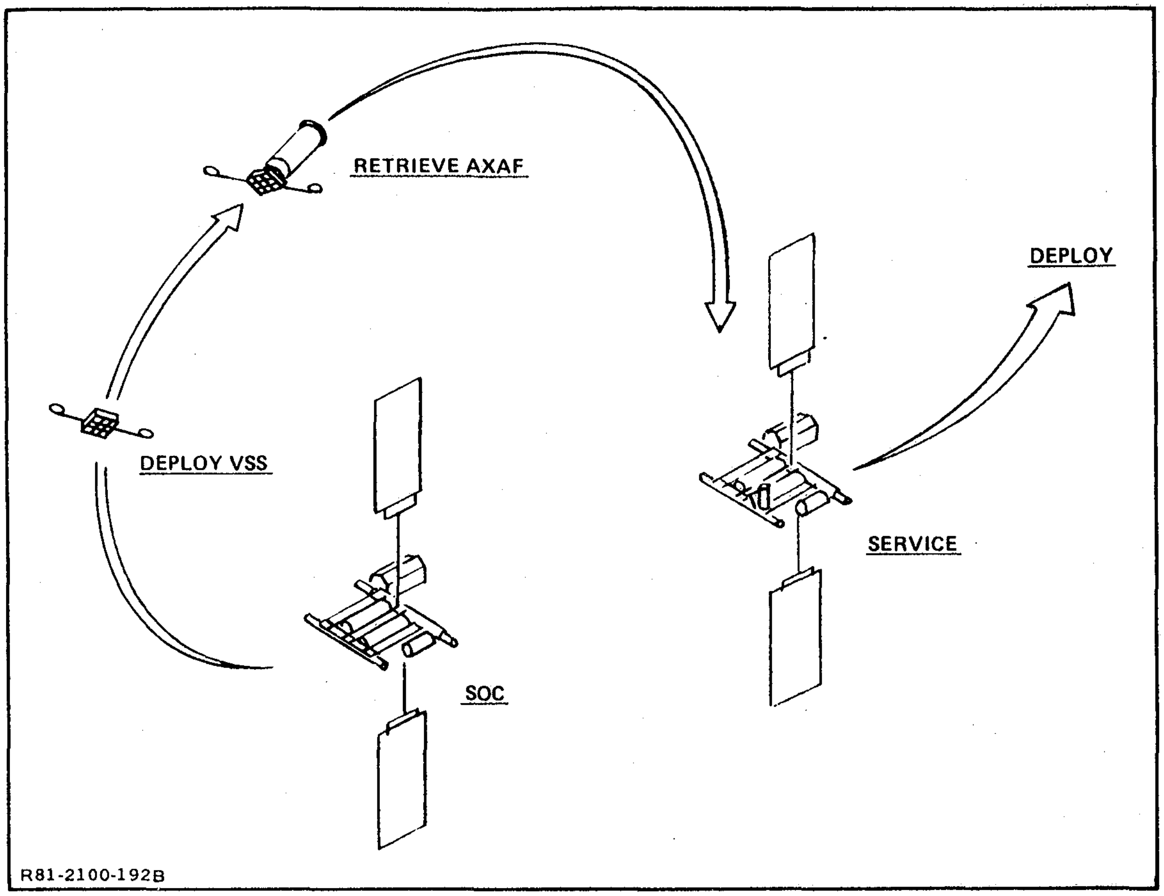


Fig. II-46 AXAF Service Mission Scenario

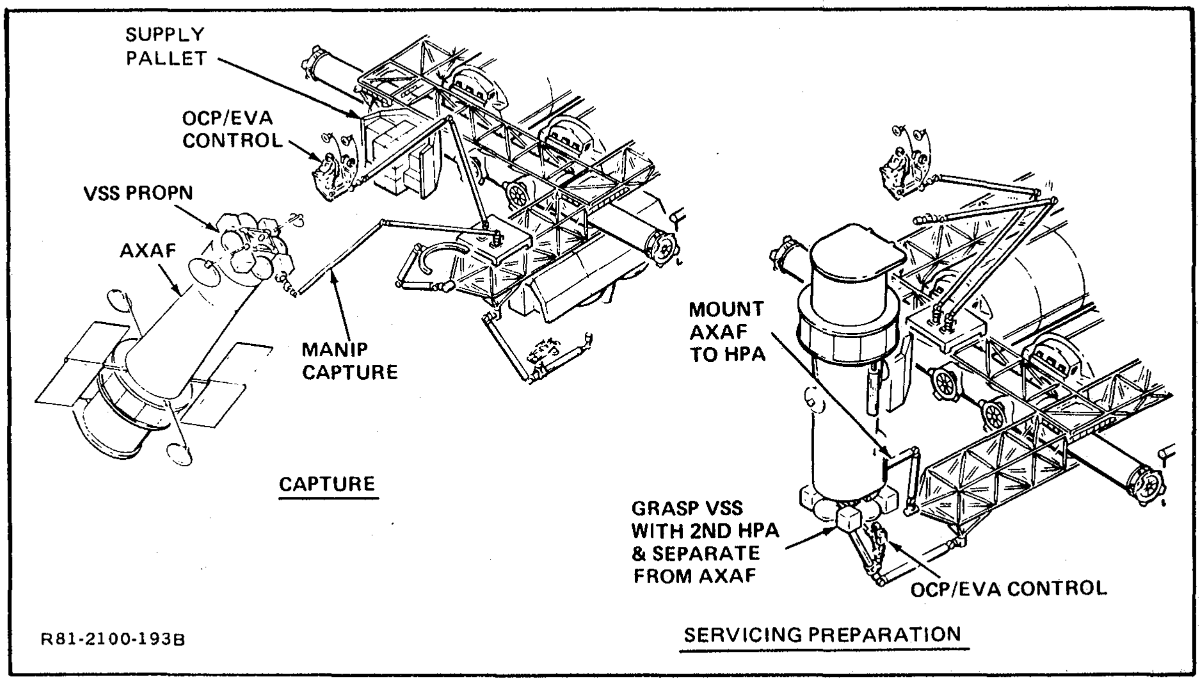


Fig. II-47 AXAF Satellite Service – Satellite Capture & Preparation for Service the VSS/AXAF to berth it to the end effector on the satellite service HPA. For this mission, the end effector has a yoke which holds the base of the AXAF. The propulsion service HPA is then moved to grasp the VSS with its end effector. The AXAF and VSS are then demated at their docking interface. The VSS is transferred, on its HPA mount, to the propulsion service area. There it is serviced by the EVA crewman operating the OCP which has module handling devices. After servicing, the HPA transfers VSS to the refueling pallet where it mates to the fuel transfor umbilical.

