SPACE OPERATIONS CENTER

SYSTEM ANALYSIS

FINAL REPORT VOLUME III

BOOK 1 of 2

SOC SYSTEM DEFINITION REPORT

D180-26495-3
REV. A

JANUARY, 1982

DRL T-1591
LINE ITEM 4
DRD MA-697T

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 1 OF 2

SOC SYSTEM DEFINITION REPORT

D180-26495-3

Rev A

January, 1982

Gordon R. Woodcock
Approved by
Gordon R. Woodcock,
SOC Study Manager

BOEING AEROSPACE COMPANY

P.O. BOX 3999

Seattle, Washington 98124

N82-20201 #

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.

---

*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.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

BOOK 2 OF 2

SECTION II - OPERATIONS

TABLE OF CONTENTS (Continued)

SECTION III - PROGRAMMATICS AND COST

REFERENCES

THE BOEING COMPANY

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		

THE BOEING COMPANY

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 - O_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 (°F) - 21 Day Emergency (ft/min) p.134 - Performance And Design Data - 21 Day Emergency (mmHg) - 21 Day Emergency (°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	

DO 6000 2150 ORIG. 4/71

THE BOEING COMPANY

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 $\pm$ 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	

THE BOEING COMPANY

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	

THE BOEING COMPANY

REVISIONS

LTR	DESCRIPTION	DATE	APPROVAL
A	last paragraph, first line: replace "AAP" with "SAP"	Dec 81	
	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 estim-ate.		

THE BOEING COMPANY

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
Electrical Power	L. Murgia	S. W. Silverman
ECLSS/EVA	D. Thompson	K. H. Miller H. Brose (Ham Std) G. Rannenberg (Ham Std) R. Cushman (Ham Std)
Communications & Tracking	R. Dietz	F. M. Kim
Structures/Dynamic Control	R. Wren	R. M. Gates
Stab/Control	J. Bigham	J. H. Mason
Propulsion/Propellant Storage	D. Kendrick	G. R. Woodcock
Subsystem Interface	L. Monford	M. A. Stowe G. R. Woodcock
Programmatics	R. Kennedy	G. R. Woodcock
Software/Processing	E. Dalke	L. E. Silva G. L. Hadley
Config. Design/Docking & Berthing	J. Jones	J. J. Olson K. H. Miller
Health Maintenance Facility	D. Nachtwey	K. H. Miller
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 Cartrige
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	Decibles
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 Distallation
VDC	Volts Direct Current
WBS	Work Breakdown Structure
WMS	Waste Management System

INTRODUCTION

1.0 DOCUMENT PURPOSE AND ORGANIZATION

This document provides a description of the SOC program and its elements as defined by this first system analysis study.

In Section I, all of the SOC elements defined to date are described to the level of detail that they have been studied to date. This section is organized by the Work Breakdown Structure shown in Figure 1. Each element is given a WBS dictionary definition. The element is then briefly described and illustrated. The basis for the element's design is then given along with references to pertinent analyses, trade studies, and descriptions given in NASA and contractor documents. If viable alternative concepts are available, they are so noted and a reference is given as to where to find further information. Finally, the mass estimate for the element is given. In most cases, this mass estimate is given in the higher-level WBS descriptions only.

In Section II, descriptions of SOC operations are given. This includes the SOC build-up operations, construction, flight support, and satellite servicing operations.

In Section III the SOC programmatics and cost analysis are presented.

2.0 SOC CONFIGURATIONS

This study has produced several SOC configurations. Figures 2, 3, and 4 illustrate three reference configurations that will be referred to throughout this and the other final documents.

The Initial SOC Configuration (shown in Figure 2) is an example SOC configuration that could be permanently manned by a crew of 4 after 3 module delivery flights.

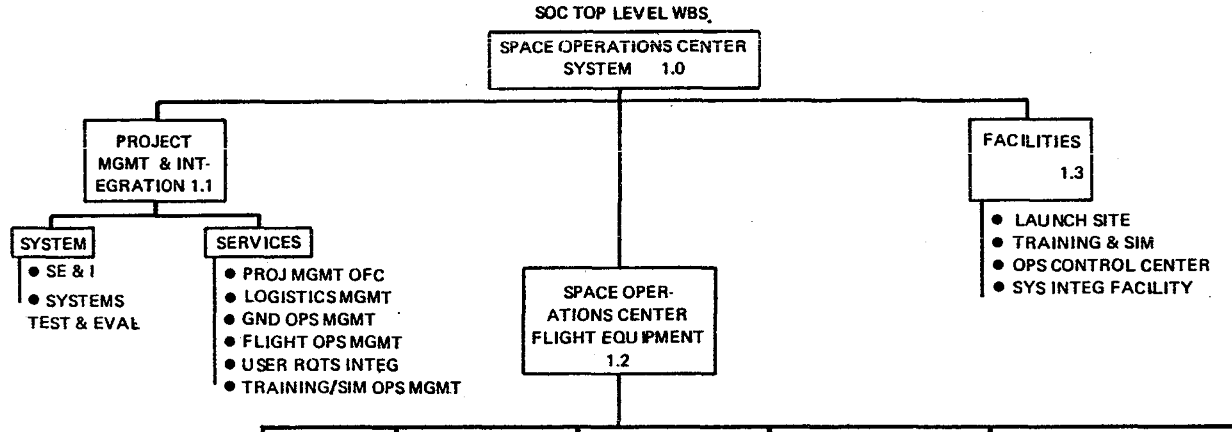
The Operational SOC Configuration (shown in Figure 3) is an example SOC configuration that could be permanently manned by a crew of 8 after 6 module delivery flights. (Note - several months to several years will have elapsed from the time Initial SOC Configuration was established until the time that this

Operational SOC Configuration has been established. This is a programmatics issue that is addressed in Section III).

The Growth SOC Configuration (shown in Figure 4) is an example SOC configuration that would be permanently manned by a crew of 8 after 9 module delivery flights. This configuration shown here includes provisions for space-basing of OTV's and provisions for constructing very large satellites.

There are, of course, several intermediate configurations between the three shown here that would be established during the build-up process. In addition, there are several alternative configurations that could be made up by combining the SOC modules into other combinations. The three configurations shown in Figures 2, 3, and 4 represent Reference concepts.

Alternative Modular SOC Configurations - During the Study Extension, alternative modular SOC concepts were explored on Boeing discretionary funds. This work has led to a modular concept which is recommended to be the focus for future system analysis studies. Figure 5 illustrates a 4-man SOC composed of these modular elements. Section III of this document provides additional details on this recommended system concept.



GENERIC SUBSYS. HARDWARE & SOFTWARE	HABITAT MODULE 1.2.1		SERVICE MODULE 1.2.2			GENERAL PURPOSE SUPPORT EQUIPMENT 1.2.3			CONSTRUCTION SUPPORT EQUIPMENT 1.2.4			TRANSPORTATION SUPPORT EQUIPMENT 1.2.5				RESUPPLY & LOGISTICS SUPPORT SYSTEMS 1.2.6		
	HM-1, 1.2.1.1	HM-2 1.2.1.2	SM-1, 1.2.2.1	SM-2, 1.2.2.2	DT 1.2.2.3	MOB/ ACCESS 1.2.3.1	CP	MRWS	TT&F			HANG-AR 1.2.5.1	DOLLY 1.2.5.2	PROP SYS 1.2.5.3	SPARES 1.2.5.4	LM 1.2.6.1	TKR 1.2.6.2	
1.2.X.X.1 STRUCTURES	x	x	x	x	x	x	x	x	x			x	x	x		x	x	
2 MECHANISMS	x	x	x	x	x	x	x	x	x			x	x	x		x	x	
3 THERMAL CONTROL	x	x	x	x		x	x	x	x			x	x	x		x	x	
4 PRIMARY PROPULSION																		
5 AC PROPULSION			x	x														
6 ORDNANCE	x	x	x	x	x	x	x	x									x	
7 ELEC POWER	x	x	x	x	x	x	x	x	x			x	x	x		x	x	
8 GN&C	x	x	x	x														
9 TRACKING & COMMUNIC.	x	x	x	x				x					x					
10 DATA MGMT & FLTS/W	x	x	x	x	x	x	x	x	x			x	x	x		x	x	
11 INSTRUMENTATION	x	x	x	x	x	x	x	x	x			x	x	x		x	x	
12 CREW ACCOMM.	x	x	x	x	x			x								x		
13 EC/LSS	x	x	x	x				x										
14 ASE, GSE, & STE	x	x	x	x	x	x	x	x	x			x	x	x		x	x	
15 ASSY & C/O	x	x	x	x	x	x	x	x	x			x	x	x		x	x	
16 SYSTEMS E&I	x	x	x	x	x	x	x	x	x			x	x	x		x	x	
17 MISSION EQUIPMENT	x	x	x	x			x	x							x	x		

SERVICES 1.2.7
- SE & I
- LOGISTICS
- OPS SUPPORT
- CREW
- EQUIPMENT
  - SUITS
  - EVA GEAR
  - PERS. EFFECTS
  - UTENSILS & TOOLS
  - ETC.

Figure 1. Space Operations Center Work Breakdown Structure(WBS)

SOC-803

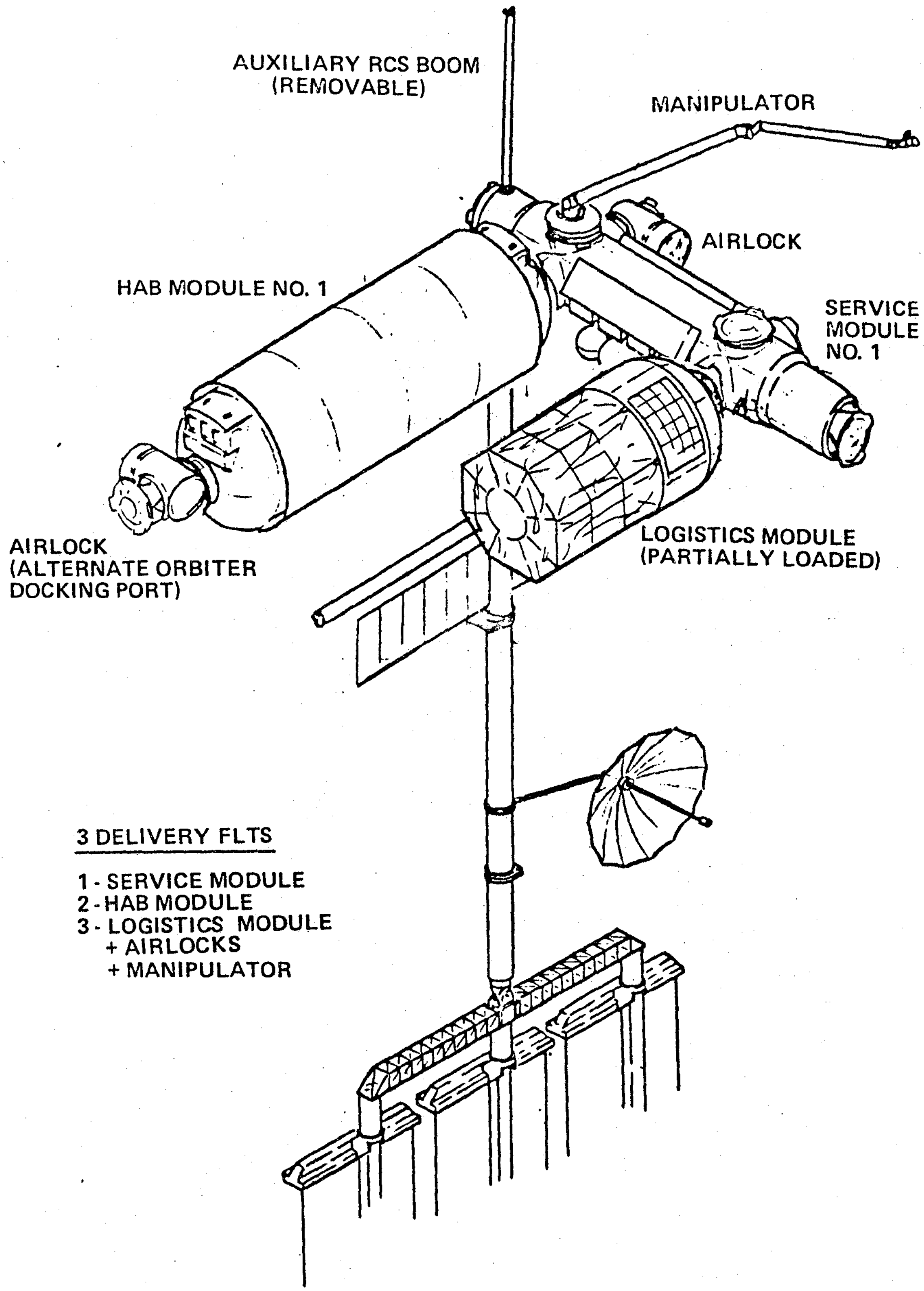


Figure 2. Initial SOC Configuration

A

SOC-1323

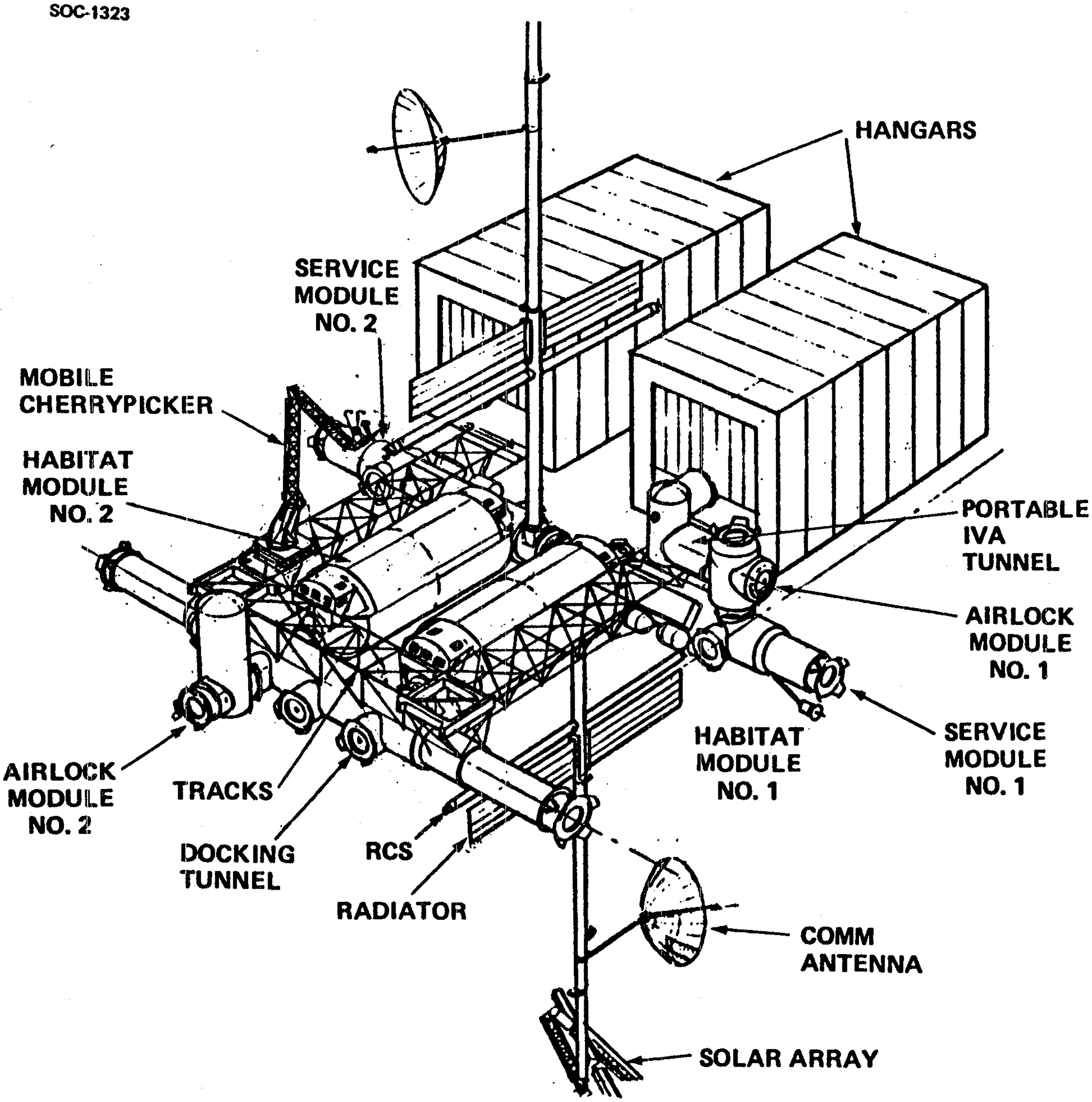


Figure 3 Operational SOC Configuration

SOC-1329

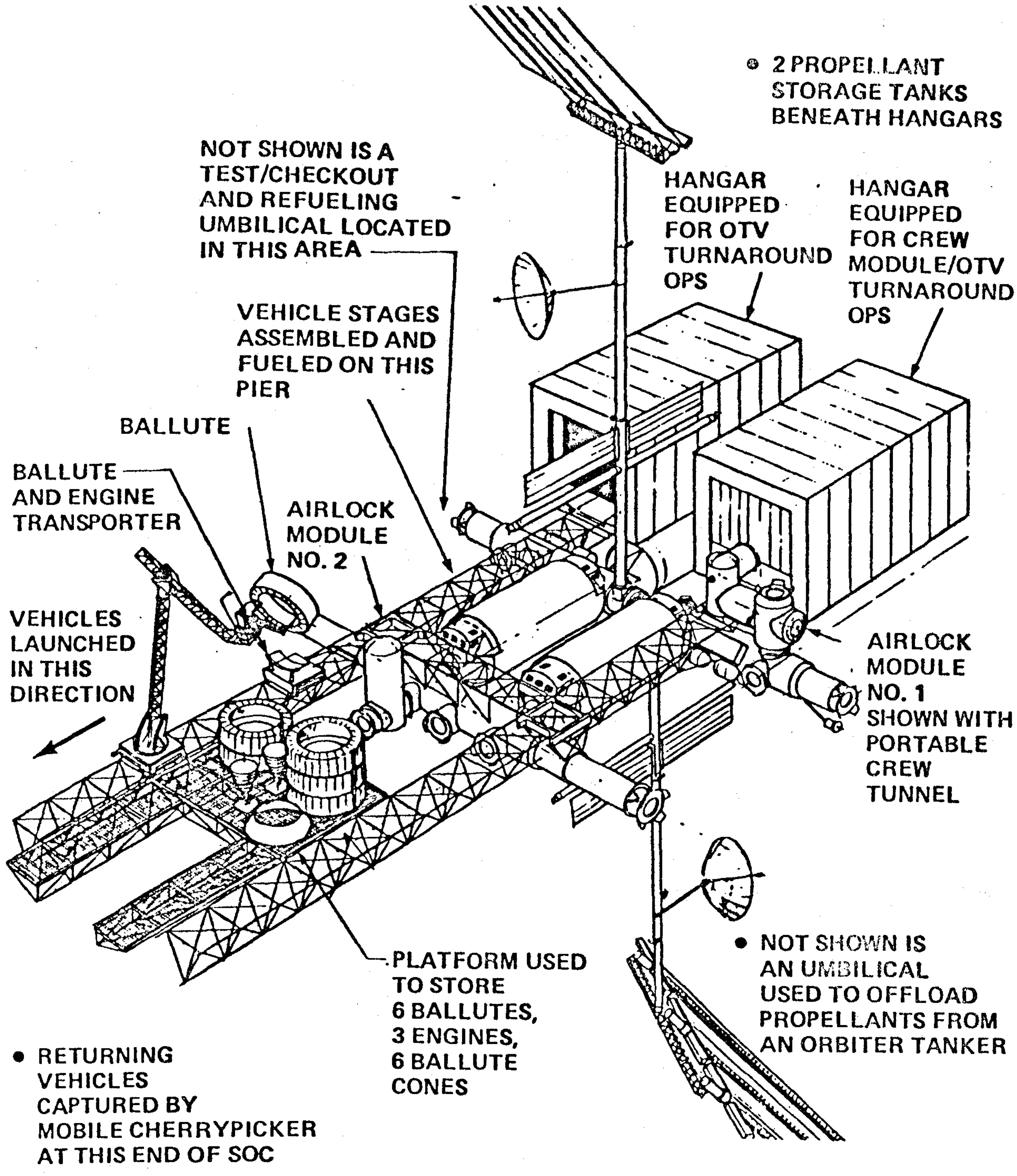


Figure 4. Growth SOC Configuration

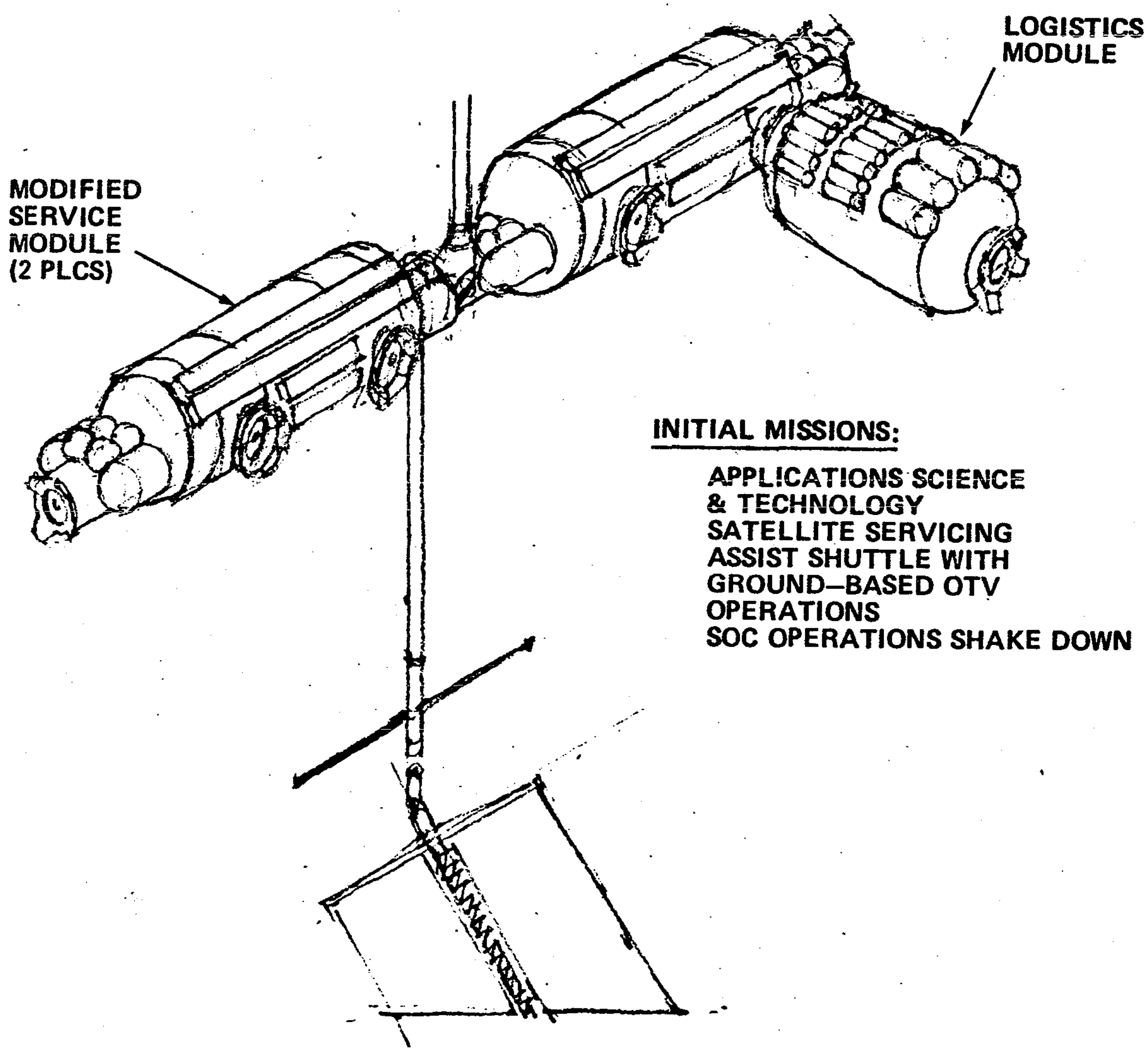


Figure 5 4-Man SOC Concept Using Modular Elements

WBS 1.0 SPACE OPERATIONS CENTER SYSTEM

1.0 WBS Dictionary

This element includes the entire SOC program.

2.0 Description

The Space Operations Center system includes the Space Operations Center flight systems, the logistics operations required to support the flight systems, and the program management, mission control, simulation, training, and other support operations needed to maintain efficient and safe operation of the Space Operations Center in orbit.

The logistics operations consist of those operations using the shuttle and ground turnaround facilities and equipment necessary to exchange SOC flight crews and resupply consumables and spares. The logistics module flight article used for resupply is a part of the SOC flight system.

Other support operations were not defined in detail by the study. Program management and mission control will use facilities and personnel available at NASA JSC. The operations concept will minimize the need for extensive ground-based mission control. Existing personnel allocations and facilities are believed adequate to handle the expected level of shuttle, SOC, and OTV operations.

The SOC program has been defined as including a ground-based set of prototype flight hardware. This equipment will be used for systems integration tests and interface verification during the SOC buildup phase. For SOC operations, this equipment will serve as a "hangar queen" at JSC for training, checkout of procedures and software changes, and checkout of hardware changes to be later made in orbit. Whether existing facility space at JSC is adequate for this is not presently known. A six-degree-of-freedom training and simulation facility may also be required for cherrypicker operations.

WBS 1.2 SPACE OPERATIONS CENTER FLIGHT EQUIPMENT

1.0 WBS Dictionary

This element includes all of the SOC elements that will be placed into orbit. It includes elements for the Initial, Operational, and Growth Configurations.

2.0 Description

The three reference configurations for the Space Operations Center were shown in Figures 2, 3, and 4 of the Introduction. Table A lists the WBS sub-elements that are pertinent to these 3 configurations.

Initial SOC Configuration

Figure 2 illustrated an Initial SOC Configuration which can be permanently manned by a crew of 4 after 3 module delivery flights. The Habitat Module (WBS 1.2.1.1) provides the primary living and working area for the crew. The Service Module (WBS 1.2.2.1) provides most of the subsystems (power, attitude control, communications, etc.) as well as being equipped to provide emergency habitability for 14 days. Two Airlock Modules (WBS 1.2.2.4) are required - one attached to the Habitat Module and one attached to the Service Module. The Logistics Module (WBS 1.2.6.1) is a recyclable module that is used to transport the crew provisions, propellants, spare parts, etc. required during a 90 day period. At the end of 90 days, the crew is changed out and a new Logistics Module is supplied. The other LM (loaded with waste products) is then returned to Earth with the returning crew.

This Initial SOC is equipped with a manipulator (WBS 1.2.3.2.1), a turntable/tiltable (WBS 1.2.3.4), and umbilical system (WBS 1.2.3.5) so that it can provide mission support.

Operational SOC Configuration

Figure 3 illustrated an Operational SOC Configuration that can be permanently manned by a crew of 8. It will require 3 module delivery flights to build-up from the configuration shown in Figure 2 to that shown in Figure 3 (see Section II of this document for the build-up sequence description).

		Configurations			
	WBS Element	**Initial SOC**	**Operational SOC**	**Growth SOC**	
WBS 1.2.1.1	Habitat Module No. 1	*	*	*	
WBS 1.2.1.2	Habitat Module No. 2		*	*	
WBS 1.2.1.3	Mini-Habitat Module			*	A*
WBS 1.2.2.1	Service Module No. 1	*	*	*	
WBS 1.2.2.2	Service Module No. 2		*	*	
WBS 1.2.2.3	Docking Tunnel		*	*	
WBS 1.2.2.4.1	Airlock Modules	*	*	*	
WBS 1.2.2.4.2	Portable IVA Tunnel			*	A
WBS 1.2.3.1	Mobility/Access System		*	*	
WBS 1.2.3.2.1	Manipulator	*			
WBS 1.2.3.2.2	Mobile Cherrypicker		*	*	
WBS 1.2.3.2.3	Payload Handling Tools		*	*	
WBS 1.2.3.3	EVA Workstation		*	*	
WBS 1.2.3.4	Turntable/Tiltable	*	*	*	
WBS 1.2.3.5	Umbilical System	*	*	*	
WBS 1.2.3.6.1	Storage Rack		*	*	
WBS 1.2.3.6.2	Storage Facility			*	
WBS 1.2.4.1	Construction Fixture		*		
WBS 1.2.4.2	Modular Const. Fixture			*	
WBS 1.2.4.3	Beam Builder			*	
WBS 1.2.4.4	Contour Meas. System			*	
WBS 1.2.5.1	Hangar		*	*	
WBS 1.2.5.2	Dolly		*	*	
WBS 1.2.5.3	Propellant Storage			*	
WBS 1.2.6.1	Logistics Module	*	*	*	
WBS 1.2.6.2	OTV Prop. Deliv. Mod.			*	

TABLE A WBS ELEMENTS APPLICABLE TO THE VARIOUS SOC CONFIGURATIONS

* The letter A in the margin denotes the location of Rev A additions, corrections, etc.

In addition to a second Habitat Module and a second Service Module, this configuration includes a Docking Tunnel (WBS 1.2.2.3). This module provides an IVA path between the 2 HM's as well as providing exterior tracks for operation of the mobile cherrypicker (WBS 1.2.3.2.2). Piers (WBS 1.2.3.1.1) are included so that the cherrypicker can maneuver towards the SM's.

Growth SOC Configuration

Figure 3 illustrated a SOC Growth configuration with the extended-capability construction and flight support facilities for space-based OTV's.

The flight support facility includes two OTV propellant storage tanks, two hangars, and the propellant transfer equipment. One of the piers is a stage-payload mating facility. The track is common with that used by the construction facility. The mobile cherrypicker and OTV handling carriage can be used for either flight support or construction operations. These equipments are used for OTV-to-OTV mating and for OTV-to-payload mating. Large payloads can be accommodated by running the OTV to the end of the track.

The construction facility is located on the other pier. The construction tools and equipment are designed to be flexible and reconfigurable to adapt to a variety of projects. Storage space for Shuttle payloads is provided between the two structural piers so that the Shuttle need not be used as a warehouse.

The Shuttle is shown in the picture for relative scale. The normal Shuttle docking attitude is Y-POP and X-vertical.

3.0 Design Basis

The SOC modules, systems, subsystems and configurations were designed to meet the requirements found in Boeing-18. Table B lists the primary design drivers and their influence on the SOC configuration.

4.0 Mass

Table C summarizes the mass of the 3 SOC configurations.

Table B. SOC Overall Configuration Design Drivers

SOC-518

DESIGN DRIVER	CONFIGURATION INFLUENCE
• CONTROLLABILITY • DRAG SYMMETRY ABOUT ORBIT PLANE • PRINCIPAL AXES: MAX INERTIA NORMAL TO ORBIT PLANE, MIN. INERTIA VERTICAL	• TWO EQUAL SOLAR ARRAY WINGS • CONSTRUCTION ACTIVITIES IN ORBIT PLANE • HAB MODULES & SM's IN ORBIT PLANE • PROPELLANT STORAGE ON VERTICAL CENTERLINE
• WORK SPACE	• FLIGHT SUPPORT & CONSTRUCTION FACILITIES ADEQUATELY SEPARATED • PLENTY OF DOCKING/BERTHING PORTS • MOBILE CRANE
• CREW ESCAPE ROUTES	• RETAIN BASIC JSC "RACETRACK" ARRANGEMENT
• EASE OF SHUTTLE DOCKING	• ADEQUATE CLEARANCE • NORMAL MODE IS V-BAR, TAIL UP OR DOWN
• QUICK SHUTTLE TURNAROUND	• ADEQUATE PAYLOAD HANDLING & STORAGE FACILITIES
• COMMONALITY	• TWO IDENTICAL HAB MODULES & SERVICE MODULES • USE SM STRUCTURE FOR TUNNEL.

		MASS SUMMARY, KG		
		Configurations		
	WBS Element	**Initial SOC**	**Operational SOC**	**Growth SOC**
WBS 1.2.1.1	Habitat Module No. 1	21518	21518	21518
WBS 1.2.1.2	Habitat Module No. 2		21518	21518
WBS 1.2.2.1	Service Module No. 1	21798	21798	21798
WBS 1.2.2.2	Service Module No. 2		21409	21409
WBS 1.2.2.3	Docking Tunnel		7950	7950
WBS 1.2.2.4.1	Airlock Module No. 1	1362	681	681
WBS 1.2.2.4.2	Airlock Module No. 2		920	920
WBS 1.2.2.4.3	Portable IVA Tunnel		920	920
WBS 1.2.3.1	Mobility/Access System		293	593
WBS 1.2.3.2.1	Manipulator	524		
WBS 1.2.3.2.2	Mobile Cherrypicker		1543	1543
WBS 1.2.3.2.3	Payload Handling Tools		300	300
WBS 1.2.3.3	EVA Workstation		410	410
WBS 1.2.3.4	Turntable/Tiltable	750	750	1204
WBS 1.2.3.5	Umbilical System	273	545	1200
WBS 1.2.3.6.1	Storage Rack		75	75
WBS 1.2.3.6.2	Storage Facility			2954
WBS 1.2.4.1	Construction Fixture		582	
WBS 1.2.4.2	Modular Const. Fixture			1000
WBS 1.2.4.3	Beam Builder			2784
WBS 1.2.4.4	Contour Meas. System			50
WBS 1.2.5.1	Hangar		5908	5908
WBS 1.2.5.2	Dolly		454	908
WBS 1.2.5.3	Propellant Storage			114,400
WBS 1.2.6.1	Logistics Module	12365	17980	17980
WBS 1.2.6.2	OTV Prop. Deliv. Mod.			TBD
	TOTALS	58,590 kg (129,190 lbs)	125,554 kg (276,847 lbs)	226,505 kg (499,444 lbs)

TABLE C MASS SUMMARIES FOR THE VARIOUS SOC CONFIGURATIONS

WBS 1.2.1 HABITAT MODULES

1.0 WBS Dictionary

This element includes the Habitat Modules which are the primary living and working areas for the crew. A

2.0 Description

The Habitat Modules (HM's) (WBS 1.2.1.1 and 1.2.1.2) are 4.877m diameter x 14m long (16 ft. diam. x 45.93 ft. long) pressurized modules that provide the primary living and working areas for the SOC crew, see Figure A. These modules are connected to the Service Modules and Docking Tunnel via berthing ports. The exterior of the HM is surrounded by a radiator/meteoroid protection shell. Each end of the HM has a protuberance which houses the Command Center on one end and an Observatory on the other end, see Figure B. The interiors of the two HM's are virtually identical (refer to WBS 1.2.1.1 for descriptions of the interior furnishings and equipment). The HM's interior is based on a longitudinal deck configuration, see Figure C. (See Boeing -20, Section 7.0 for discussion of alternative arrangements). Each HM is designed to house 4 people in the normal mode of operation with provisions for housing up to 8 people in a degraded/emergency mode and during crew exchange overlap periods.

The Habitat Module configuration has been revised to offset the berthing ports from the centerline. A

The Mini-Habitat Module (WBS 1.2.1.3) is a smaller version of the Habitat Module that provides sleeping quarters for four people. A

3.0 Design Basis

The HM's were designed to adhere to all of the pertinent requirements defined in Boeing -18.

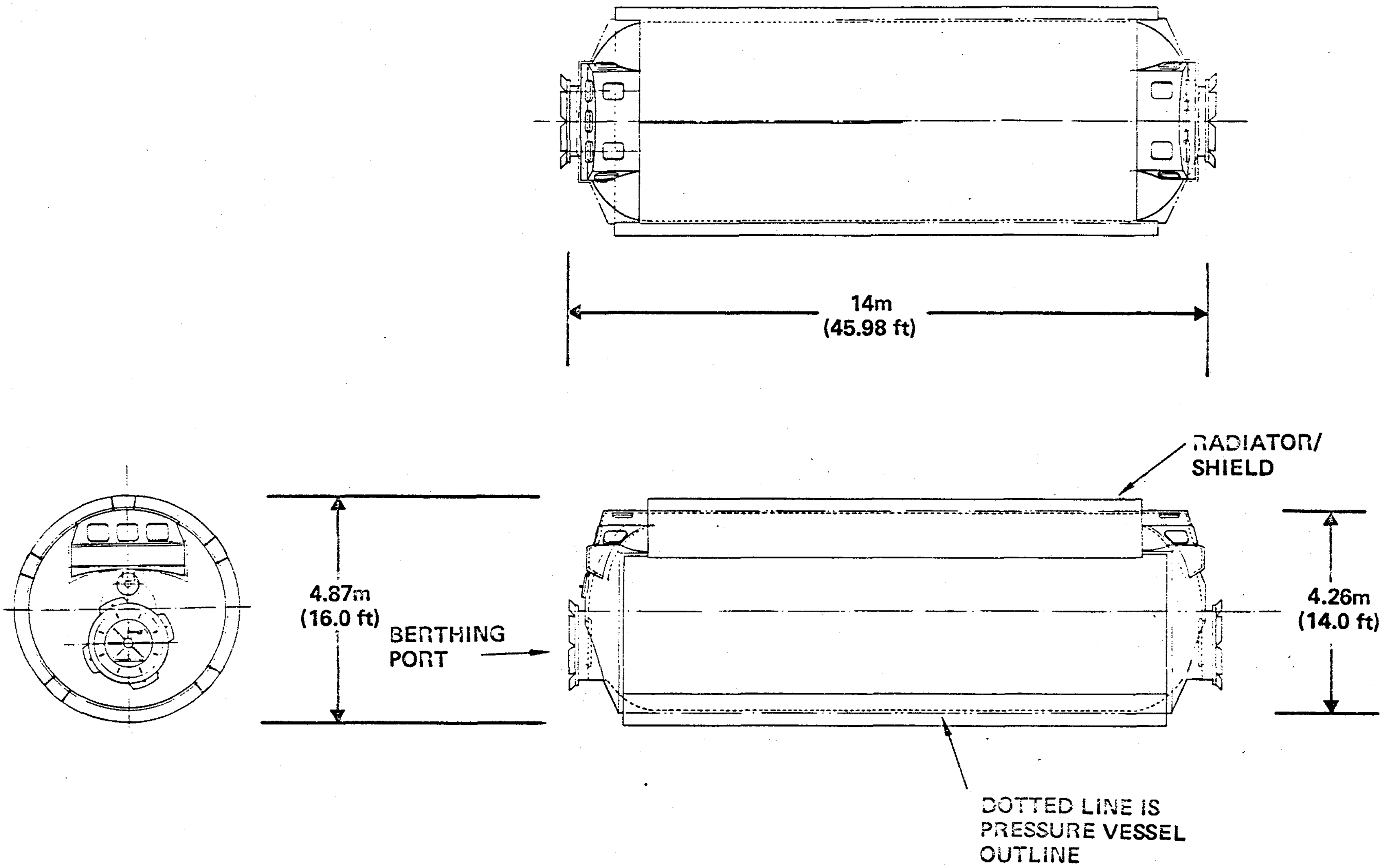


Figure A. Habitat Module

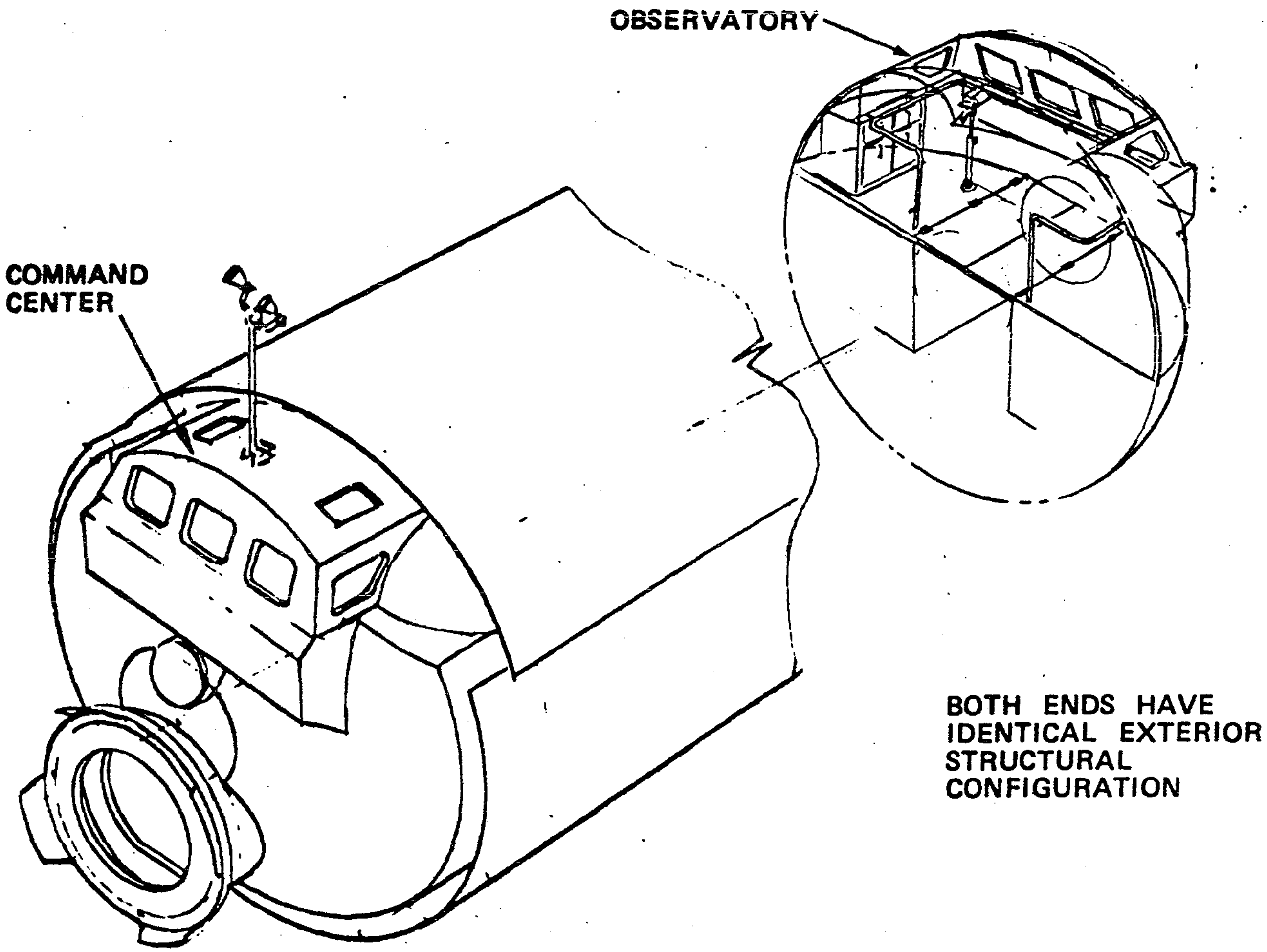


Figure 8. Habitat Module End Configuration

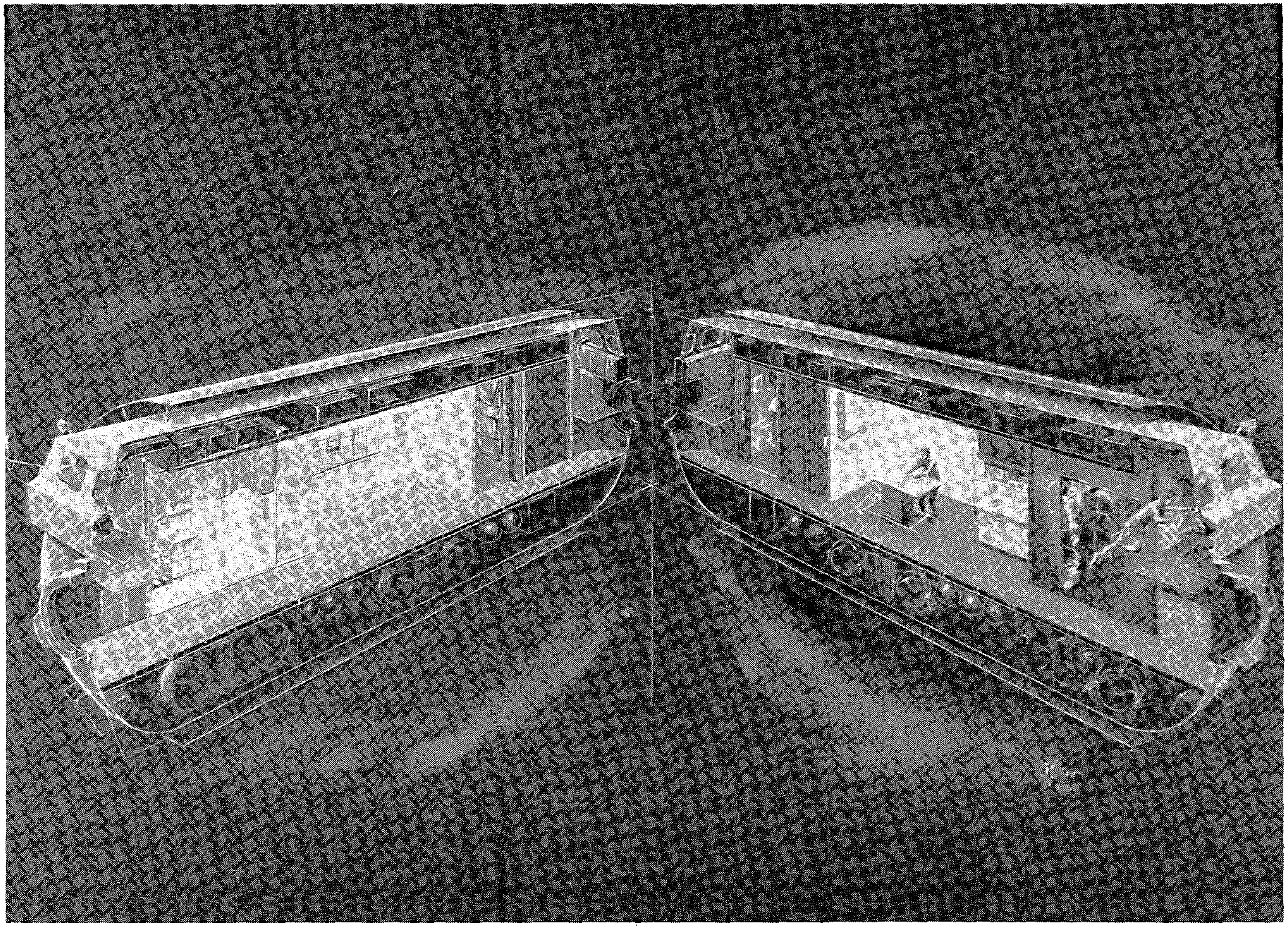


Figure C. Habitat Module Interior Arrangement Concept

The berthing ports were offset from the HM centerline so that the command center and observatory windows could be elevated so that the crewmen can see over the top of the adjacent modules. A

The HM length of 46 ft. was dictated by consideration of the center of gravity requirements for delivery by the Shuttle (see Boeing-10, Appendix 3 for discussion).

The radiator/meteoroid shield has to be attached to the pressure shell via a hinge assembly such that it can be deployed from its shipping location (stowed tight to the pressure shell) to a position that gives it a 30 cm standoff. This standoff distance was dictated by an analysis of the orbital debris collision hazard (see Boeing-13 for discussion).

Several alternative HM configurations have been explored during this study. The starting point was a configuration shown in the NASA reference concept (NASA-3). The other concepts that evolved from these are described in Boeing -6, -9, -11, -12, -13, -14, -15, and -20. The most viable alternative concepts are described in Boeing-11 and -15.

The Mini-Habitat Module was added to provide additional private crew quarters for crew sizes that exceed 8 people. A

4.0 Mass

The present habitat module is 14 meters (46 feet) in length. The internal airlock shown in earlier configurations has been removed. A detailed weight statement is presented in Table A.

The weights as presented include mission equipment for the SOC operational missions that would mormally be launched with the habitat module. It does not include any science and applications experiments that might be located within the habitat module.

The thickness of the main pressure membrane was dictated by collision criteria. The collision protection analysis assumed the 1980 debris flux model published by Kesler of JSC and employed a non-penetration criterion of 10^{-4} per year. Because the penetration criterion was somewhat arbitrary, it was assumed that to accommodate more thorough analyses and testing at a later date the criterion could be allowed to vary rather than varying the pressure wall thickness. Accordingly, the weight, growth and allowance in this statement is not applied to the main pressure membrane. The growth allowance also is not applied to comsumables and mission equipment. A growth figure of 33% was used. This figure is consistent with historical data on this type of system. The critical weight for the SOC is the launched weight and the center of gravity. The margins for launched weight include the growth allowance plus most of the mission equipment which could be launched on a separate launch or with a logistics module, if necessary. The total launched weight includes fixture and air lock for the shuttle payload bay estimated at 1800 kilograms plus the RMS arm estimated at 450 kilograms. The total launched weight including all margins is 26,000 kilograms.

Table A — Habitat Module Mass Statement

IN-DEX #	IN-DENT #	WBS #	TITLE	MASS KG(LB)	OFFSETS,M(FT) X	Y	Z	RATIONALE FOR ESTIMATE
1	1	1.2.1.1	HAB MODULE	21518	5.2	0	0	SUM
				(47437	17	0	0)	
2	2	1.2.1.1.1	STRUCTURES	7637	6.7	0	.1	SUM
				(16837	22.1	0	.5)	
3	3	1.2.1.1.1.1	PRESSURE MEMBRAN	4963	7	0	0	- D=4.267M
				(10941	22.9	0	0)	- L-CYL=9.82M
								- T=1 CM
								- .707 ELLIPT DOMES
								- CUTOUTS: 3@1M, 6@.4M, 4@.4MX.5M
								- S-CYL=131.6 M2
								- S-DOMES=46.3M2
								- S-CUT=-3.91M2
								- NET=174.05M2
								- 2219 ALUM
								- 1% FOR WELDS, WELD LANDS, AND SKIN THICKNESS TOLERANCES
4	3	1.2.1.1.1.2	RING FRAMES	310	7	0	0	- DEPTH=0.1M
				(683	22.9	0	0)	- X-SEC AREA=3.23 CM2
								- SPACING=0.5M
								- 2219 ALUM
5	3	1.2.1.1.1.3	DOME RING FRAMES	50	7	0	0	ESTIMATE
				(110	22.9	0	0)	
6	3	1.2.1.1.1.4	MAIN SUPT RINGS	276	3	0	0	- DEPTH=.25M
				(608	9.8	0	0)	- X-SEC AREA=38.7 CM2
								- 2219 ALUM

Table A — Habitat Module Mass Statement (Continued)

INDEX #	INDENT #	WBS #	TITLE	MASS KG(LB)	OFFSETS,M(FT) X	Y	Z	RATIONALE FOR ESTIMATE
7	3	1.2.1.1.1.5	MAIN SUP LONGERO	134 (295	4 13.1	0 0	0 0)	- LENGTH=4.6M - X-SEC AREA=51.5 CM2 - 2219 ALUM
8	3	1.2.1.1.1.6	MAIN SUP TRUNNIO	69 (152	12 39.3	0 0	0 0)	- FORWARD TRUNNIONS - 2 SIDE FTGS - 1 KEEL FTG - FWD Y-Z LOADS & TORSION - TITANIUM
9	3	1.2.1.1.1.7	MAIN SUP TRUNNIO	136 (300	3 9.8	0 0	0 0)	- AFT TRUNNIONS - 2 SIDE FTGS - X LOADS & AFT YZ LOADS - TITANIUM
10	3	1.2.1.1.1.8	GROUND SERV DOOR	91 (201	6 19.6	0 0	0 0)	BASED ON MASS OF 747 PASSENGER DOOR
11	3	1.2.1.1.1.9	GND SERV DOOR FR	68 (150	6 19.6	0 0	0 0)	ESTIMATE - LOW STRESS REGION
12	3	1.2.1.1.1.10	ENTRY HATCH & ME	113 (249	7 22.9	0 0	0 0)	ORBITER AIRLOCK HATCH & MECH
13	3	1.2.1.1.1.11	ENTRY HATCH FRAM	82 (181	7 22.9	0 0	0 0)	ESTIMATE
14	3	1.2.1.1.1.12	VIEWPORT ASSEMBL	725 (1598	7 22.9	0 0	2 6.5)	- VIEWPORT AT EACH END - 3.7 M2 EACH - 97 KG/M2

Table A — Habitat Module Mass Statement (Continued)

INDEX #	INDENT #	WBS #	TITLE	MASS KG(LB)	OFFSETS, M(FT) X	Y	Z	RATIONALE FOR ESTIMATE
15	3	1.2.1.1.1.13	FLOOR BEAMS	102	7	0	-1	- LENGTH 3.2M
				(225	22.9	0	-3.3)	- DEPTH 0.15M
								- X-SEC AREA 5.8 CM2
								- SPACING 0.5 M
								- ALUMINUM
								- UNIT WT 3.27 KG/M2
16	3	1.2.1.1.1.14	DOME FLOOR BEAMS	19	7	0	-1	- SAME UNIT WT AS ABOVE
				(42	22.9	0	-3.3)	- AREA 5.68 M2
17	3	1.2.1.1.1.15	CEILING BEAMS	33	7	0	1	- LENGTH 2.8 M
				(73	22.9	0	3.2)	- DEPTH 0.1 M
								- X-SEC AREA 1.9 CM2
								- SPACING 0.5 M
								- ALUMINUM
								- UNIT WT 1.1 KG/M2
18	3	1.2.1.1.1.16	EQUIP SUP RAILS	134	7	0	0	- LENGTH 10.77 M
				(295	22.9	0	0)	- X-SEC AREA 3.23 CM2
								- ALUMINUM
19	3	1.2.1.1.1.17	FLOOR DECKING	196	7	0	-1	- REMOVABLE PANELS
				(432	22.9	0	-3.3)	- ALUMINUM HONEYCOMB CONSTRUCTION
								- EST 4.88 KG/M2
								- AREA 40.14 M2

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
20	3	1.2.1.1.1.18	EC/LSS DUCTING	45	7	0	0	ESTIMATE
				(99	22.9	0	0)	
21	3	1.2.1.1.1.19	MISC SECONDARY S	91	7	0	0	ESTIMATE
				(201	22.9	0	0)	
22	2	1.2.1.1.2	MECHANISMS	136	7	0	0	SUM
				(300	22.9	0	0)	
23	3	1.2.1.1.2.1	UNIV BERTH PORTS	136	7	0	0	- ONE EACH END
				(300	22.9	0	0)	- 60% OF DOCKING PORTS
24	2	1.2.1.1.3	THERMAL CONTROL	2992	6.9	0	0	SUM
				(6596	22.7	0	0)	
25	3	1.2.1.1.3.1	RADIATOR SKIN	1437	7	0	0	D=4.57M
				(3168	22.9	0	0)	- L=11.82M - T=0.3 CM (SELECTED FOR COLLISION SHIELDING) - S=170 M2 - ALUMINUM - 2% FACTOR FOR OVERLAP
26	3	1.2.1.1.3.2	RADIATOR TUBES	206	7	0	0	- ID 12 MM
				(454	22.9	0	0)	- T=1 MM - 2219 ALUMINUM - WT=0.1197 KG/M - SPACING=0.1M - 80% COVERAGE (ALLOWANCE FOR OVERLAP) - 10% FACTOR FOR FLEX CONNECTS

Table A — Habitat Module Mass Statement (Continued)

IN-DEX #	IN-DENT #	WBS #	TITLE	MASS KG(LB)	OFFSETS,M(FT) X	Y	Z	RATIONALE FOR ESTIMATE
27	3	1.2.1.1.3.3	TUBE PEDESTALS	420 (926	7 22.9	0 0	0 0)	- X-SEC AREA 0.97 CM2 - TOTAL LENGTH 1566M - ALUMINUM
28	3	1.2.1.1.3.4	FREON COOLANT	346 (763	7 22.9	0 0	0 0)	- TUBE ID 12 MM - TUBE LENGTH 1566 M - DENSITY 1458 KG/M2
29	3	1.2.1.1.3.5	STANDOFF SUPT SY	200 (441	7 22.9	0 0	0 0)	ESTIMATE INCLUDES STRUTS, HINGE BRACKETS, SPRINGS, & STRUCTURES REQD FOR LAUNCH LOADS SUPPORT
30	3	1.2.1.1.3.6	MULTILAYER INS	88 (194	7 22.9	0 0	0 0)	- 30 LAYERS - 0.15 MIL MYLAR SHIELDS - SKIN AREA 207 M2 - UNIT WT 0.34 KG/M2 - 25% FACTOR FOR INSTL
31	3	1.2.1.1.3.7	COLD PLATES	114 (251	5 16.4	0 0	0 0)	BASED ON HAM STANDARD WTS FOR COLD PLATES
32	3	1.2.1.1.3.8	MISC FREON LOOP	181 (399	7 22.9	0 0	0 0)	ESTIMATE - HTX'S, INSTRUMENTATION, DUCT, ACCUMULATORS, PUMPS, FILTERS, VALVES, HEATERS, CONTROLS

Table A — Habitat Module Mass Statement (Continued)

IN- DEX #	IN- DENT #	WBS #	TITLE	MASS KG(LB)	OFFSETS,M(FT) X	Y	Z	RATIONALE FOR ESTIMATE
33	2	1.2.1.1.4	PRIME PROPULSION	0	0	0	0	(NO PRIME PROPULSION)
				(0	0	0	0)	
34	2	1.2.1.1.5	AUX PROPULSION	0	0	0	0	(NO AUX PROPULSION)
				(0	0	0	0)	
35	2	1.2.1.1.6	ORDNANCE	32	7	0	0	32 PIN PULLERS ON
				(71	22.9	0	0)	OUTER WALL @ 1 KG
36	2	1.2.2.1.7	ELECTRICAL POWER	665	6.2	0	0	SUM
				(1466	20.4	0	0)	
37	3	1.2.2.1.7.1	BUSSING	25	7	0	0	SID SILVERMAN ESTIMATE
				(55	22.9	0	0)	
38	3	1.2.2.1.7.2	HARNESSES	500	6	0	0	SID SILVERMAN
				(1102	19.6	0	0)	ESTIMATE
39	3	1.2.2.1.7.3	MISC.EQUIPMENT	50	7	0	0	SID SILVERMAN
				(110	22.9	0	0)	ESTIMATE FOR BOXES,CONNECTORS,SWITCHES,ETC.
40	3	1.2.2.1.7.4	INTERIOR LIGHTIN	40	7	0	0	G. WOODCOCK ESTIMATE
				(88	22.9	0	0)	
41	3	1.2.2.1.7.5	EMERGENCY BATTER	50	7	0	0	G. WOODCOCK ESTIMATE
				(110	22.9	0	0)	- THIS BATTERY FOR EMERGENCY LIGHTS AND CRITICAL ELEX.
42	2	1.2.1.1.8	GN&C	100	2	0	0	BACKUP COMPUTER IN
				(220	6.5	0	0)	CONTROL STATION - MAIN GN&C IS IN SERVICE MODULE
43	2	1.2.1.1.9	TRACKING & COMM	275	2.9	0	0	SUM
				(606	9.6	0	0)	