While VSS servicing and refueling is going on, the AXAF is rotated by the satellite service HPA to the "horizontal" position for servicing (Fig. II-48). The mobile platform has been moved along the SOC track from its satellite capture location at the tip of the extension pier to the location shown here. Considering a one man AXAF service operation, the EVA crewman locates his OCP so that he can service the subsystems area of the satellite. He also controls the second manipulator to fetch and carry change-out modules from the services pallet. Having serviced the subsystems, the Mobile Platform is relocated so that the crewman can service the scientific instrument area in a similar manner. This last operation is not shown in this figure. Instead, a second crewman is shown as an alternate for servicing the instrument area from an OCP mounted to the HPA arm, much as the propulsion stage servicing is performed.

After servicing AXAF and VSS, the two bodies are mated. The AXAF is then berthed to VSS by its HPA, controlled from the Mobile Platform OCP. This HPA is now withdrawn, leaving the mated VSS/AXAF mounted on the other HPA which now locates the Satellite for separation. Final checkout is performed, then VSS/AXAF is separated from SOC.

Functional analysis of on-orbit maintenance operations associated with the following tasks was performed:

- Replace subsystem orbital replacement units (ORU)
- Replace instruments
- Replace solar array or antenna

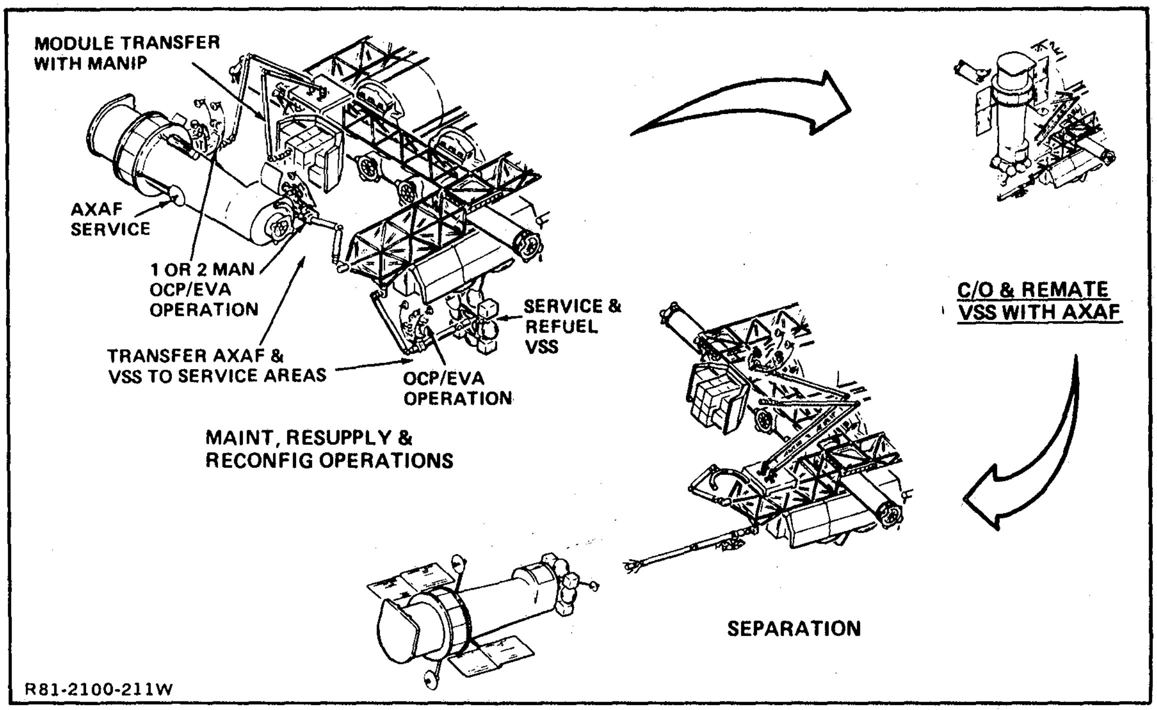


Fig. II-48 AXAF Satellite Service, Checkout & Separation

- Repair damage/replace equipment
- Clean optical surfaces

Subfunctions of the operational functions were determined and task times were assigned to each of the subfunctions, then summed, to establish the time to perform each maintenance function.

After the AXAF has been maintained, it operability will be verified. Time for subsystem checkout and instruments is estimated at 90 minutes each. At the end of the checkout, the equipment is turned off or put in a standby mode. The solar arrays and TDRS antennas remain deployed.

Next, a propulsion stage, the Versatile Service Stage (VSS), is attached to the AXAF to boost it to operating altitude. Only the interface between the AXAF and VSS requires verification and this consists of power/control of communication equipment and monitoring temperature of critical equipment.

5.1.3 Satellites with Propulsion

Satellites with propulsion are manuevered to the vicinity of SOC, controlled by their respective Payload Operations Control Center, so that SOC operations can implement retrieval using a POM. The same types of services would be provided as those satellites fetched by SOC based vehicles. An additional item is servicing of the onboard propulsion system. Scientific satellites, such as the X-Ray Observatory, are expected to require about one visit every 2 years. The most practical mode of operation will be for these satellites to rendezvous with the SOC and be berthed for the service interval.