Table A — Habitat Module Mass Statement (Continued)

IN-DEX #	IN-DENT #	WBS #	TITLE	MASS KG(LB)	OFFSETS,M(FT) X	Y	Z	RATIONALE FOR ESTIMATE
44	3	1.2.1.1.9.1	RF EQUIPMENT	167	2	0	0	SUM
			(	368	6.5	0	0)	
45	4	1.2.1.1.9.1.1	SIGNAL PROC	22	2	0	0	STAFF ESTIMATE
			(	49	6.5	0	0)	
46	4	1.2.1.1.9.1.2	DIGITAL PROCESSO	22	2	0	0	STAFF ESTIMATE
			(	49	6.5	0	0)	
47	4	1.2.1.1.9.1.3	SWITCHING NETWOR	20	2	0	0	STAFF ESTIMATE
			(	44	6.5	0	0)	
48	4	1.2.1.1.9.1.4	MODUL & PREAMP	40	2	0	0	- 8 UNITS @ 5 KG
			(	88	6.5	0	0)	- RF POWER AMPS ARE IN SM
49	4	1.2.1.1.9.1.5	GPS RCVR & PROC	23	2	0	0	STAFF ESTIMATE
			(	51	6.5	0	0)	
50	4	1.2.1.1.9.1.6	EVA RCVR/XMTR	20	2	0	0	2 UNITS
			(	44	6.5	0	0)	
51	4	1.2.1.1.9.1.7	RADAR PROCESSOR	20	2	0	0	BALANCE OF RADAR IS
			(	44	6.5	0	0)	IN SM
52	3	1.2.1.1.9.2	INTRA-SOC VOICE	30	7	0	0	SUM
			(	66	22.9	0	0)	
53	4	1.2.1.1.9.2.1	VOICE TERMINALS	10	7	0	0	TEN UNITS AT 1 KG
			(	22	22.9	0	0)	
54	4	1.2.1.1.9.2.2	C & W EQUIPMENT	20	7	0	0	ESTIMATE
			(	44	22.9	0	0)	
55	3	1.2.1.1.9.3	C & T SUPPORT	78	3.3	0	0	SUM
			(	172	10.9	0	0)	
56	4	1.2.1.1.9.3.1	TV CAMERA	20	2	0	0	FOUR AT 5 KG
			(	44	6.5	0	0)	
57	4	1.2.1.1.9.3.2	DIGITAL PROCESSO	23	2	0	0	ESTIMATE
			(	51	6.5	0	0)	

Table A — Habitat Module Mass Statement (Continued)

IN-DEX #	IN-DENT #	WBS #	TITLE	MASS KG(LB)	OFFSETS,M(FT) X	Y	Z	RATIONALE FOR ESTIMATE
58	4	1.2.1.1.9.3.3	CABLE HARNESSES	35	5	0	0	15 M AT 1 KG/M AND 40
				(77	16.4	0	0)	M AT 1/2 KG/M
59	2	1.2.1.1.10	DATA MGMT	568	3.4	0	.4	SUM
				(1252	11.3	0	1.6)	
60	3	1.2.1.1.10.1	DIS & CON PANEL	108	1	0	1	ESTIMATED 20 M2
				(238	3.2	0	3.2)	ALUMINUM SHEET EQUIVALENT
61	3	1.2.1.1.10.2	CRT'S	120	1	0	1	6 AT 20 KG EACH (MAIN
				(265	3.2	0	3.2)	PANEL)
62	3	1.2.1.1.10.3	KEYBOARDS & DISP	50	1	0	1	ESTIMATE]
				(110	3.2	0	3.2)	
63	3	1.2.1.1.10.4	REMOTE TERM	120	10	0	0	6 AT 20 KG EACH,
				(265	32.8	0	0)	1-GALLEY, 1-MED, 1 EACH 4 CREW QTRS
64	3	1.2.1.1.10.5	COMPUTERS	120	2	0	0	6 AT 20 KG EACH
				(265	6.5	0	0)	
65	3	1.2.1.1.10.6	WIRING & BUSSING	50	5	0	0	ESTIMATE
				(110	16.4	0	0)	
66	2	1.2.1.1.11	INSTRUMENTATION	100	7	0	0	ALLOWANCE FOR
				(220	22.9	0	0)	NON-DEDICATED INSTRUMENTATION
67	2	1.2.1.1.12	CREW ACCOMM.	853	8.7	.3	0	SUM
				(1881	28.6	.9	0)	
68	3	1.2.1.1.12.1	DINING TABLE	41	8	-1	0	ESTIMATE
				(90	26.2	-3.3	0)	
69	3	1.2.1.1.12.2	RECREATION	100	8	1	0	ESTIMATE
				(220	26.2	3.2	0)	

Table A — Habitat Module Mass Statement (Continued)

IN-DEX #	IN-DEPT #	WBS #	TITLE	MASS KG(LB)	OFFSETS,M(FT) X	Y	Z	RATIONALE FOR ESTIMATE
70	3	1.2.1.1.12.3	HEALTH MAINT	200	8	1	0	ESTIMATE
				(441	26.2	3.2	0)	
71	3	1.2.1.1.12.4	SLEEP RESTRAINTS	41	12	0	0	ESTIMATE
				(90	39.3	0	0)	
72	3	1.2.1.1.12.5	WRITING DESK	41	12	0	0	ESTIMATE
				(90	39.3	0	0)	
73	3	1.2.1.1.12.6	SIDEWALL LINER	122	7	0	0	SIMILAR TO COMMERCIAL
				(269	22.9	0	0)	AIRLINER
74	3	1.2.1.1.12.7	CEILING LINER	50	7	0	0	SAME
				(110	22.9	0	0)	
75	3	1.2.1.1.12.8	PERSONAL STORAGE	40	12	0	0	ESTIMATE
				(88	39.3	0	0)	
76	3	1.2.1.1.12.9	PARTITIONS	159	9	0	0	SIMILAR TO COMMERCIAL
				(351	29.5	0	0)	AIRLINER
77	3	1.2.1.1.12.10	FOLDING DOORS	36	11	0	0	ESTIMATE
				(79	36	0	0)	
78	3	1.2.1.1.12.11	MISC. ITEMS	23	10	0	0	ESTIMATE
				(51	32.8	0	0)	
79	2	1.2.1.1.13	EC/LSS	1498	4.1	-.1	-.3	SUM
				(3302	13.5	-.2	-1)	
80	3	1.2.1.1.13.1	CONTROLS & DISPL	23	3	0	0	HAM STANDARD ESTIMATE
				(51	9.8	0	0)	
81	3	1.2.1.1.13.2	HUM CONTROL PACK	26	7	0	0	SAME
				(57	22.9	0	0)	
82	3	1.2.1.1.13.3	THERMO. REGEN	14	5	0	0	SAME
				(31	16.4	0	0)	
83	3	1.2.1.1.13.4	CO2 CONTROL PACK	54	5	0	1	SAME
				(119	16.4	0	3.2)	
84	3	1.2.1.1.13.5	TRACE CONTAM CON	49	5	0	1	SAME
				(108	16.4	0	3.2)	

Table A — Habitat Module Mass Statement (Continued)

IN-DEX #	ID-DENT #	WBS #	TITLE	MASS KG(LB)	OFFSETS, M(FT) X	Y	Z	RATIONALE FOR ESTIMATE
85	3	1.2.1.1.13.6	WATER PROC EVAP	376	5	0	0	SAME
				(829	16.4	0	0)	
86	3	1.2.1.1.13.7	HOT/COLD WATR	23	4	0	0	SAME
				(51	13.1	0	0)	
87	3	1.2.1.1.13.8	WATER QUAL MON	27	4	0	0	SAME
				(60	13.1	0	0)	
88	3	1.2.1.1.13.9	POTABLE WATER	69	3	0	-1	SAME
				(152	9.8	0	-3.3)	
89	3	1.2.1.1.13.10	WASTE WATER STOR	69	3	0	-1	SAME
				(152	9.8	0	-3.3)	
90	3	1.2.1.1.13.11	EMERG WATER STOR	386	3	0	-1	SAME
				(851	9.8	0	-3.3)	
91	3	1.2.1.1.13.12	THERMAL/VENT	78	7	0	0	SAME
				(172	22.9	0	0)	
92	3	1.2.1.1.13.13	EMU RECHG STA	27	3	-2	0	SAME
				(60	9.8	-6.6	0)	
93	3	1.2.1.1.13.14	FOOD FREEZER	27	5	-1	0	SAME
				(60	16.4	-3.3	0)	
94	3	1.2.1.1.13.15	WASTE COLL SYS	41	2	2	0	SAME
				(90	6.5	6.5	0)	
95	3	1.2.1.1.13.16	HAND WASH	11	3	-1	0	SAME
				(24	9.8	-3.3	0)	
96	3	1.2.1.1.13.17	SHOWER	54	3	1	0	SAME
				(119	9.8	3.2	0)	
97	3	1.2.1.1.13.18	CLOTHES WASHER	41	4	-1	0	SAME
				(90	13.1	-3.3	0)	
98	3	1.2.1.1.13.19	TRASH COMACT	18	8	-1	0	SAME
				(40	26.2	-3.3	0)	
99	3	1.2.1.1.13.20	FOOD REFRIGERATO	45	5	-1	0	SAME
				(99	16.4	-3.3	0)	
100	3	1.2.1.1.13.21	DISHWASHER	14	4	-1	0	SAME
				(31	13.1	-3.3	0)	

Table A — Habitat Module Mass Statement (Continued)

INDEX #	INDENT #	WBS #	TITLE	MASS KG(LB)	OFFSETS,M(FT) X	Y	Z	RATIONALE FOR ESTIMATE
101	3	1.2.1.1.13.22	OVEN	17	5	-1	0	SAME
				(37	16.4	-3.3	0)	
102	3	1.2.1.1.13.23	ODOR CONTROL	9	.3	.3	.3	SAME
				(20	.9	.9	.9)	
103	2	1.2.1.1.17	MISSION EQUIPMEN	3655	4.6	0	-.3	SUM
				(8058	15.3	.2	-.9)	
104	3	1.2.1.1.17.1	EVA SUITS	274	2.5	-1.5	0	THREE SUITS
				(604	8.2	-5	0)	
105	3	1.2.1.1.17.2	CREW PERS EFFECT	300	7	0	0	MAYNARD DALTON
				(661	22.9	0	0)	ESTIMATE
106	3	1.2.1.1.17.3	MANUALS	200	2	0	1	ESTIMATE
				(441	6.5	0	3.2)	
107	3	1.2.1.1.17.4	UTENSILS & TOOLS	235	2	0	-1	MAYNARD DALTON
				(518	6.5	0	-3.3)	ESTIMATE
108	3	1.2.1.1.17.5	CONSUMABLES	1679	5.2	0	-.6	SUM
				(3702	17.2	0	-1.9)	
109	4	1.2.1.1.17.5.1	ATMOSPHERE	205	7	0	0	DENSITY X VOLUME
				(452	22.9	0	0)	
110	4	1.2.1.1.17.5.2	SPARES	474	5	0	-2	ROUGHLY 15% OF
				(1045	16.4	0	-6.6)	SUBSYSTEMS & EQUIPMENT MASS
111	4	1.2.1.1.17.5.3	FOOD	1000	5	0	0	MAYNARD DALTON
				(2205	16.4	0	0)	ESTIMATE
112	3	1.2.1.1.17.6	SUPPLIES	967	4.7	.6	0	SUM
				(2132	15.6	2.2	0)	
113	4	1.2.1.1.17.6.1	HOUSEK/HYGIENE	254	6	0	0	MAYNARD DALTON
				(560	19.6	0	0)	ESTIMATE

Table A — Habitat Module Mass Statement (Continued)

IN-DEX #	IN-DENT #	WBS #	TITLE	MASS KG(LB)	OFFSETS,M(FT) X	Y	Z	RATIONALE FOR ESTIMATE
114	4	1.2.1.1.17.6.2	COMMODE	250	2	2	0	SAME
				(551	6.5	6.5	0)	
115	4	1.2.1.1.17.6.3	ECLS SUPPLIES	300	7	0	0	SAME
				(661	22.9	0	0)	
116	4	1.2.1.1.17.6.4	EVA SUPPLIES	163	3	1	0	SAME
				(359	9.8	3.2	0)	
117	2	1.2.1.1.18	GROWTH	3007	0	0	0	33% OF DRY WEIGHT EXCEPT COLLISION SHIELD
				(6628	0	0	0)	

WBS 1.2.1.1 HABITAT MODULE NO. 1

1.0 WBS Dictionary

This element is the first Habitat Module to be installed in the SOC. It provides one of the primary living and working areas for the crew.

2.0 Description

The Habitat Module No. 1 interior arrangement is shown in Figures A through D.

The Command Center end will berth to Service Module No. 1 (WBS 1.2.2.1). The opposite end will berth to an Airlock Module (WBS 1.2.2.4) in the Initial SOC Configuration and will berth to the Docking Tunnel (WBS 1.2.2.3) in the Operational and Growth SOC Configurations.

The only provisions in HM1 that are not included in HM2 (WBS 1.2.1.2) are the clothes washer/dryer, voice communications antenna, and electrical power jumper cables which are required in HM1 to make it independent of the SM1 in an emergency mode where the SM1 has to be evacuated (see Boeing -11, Appendix 3 for discussion of these requirements).

3.0 Design Basis

Refer to WBS 1.2.1, section 3.0 and to the Boeing -11 reference cited above.

The Command Center is on the Service Module end so that the crew can observe the exterior operational areas during the Initial SOC Configuration.

4.0 Mass

Refer to WBS 1.2.1, section 4.0.

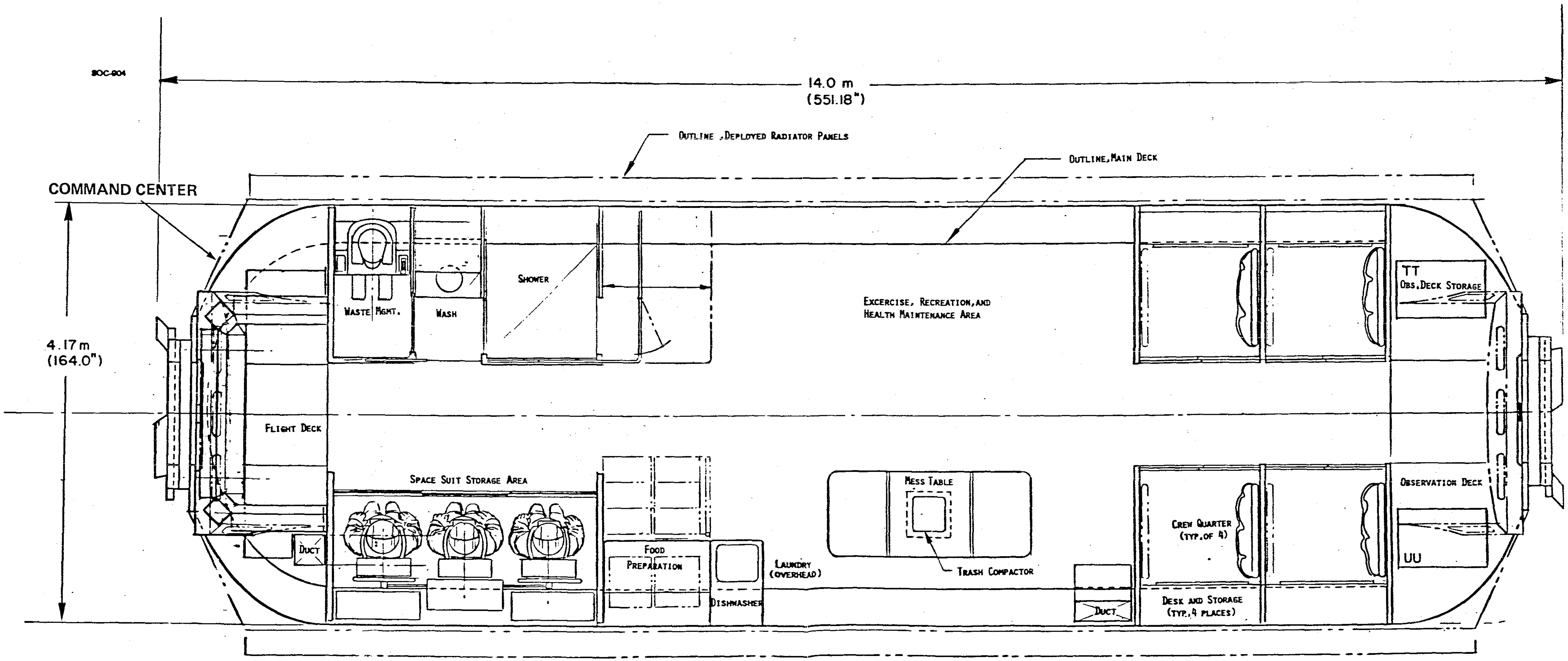
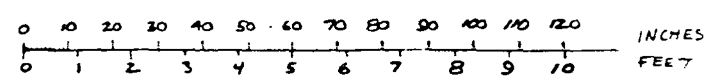


Figure A.

GENERAL ARRANGEMENT HABITAT MODULE
PLAN VIEW



This Page Intentionally Left Blank

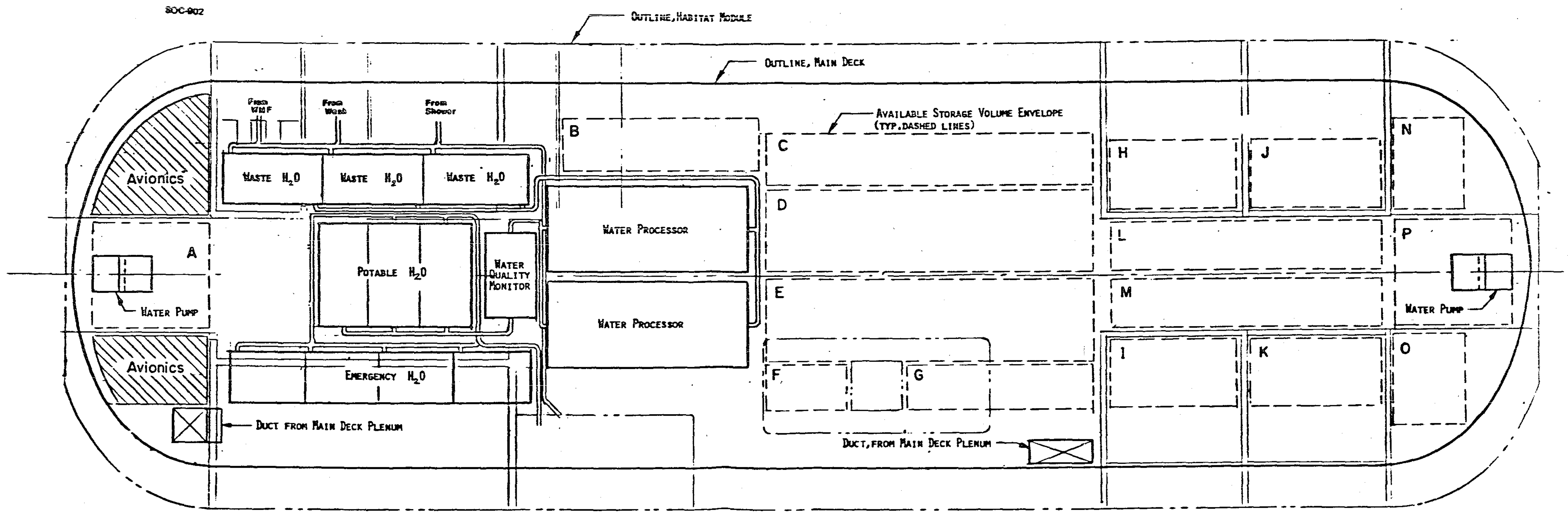


Figure B

GENERAL ARRANGEMENT UNDER MAIN DECK

This Page Intentionally Left Blank

SOC-903

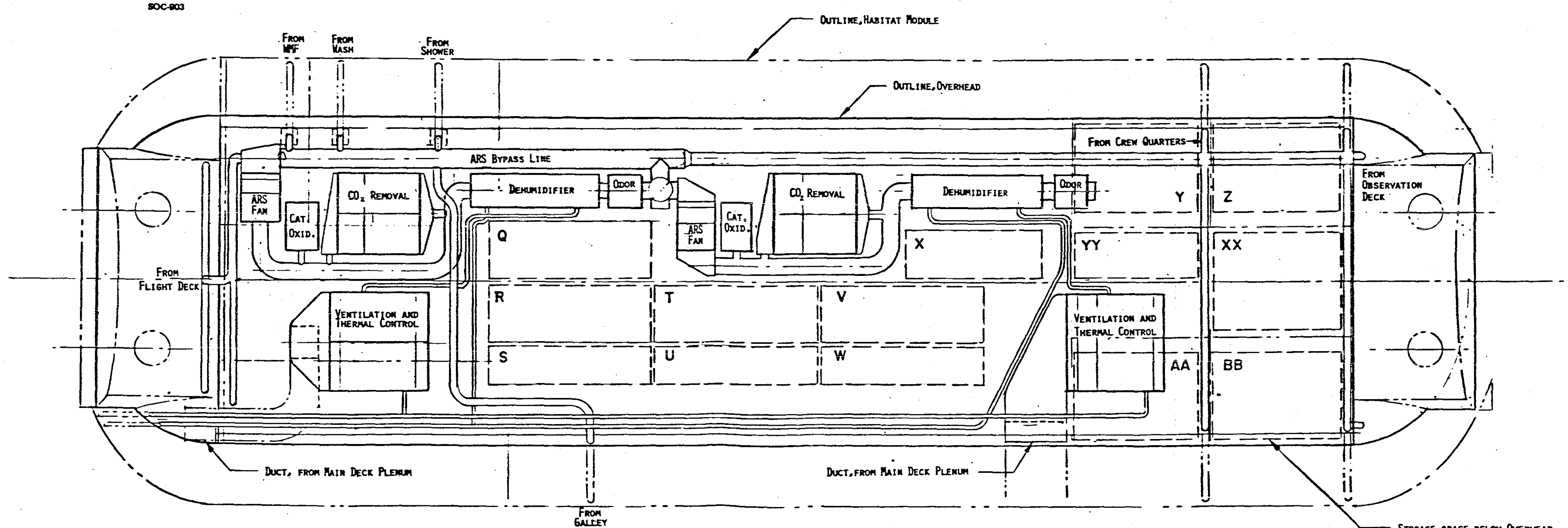


Figure C.

GENERAL ARRANGEMENT OVERHEAD

This Page Intentionally Left Blank

SOC-1373

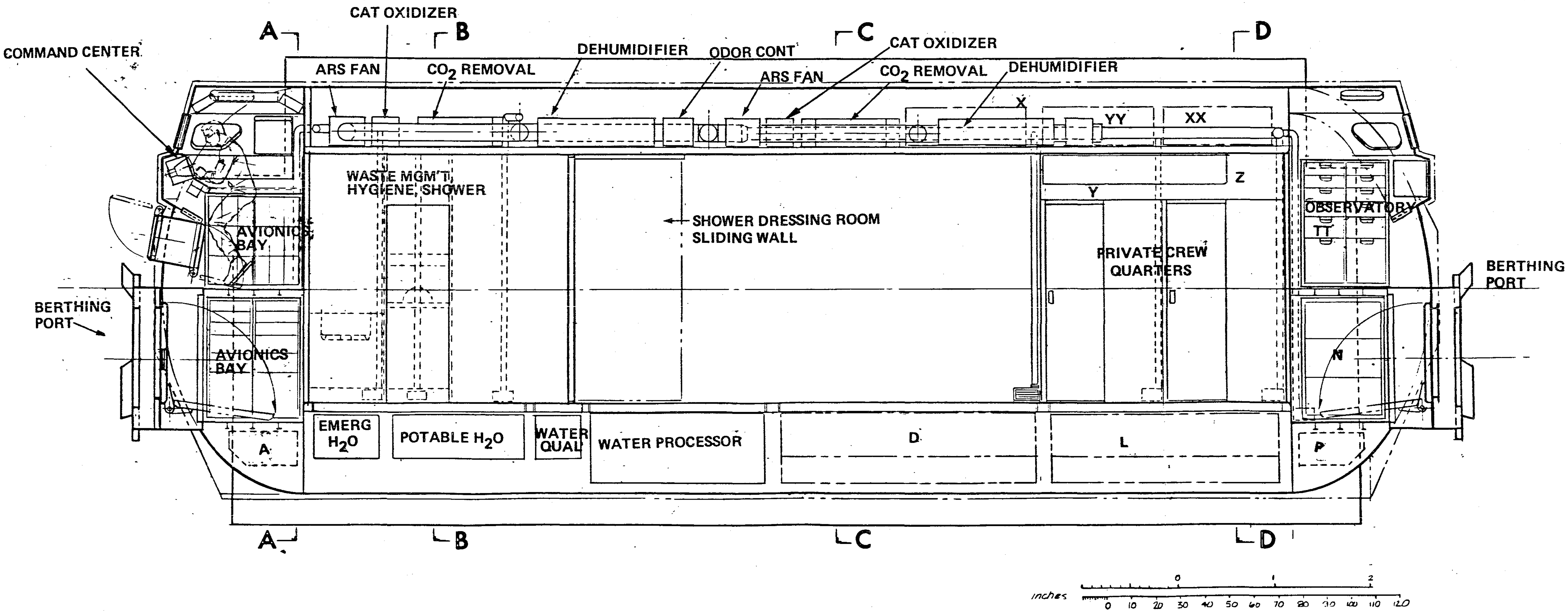


Figure D. Habitat Module Side View

This Page Intentionally Left Blank

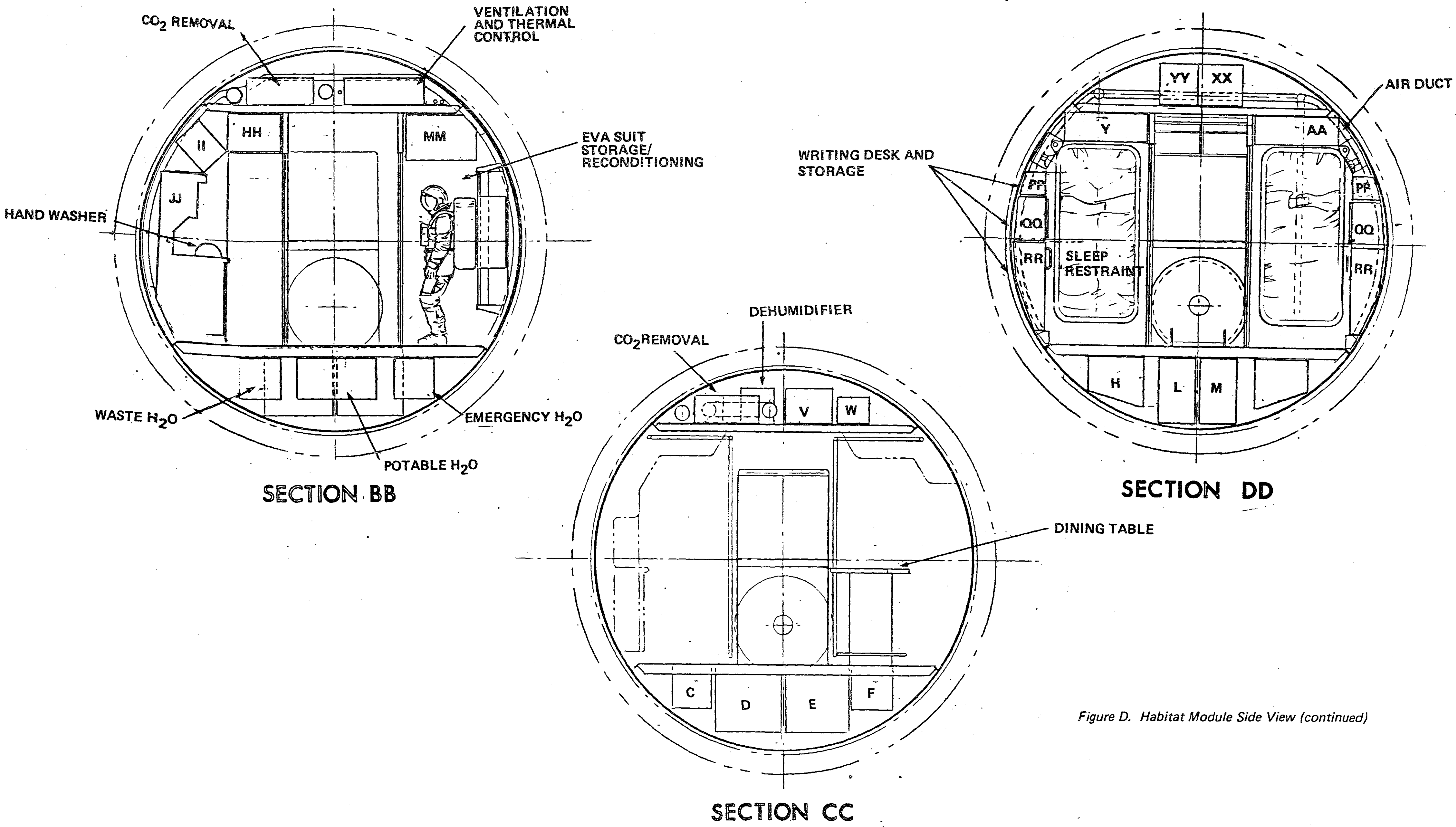


Figure D. Habitat Module Side View (continued)

This Page Intentionally Left Blank

WBS 1.2.1.1.1 STRUCTURES

1.0 WBS Dictionary

This element includes the Habitat Module pressure vessel and interior secondary structures.

2.0 Description

Figure A illustrates the cabin wall design approach, including a spring-loaded standoff radiator and collision shield. The shield needs to be at least 30 cm from the main wall to be effective. In order to maximize the internal pressure volume available to the crew, the collision shield is packaged adjacent to the wall for launch and released to the shield position after the SOC is assembled in orbit. The shield-radiator is in four sections for each habitability module.

In the reference concept, the HM pressure vessel is composed of 1.0 cm aluminum. Manufacturing splices have not been defined.

The interior secondary structure has not been defined beyond the conceptual configuration shown in Figures A through D in WBS 1.2.1.1.

3.0 Design Basis

The SOC cabin wall is designed to collision criteria, based on the estimated 1990 debris flux model (Kessler et al, IEE Spectrum, June 1980), and a probability of penetration of 10^4 per year (see Boeing-13).

4.0 Mass

See WBS 1.2.1 mass statement.

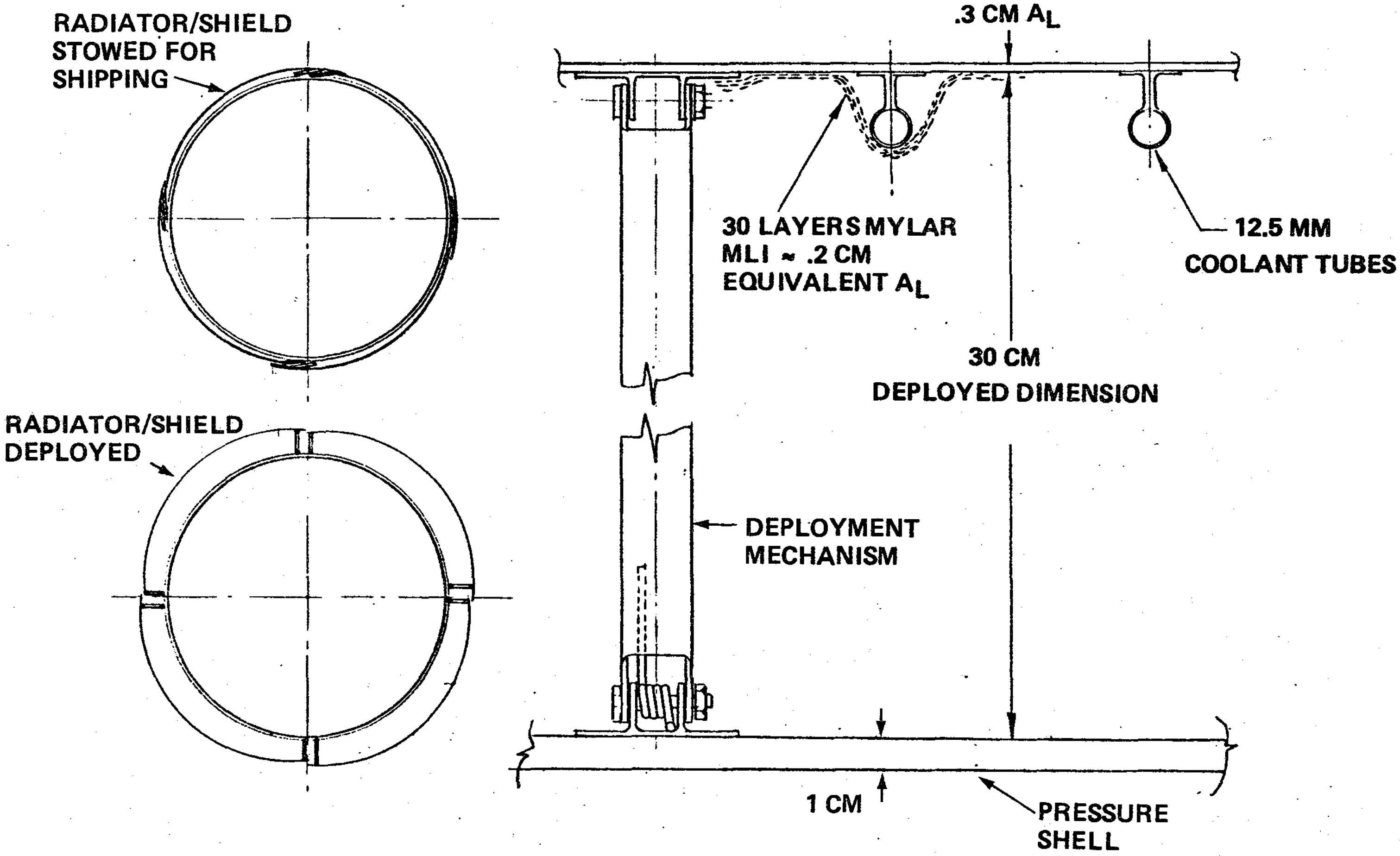


Figure A. Cabin Wall Concept

WBS 1.2.1.1.2 MECHANISMS

1.0 WBS Dictionary

This element includes the berthing ports, umbilical actuators, and the radiator/ collision shield deployment actuators.

2.0 Description

Figures A and B illustrate the berthing port concept showing the mechanical, electrical, fluid line and gas line interfaces (Reference: Rockwell-9). The hatch, latches, and hinges have not been configured. They would probably be similar to the Orbiter's airlock hatch.

There will be external umbilical connectors that will connect external hydrazine and hydrogen lines across the module-to-module interface. Figure C illustrates a concept for a remotely actuated connector (Reference: Rockwell-9).

The collision radiator/shield will be composed of 4 segments that will be stowed against the HM pressure vessel wall during launch and then will be deployed to a 30m stand-off after the HM is installed at the SOC (see WBS 1.2.1.1.1). This deployment will require remotely controlled actuators. These actuators have not been configured.

3.0 Design Basis

The berthing port concept was derived from the docking port concept (see WBS 1.2.2.1.2). Also see MacDac-1 and -2 for alternative concepts.

The external umbilical connectors/actuators result from safety requirements that dictate that pressurized gases and toxic gases must be plumbed outside of the pressure volume. The concept shown in Figure C is only one concept. (Also see MacDac-1 and -2.)

The rationale for the deployable radiator/collision shield was that it was desirable to provide the maximum internal pressure envelope diameter. It was deemed to be practical to collapse the shield around the pressure shell to get the total packaged diameter within the cargo bay envelope.

4.0 Mass

See WBS 1.2.1 mass statement.

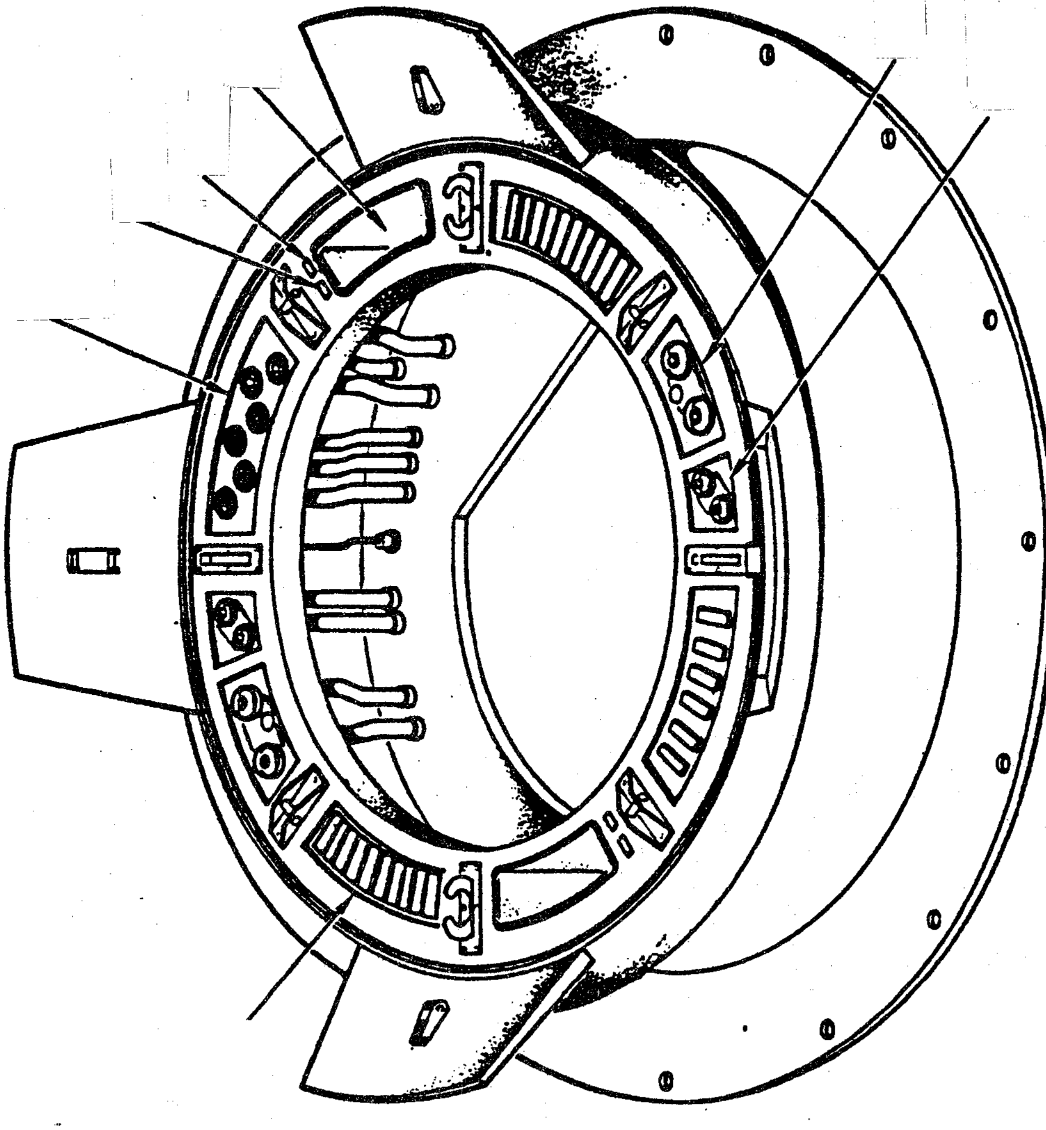


Figure A. Berthing Port Concept

SOC-872

SOC-876

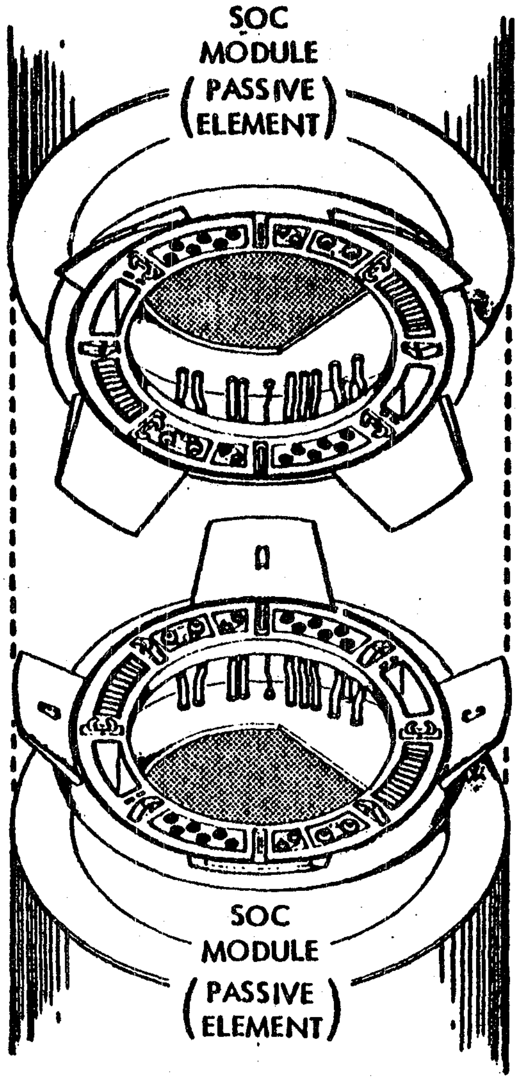


Figure B. Berthing Port-to-Berthing Port Mating Concept

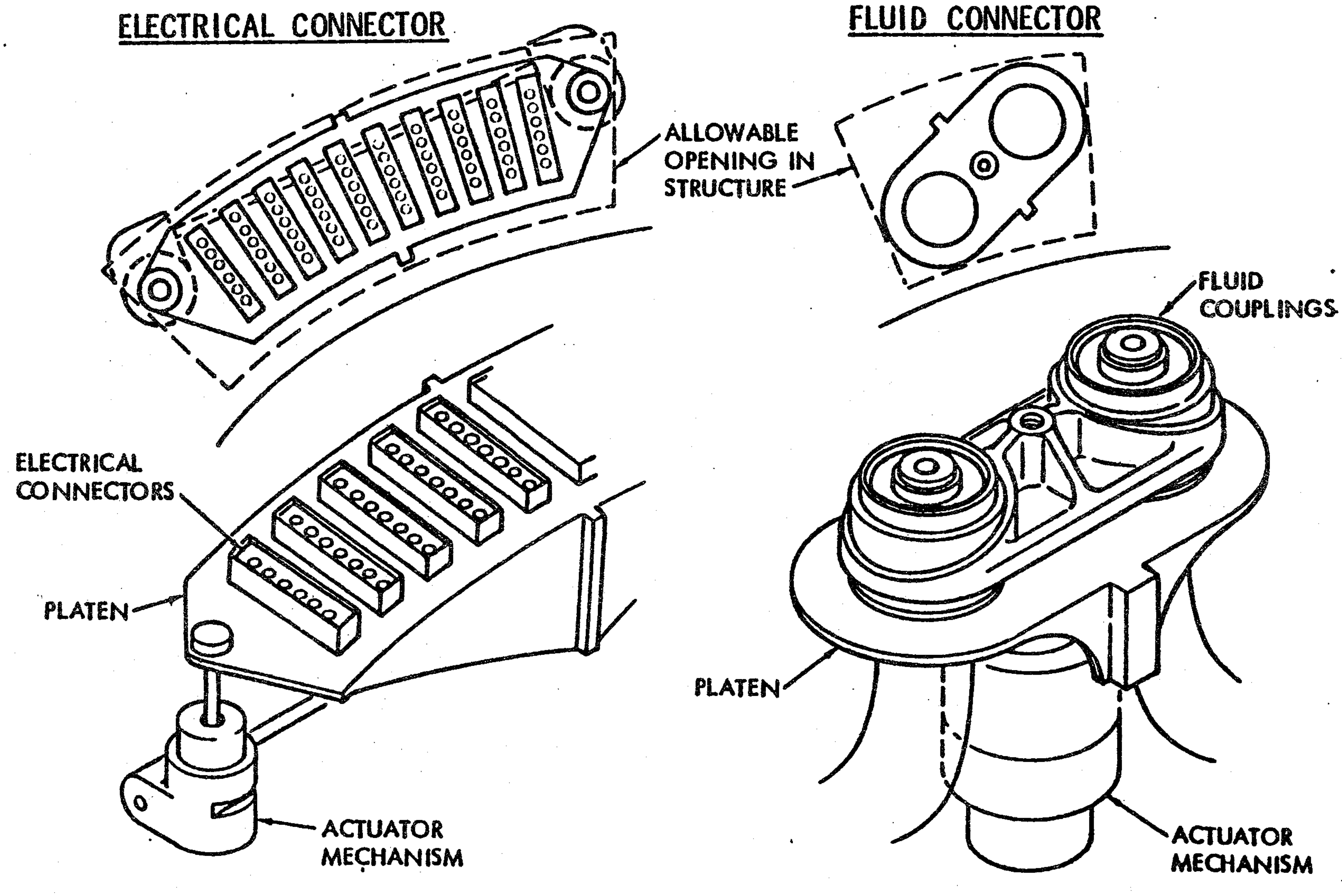


Figure C. Remote Actuated Interface Connectors Concepts

WBS 1.2.1.1.3 THERMAL CONTROL

1.0 WBS Dictionary

This element includes the external radiator, the flexible lines between the radiator segments and the freon pumps, freon-to-water heat exchangers, water pumps, internal coolant lines, and cold plates.

2.0 Description

The habitat module thermal control system is integrated with the collision protection bumper that surrounds the habitat module's cylindrical wall. The thickness of the bumper was selected for the collision criterion at 3 mm. The radiator system is divided into eight subsections. Each subsection extends 90° in arc around the cylinder of the habitat module and is half of the habitat module length. Each radiator subsection can be isolated by valves to minimize the fluid loss in the event of a puncture or damage. Each radiator section includes two fluid loops with the tubes sharing the radiator fin area such that loss of a single loop will result in relatively little loss of radiator cooling performance.

The division of the radiator and the subsections allows the radiator and bumper assembly to be packaged close to the SOC pressure membrane for launch and then by means of a spring and hinge mechanism be extended to provide a 30 cm gap between the bumper and the main pressure membrane after reaching orbit. This optimizes the bumper protection performance.

Coolant tubes are mounted on pedestals inside the bumper skin area as shown in Figure A in WBS 1.2.1.1.1 to minimize the risk of puncture due to collision or other damage. The habitat module's inner skin is covered with multilayered insulation to isolate it from the radiator system. This is important to maintain the inner skin at the habitat air temperature to prevent condensation of humidity on the habitat wall.

The habitat module radiator skin surface uses a white paint type coating with an estimated absorptivity of 0.2 and emissivity of 0.9. This allows the habitat radiator to operate at approximately $18^{\circ}C$ under the SOC illumination conditions.

Figure A shows the HM radiator performance characteristics. Figure B shows the seasonal variation in heat rejection capability. A

3.0 Design Basis

The thermal control radiator was integrated with the collision protection system in the interest of saving weight and since both subsystems must occupy the same structure and the same location. A white paint thermal control radiator approach was selected because the station configuration and flight attitude is such that significant solar input to the radiator will occur. The radiator must function at temperatures low enough, i.e., in the 55°F range, that selective coatings are important to achieve satisfactory performance. The radiator area was selected as the maximum available in order to provide as much design margin as practicable. The use of a two-loop system with a water loop internal to the habitat module and a Freon loop for the radiator system is conventional spacecraft design. The water is used internally because of its non-toxicity, and Freon is used externally because it will not freeze at the expected minimum radiator temperatures.

4.0 MASS

Refer to WBS 1.2.1 mass statement.

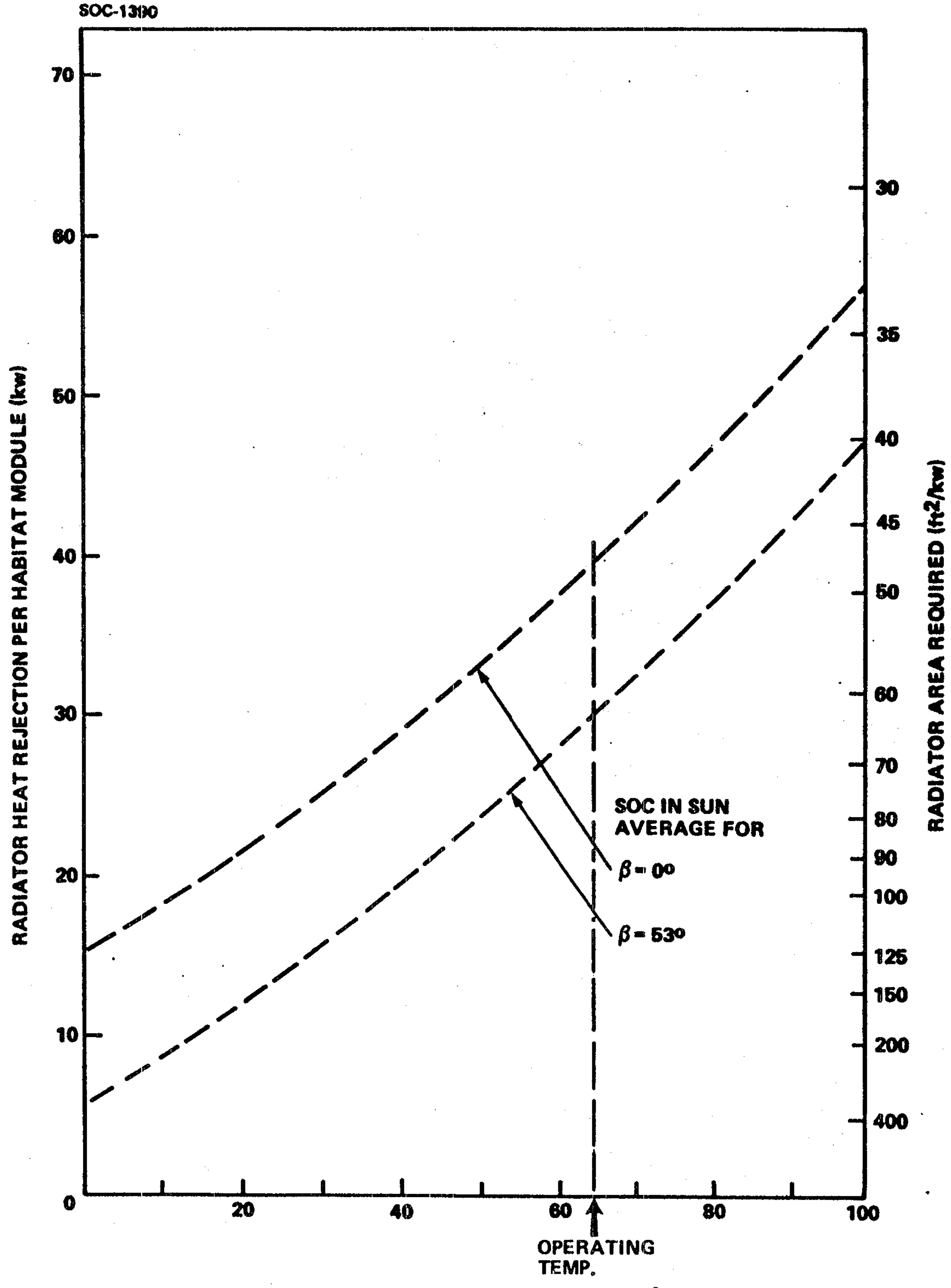


Figure A. SOC Habitat Module Radiator Performance

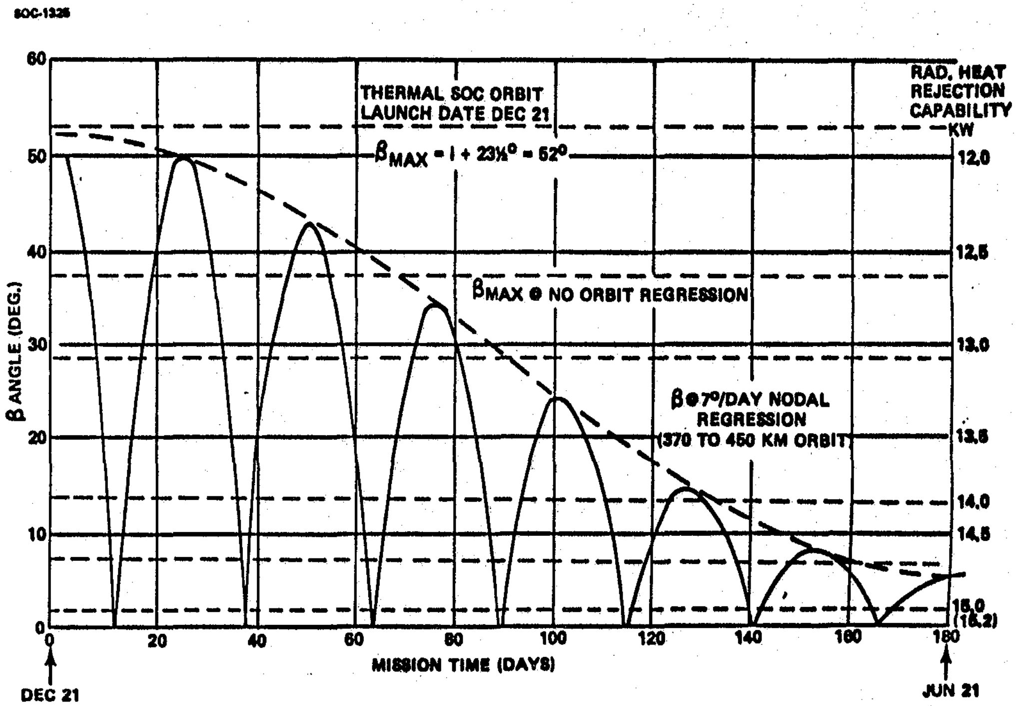


Figure B. SOC Habitat Module Heat Rejection Capability vs Time

WBS 1.2.1.1.7 ELECTRICAL POWER

1.0 WBS Dictionary

This element includes the distribution and control, battery charger, emergency battery, unregulated DC bus, DC regulator, DC-AC inverter, emergency bus, DC regulated bus, AC regulated bus, and automatic power system management system.

2.0 Description

The HM electrical power system schematic diagram is shown in figure A. The electrical loads for the elements shown in this schematic are summarized in WBS 1.2.2.1.7. The elements shown here have not been configured. The electrical power system is more fully described in WBS 1.2.2.1.7.

3.0 Design Basis

Refer to WBS 1.2.2.1.7.

4.0 Mass

See WBS 1.2.1 mass statement.

SOC-917

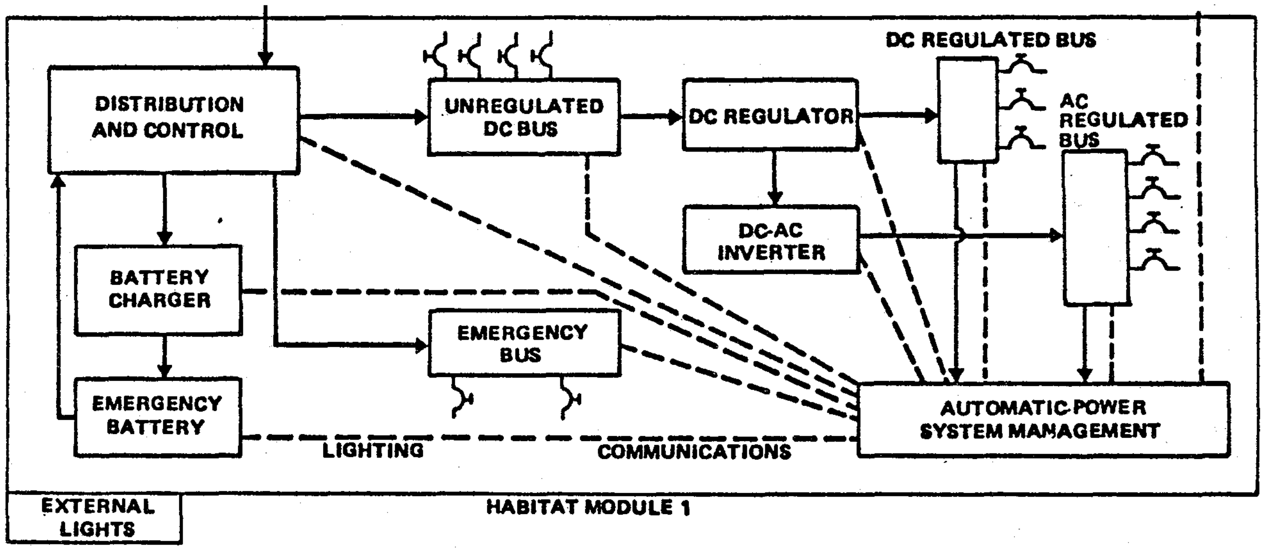


Figure A. Electrical Power System Schematic

WBS 1.2.1.1.8 GUIDANCE, NAVIGATION, AND CONTROL

1.0 WBS Dictionary

This element includes the control and displays dedicated to guidance, navigation, and control.

2.0 Description

The main SOC guidance navigation and control equipment is in the service module (refer to WBS 1.2.2.1.8). The habitat module includes a backup computer for the GN&C function. Normally this computer would be able to command the service module propulsion subsystem for attitude control and orbit makeup. It also will provide the SOC crew with navigational information. Under emergency conditions this backup capability would allow the SOC crew to take over manual control of the propulsion subsystem for attitude control and orbit makeup.

3.0 Design Basis

(Refer to WBS 1.2.2.1.8)

4.0 Mass

Refer to WBS 1.2.1 mass statement.

WBS 1.2.1.1.9 TRACKING AND COMMUNICATIONS

1.0 WBS Dictionary

This element includes the communications and tracking hardware incorporated in the Habitat Module.

2.0 Description

The tracking and communications systems concept is described in detail in WBS 1.2.2.1.9. The equipment in the Habitat Module is shown in Figure A.

Analog signals (TV, voice) and digital signals requiring conversion to analog signals are processed in the signal processor. The digital data processor performs numerous functions including data management, error correction coding/decoding, data multiplexing/demultiplexing, interrogator/transponder data formatting, control of antenna switches and antenna positioning, plus interface with the CRT terminal/annunciator, CPU's, telemetry sources and the C & W data bus.

A set of radio units are shown including transponders, GPS receiver/processor, EVA voice (and voice band data) terminals, radar processor and display units. Also shown is a caution and warning system, similar to that used in the Shuttle.

When two habitat modules are available, one module is designated as the master at any given time and most or all of its line equipment will be functional. The other habitat module will have activated (as a minimum) the caution and warning system, the signal processor, data processor, voice terminals, switching network (voice, TV), and the CRT terminal/annunciator.

3.0 Design Basis

The concept was designed to enhance SOC reliability and survivability and simplify the transition of SOC from a single to a dual habitat module spacecraft.

4.0 Mass

See WBS 1.2.1 mass statement.