5.1.4 SOC Assembled & Launched Satellites

The assembly and launch mode (Fig. II-49) consists of satellites such as the GEO Communications Platform that are delivered to SOC by Orbiter for subsequent launch. These satellites could be launched at the appropriate time into a near SOC co-orbiting operational location. Other satellites in this mode require a propulsion stage to transport them to operational location. Therefore, an appropriate propulsion

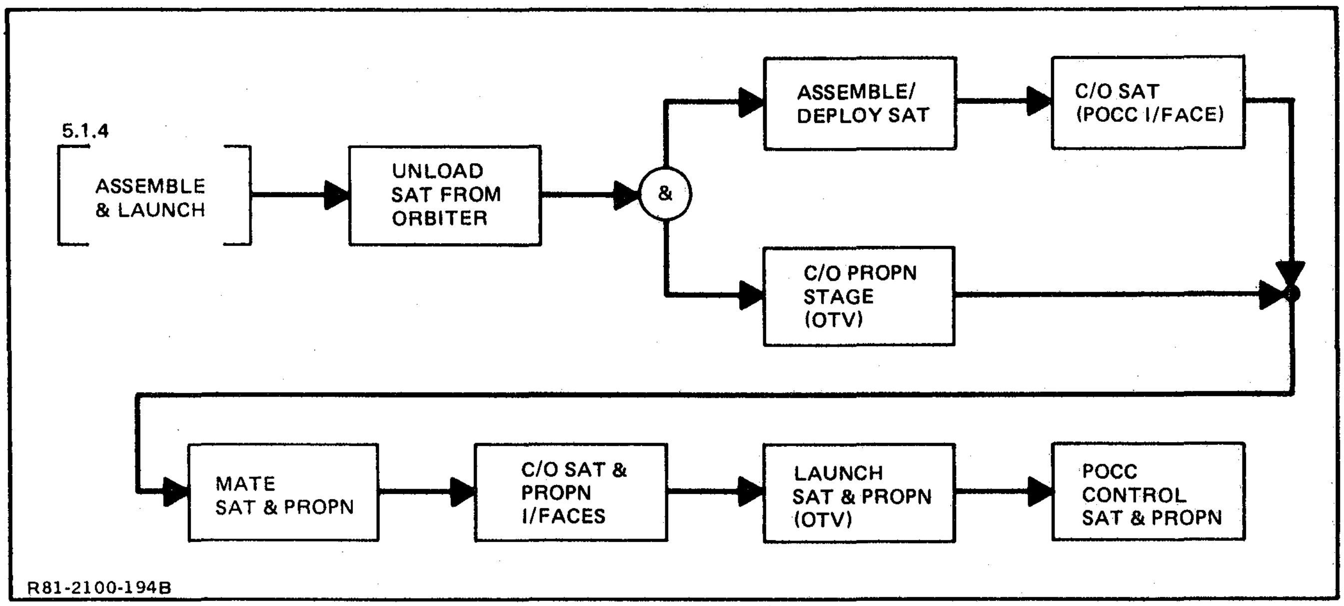


Fig. II-49 Satellite Assembly & Launch Services stage would be checked out and attached to the satellite prior to launching operations.

The folded GEO communication platform completely fills the Orbiter payload bay and may require a dedicated flight to deliver it to SOC. It is unloaded from the Orbiter cargo bay and supported by an HPA during unfolding operations (see Fig. II-50). After checkout, an Orbital Transportation Vehicle (OTV) that is based on SOC is mated to the GEO Platform, interfaces verified, and then released for transfer to geostationary orbit.

GEO Communication Platform Launch Operations - Two assumptions were used during the compilation of launch operations:

(1) The nominal plan for unfolding the platform is to control the operations remotely from the SOC control room. If appendages get hung-up, then EVA operations if warranted, will be used to solve the problem.

(2) The fuel of the SOC based OTV is assumed to be scavenged from Orbiter external tanks during previous delivery flights.

Launch of a communication platform to geosynchronous orbit from SOC starts with delivery of the platform by an Orbiter which docks to SOC (Figure II-51). The platform, folded for stowage in the Orbiter cargo bay, is transferred by the Mobile Platform Manipulator to be berthed to the satellite servicing HPA on SOC. The HPA then articulates to move the platform to its preferred location for deployment of appendages.

Figure II-51 shows deployment of the appendages which mount antennas, reflectors, experiments, solar arrays and radiators. Most are deployed automatically, others may need assistance by the OCP mounted EVA crewman (Figure II-52). The platform can be rotated on the HPA, to bring a radial appendage arm within reach of the OCP.

After deployment of the platform appendages, checkout of the systems and subsystems is commenced. A major portion of the time required for checkout of the communications platform is measuring the antenna patterns to calculate gain. The MTV will separate incrementally from SOC, e.g., at 25 and 50 km, and a signal generator on