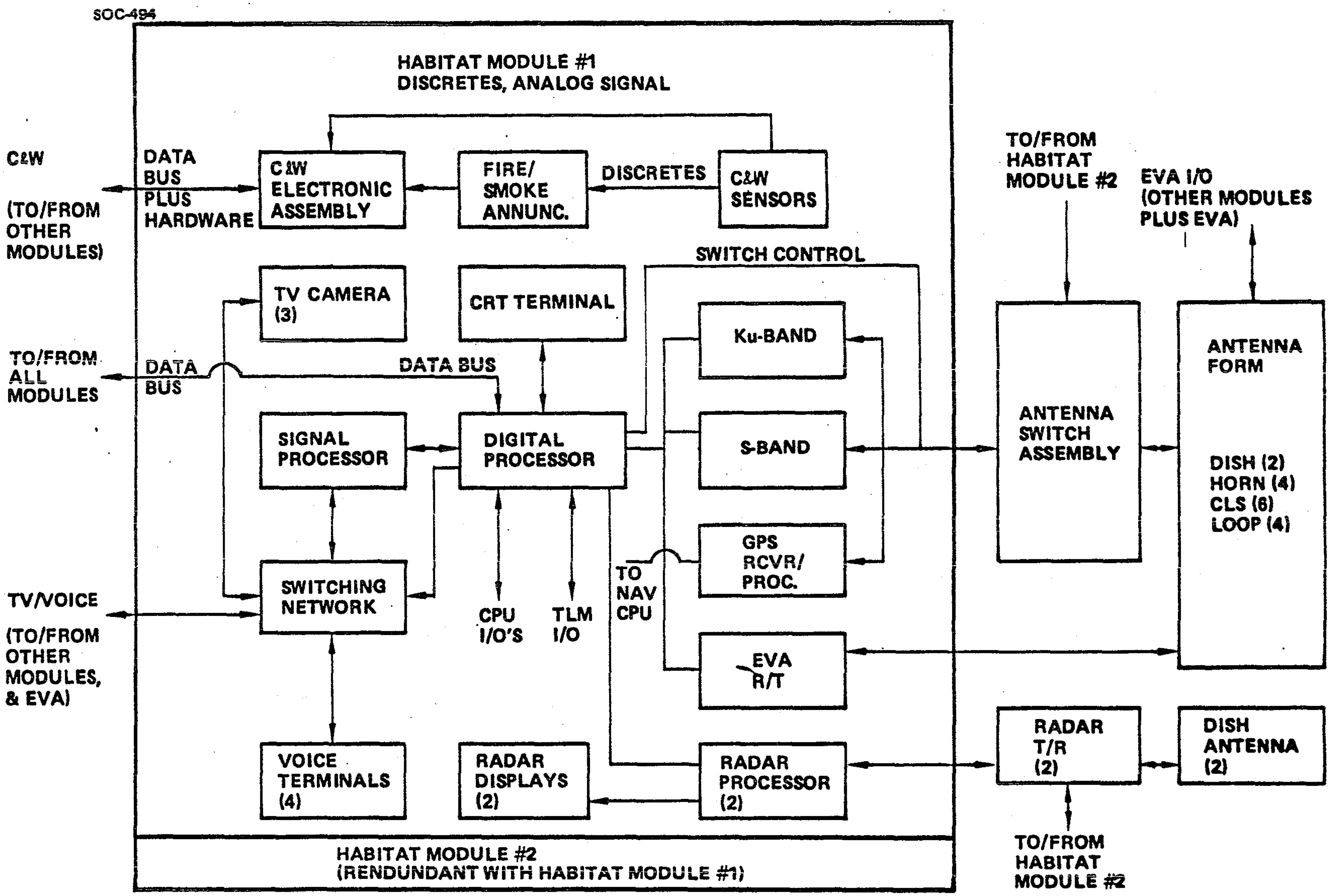


Figure A. SOC Communications and Tracking Habitat Module Schematic

WBS 1.2.1.1.10 DATA MANAGEMENT AND SOFTWARE

1.0 WBS Dictionary

This element includes the data management system hardware and software for the entire SOC.

2.0 Description

The overall system structure approximately mimics the hardware work breakdown structure, to maintain close association between software elements and hardware elements. Accordingly, the flight software and data management includes a Space Operations Center main processor in each habitability module. This processor will interface with the remainder of the systems through a contention-protocol data bus served by a common data base management processor. The remainder of the processors will be specifically function or hardware oriented as shown in Figure A. The system will employ a primary and a backup bus. The backup bus will normally handle priority interrupts. This bus can take over the primary bus role for redundancy. The bus path is circular, providing access to all processors even with local outage. The primary and backup busses shall be separately routed so that an event damaging one will be unlikely to damage the other.

3.0 Design Basis

The Space Operations Center preferred approach for data management software employs distributed processing. The distributed concept has been selected in order to associate software elements as closely as possible with the hardware elements they serve, to minimize software development problems, and maximize the final software effectiveness. Table A lists some of the benefits of distributed processing. The Space Operations Center includes several modules and subsystems, each of which will include associated processing and software. Because of the need for integrative function, a hierarchical approach rather than an equal authority distributed approach, has been selected.

A further important consideration in the data management and software system design is the recognition of the significance of interfacing with the on-board crew

SOC-588

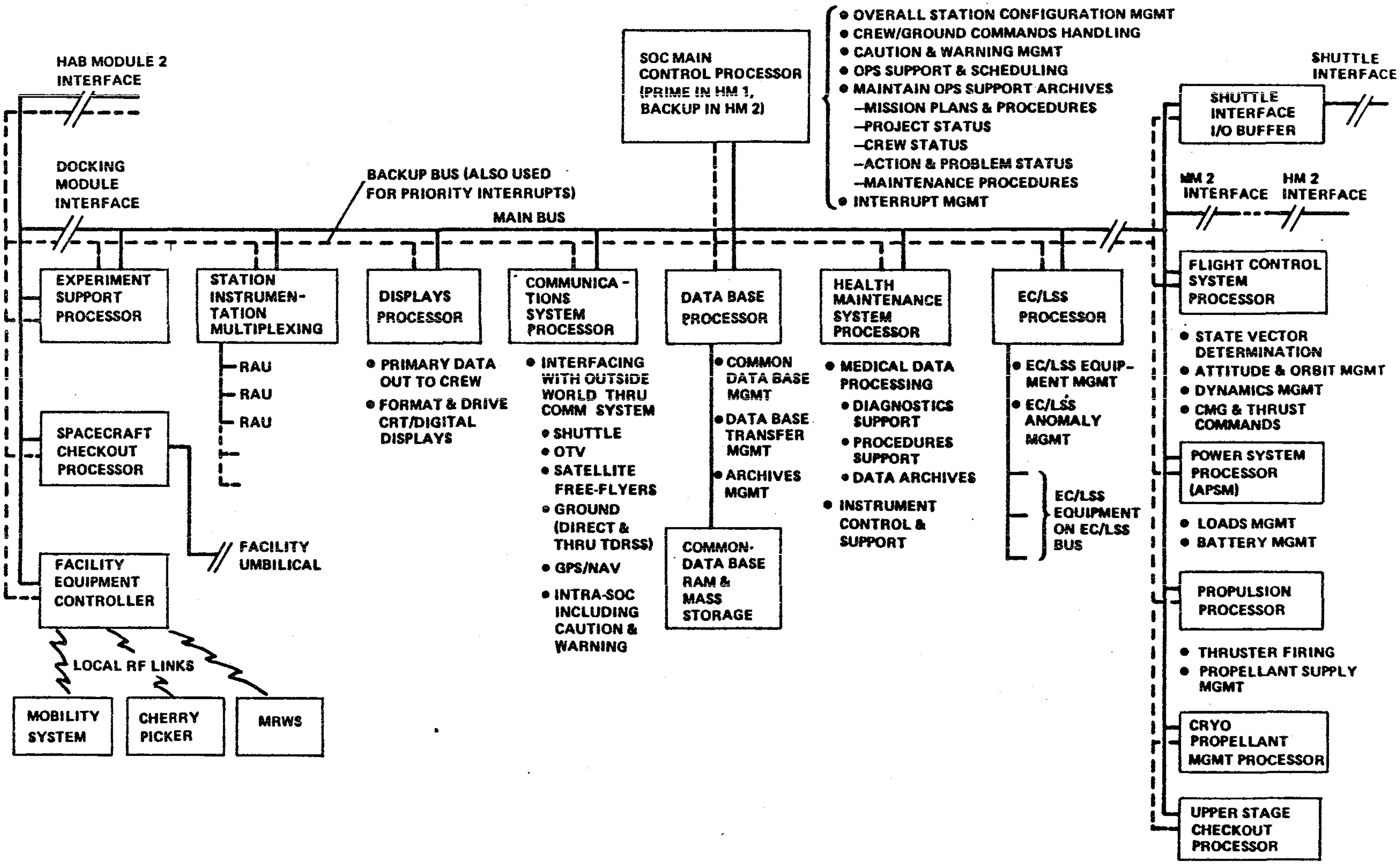


Figure A. SOC Data Management Distributed Architecture Functional Requirements

Table A. Distributed Processing Benefits

- SUPPORTS LONG MISSION REQUIREMENTS FOR GROWTH/CHANGE
- ALLOWS EFFICIENT UTILIZATION OF PROCESSOR POWER AT SUBSYSTEM LEVEL
- ASSOCIATES HARDWARE AND SOFTWARE AT SUBSYSTEM LEVEL
- DEVELOP SOFTWARE IN SMALL AUTONOMOUS UNITS
- DEVELOPMENT AND CHECKOUT OF S/W BEFORE AVIONICS INTEGRATION TESTING
- FAULT TOLERANCE/REDUNDANCY DESIGNED AT SUBSYSTEM LEVEL FOR LESS COMPLEXITY
- COMMON SIMULATOR INTERFACE AT BUS TERMINAL

through controls and displays, and interfacing with external sources of data and commands, such as ground mission control and other flight systems.

The SOC Data Management System has both unique requirements and requirements which are functionally similar to existing command and control systems. The SOC DMS has the requirement to be incrementally built-up during early stages of the mission. The first segments of the SOC put into space will eventually become part of the SOC DMS but initially it must function autonomously. These parts of the DMS must first perform independently without the resources of the full SOC DMS and later become integrated into the full DMS. These system considerations must be taken into account early in the design of the DMS.

More common requirements of the DMS include the relatively long lifetime for SOC with its changing operational environment and the presence of a crew. The latter provides great flexibility in the design of the DMS with the added burden of defining an appropriate man-machine interface. These design considerations are common to several existing command, control and surveillance systems such as AWACS.

4.0 Mass

See WBS 1.2.1 mass statement.

WBS 1.2.1.1.10.1 HARDWARE

1.0 WBS Dictionary

This element includes the data processors, data bus, controls/displays, mass storage device, and multiplexers.

2.0 Description

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

3.0 Design Basis

Consideration of the selection and/or design of data processing hardware for SOC include the following:

- For development cost savings, both hardware and software, common hardware design is needed. This may not mean that all processing elements are identical but they should be software compatible and probably from the same generic family.
- Provide redundancy at the subsystem level.

4.0 Mass

See WBS 1.2.1 mass statement.

WBS 1.2.1.1.10.1.1 PROCESSORS

1.0 WBS Dictionary

This element includes all of the processors throughout the SOC.

2.0 Description

Figure A of WBS 1.2.1.1.10 showed the schematic for the data management system which includes the processors. These processors and their requirements are described below:

1. It is a design goal to have all of the processors and mass storage media compatible software-wise, such that the various processors can back one another up to a degree, with the machine code transportable from one module to another.

2. It is assumed that each processor will include an associated mass storage medium analogous to a floppy disk system as required, depending on the quantity of code and data that processor is intended to handle.

3. Availability of crew persons to change mass storage media as necessary is assumed. Media change out should be an infrequent imposition on crew duties except for crew persons stationed at the command center.

4. SOC Main Processor.

4.1 This processor shall provide overall station configuration management under crew supervision. In this sense the main processor will provide high level commands, including override capabilities to the various subsystems or functional processors. Examples include overriding the normal attitude and orbit management strategy for the flight control system processor, issuing cabin temperature and pressure commands to the environmental control and life support system, and issuing emergency management commands to the other subsystems.

4.2 Data Archives Management. The SOC will need to maintain a relatively large archive for mission operations support and procedures, as well as for crew entertainment and data bases for system maintenance and emergency operations procedures.

4.3 Caution and Warning Management. The main processor will receive caution and warning and anomaly information from the subsystems processors, and from the station instrumentation data management, and will distribute the caution and warning data to the controls and displays processor and the communications system processor for crew annunciation.

4.4 Data Bus Control. The main processor will also control the data busses, manage the common data base, manage data base transfer between processors, and handle interrupt management.

4.5 Other Services. The processor will also serve as the primary processor for operations support and scheduling software, to provide the day-to-day software and data management support to crew operations. It will maintain the working archives on mission plans and procedures, project status, crew status, schedule status, and action and problem status. It will provide caution and warning handling.

5. Common Data Base Buffer. The common data base buffer will be a random access memory, controlled by the data bus controller to provide multiple access to frequently used common data bases for the various processors.

6. Station Instrumentation Data Management Processor. The SOC will include a set of instrumentation primarily concerned with measuring temperatures, pressures, consumables, quantities, and other items not associated with a specific subsystem. The instrumentation data management processor will be on the data bus, and provide data to the common data base buffer as necessary, for access by the various subsystems and the SOC main processor.

7. Displays Processor. The data interface to the displays processor will be formatted to minimize the processing requirements on other processors to interpret or format displays. The displays processors will access or receive, and transmit displays information to remote terminals such as those in the galley and in

the crew private quarters. This processor will also format data and drive the CRT and digital displays.

8. Communication System Processor. The communication system processor will orchestrate the operation of the communication subsystem and will handle the interfacing of the SOC data management system with the outside world through the communication system, including communications with shuttle, orbit transfer vehicles, free flyers, ground, either directly or through the tracking and data relay satellite, navigation data from the global positioning system, and intra-SOC communications, including audio and caution and warning.

9. Flight Control System Processor. The flight control system processor will determine the SOC state vector using information from the communication system processor as to navigation data from the GPS. The flight control system processor will provide the normal attitude control and orbit management function. The algorithms will be designed to maintain continuous attitude control with CMGs and to provide CMG desaturation either through utilization of orbit makeup thrusters or through utilization of attitude offsets to minimize or counter gravity gradients. Systems dynamics and adaptive control routines will reside in this system. The flight control system processor will also control and command the CMG system and will issue thrust commands to the propulsion processor.

10. Environmental Control and Life Support System Processor. The ECLSS processor will orchestrate the various elements of the ECLSS system (with suitable data exchange with the automated power systems management subsystem) in order to minimize the battery draw-down of the environmental control and life support system, consistent with maintaining proper environmental control of the station. Each subelement of the environmental control and life support system such as the humidity control, water electrolysis, CO_2 removal, etc., will have digital interfaces with the environmental control and life support processor and local component microprocessing as necessary to control the proper operation of that component. The environmental control and life support system processor will also handle normal anomaly and emergency management for the environmental control and life support system including subsystem or element failures, atmosphere cleanup, pressure control, etc. These functions will be overrideable by the crew through the command and display system and in addition, certain override functions may be provided by the SOC main processor.

11. Automated Power Systems Management. The APSM processor will control the solar array and battery systems for power management to minimize battery degradation. It will maintain cognizance and provide data to the data bus on array status, battery status, power processor status, any anomalies, emergencies or failures, and will provide emergency override and load leveling management of discretionary or optional loads such as some of those associated with cooking, lighting, etc.

12. Propulsion. This processor will monitor and maintain status of the propulsion system, distribute thrust commands to primary or secondary thrusters, detect failures or anomalies, determine and maintain status of propellant remaining, and provide data feedback on propulsion systems status and performance.

13. Propellant Storage and Transfer. This system will maintain status information on the cryogenic propellant storage and transfer systems and will provide the necessary control and management of propellant transfer operations. This will include propellant gaging, pump operation, valve control, thermal management of cryogenic propellants, and status information to the data bus.

14. Spacecraft and Project Test/Checkout Computer. This processor will provide the principal interface to checkout and test of spacecraft or construction projects being conducted by the Space Operations Center. In many instances, it will be a conduit and formattor for data and stimuli exchange between a ground-based computer and the system being checked out. It will control the remote umbilical bus on the construction facility that interfaces with the spacecraft or other project being tested.

15. Orbit Transfer Vehicle Test and Checkout Processor. This processor will provide a function similar to the spacecraft and project test and checkout processor, but for the manned and automated components of the orbit transfer vehicle. It will also interface with a data remote umbilical and will interface with the computers on board the OTV and its manned capsule to effect test checkout and readiness analysis. It will be connected to the main data bus to provide information to the command and control station.

16. Construction and Flight Support System Processor. This processor will orchestrate and control the operation of the mobility system, the cherrypicker system, and the mobile remote work station system. Data connections between these systems may be by local RF link rather than by hardwired data bus. This processor will accept crew commands from the controls and displays system or from a remote crew station adjacent to this processor, and translate these commands into commands to the individual elements of the construction system.

17. Mobility Processor, Cherrypicker Processor, and Mobile Remote Work Station Processor. These processors will service the function of translating higher level commands (such as move from here to there) into the individual motor or actuator drive commands necessary to cause the device to accomplish the command issued from the construction and flight support system processor. These systems will include position detection and anti-collision algorithms insofar as is practicable, and will also include control algorithms to suppress oscillations or spurious motions. In addition, the MRWS processor (for the pressurized version) will include all functions necessary to provide environmental control and life support in the MRWS.

18. Medical Processor. The health maintenance subsystem will include a dedicated processor that provides diagnostic and process instrumentation support for the health maintenance facility and other data base management, such as crew medical history archives. Requirements for medical data processing are discussed in more detail in the SOC requirements document.

19. Shuttle Interface. An input/output buffer and formattor shall be provided to allow digital data transfer between the space shuttle and the SOC data management system.

20. An experiment support processor will be available in the HM to provide support to SOC-based experiments.

3.0 Design Basis

The above descriptive material is oriented to spelling out functional requirements for the SOC processors. The distribution and organization of these requirements was developed to be functionally logical, and to associate data processing equipment as closely as possible with its corollary hardware as possible.

A number of processor devices are capable of serving the processing requirements described above. It is anticipated that 32-bit microprocessor systems will be the most logical choice for the SOC. Several such systems are presently in development.

4.0 Mass

See WBS 1.2.1 mass statement.

WBS 1.2.1.1.10.1.2 DATA BUS

1.0 WBS Dictionary

This element includes all of the data busses on the SOC.

2.0 Description

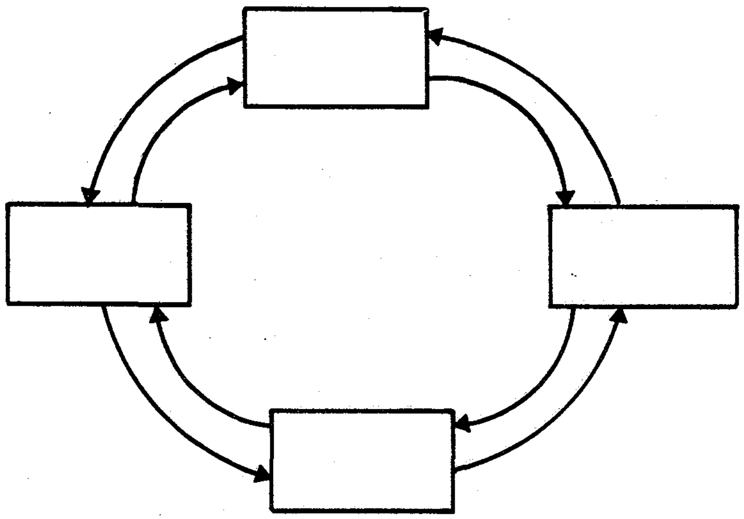
The SOC data management subsystem employs a redundant data bus structure. A final selection of data bus concepts has not been made. The preferred concept at this time is a multi-redundant bus system and an alternate bus architecture is one with bypass redundancy, see Figure A. The data bus system uses fiber optics for high bit rate capability and minimum susceptibility to electromagnetic interference.

The individual processors on the data bus are quasi-independent in that each processor can carry out its function of subsystem management without communication from other processors. Some subsystem performance will be degraded, if the data bus system is completely inoperative, but all critical functions can be maintained in an adequate state.

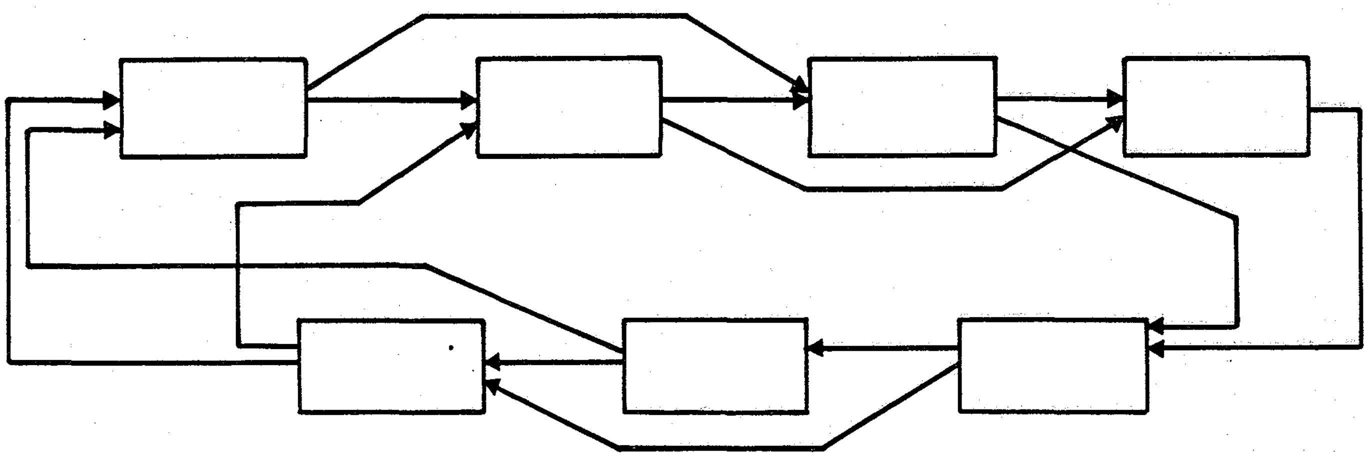
3.0 Design Basis

The data bus connecting the subfunctions is at the heart of the DMS system. The design of this subsystem has to address several considerations.

- Technology
- Interconnect topology for system responsibleness and fault tolerance
- Bus protocols
- The current study called for the NASA multi-wavelength monolithic fiber optics terminal as a baseline for system study purposes. Several hardware technologies are available for interconnection of the elements of the data management system, and several arrangements of the hardware are possible. Presently, fiber optics for data bus interconnections are favored because a) this medium is highly resistant to electromagnetic interference, and b) it readily permits very high data rates. However, fiber optic systems have



MULTI-REDUNDANT (PREFERRED CONCEPT)



BYPASS REDUNDANT (ALTERNATIVE CONCEPT)

Figure A. Data Bus Architectures

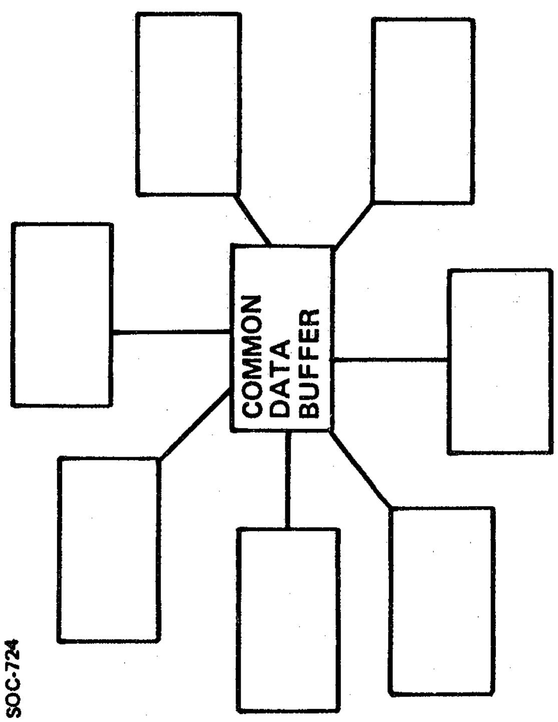
their technology mature enough that, despite some limitations, this technology can be recommended for SOC applications.

- Alternate interconnect architectures for a data bus design have been investigated, see figure B, with several design options considered more attractive. If fiber optics is the assumed bus technology, then several of the common bus structures are immediately eliminated (e.g., the star and linear bus with Tee connectors) because current fiber optics technology only has passive fiber optic connectors. The signal attenuation through these devices would be excessive for the number of subsystems assumed for the SOC DMS. Some kind of modified loop or ring architecture looks promising.
- Several bus protocols were examined. The polling protocol of MIL-STD-1553 does not appear to have the flexibility necessary for an expanding SOC mission. MIL-STD-1765 is a newly defined protocol for missiles (not yet a full standard, only under consideration). It uses a contention protocol which does allow for easy subsystem addition although not enough is yet known about the protocol to make a definite statement as to its applicability to SOC. Several commercial protocols, e.g., Ehernet, have the potential for satisfying the SOC requirements. A goal for SOC should be not to have to develop and validate a new bus protocol. This would only add schedule risk and costs to the program.

4.0 Mass

See WBS 1.2.1 mass statement.

SOC-724



STAR (LIKE KSC LPS)

Figure B—Alternative Data Bus Architecture

WBS 1.2.1.1.10.1.3 CONTROLS/DISPLAYS

1.0 WBS Dictionary

This element includes the command center controls and displays, portable control/display units, and auxiliary control/display units located in the Habitat Modules. This does not include maintenance controls and displays located on EC/LSS equipment, the health maintenance equipment controls/displays, (except for the auxiliary control/display unit), entertainment devices controls, and interior lighting controls.

2.0 Description

Figures A, B and C illustrates the command center concept. Figure D illustrates the preliminary control panel layout. Table A describes the characteristics of each of the panels. Table B lists the approximate panel area available for controls and displays. The control and display concept calls for the use of multifunction switch/keyboards, flat panel displays, color CRT's, voice interactive controls, and computer voice synthesis. Boeing-11 describes these technologies in some depth.

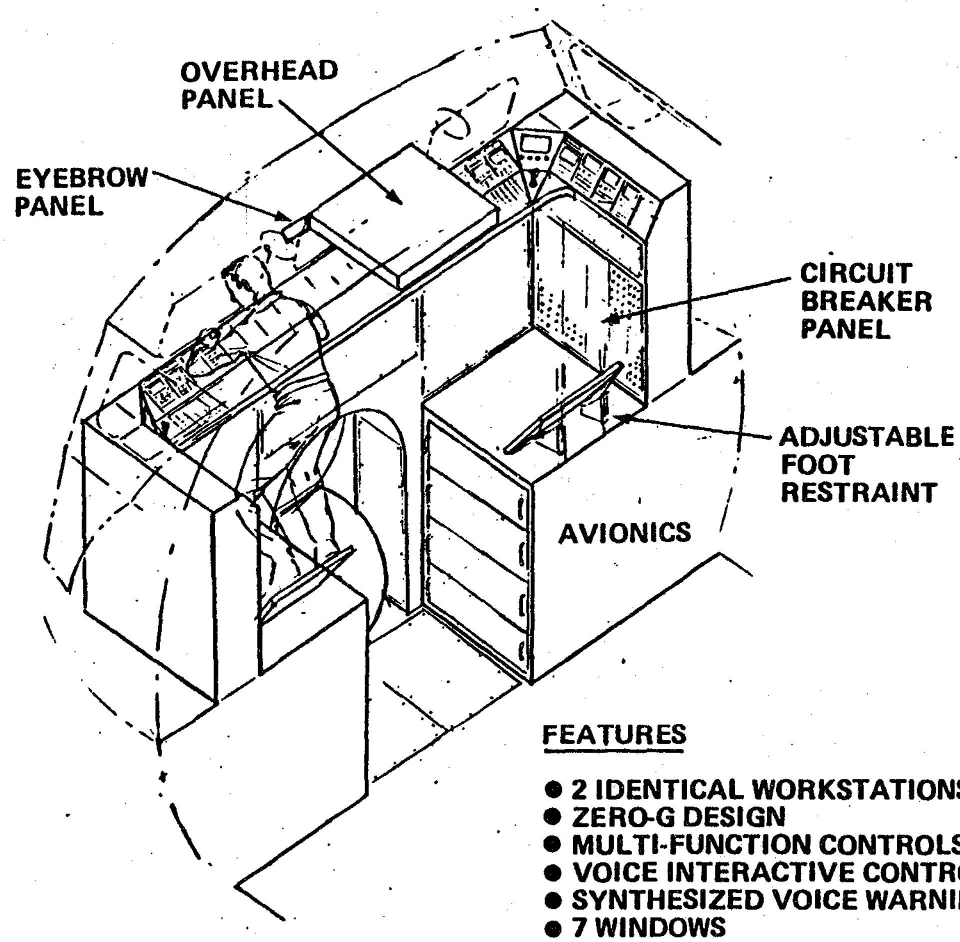
3.0 Design Basis

The rationale for the selection of the command center elements is summarized in Table C.

4.0 Mass

See WBS 1.2.1 mass statement.