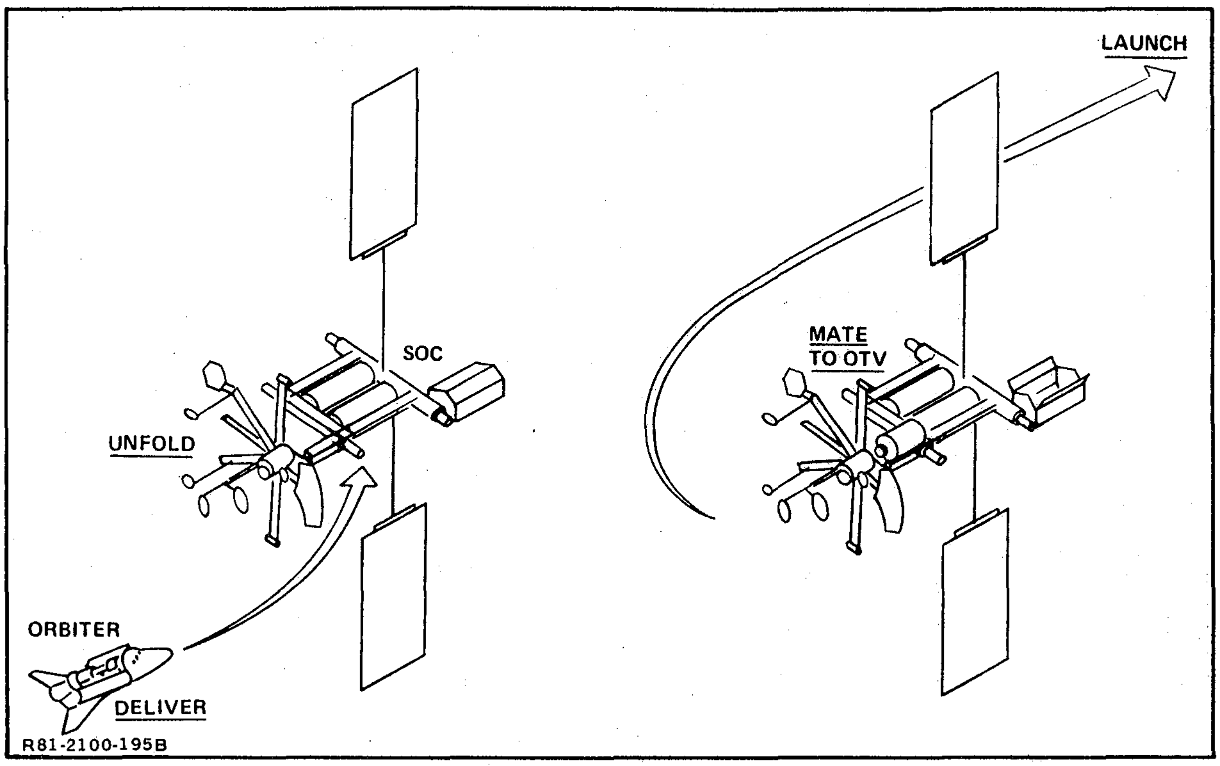


Fig. II-50 GEO Communications Platform Launch Mission Scenario

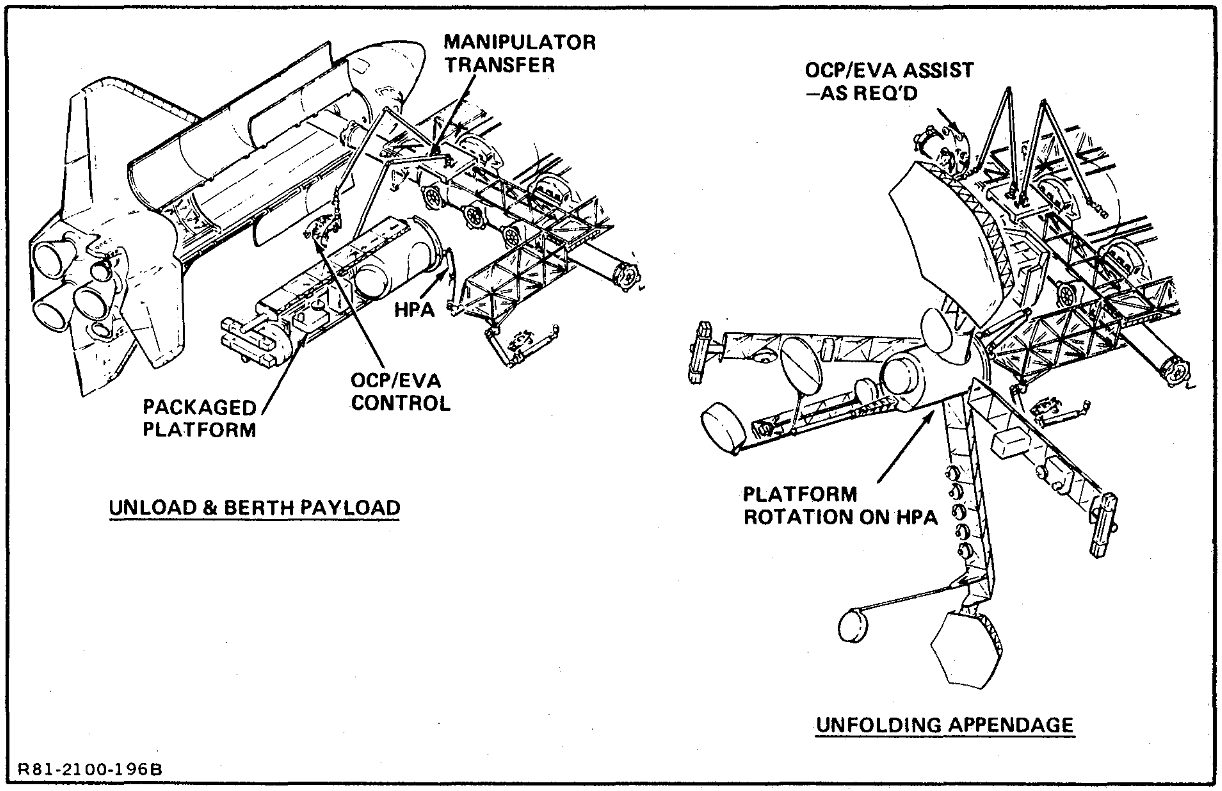


Fig. II-51 GEO Comm Platform Launch – Unload & Unfold Payload

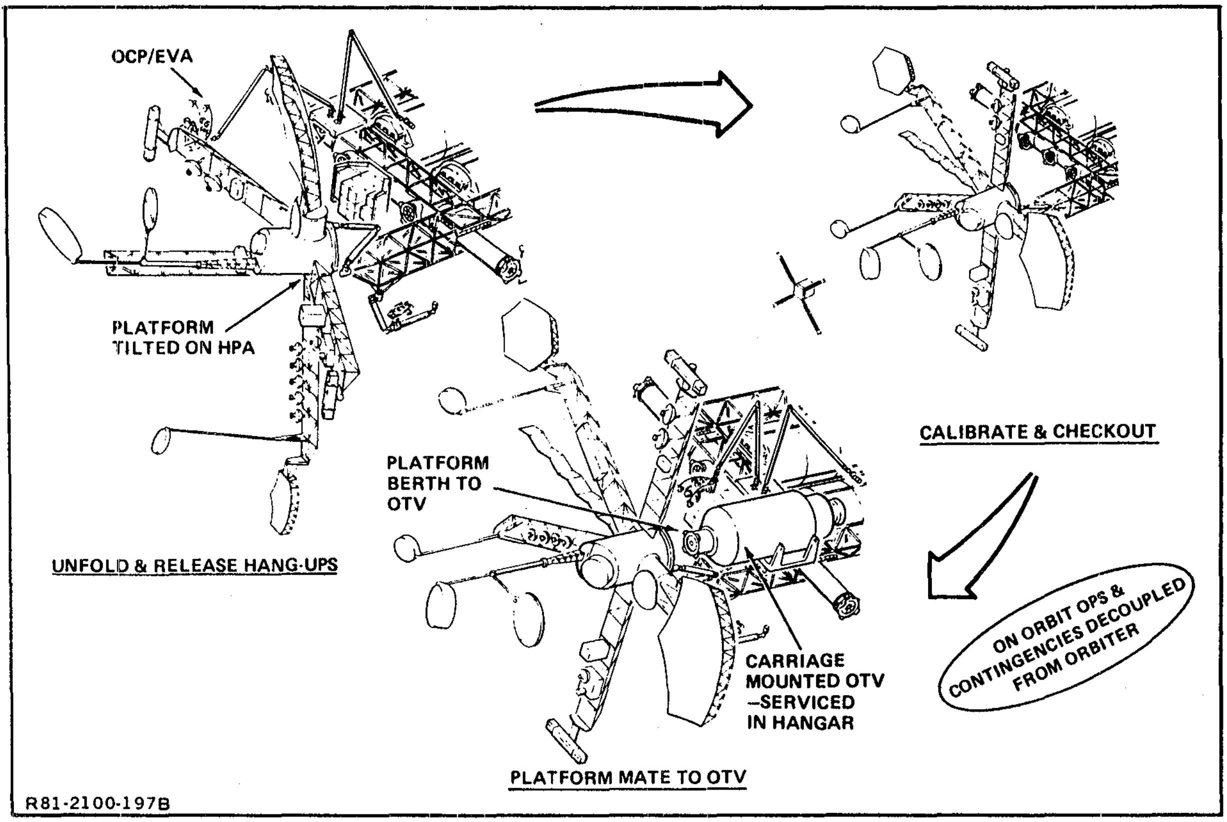


Fig. II-52 GEO Comm Platform Launch -- Checkout, Mate to OTV the MTV will radiate energy to the communication platform. The antenna will be rotated incrementally about its boresight 360 degrees. At each position, the antenna will be pitched one or two degrees each side of its boresight while received signal level is recorded. Several other items of equipment such as the DMSP data relay, tactical satcom, lightning mapper and magnetic substorm monitor also require verification of operability.

The carriage-mounted OTV has been serviced in its hangar and refueled. It is then run out of the hangar on the track system to the tip of the SOC extension pier. The satellite servicing HPA then berths the platform to the OTV. After the interfaces are verified, the Platform/OTV is separated from SOC for transfer to geosynchronous orbit.

5.2 REMOTE FROM SOC

In later years, the availability of a manned OTV will greatly xtend the range of access for LEO SOC satellite servicing. Satellites in other orbits of significantly different inclination and altitude than SOC will be accessible for service, even to GEO orbit. At this time, satellite servicing will become a significant part of SOC operational activities. Staging OTV service operations from the SOC with a manned OTV will reduce the number and complexity of Shuttle flights required. This is especially true where multiple-flight missions would otherwise be needed; space-basing decouples OTV operations from Shuttle operations.

SECTION III

MODULAR SOC CONCEPT

The need to create a manned space station technology adaptable to diverse missions has led to a versatile modular approach to space station design. The keys to this approach are (1) standard subsystems employing advanced technology to permit a long, useful life without obsolescence, and (2) modularization of the design at a level below that of complete station modules to allow creation of a variety of system configurations. Results thus far obtained confirm the benefits of the approach and indicate versatility to render a design as small as a single Shuttle-launched station and one large enough to support a crew of 12 to 20, all employing the same basic hardware set.

The key to this alternative design approach evolved from the original SOC Service Module. The Service Module includes the essential elements of a space station, including electrical power supply, consumables supply, and elements of the environmental control, thermal control, data management, and communications subsystems.

The first step in this evolution was equipping of the reference Service Module with emergency survival equipment, so that in an emergency, one Service Module could provide subsistence and life support for up to four crew members.

The next logical step in this evolution was to improve the habitability provisions in the Service Module so that it alone could serve as a modest space station with adequate, if austere, habitability provisions for normal operations for a period of one to four years. The improvement of accommodations led to increasing part of the service module diameter to improve its habitability, a concept initially explored in an IR&D investigation of a small single-launch military space station.

An alternative Service Module option evolved. This design approach has indicated a preference for a 145 inch diameter habitability section for the modified Service Module, see Figure III-1. This diameter allows masts and booms to be packaged alongside the larger diameter section. This minimizes the number of joints. Packaging volume along the small-diameter section is provided for tanks and other external stores. External stores requirements, in turn, are