SOC-638



FEATURES

- 2 IDENTICAL WORKSTATIONS
- ZERO-G DESIGN
- MULTI-FUNCTION CONTROLS/DISPLAYS
- VOICE INTERACTIVE CONTROLS
- SYNTHESIZED VOICE WARNINGS
- 7 WINDOWS
- ALL DIGITAL AVIONICS

Figure A. Command Center Concept

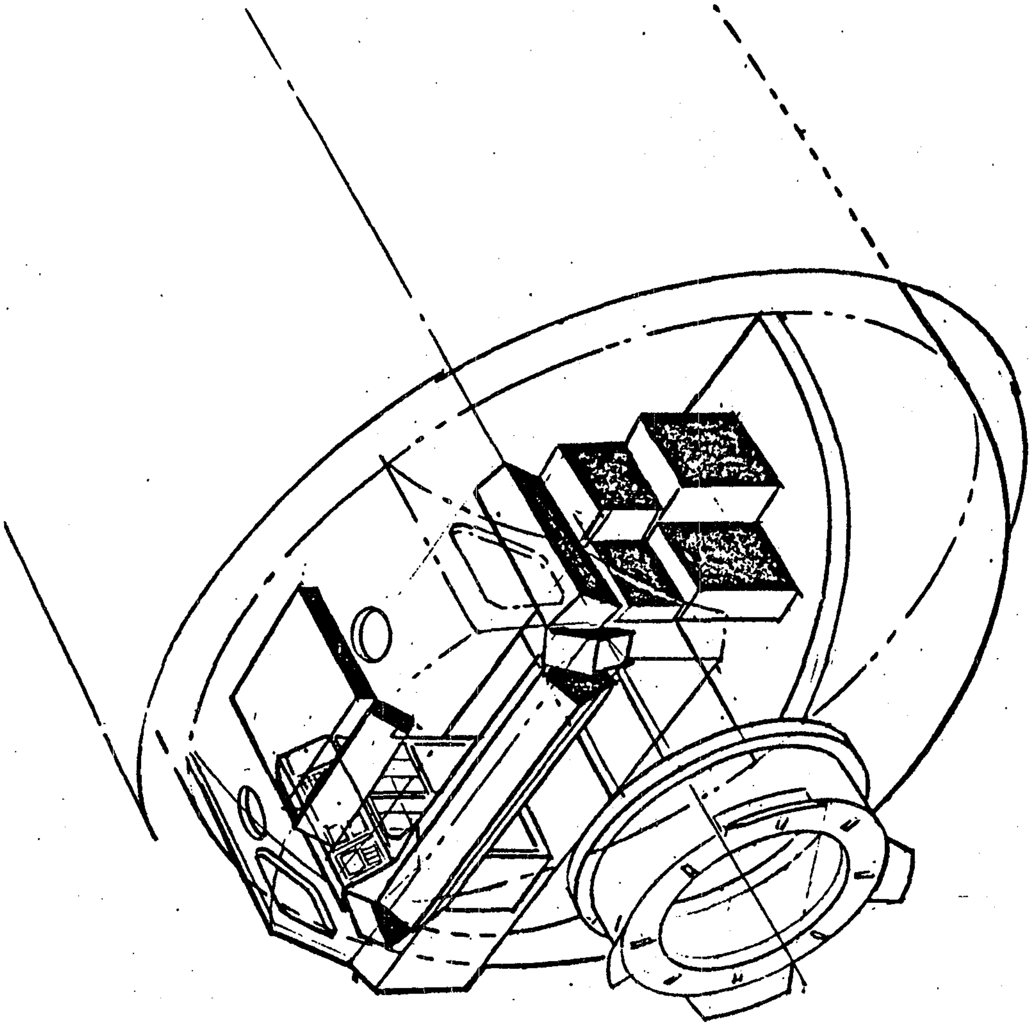


Figure B. Command Center Concept

SOC-634

SOC-905

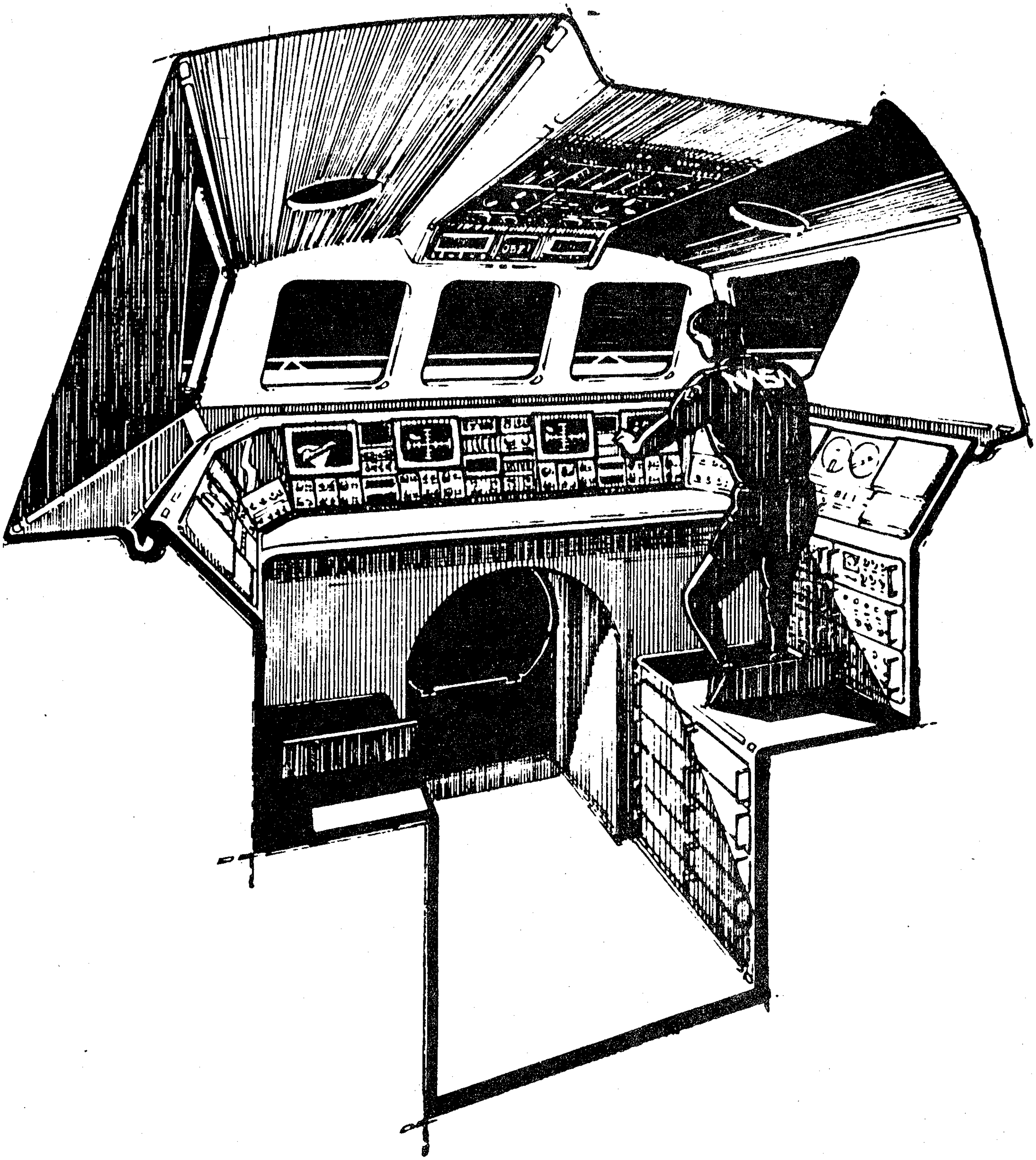


Figure C. Command Center Concept

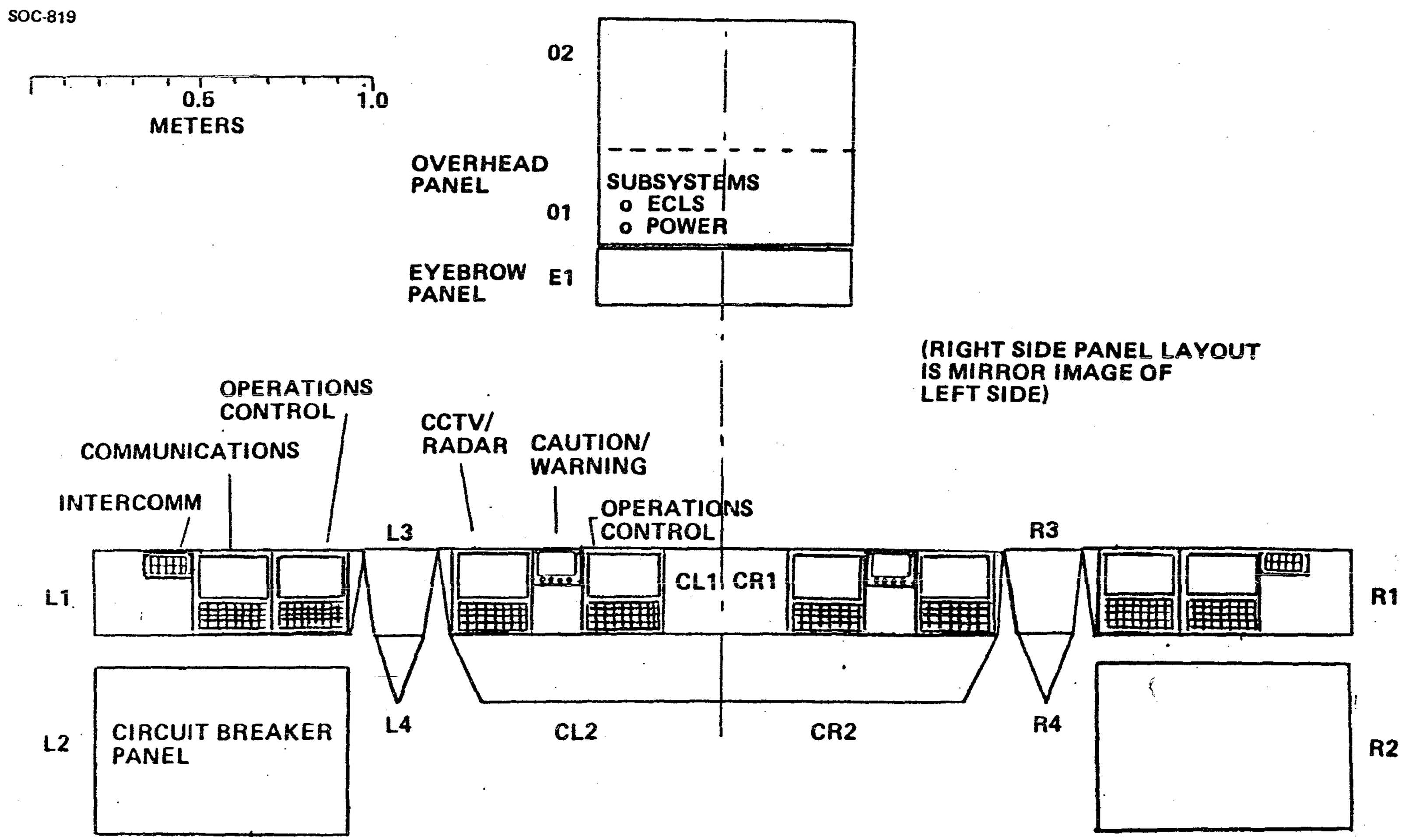


Figure D. Command Center Control/Display Panels

TABLE A
CONTROL/DISPLAY PANEL CHARACTERISTICS

PANEL	SUB-PANEL	CHARACTERISTICS

CLI, CRI	Caution and Warning Panel	o Flat Panel Display
		    o Displays Prioritized List of Anomaly Messages
		o Synthesized Voice
		    o Calls out Priority 1 Alerts
		o Audible Alarms
		    o Signals Priority 2,3, . . . Alerts
		o Dedicated Controls
		    o Speaker Volume Cont.
		    o Acknowledge/Cancel SW.
		    o Brightness Cont.

CLI, CRI	CCTV/RADAR PANEL	o Color CRT
		    o Displays SOC CCTV
		    o Displays Tracking Radar Images
		o Multifunction Switch/Keyboard
		    o Controls CCTV
		    o Controls Radar
		o Dedicated Controls
		    o TV Camera Tilt/Pan/Focus Controls
		    o Camera Select
		    o Brightness Cont.

TABLE A
CONTROL/DISPLAY PANEL CHARACTERISTICS (Cont)

PANEL	SUB-PANEL	CHARACTERISTICS

L1, R1
CL1, CR
	OPS Control Panel	o Color CRT
		  o Displays Alpha/Numerics
		  o Displays Graphics (E.G., Circuit Diagram)
		o Multifunction Switch/Keyboard
		  o First Tier Modes (Preliminary List)
		    o Checklists
		    o Flt Mgmt
		    o Flt Support Facility Systems
		    o Construction Facility Systems
		    o Track/Carriage Systems
		    o Docking/Berthing Ports
		    o Storage Fac. Systems
		    o Stores Mgmt

L1, R1
CL1, CR1
	OPS Control Panel	o Voice Actuated Controls
		  o Controls Same Functions as Multifunction Switch/Keyboard
		o Synthesized Voice
		  o Voice Call-Out of Input Errors
		o Dedicated Controls
		  o CRT Controls
		  o Voice/Keyboard Input Mode Select
		  o Checklist Line Carot Switches (6)
		  o Volume

TABLE A
CONTROL/DISPLAY PANEL CHARACTERISTICS (Cont)

PANEL	SUB-PANEL	CHARACTERISTICS

L1, R1	Comm Panel	o Flat Panel Display
		    o Displays Alphanumerics
		o Multifunction Switch/Keyboard
		    o First Tier Modes (Preliminary List)
		        o KU-Band
		        o S-Band
		        o L-Band
		        o UHF

L1, R1 and Elsewhere	INTERCOMM	o Dedicated Switches
		    o Station Select (12)
		    o Volume Control
		    o Displays Graphics (e.g., Circuit Diagram)

Table B. Approximate Panel Area Available for Controls and Displays

SOC-823

	PANEL NO.	APPROXIMATE DIMENSIONS, in	APPROXIMATE AREA', in^2	APPROXIMATE SUBTOTAL, in^2
PRIMARY	CL1	10 x 30	300	1080 in^2
	CL2	8 x 30	240	
	CR1	10 x 30	300	
	CR2	8 x 30	240	
SECONDARY	L1	10 x 30	300	1482 in^2
	L3	10 x 7	70	
	L4	8 x 7	56	
	R1	10 x 30	300	
	R3	10 x 7	70	
	R4	8 x 7	56	
	O1	15 x 28	420	
	E1	7 x 30	210	
TERTIARY	R2	20 x 30	600	1200 in^2
	L2	20 x 30	600	

Table C. Command Center Workstation Design Concept Rationale and Alternatives

SOC-623

CONCEPT	WHY SELECTED	ALTERNATIVES
• COMMAND CENTERS IN EACH HAB MODULE	• REDUNDANCY	• NONE—NOT ENOUGH ROOM IN OTHER PRESSURIZED MODULES
• COMMAND CENTER AT END OF HAB MODULE	• PROVIDES DIRECT VIEWING OF MOST OF FLIGHT SUPPORT AND CONSTRUCTION AREAS	• SIDE FACING CMD CTR – COULD BE LOCATED ANYWHERE BUT DOES NOT PROVIDE DIRECT VIEWING OF OPS
• HAB MOD. 1 CMD CTR FACES DOCKING MODULE	• PROVIDES DIRECT VIEW OF CONSTRUCTION OPS	• FACE SERVICE MODULE – WOULD FORCE HM 2 CMD CTR TO FACE DM BUT THIS WOULD NOT PROVIDE AS GOOD A VIEW OF CONST AREAS
• HAB MOD. 2 CMD CTR FACES SERVICE MOD. 2	• PROVIDES DIRECT VIEW OF SOME OF FLT SUPPORT AREA	• SEE ABOVE
• 2 WORKSTATIONS IN EACH CMD CTR	• BASED ON ANAYSIS OF SIMULTANEOUS OPERATIONS AND REDUNDANCY REQM'TS	• NONE

Table C. Command Center Workstation Design Concept Rationale and Alternatives (continued)

SOC-644

CONCEPT	WHY SELECTED	ALTERNATIVES
• WORKSTATIONS ELEVATED ABOVE HAB MOD FLOOR	• VIEWPORTS HAVE TO BE ABOVE ADJACENT MODULE BODY TO PROVIDE VIEWING OF WORK AREAS.	• NONE --SEE RATIONALE FOR PLACING CMD CTR AT END OF HAB MODULES
• PRIMARY, SECONDARY, TERTIARY CONTROL PANEL LOCATIONS	• BASED ON HUMAN ENGINEERING PRINCIPLES	• REQUIRES DETAILED ANALYSIS
• CONTROL PANELS	• FUNCTIONAL GROUPINGS BASED ON HUMAN ENGINEERING PRINCIPLES	• REQUIRES DETAILED ANALYSIS
• CONTROL/DISPLAY DEVICES		
• COLOR CRT'S	• STATE–OF–THE ART, HUMAN FACTORS	• FLAT PANEL DISPLAYS - TECHNOLOGY IMPROVEMENTS REQUIRED TO GET LARGE DISPLAYS
• LIQUID CRYSTAL FLAT PANEL DISPLAYS	• LIFE CYCLE COST	• LED'S, ELECTRO- LUMINESCENCE, PLASMA DISPLAYS - TECHNOLOGY ADVANCEMENTS REQUIRED
• MULTIFUNCTION SWITCH KEYBOARDS	• STATE–OF–THE–ART, HUMAN FACTORS, CONSERVES PANEL AREA, LOWER COST	• DEDICATED CONTROLS
• SYNTHESIZED VOICE	• HUMAN FACTORS, STATE–OF–THE–ART	• AUDIBLE ALARMS
• VOICE-ACTUATED CONTROLS	• HUMAN FACTORS	• KEYBOARDS

WBS 1.2.1.1.10.1.4 MASS STORAGE DEVICE

1.0 WBS Dictionary

Mass storage systems include all means of data storage not directly addressable by the computer processor. Mass storage media for the Space Operation Center may include floppy or hard magnetic disc, magnetic tape, video disc, and other possible means, such as holographic optical memories.

2.0 Description

A final selection of mass storage media was not made. It is anticipated that space qualifiable hard disc drive equipment will be available in the SOC time frame. Certain types of archival storage, i.e., those not requiring update or modification can be stored on video disc. This form of storage is expected to be useful for voluminous manuals, procedures, and graphics information. Video disc were also considered applicable to crew entertainment.

WBS 1.2.1.1.10.5 MULTIPLEXERS

1.0 WBS Dictionary

Multiplexers will be used as necessary to multiplex instrumentation outputs for insertion into the SOC data management data stream. Where multiplexing requirements can logically be imposed on a given subsystem data processing function, they will be. This WBS item has been reserved for multiplexing functions serving instrumentation not part of any specific subsystem.

2.0 Description

Requirements are insufficiently understood at this level of detail to define a multiplexer design. Existing hardware designs are believed adequate.

3.0 Design Basis

Multiplexers are used to convert parallel instrument inputs into a sampled serial data stream compatible with a data bus or telemetry digital format. Multiplexing reduces wire mass and simplifies data bus architecture.

4.0 Mass

Refer to WBS 1.2.1.1 mass statement.

WBS 1.2.1.1.10.2 SOFTWARE

1.0 WBS Dictionary

This element includes all of the software for the SOC.

2.0 Description

The SOC software has not been defined. See section 3.0 below.

3.0 Design Basis

An attempt was made to scope the software effort by estimating the size of functional programs, see Figure A. The estimate was based on past experience with similar real-time systems and an assessment of the functional complexity of each function. An assignment of software by program type was made to aid in the SOC costing exercise.

It has been shown that one of the most effective ways to reduce software life cycle costs and schedule risk is by utilizing high level languages (HLL). The diverse requirements for SOC mandates that a rich and powerful programming language be utilized. Several acceptable languages are currently available, JOVIAL, PASCAL, FORTRAN-77 to name a few. Ada is on the horizon and must be considered a HLL candidate. It must be recognized, however, that the choice of an unfamiliar or untried language incurs the added cost of programmer training and the errors inherent in any new language and compiler design.

4.0 Mass

Not applicable.

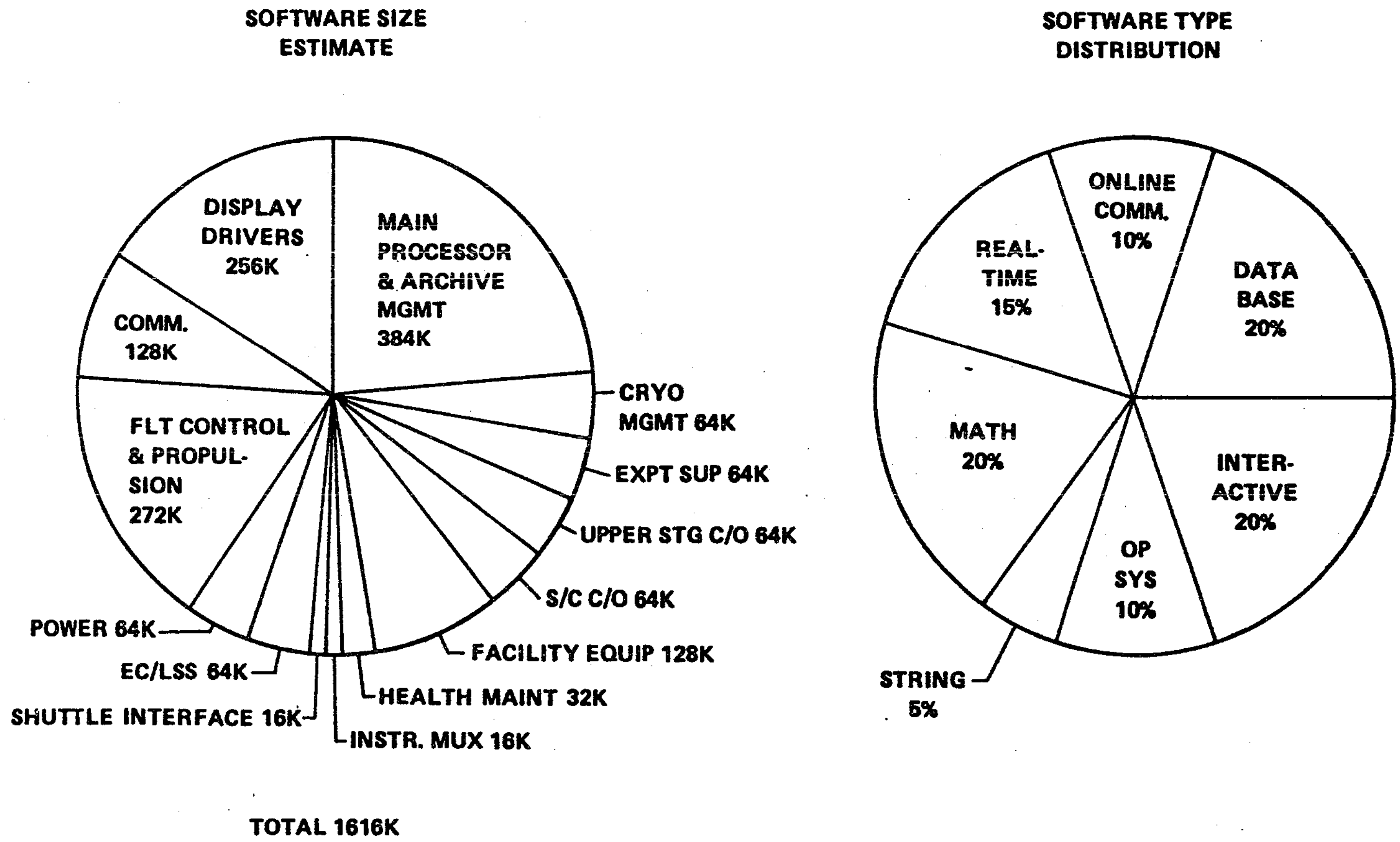


Figure A. Software Estimates

WBS 1.2.1.1.11 INSTRUMENTATION

1.0 WBS Dictionary

The instrumentation category includes all instrumentation providing measurements of conditions or states not specifically included in the subsystem. This WBS dictionary element is important since there will be temperature and pressure measurements, as well as accelerometer measurements that are not associated with any specific subsystem.

2.0 Description

A mass allowance of 100 kilograms was made for instrumentation such as skin temperatures not associated with a specific subsystem. No specific definition of this equipment was developed.

WBS 1.2.1.1.12 CREW ACCOMMODATIONS

1.0 WBS Dictionary

This element includes the crew quarters, observatory, food preparation equipment, dining table, physical fitness equipment, health maintenance equipment, and stowage provisions within the Habitat Module. (WBS 1.2.1.13 - Environmental Control/Life Support and WBS 1.2.1.10.3 - Controls and Displays incorporate all the other interior equipment that the crew interfaces with).

2.0 Description

These elements are described in lower-level WBS descriptions.

3.0 Design Basis

The crew accommodations are designed to meet the requirements in Boeing -18.

4.0 Mass

See WBS 1.2.1 mass statement.

WBS 1.2.1.1.12.1 CREW QUARTERS

1.0 WBS Dictionary

This element includes the crew quarters enclosures, sleep restraints, writing desks, and entertainment provisions. The personal gear storage is included in WBS 1.2.1.1.12.6. Lighting provisions are included in WBS 1.2.1.1.12.7.

2.0 Description

Refer to Figures A through D in WBS 1.2.1.1 for locations of the elements described below.

Crew Quarters Enclosure. There are four private crew quarters in each HM. Each of these has a floor space of 48 x 48 inches. They each have a sliding or accordian folded door.

Sleep Restraints. A Skylab sleep restraint is installed in the wall of each crew quarters. Provisions for hanging a second sleep restraint on another wall of each private crew quarters are also provided. This second sleep restraint is normally stowed and is used only during crew rotation overlap periods.

Writing Desk. Each private crew quarters is equipped with a fold-down writing desk. Provisions for restraining writing materials are included.

Entertainment Provisions. Each private crew quarters will be equipped with stereo earphones and an audio tape deck. Provisions for a small TV and video games may also be included.

3.0 Design Basis

The private crew quarters are located on the opposite end of the HM from the noisy work areas. Privacy is a fundamental psychological/sociological requirement for humans living in close proximity to other humans.

The Skylab sleep restraint worked pretty well and no reason was seen to change.

4.0 Mass

See WBS 1.2.1 mass statement.

WBS 1.2.1.1.12.2 FOOD PREPARATION AND DINING

1.0 WBS Dictionary

This element includes the food preparation fixtures, warming table, and dining table. Other galley equipment, such as the oven, freezer, dishwasher, refrigerator, hot and cold water supply, and trash compactor are covered in WBS 1.2.1.1.13 - Environmental Control/Life Support System. Galley stowage provisions are included in WBS 1.2.1.1.12.6.

2.0 Description

Figure A illustrates a concept for the galley and dining area.

3.0 Design Basis

A food system for relatively large numbers of people confined in a space station for periods of 90 days or more must be highly palatable, flexible, and satisfying. All of the crew on a space station will not be dedicated scientists, therefore, food will be even more important in contributing to the morale and well being of the crew. A food system which would provide maximum acceptability and palatability should consist of frozen precooked portions, supplemented with flexible retort pouches and dehydrated foods. These items should be served cafeteria style so that crewmembers would have free choice of meal combinations within reasonable restraints. (See Boeing-20, Section 7.6).

4.0 Mass

See WBS 1.2.1 mass statement.

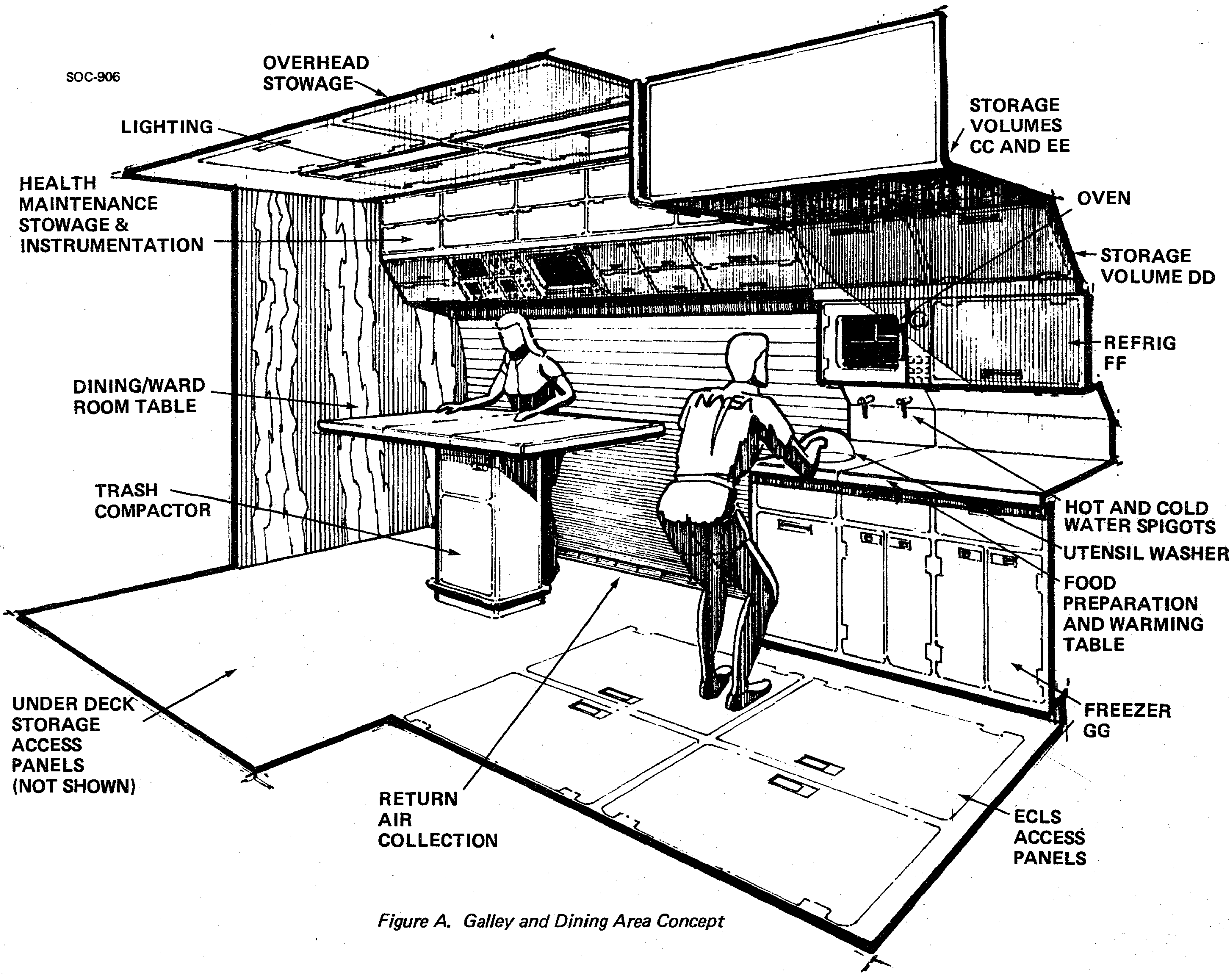


Figure A. Galley and Dining Area Concept

D180-26495-3

WBS 1.2.1.1.12.3 PHYSICAL FITNESS EQUIPMENT

1.0 WBS Dictionary

This element includes exercise cycles, treadmills, spring exerciser, and any other equipment dedicated to crew physical fitness.