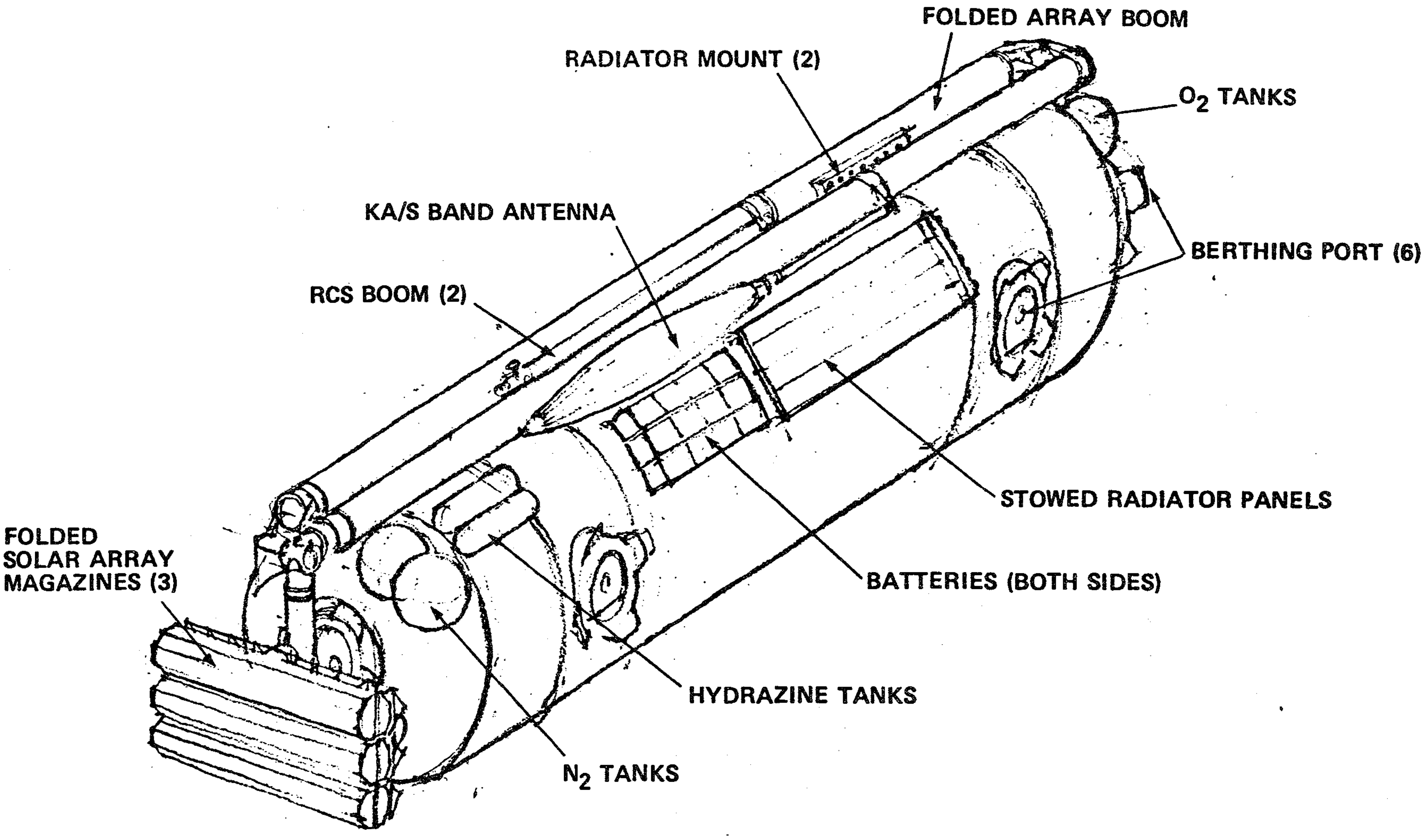


Figure III-1 Alternative Service Module dictated by the requirements for electrical power, propulsion and repressurization consumables and subsystems. A comparison of external stores requirements for two alternative subsystem approaches is presented in Table III-1. The subsystems alternatives are discussed later in this section. Table III-2 gives a detailed mass estimate for this Service Module.

Berthing ports are required to accommodate space transportation equipment in the space-based upper stage scenario. A space-based upper stage used for the median traffic model requires two berthing ports for propellant tanks, and two additional ports for OTV hangars. At least one further port is required for the manned cabin section of the manned orbit transfer vehicle. This port need not necessarily be on the bottom side of the configuration.

Additional ports are also needed for resupply modules, experiment modules, and space testing pallets. It is important that accommodations for these equipments not encroach into the satellite servicing and space construction section of the station. Accordingly, the Service Module must provide an adequate number of ports.

Full diameter Habitat Modules can be added to the program at a later date. The versatile modular design approach allows the length and interior arrangements of these habitats to be tailored to the mission requirements. For the low inclination, low Earth orbit SOC designed for space operations service, a full-length (14-meter) habitat system can be incorporated. Two such habitats will accommodate up to eight additional crew, for a total of 12. Overflow capacity within these modules is also available in the form of additional area that can be devoted to sleep stations for transient visitors not allocated a private quarters area.

The versatile modular design approach also allows one habitat to be devoted primarily to crew living and the other to crew work with a minimum cost for the differences in interior arrangement. The standardized subsystems will be essentially the same within the two modules, and the interior arrangement differences are accommodated by selection of crew accommodations equipment and non-structural partitions.

TABLE III-1

EXTERNAL STORES FOR ONE SERVICE MODULE

	Reference		Fuel Cell-Electrolysis	
	Vol, m^3 (in^3)	Mass, kg (lb)	Vol, m^3 (in^3)	Mass, kg (lb)
Hydrazine	0.84 (51260)		0	
Batteries	3.53 (215,400)	1941 (4279)	0	
0_2 Repress Gas	0.6 (36,600)		0.6 (36,600)	
0_2 Fuel	0		0.487 (29,700)	
N_2 Repress Gas	1.21 (73,800)		1.21 (73,800)	
H_2 Fuel	0		0.951 (58,000)	
PPU's	0.5 (30,500)		0.5 (30,500)	
Fuel Cells	0		0.61 (37,200)	364 (802)
Electrolysis Units	0		0.61 (37,200)	364 (802)
TOTALS	6.68 (407,600)		4.968 (303,200)	

Table III-2
Habitable Service Module
Mass Summary

Title	Mass kg (lb)
Structures	6798 (14987)
Mechanisms	408 (899)
Thermal Control	1454 (3206)
Aux Propulsion	483 (1065)
Ordnance	10 (22)
Electrical Power	3983 (8781)
G N & C	420 (926)
Tracking & Communication	653 (1440)
Data Management	481 (1060)
Instrumentation	100 (220)
Crew Accommodation	306 (675)
EC/LSS & Crew Systems	1911 (4213)
Mission Equipment	2594 (5719)
Growth	4082 (8999)
Total	23683 (52212)

Electrical power modularity and adaptability is provided by design of a standard power section incorporating solar arrays and energy storage. These elements are modular at a level that permits a smallest increment of raw power supply on the order of 10 kilowatts. Units can be grouped together to provide higher power levels. The array size is tailored to the power level desired. System redundancy improves as power level is increased. Each module of any station element will receive raw power from the power supply and will provide its own power conditioning.

Data management modularity is provided through federated processing. This is a variant of distributed processing in which each processing element is capable of operating stand-alone, but is tied to a data bus for sharing of data with other processors to enhance integrated operation of the entire system. Advanced processors will ensure that adequate capability exists to accommodate any conceivable requirement. Rapid advances in microprocessor technology now offer computing power overkill as cheap insurance against future limitations. A standardized high level language, probable ADA, will be employed.