2.0 Description

This equipment has received very little attention during this study. The items listed above are recognized to be potential equipment to satisfy the physical fitness requirements.

3.0 Design Basis

None at this time except common sense.

4.0 Mass

See WBS 1.2.1 mass statement.

WBS 1.2.1.1.12.4 HEALTH MAINTENANCE EQUIPMENT

1.0 WBS Dictionary

This element includes all of the equipment devoted to the health maintenance of the crew. Storage provisions for this medical equipment and the medical supplies are included in WBS 1.2.1.1.12.6.

2.0 Description

The specific health maintenance equipment and the distribution of this equipment amongst the SOC modules has not been defined. The preliminary health maintenance concept entails the following features:

o Habitat Module No. 1 would be equipped with "doctor's office-type" provisions.

o Habitat Module No. 2 would be equipped with more elaborate "emergency room-like" provisions.

o Service Module No. 1 would be equipped with a first aid kit.

Health maintenance equipment that has been tentatively identified is listed below:

a. Computer—The purpose of the computer will be for storage of diagnostic and treatment program, medical records, and treatment data. Data retrieval will be accomplished by CRT or similar terminal. Hard copy output shall be available at the discretion of the operator. It is possible to share a computer with other onboard systems if the computer will be available at any time, and a terminal is located in the HMF.

b. Diagnostic equipment—

1. Portable X-ray devices
2. Microbiology equipment-(incubator, growth plates)
3. Microscope-(X10 and X100 magnification)

4. Centrifuge-
5. Slides stain machine-(this piece of equipment will be used to perform Wright stains of blood smears)
6. A machine for analysis of blood chemistries including glucose, urea nitrogen, sodium chloride, potassium, carbon dioxide calcium, phosphorous, liver enzymes, muscular enzymes, and bone enzymes
7. Electrocardiographic machine

c. Medications—Oral, topical, and injectable medications

d. Surgical equipment—(specific instruments TBD)

e. Dental equipment—(similar to the equipment used in Skylab Dental Kit)

f. Monitor equipment—This will include EKG leads, an automatic blood pressure recorder, and temperature probes. This monitoring equipment to be interfaced with the SOC communication system so that vital signs can be transmitted to Earth.

g. Medical suction device—(for the aspiration of blood and body fluids)

h. Respirator—

i. Defibrillator—

j. Airway maintenance equipment—(larecroscope, endotrachyl tubes, and adaptors for the respirator) (The suction cup apparatus will be used in support of airway maintenance)

k. Restraint systems—(Special quick-release restraint systems. Such restraints would be used by both a treating medical crewman as well as on the injured or ill crewman.)

l. IV fluid system—(need a nominal amount of approximately 20 liters of intravenous solution. In addition, there will be need for 2 or 3 electrical pumps which would be used in the effective administration of IV fluids in weightlessness)

m. Cardiovascular Countermeasures—

o. Environmental monitoring equipment for the following environments:

- o Air samples for anomalies and toxic substances
- o Light, noise, and heat
- o Radiation from natural sources and from radioactive substances used in medical diagnostic procedures
- o Trace gasses
- o Radiological waste
- o Microorganism buildup

3.0 Design Basis

The equipment and concepts described above are very preliminary in nature. They are based on concepts created by the NASA-JSC Medical Operations Branch incorporated into an unpublished draft document by Joseph Degioanni, M.D., Medical Requirements and Care Systems for the Space Operations Center and Solar Power Satellite, November 1979.

4.0 Mass

See WBS 1.2.1 mass statement.

WBS 1.2.1.1.12.5 OBSERVATORY

1.0 WBS Dictionary

This element includes the equipment located in the Observatory. Storage provisions are included in WBS 1.2.1.1.12.6.

2.0 Description

Figure A illustrates the concept for an Observatory which will be located in the HM end dome opposite the Command Center. The structure of the Observatory is identical to that of the Command Center. The Observatory should be equipped with a telescope, photographic equipment, a stereo tape deck, TV camera, restraints, hand holds, light switches, etc. This area will become a lounge for the crew's enjoyment during off-duty hours so it should be equipped to be as comfortable as possible.

3.0 Design Basis

This Observatory was created after the Command Center concept was established. It became apparent that the same structural concept could be applied at each end of the habitat. The Observatory provides the recreational outside viewing of SOC, the Earth, and space essential for the crew's morale.

4.0 Mass

See WBS 1.2.1 mass statement.

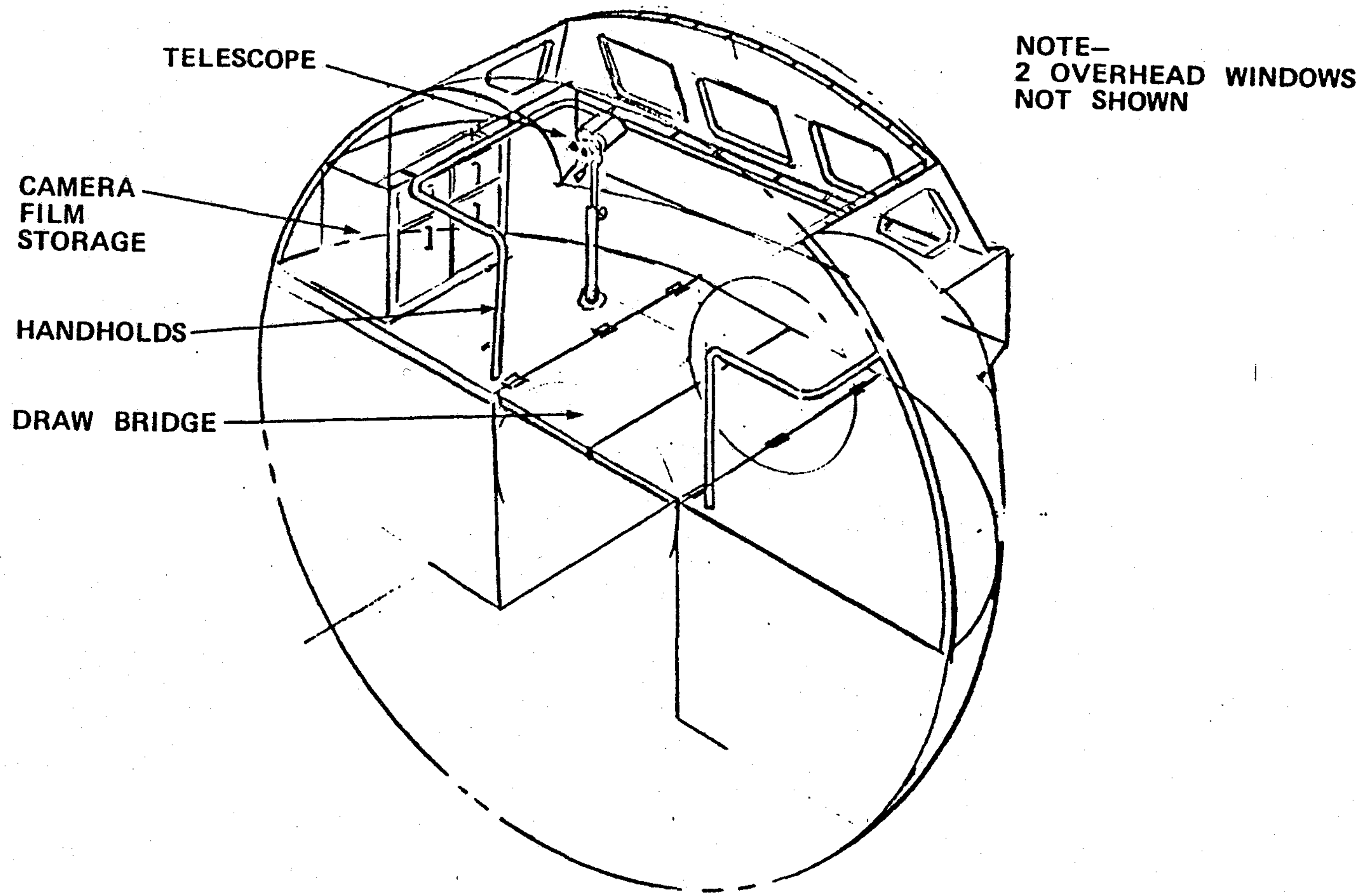


Figure A. Observatory Concept

WBS 1.2.1.1.12.6 STOWAGE

1.0 WBS Dictionary

This element includes all storage provisions.

2.0 Description

Table A lists the HM storage locations, dimensions, and volumes. These locations are found in Figures A thru D in WBS 1.2.1 and Figures A, B, and C in WBS 1.2.1.1.12.2. The configurations of these various storage provisions have not been defined.

3.0 Design Basis

Table B lists the storage requirements as defined by the analysis to date and the source of the requirement.

4.0 Mass

See WBS 1.2.1 mass statement.

Table A. Habitat Module Storage Locations and Volumes

SOC-870

STORAGE LOCATION CODE	LOCATION	DIMENSIONS, INCHES L x W x H	VOLUME FT ^{3}
A	BELOW MAIN DECK, COMMAND CENTER	40 x 37 x 15	12.85
B	BELOW MAIN DECK, WARD ROOM	72 x 16 x 10	6.67
C	BELOW MAIN DECK, WARD ROOM	106 x 18 x 18	19.87
D	BELOW MAIN DECK, WARD ROOM	106 x 28 x 30	51.53
E	BELOW MAIN DECK, WARD ROOM	106 x 28 x 30	51.53
F	BELOW MAIN DECK, WARD ROOM	28 x 15 x 18	4.37
G	BELOW MAIN DECK, WARD ROOM	66 x 15 x 18	10.31
H	BELOW MAIN DECK, CREW QTRS	44 x 24 x 18	11.0
I	BELOW MAIN DECK, CREW QTRS	44 x 24 x 18	11.0
J	BELOW MAIN DECK, CREW QTRS	44 x 24 x 18	11.0
K	BELOW MAIN DECK, CREW QTRS	44 x 24 x 18	11.0
L	BELOW MAIN DECK, CREW QTRS	95 x 30 x 16	26.39
M	BELOW MAIN DECK, CREW QTRS	95 x 30 x 16	26.39
N	BELOW DECK, OBSERVATORY	45 x 32 x 25	20.83
O	BELOW DECK, OBSERVATORY	45 x 32 x 25	20.83
P	BELOW MAIN DECK, OBSERVATORY	40 x 37 x 15	12.85
Q	ABOVE CEILING, WARDROOM	60 x 21 x 15	10.94
R	ABOVE CEILING, WARDROOM	60 x 21 x 15	10.94
S	ABOVE CEILING, WARDROOM	60 x 14 x 12	5.83
T	ABOVE CEILING, WARDROOM	60 x 21 x 15	10.94
U	ABOVE CEILING, WARDROOM	60 x 14 x 12	5.83
V	ABOVE CEILING, WARDROOM	60 x 21 x 15	10.94
W	ABOVE CEILING, WARDROOM	60 x 14 x 12	5.83
X	ABOVE CEILING, WARDROOM	50 x 18 x 15	7.81
Y	UNDER CEILING, CREW QTRS	45 x 35 x 12	10.94
Z	UNDER CEILING, CREW QTRS	45 x 35 x 12	10.94

CONTINUED

SOC 871

Table A. Habitat Module Storage Locations and Volumes (continued)

STORAGE LOCATION CODE	LOCATION	DIMENSIONS, INCHES L x W x H	VOLUME FT^3	
AA	UNDER CEILING, CREW QTRS	45 x 35 x 12	10.94	
BB	UNDER CEILING, CREW QTRS	45 x 35 x 12	10.94	
CC	UNDER CEILING, GALLEY	36 x 18 x 22	8.25	
DD	GALLEY	18 x 15 x 18	2.81	
EE	GALLEY	18 x 15 x 18	2.81	
FF	REFRIGERATOR	20 x 20 x 26	6.01	A
GG	FREEZER	20 x 20 x 36	8.33	A
HH	HYGIENE COMPARTMENT	25 x 18 x 18	4.68	
II	(NOT DESIGNATED)			
JJ	(NOT DESIGNATED)			
KK	ABOVE DISHWASHER	18 x 16 x 16	2.67	
LL	(NOT DESIGNATED)			
MM	EVA SUIT CLOSET	102 x 28 x 18	29.75	
NN	BELOW DECK, COMMAND CENTER			
OO	BELOW DECK, COMMAND CENTER			
PP	CREW QUARTERS CLOSETS	45 x 10 x 10 (4PLCS)	10.4	
QQ	CREW QUARTERS CLOSETS	45 x 15 x 18 (4PLCS)	28.12	
RR	CREW QUARTERS CLOSETS	45 x 12 x 25 (4PLCS)	31.25	
SS	(NOT DESIGNATED)			
TT	OBSERVATORY LOCKER	35 x 23 x 50	23.29	
UU	OBSERVATORY LOCKER	35 x 23 x 50	23.29	
VV	(NOT DESIGNATED)			
XX	ABOVE CEILING, CREW QTRS	45 x 36 x 18	16.88	
YY	ABOVE CEILING, CREW QTRS	45 x 16 x 18	7.5	
ZZ	(NOT DESIGNATED)			
		TOTAL IN EACH HABITAT MODULE	627.28 FT^3	A

Table B. Dry Storage Requirements For The Initial SOC

SOC-868

ITEMS	TOTAL [1] VOL, FT³	TOTAL [1] WT, LBS	WHERE LOCATED/VOLUME HM/FT³	WHERE LOCATED/VOLUME SM 1/FT³	WHERE LOCATED/VOLUME LM/FT³	SOURCE OF REQMIT
• FOOD			[5]			
• SHELF STABLE FOOD						
• 90 DAY SUPPLY	[3] 192	2592 [3]	} 119 [3]		} 192 [3]	
• CONTINGENCY SUPPLY	[4] 165	2227.5 [4]		7.5		BOEING -10,-11,-15
• FROZEN FOOD						
• 90 DAY SUPPLY [2]	[3] 40	720 [4]	13.2 [3]		40 [3]	BOEING -10,-15
• ECLS						
• SPARES	51.3	611.3	[6]	[6]		HAM STD, SEE BOEING -20
• 90 DAY SUPPLY	61.3	702.4	[6]	[6]	61.3	HAM STD, SEE BOEING -20
• EVA						
• SPARES	8.2	93.1	[6]	[6]		NASA JSC
• 90 DAY SUPPLY	52.6	1505.7	[6]	[6]	52.6	HAM STD ,SEE BOEING -20
• CONTIGENCY SUPPLY	15.3	260.1		15.3		HAM STD, SEE BOEING -20
• PERSONAL GEAR [2]	52	664	52		52	NASA –JSC
• SHIP STORES						
• INITIAL SUPPLY	34	520	[6]	[6]		NASA–JSC
• RESUPPLY	3.4	52			3.4	NASA–JSC
• HOUSEKEEPING/HYGIENE [2]	28	354	[6]	[6]	28	NASA–JSC
• MAINTENANCE/HOUSEKEEPING						
• INITIAL SUPPLY	11	206	[6]	[6]		NASA–JSC
• RESUPPLY	2.8	51.5			2.8	
• OTHER SOC SPARES						
• INITIAL SUPPLY	25	300	[6]	[6]		BOEING ESTIMATE
• RESUPPLY	12.5	150	[6]	[6]	12.5	BOEING ESTIMATE
TOTALS	754.4	11009.6	[7] 184.2 + 178.7 = 362.9	[7] 22.8 + 178.7 = 201.5	410.8 657.2 [8]	

[1] BASED ON REQMITS FOR 4–MAN CREW–DOUBLE THESE QTY'S FOR 8–MAN CREW EXCEPT WHERE NOTED, SEE NOTE 3
[2] TOTALLY EXPENDED IN 90 DAYS–THIS REPRESENTS RESPUPPLY REQM'T AND TOTAL STORAGE REQUIREMENTS
[3] SIZED FOR 8–MAN CREW REQM'T–DO NOT DOUBLE THIS QTY
[4] INCLUDED IN HM–1 AND LM–1 STORAGE VOLUME
[5] HM–1 AND HM–2 HAVE IDENTICAL STORAGE VOLUME REQMITS
[6] THE TOTAL VOLUME OF THIS ITEM CAN BE DISTRIBUTED AMONGST THESE LOCATIONS
[7] THIS QTY IS HALF OF THOSE ITEMS THAT CAN BE DISTRIBUTED BETWEEN THE HM AND LM(SEE NOTE 6)
[8] DESIGN REQUIREMENTS FOR LM STOWAGE VOLUME BASED ON 8-MAN RESUPPLY REQUIREMENTS

WBS 1.2.1.1.12.7 LIGHTING

1.0 WBS Dictionary

This element includes the interior and exterior lighting fixtures. Instrument panel lighting is not included.

2.0 Description

Figure A illustrates a concept for the location of lighting fixtures in the interior of the HM. The specific types of lighting fixtures have not been defined.

Figure B illustrates a concept for the location of exterior lighting fixtures on the HM. The specific types of lighting fixtures have not been defined.

3.0 Design Basis

The lighting system shall be designed to the following requirements (from Boeing-18, Section 3.900):

a. Control Panels and Task Areas: 538-1076 lx (50-100 ftc) adjustable - selectable (with auxiliary 200 ftc spotlite, if required). Suitable for machining, inspection of small details, drafting and small, delicate operations.

b. Habitat Areas: 215-538 lx (20-50 ftc) adjustable - selectable. Suitable for reading and general office work.

c. General Areas: 108-205 lx (10-20 ftc). Suitable for normal activities such as kitchen, washroom, passageways and storerooms.

d. Contingency: 22-54 lx (2-5 ftc). The SOC shall have an emergency lighting system in all passageways and compartments so that the crew can proceed toward appropriate evacuation ports in an emergency. The electrical power source for the emergency lighting shall be batteries which are kept fully charged by the electrical power system. In the event of loss of electrical power, the emergency lighting shall switch on automatically.

e. Portable Lighting: Portable flashlights and lanterns shall be strategically stored in specific locations for use during maintenance, repair, and emergencies.

4.0 Mass

See WBS 1.2.1 mass statement.

NOTE: EACH ZONE HAS INDEPENDENT LIGHT SWITCH CONTROL

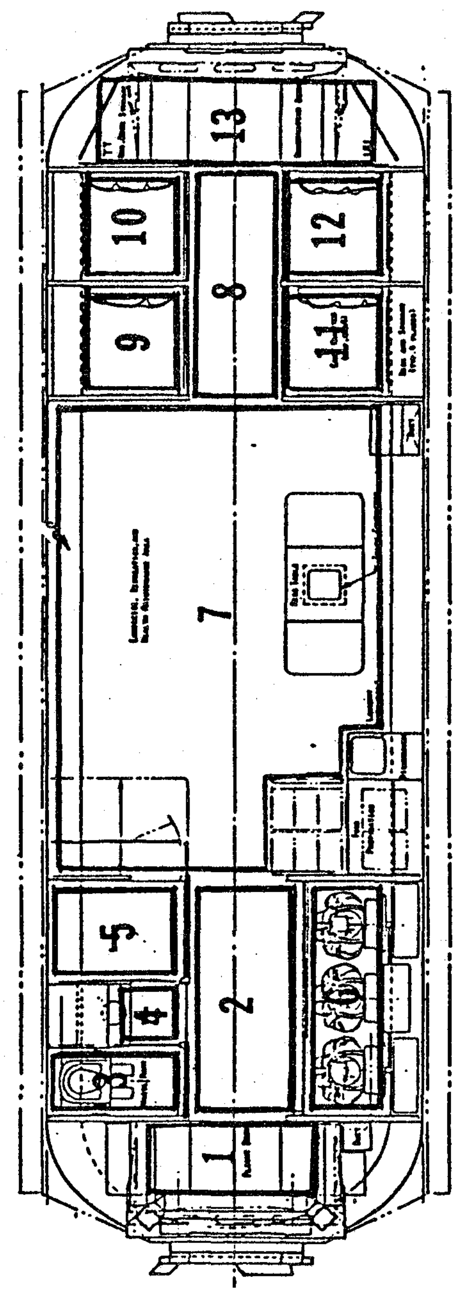


Figure A Habitat Module Interior General Lighting Zones

SOC-866

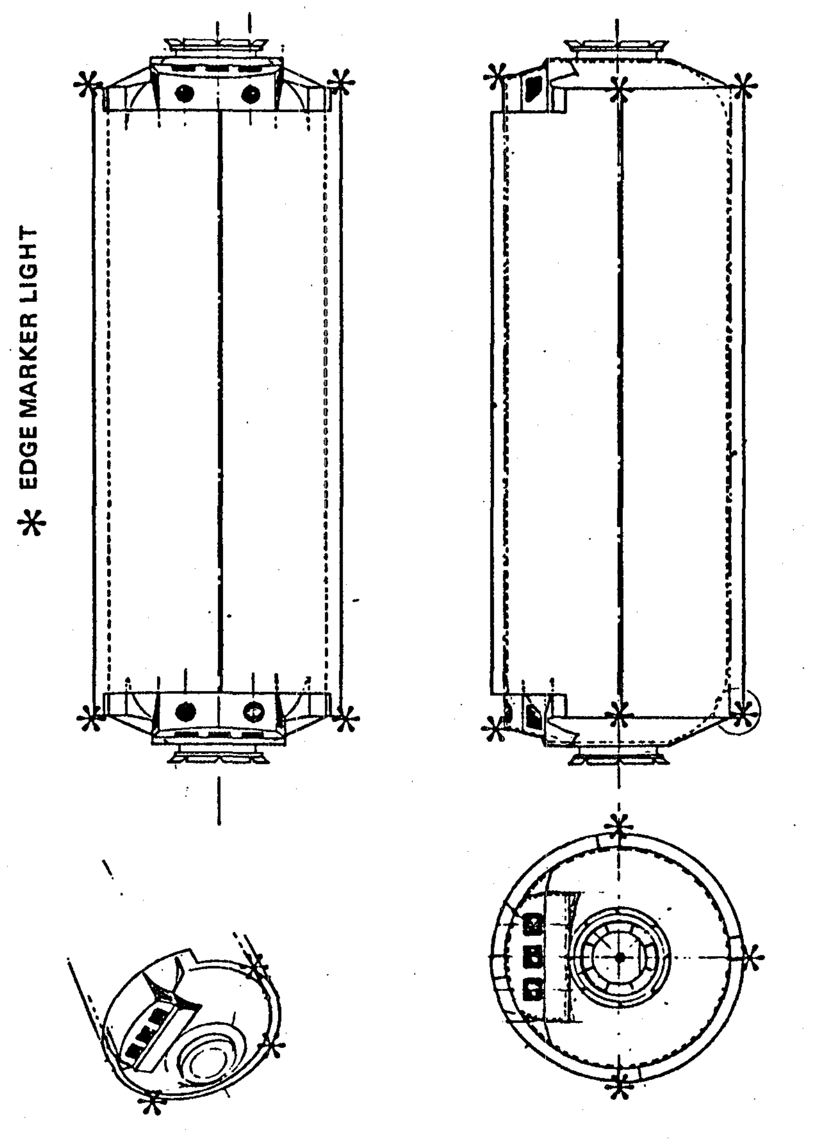


Figure B Habitat Module Exterior Lighting Concept

SOC-864

WBS 1.2.1.1.13 ENVIRONMENTAL CONTROL/LIFE SUPPORT SYSTEM

1.0 WBS Dictionary

The Environmental Control and Life Support (ECLS) system provides a comfortable environment and living conditions for the SOC crew similar to that provided in their earth bound homes. The ECLS, in addition to conditioning the environment and providing hygiene facilities, processes washwater and urine to provide potable water and processes carbon dioxide to provide crew oxygen. Thermal control is provided by the ECLS system to remove and reject into space all of the heat discharged into the SOC pressurized volumes from the electrical energy used and from the crews metabolic heat (vehicle walls can be assumed isothermal). The requirement for ECLS also extends to providing a controlled environment for the SOC crewmen during Extravehicular Activity (EVA).

The ECLS system equipment is distributed throughout the SOC's two habitats and service modules as well as the docking module. The logistics module provides ECLS system spares and expendables. Space suits and backpacks are provided for EVA.

2.0 Description

Equipment involved in recycling the water and oxygen used by the SOC crew, the crew daily needs, resupply required or any surplus is shown in Figure A. For the non-EVA day shown there is a surplus of 2.9 lbs/day of water which is due to water that is brought up in the food and from the water formed by the metabolic process. Therefore, on a non-EVA day, no water or oxygen resupply is required. The current water recycling system uses evaporative water processing in order to obtain potable quality water from urine, humidity condensate and wash water. A Sabatier reaction is used to obtain potable water by combining electrolysis process hydrogen and the CO_2 from the Solid Amine CO_2 removal system. The electrolysis system is capable of high pressure operation for EVA backpack recharging, as well as operation in a low pressure mode to provide oxygen for crew metabolic use and for vehicle leakage makeup.

A dramatic change in water balance occurs on an "EVA day" (two people on each of two shifts conducting EVA for eight hours) due to the dependency of EVA cooling by evaporating water. While 2.9 pounds of water per day are produced without EVA operation, Figure B, shows that 46.5 pounds of water per day are needed from storage on an EVA day. A desirable new technology item is the development of a regenerative heat sink for the extravehicular mobility unit (EMU) in order to eliminate the dependence on evaporating water for EVA cooling.

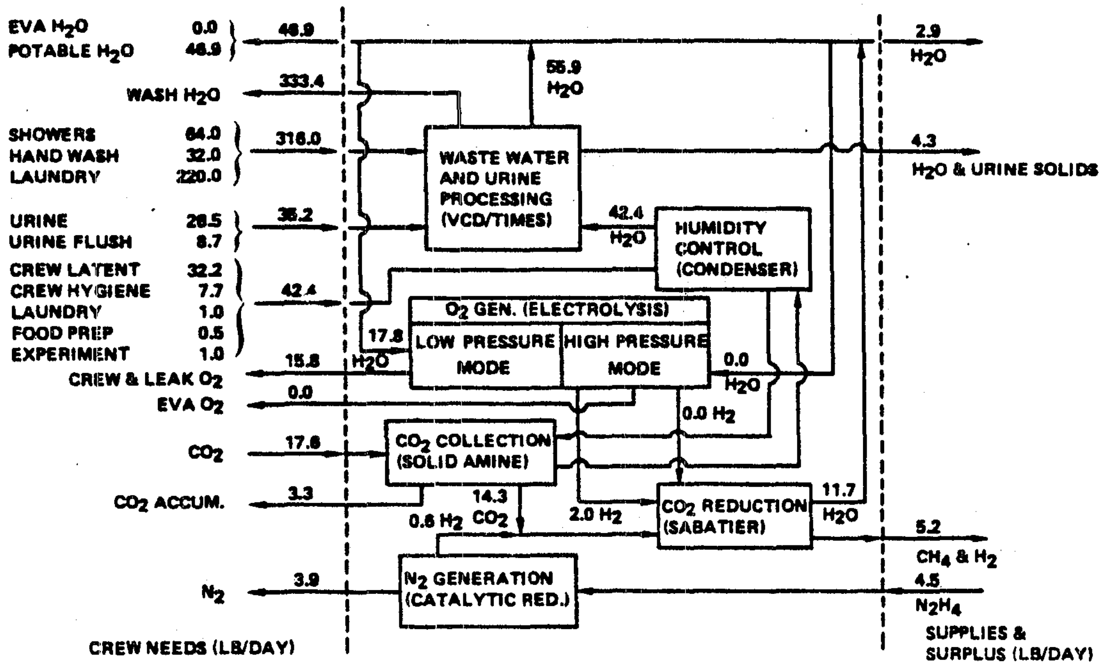


FIGURE A

24 HOUR MASS BALANCE - NON EVA DAY (8 MEN)

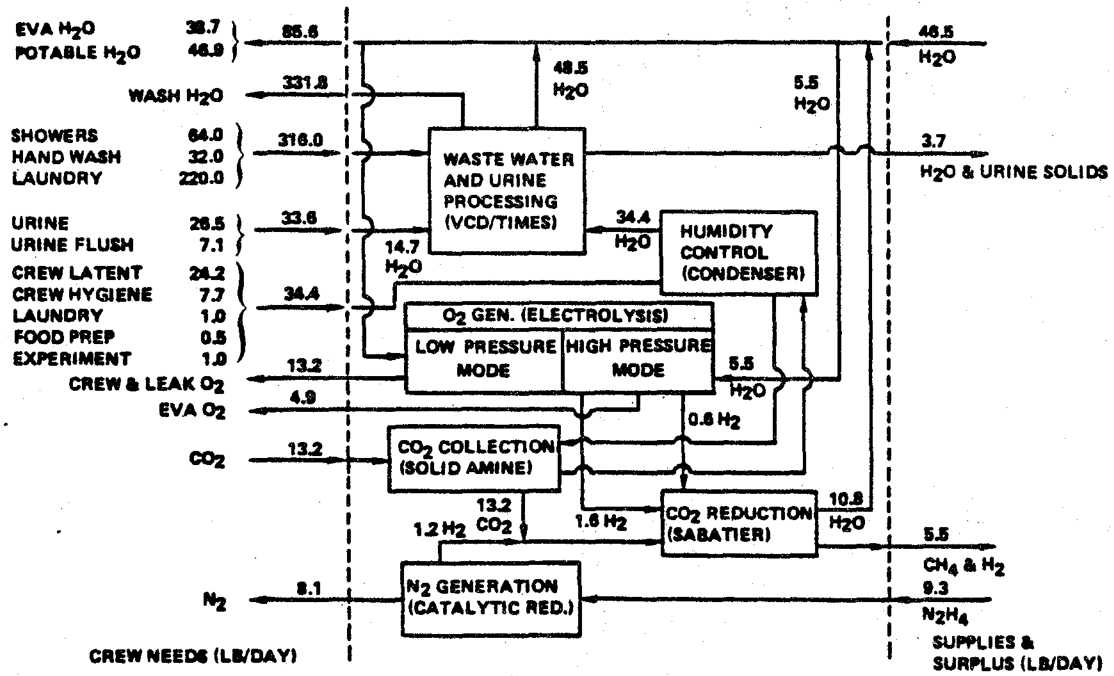


FIGURE B

24 HOUR MASS BALANCE - EVA DAY (8 MEN)

The ECLS system concept selections discussed above and the concept selections for the other ECLS system functions are shown in Table A. The concepts which are identified as new technology are concepts which have not been used in a previous space flight program. However, these concepts have undergone considerable research and development.