The processors will interface to a redundant bus system through a standardized interface communications system and protocol. The bus architecture will be flexible and will accommodate from a few to many processors on the bus with a contention protocol time slot feature that allows addition of processors as the station is expanded in space. It is expected that RF data linking will facilitate integration testing of modules on the ground awaiting launch, coupled electronically to those already in orbit. Presence of a crew will simplify software updates and checkout as well as reloads and restarts.

The environmental control and life support system will incorporate air and water processing equipment in two-man increments. Equipment is replicated to serve larger crews. The nature of this equipment is one of graceful degradation. A set of equipment designed to serve four people can serve this number even with failures with degraded but still acceptable performance. As the number of people served increases, the redundancy and resilience of the system also increases. Standardization of equipment and interfaces will enable all presently known needs to be served by the basic equipment set.

At the two-man level, i.e., in a single-launch space station, the environmental control and life support system will operate only in fully operational and fail-safe modes. A major failure in an element of the life support system in the two-man system would require initiation of emergency mode operations with attempts to restore the system to service, perhaps carried out in parallel with initiation of rescue plans. For any station larger than the basic two-man increment, fail-operational, fail-safe capability would exist.

A standard set of communications equipment will serve a variety of needs. Communication needs in UHF, S-band, K-band and micro-wave have been identified for the SOC missions. These will serve most applications. Special equipment and features may be required for certain military applications. These can be interconnected with the standard equipment set through standardized interfaces. Use of fiber optics communication buses throughout will facilitate meeting communications security requirements for any special applications.

The recommended alternative SOC implementation sequence related to the median traffic model and mission needs analysis proceeds as follows:

A single Service Module is launched by the initial Space Shuttle flight. This module will include the basic SOC command and control work station, together with food preparation, hygiene, suit storage and contingency sleep sections. This initial Service Module can function as a two-man space station. It would provide relatively comfortable accommodations for a crew of four when docked with a Shuttle Orbiter.

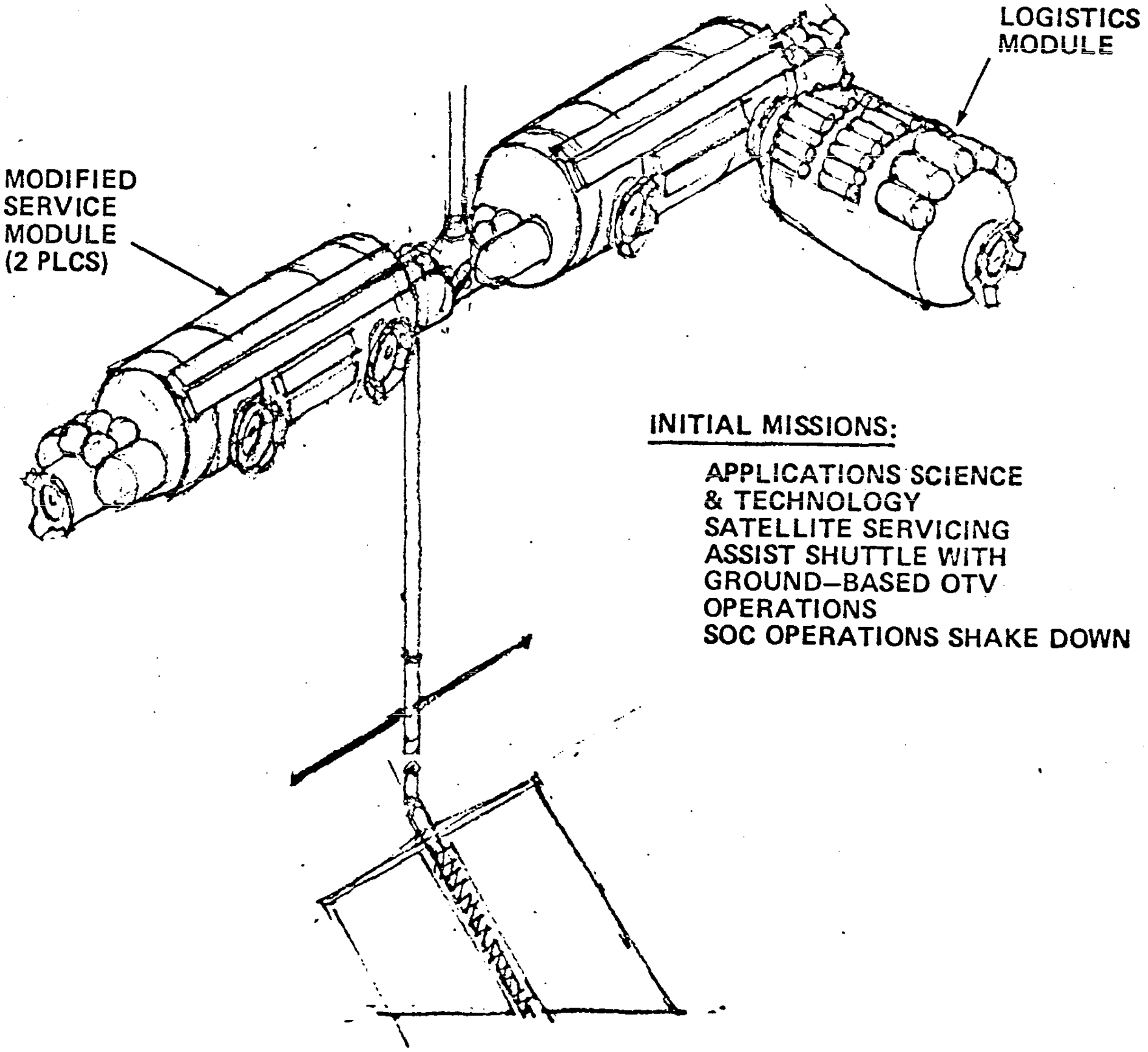
The initial module could incorporate one-half of the SOC electric power supply requirements. Alternatively, it could be docked to a separate power section launched earlier as a free-flyer. In the latter instance, the separate power section would incorporate the raw power supply capabilities needed for the complete SOC system. If the asymmetric configuration is selected, an interim propulsion boom located on the opposite side of the module from the main solar array mast would provide sufficient control authority for normal operations.

A second Shuttle launch would bring up a second Service Module identical to the first except for different interior arrangements. This second module would contribute sufficient habitability features to allow the two modules to accommodate a crew of four in reasonable comfort. Figure III-2 illustrates the 4-man SOC concept when a Logistics Module is added.

This initial station comprised of two Service Modules would satisfy the median model identified mission needs for SOC for two to three years. These mission needs include shakedown of SOC operations, early research and applications missions, demonstration of the essential technologies required for space-basing the Orbit Transfer Vehicle, and flight support operations for a ground-based Orbit Transfer Vehicle.

Roughly three years after the initial SOC launch, a sequence of three additional build-up launches would complete the basic station configuration by adding two habitat modules and a docking tunnel leading to the configuration illustrated in Figure III-3. This configuration could accommodate up to 12 people and accommodate all of the mission needs identified for SOC through 1995 to 1996. At the time transition to space-based OTV operations is desired, four additional Shuttle launches would bring up two space-based OTVs, two hangars, and two propellant storage tanks for the space-based OTVs. At this point, the SOC would be capable of accomplishing all of the mission functions identified in the mission needs analysis.

In the latter part of the 1990s, an increase in the anticipated mission needs for science and applications, especially materials processing, coupled with a gradual decline in available power for support of experiments because of degradation of the solar array, would motivate the build-up of a second SOC dedicated to the science and applications missions. This SOC would be designed to support a crew of eight with additional internal space made available for science and applications operations, as well as the use of berthing ports to support research and applications pallets and modules in place of orbit transfer vehicles and construction projects. Shorter versions of the Habitat Modules might well be used for this SOC configuration.



INITIAL MISSIONS:

APPLICATIONS SCIENCE & TECHNOLOGY
SATELLITE SERVICING
ASSIST SHUTTLE WITH GROUND–BASED OTV OPERATIONS
SOC OPERATIONS SHAKE DOWN

Figure III-2 4-Man SOC Concept Using Modular Elements

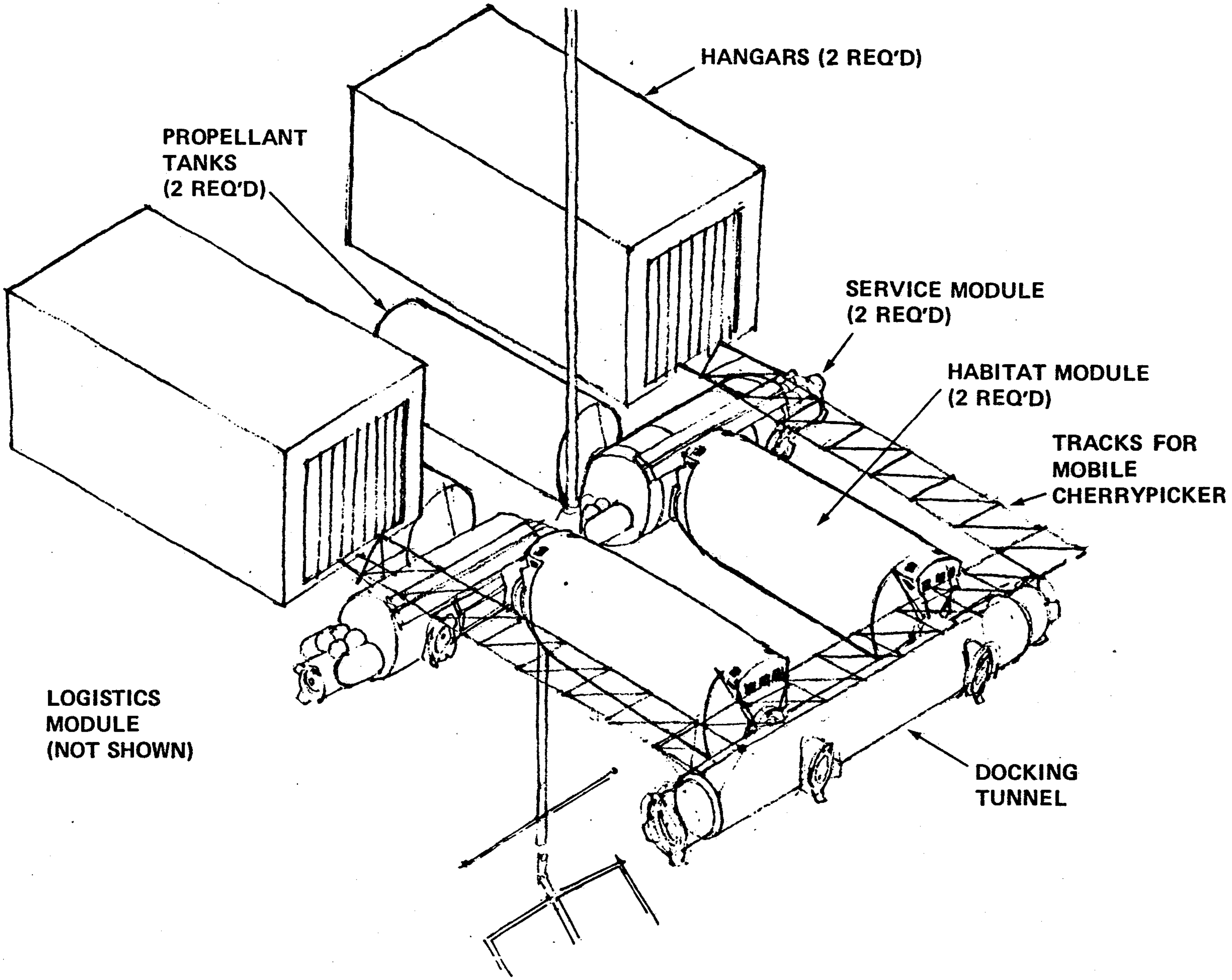


Figure III-3 12-Man SOC Concept

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