ECLS Equipment Location and Packaging

The baseline SOC habitat configuration has a floor and ceiling which run the length of each habitat. In general, the ECLS equipment which is located in the habitat is packaged above the ceiling and below the floor. The service module has an open configuration and the ECLS equipment located in the service module will be mounted into wall racks. The equipment will be packaged so that the vehicle wall can be examined visually (opening ceiling or floor panels is acceptable). The safety and reliability requirements of fail operational/fail safe dictates the use of dual coolant loops and wire runs in the SOC. It is also a safety requirement that these coolant loops and wire runs be separated from each other so that they are not damaged by a single incident. Likewise, redundant ECLS packages will also be physically separated. It is planned that the main coolant loop feed return lines will be above the ceiling and that the principal ECLS equipment users of these coolant loops will also be above the ceiling. The ventilation and thermal control packages, and the dehumidification packages will be located in the ceiling for this reason. The free area above the ceiling will be the supply plenum for cool fresh air for the entire habitat. The air will be distributed throughout the habitat by anemostats in the ceiling which will induce air mixing of about 5 times the anemostat flow. Air will pass through particulate filters which runs the entire length of the habitat along both intersecting points between the floor and outside walls. The under floor free area will be a plenum which collects the air passing through the filters. The air will then be ducted through a minimum of two return ducts which return the air to the inlets of the thermal/ ventilation packages located above the ceiling.

The CO_2 removal packages, trace gas catalytic oxidizer packages and odor control packages will also be mounted above the ceiling since they will interface with the dehumidification airflow ducts. The airflow to these air revitalization packages will be drawn from the areas in the habitats which will have the most concentrated humidity, odor or trace contaminant levels such as showers, toilet areas, suit drying stations, etc. The processed air will be discharged to the ceiling plenum area. Figure C shows the air processing equipment layout in the SOC for one habitat and one service module. Water processing equipment will be mounted below the floor areas.

TABLE A

SOC ECLS EQUIPMENT

ECLS FUNCTION	MAJOR EQUIPMENT	BASELINE CONCEPT
CABIN VENTILATION AND THERMAL CONTROL	VENTILATION FANS	400 Hz, 120 V – SHUTTLE TECHNOLOGY
	AIR COOLING HEAT EXCHANGERS	STAINLESS STEEL, PLATE FIN – SHUTTLE TECHNOLOGY
AIR REVITALIZATION	DEHUMIDIFICATION	STAINLESS STEEL, PLATE FIN, WITH H_2O SLURPER AND FAN SEPARATORS – SHUTTLE TECHNOLOGY
	CO_2 REMOVAL	SOLID AMINE, NEW TECHNOLOGY
	CATALYTIC OXIDIZER	HIGH TEMP. CATALYST BED WITH REGEN. H/X – NEW TECHNOLOGY
	CO_2 REDUCTION	HIGH TEMP. CATALYST BED WITH CONDENSING H/X AND POROUS PLATE H_2O SEP. – NEW TECHNOLOGY
	ODOR CONTROL	ACTIVATED CHARCOAL EXPENDABLE BEDS – SHUTTLE TECHNOLOGY
	ATMOSPHERE MONITORING	MASS SPECTROMETER – NEW TECHNOLOGY
HEAT TRANSPORT AND REJECTION	RADIATORS	FREON 21, EXTRUDED ALUMINUM – SHUTTLE TECHNOLOGY
	FREON COOLANT PUMP PACKAGES	400 Hz, 120 V – SHUTTLE TECHNOLOGY
	FREON TO WATER HEAT EXCHANGERS	STAINLESS STEEL PLATE FIN – SHUTTLE TECHNOLOGY
	WATER COOLANT PUMP PACKAGES	400 Hz, 120 V – SHUTTLE TECHNOLOGY
ATMOSPHERIC SUPPLY	O_2 GENERATION	SOLID POLYMER, HIGH PRESSURE – NEW TECHNOLOGY
	HYDRAZINE DECOMPOSITION N_2 STORAGE	CATALYTIC DECOMPOSITION, SILVER PALLADIUM H_2 SEP., CATALYTIC OXIDIZER – NEW TECHNOLOGY
	EMERGENCY O_2 AND N_2 STORAGE	HIGH PRESSURE STORAGE – SHUTTLE TECHNOLOGY
WATER PROCESSING AND MANAGEMENT	EVAPORATION PURIFICATION UNITS	VCD OR TIMES CONCEPTS – NEW TECHNOLOGY
	WATER QUALITY MONITORING	CONDUCTIVITY, pH, TOTAL ORGANIC CARBON – NEW TECHNOLOGY
	WASTEWATER STORAGE	STAINLESS STEEL METAL BELLOWS TANKS – SHUTTLE TECHNOLOGY
	POTABLE WATER STORAGE	STAINLESS STEEL METAL BELLOWS TANKS – SHUTTLE TECHNOLOGY
	EMERGENCY WATER STORAGE	STAINLESS STEEL METAL BELLOWS TANKS – SHUTTLE TECHNOLOGY
HEALTH AND HYGIENE	WASTE COLLECTION AND STORAGE	VACUUM DRIED STORAGE, REPLACEABLE BOWL – MODIFIED SHUTTLE TECHNOLOGY
	EMERGENCY WASTE COLLECTION	BAGS – APOLLO TECHNOLOGY
	HOT/COLD WATER SUPPLY	CAL. ROD ELECT. STAINLESS STEEL WATER HEATER, STAINLESS STEEL COOLER – SHUTTLE TECHNOLOGY
	SHOWER	ENCLOSED STALL, HANDHELD SPRAY, AIRFLOW WASTEWATER TRANSPORT – NEW TECHNOLOGY
	HAND WASH	COVERED SPRAY, AIRFLOW WASTEWATER TRANSPORT – SHUTTLE TECHNOLOGY
	CLOTHES WASHER/DRYER	SPIN TUMBLE WASH, TUMBLE AIR-DRY – NEW TECHNOLOGY
	TRASH COMPACTOR	MECHANICAL SCREW COMPRESSION – NEW TECHNOLOGY
	FOOD REFRIGERATOR/FREEZER	THERMOELECTRIC TO STAINLESS STEEL COOLANT H/X – NEW TECHNOLOGY
	MEDICAL REFRIGERATOR/FREEZER	THERMOELECTRIC TO STAINLESS STEEL COOLANT H/X – NEW TECHNOLOGY
	OVEN	CONVECTION AIR – SHUTTLE TECHNOLOGY
EVA/IVA SUPPORT	SUITS AND BACKPACKS	4 PSI, PURE O_2 – SHUTTLE TECHNOLOGY
	RECHARGE STATIONS	SUIT DRYER, O_2 REFILL – NEW TECHNOLOGY
	AIR LOCK SUPPORT	TWO STAGE AIR PUMP – NEW TECHNOLOGY AND SUIT INTERFACES – SHUTTLE TECHNOLOGY
	EMERGENCY ESCAPE SYSTEM	ESCAPE BALL, PORTABLE O_2 SYSTEM – SHUTTLE TECHNOLOGY

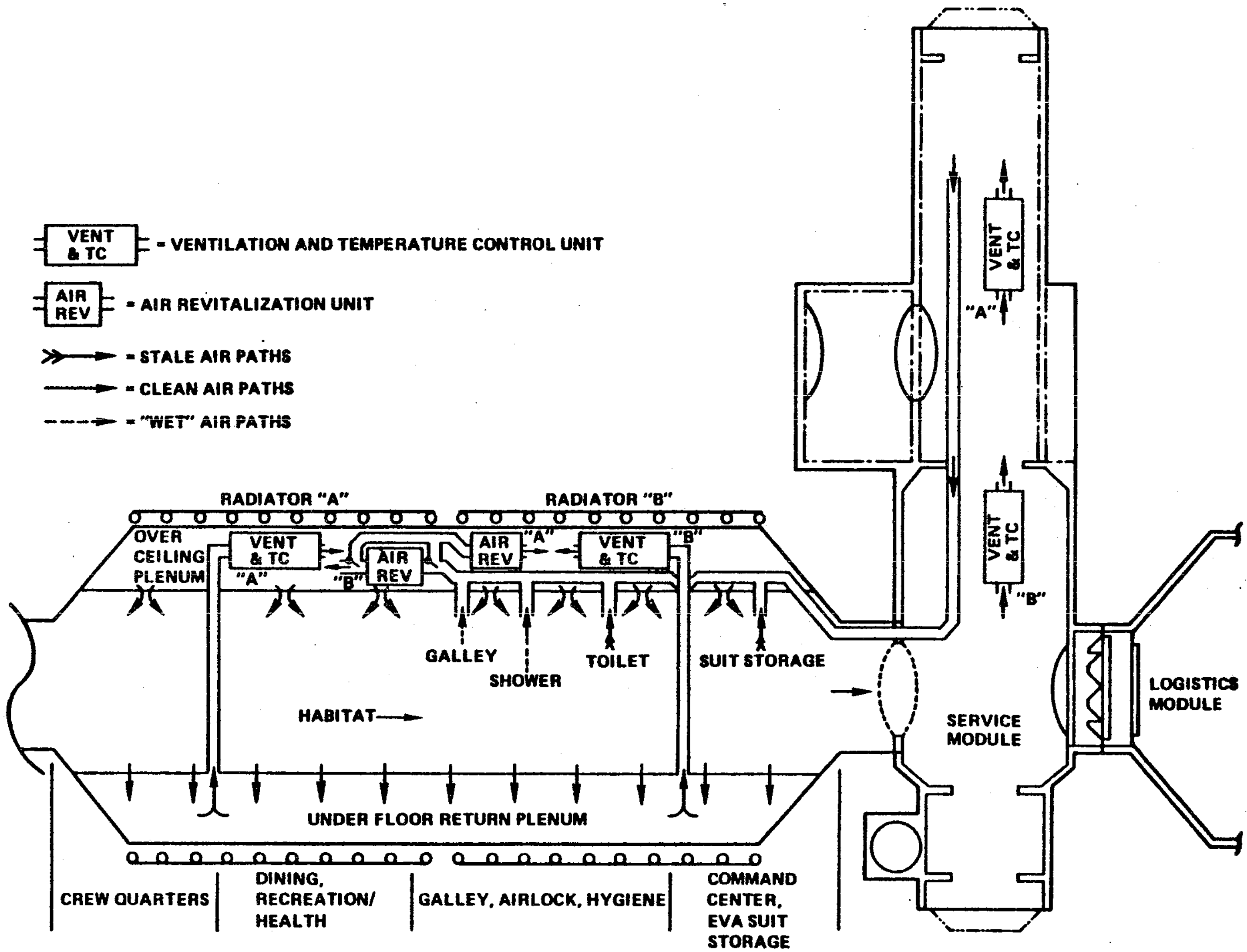


FIGURE C

AIR PROCESSING EQUIPMENT LAYOUT

In order to provide ease of maintenance, ceiling and floor panels will be removable for access to the equipment. The equipment will be packaged so that the components are generally not more than one layer deep with adequate perimeter access. Panels will be installed around and behind the package in order not to disturb the plenum airflow during maintenance.

ECLS equipment which uses or generates hydrogen has been located in the service module in order to keep this equipment outside the main habitat. The equipment will be designed so that the total quantity of hydrogen contained in the equipment processing loops would not raise the hydrogen partial pressure in the service module to an unsafe level if a line or component rupture occurs. The equipment using or generating hydrogen includes water electrolysis, hydrazine reduction and carbon dioxide reduction.

Much of the health and hygiene equipment will occupy primary habitat volume because of its direct interface with the SOC crew. The location of much of this equipment can be seen by referring back to Figure B.

Since equipment will be located in various areas throughout the SOC, provisions must be made for appropriate interface connections through docking ports. Docking ports must contain airflow-through passages and hard lines for potable water, CO_2, N_2, O_2 and coolant water.

Figures D thru J show the equipment required to perform the SOC ECLS functions and the module in which the equipment is located. The docking port passthroughs required for each functional area are also shown. Figure J shows the EVA suit, backpack and emergency equipment required to perform the maximum planned EVA's of 24 per week.

From the figures it is seen that there are several instances where equipment in one module is not duplicated in the other corresponding module. These are as follows:

A| 1) Figure G; there are seven emergency nitrogen tanks and four emergency oxygen tanks in service module #1, and three emergency oxygen tanks in service module #2.

2) Figure H; there are four emergency water tanks in habitat #1, none in habitat #2.

3) Figure I; of the two habitats, only habitat #1 contains a shower, freezer and dishwasher, while habitat #2 contains a clothes washer/dryer.

4) Figure J; three portable oxygen supply systems are shown in habitat #1, while two are shown in habitat #2.

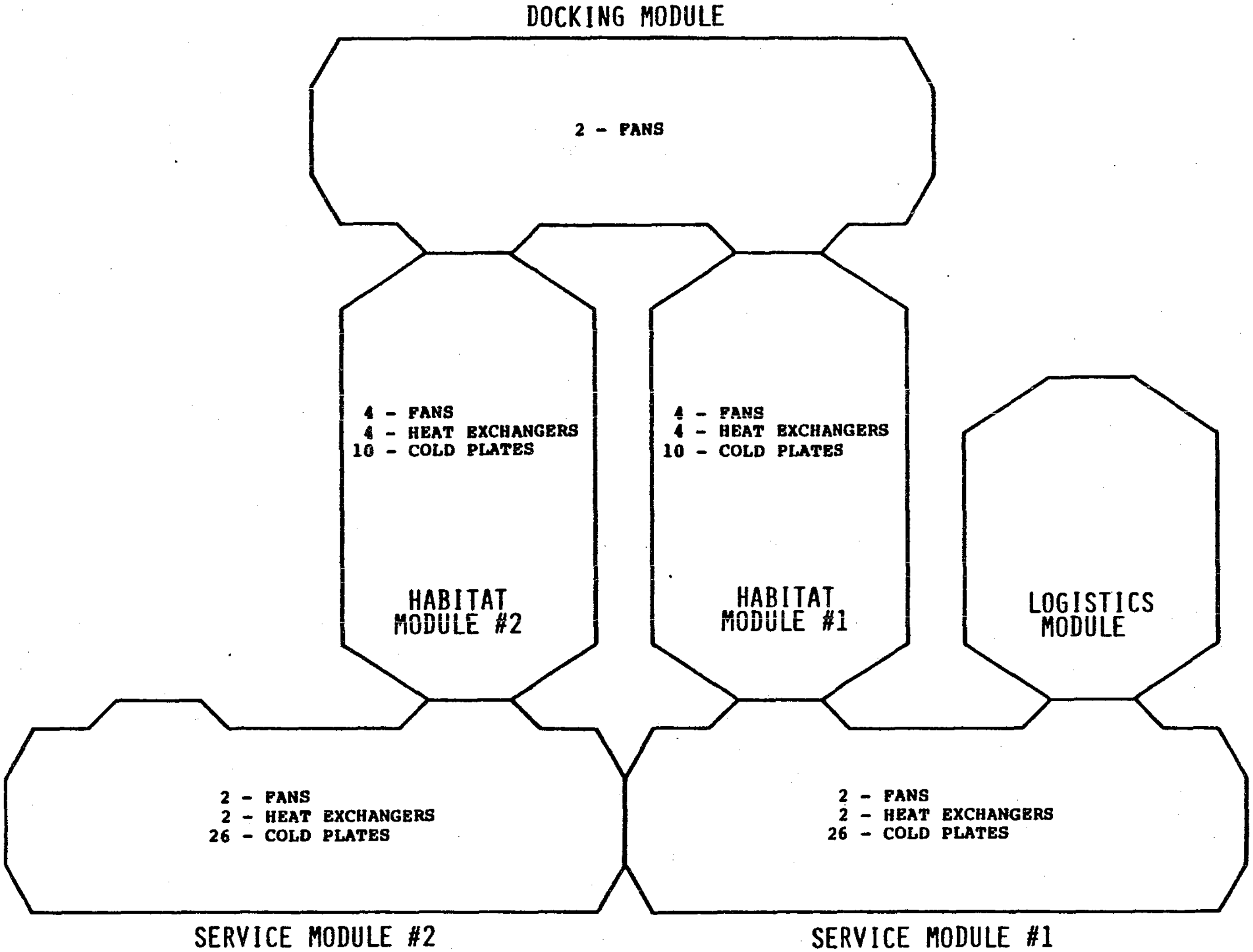


FIGURE D
CABIN VENTILATION AND THERMAL CONTROL

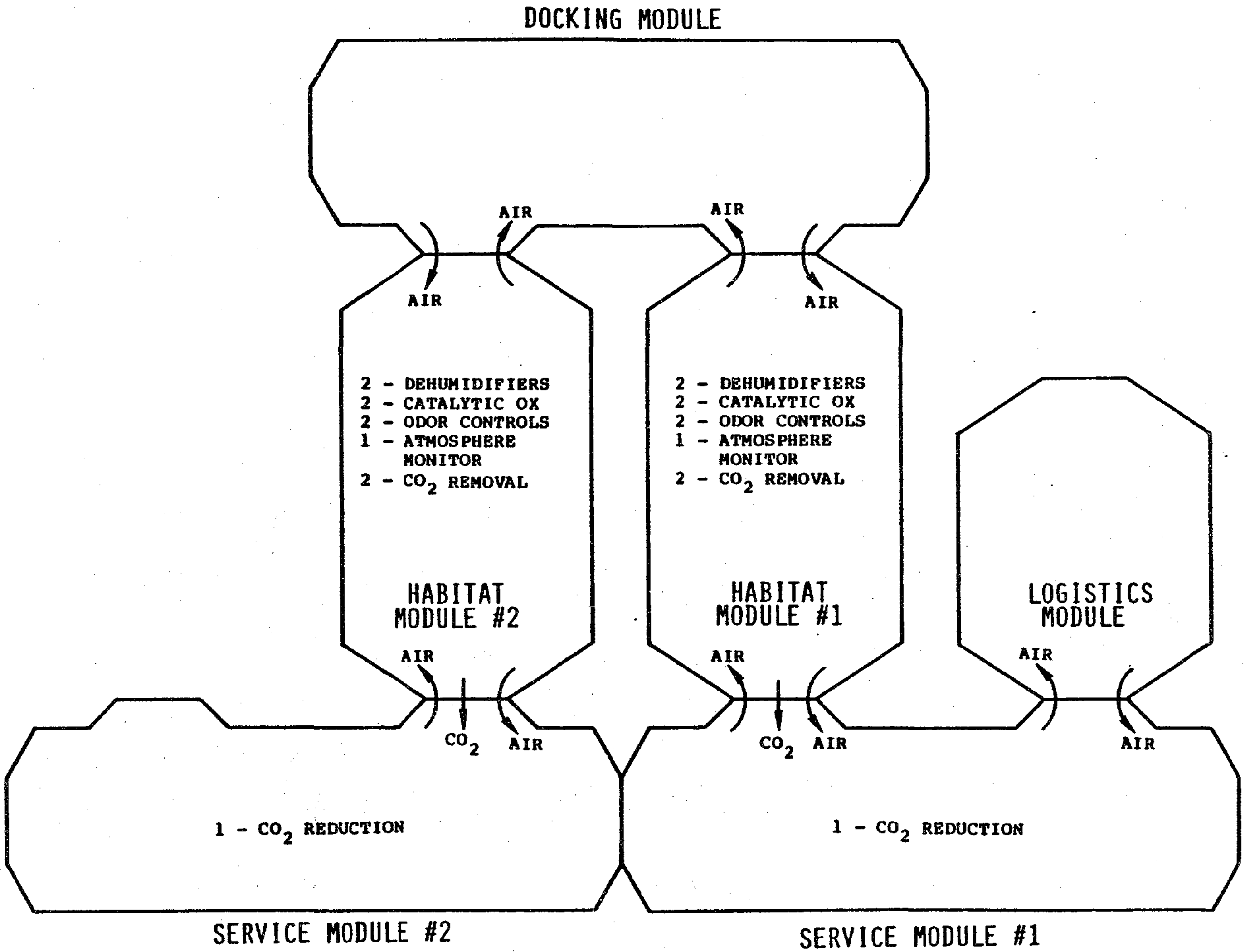


FIGURE E
AIR REVITALIZATION

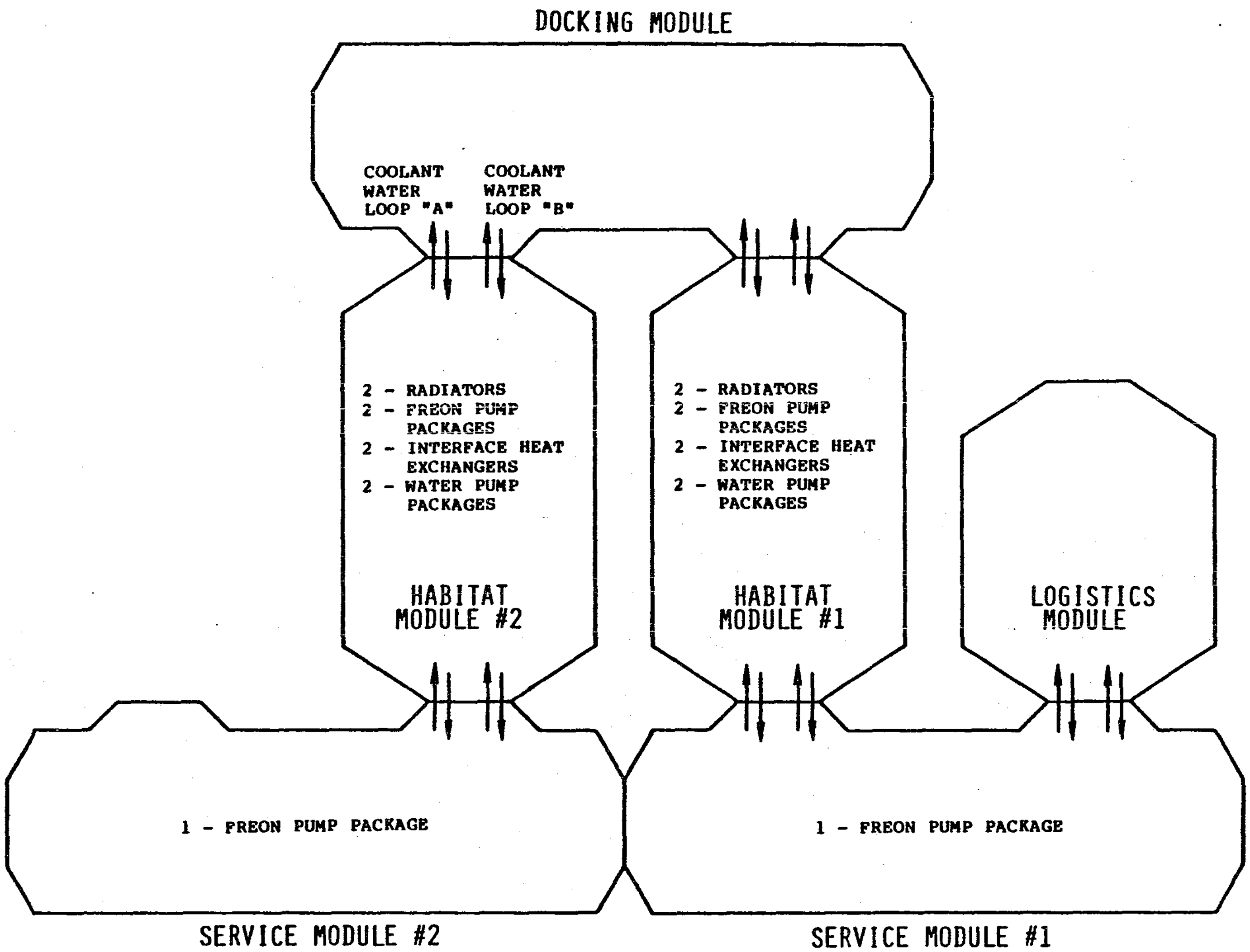


FIGURE F
HEAT TRANSPORT AND REJECTION

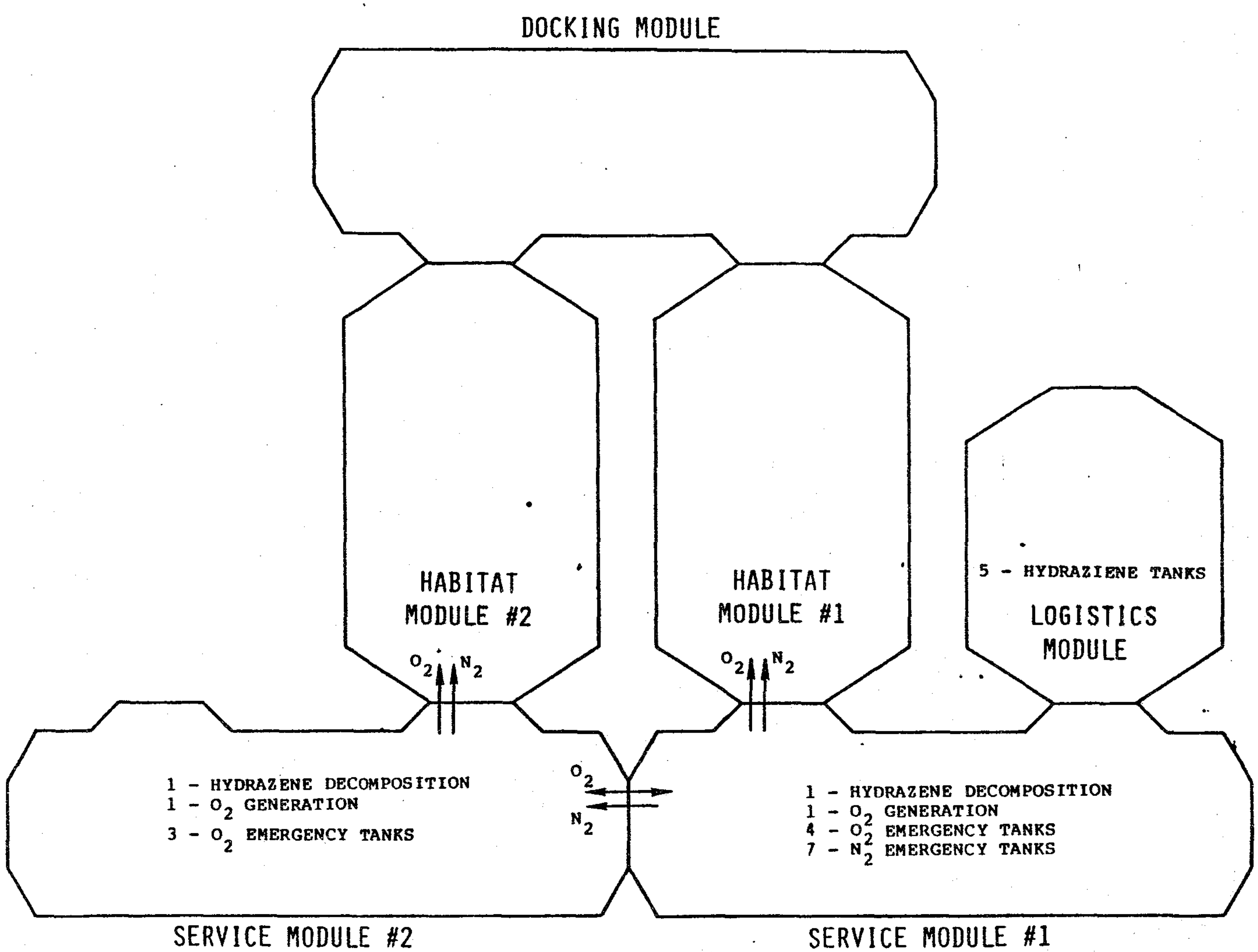


FIGURE G
ATMOSPHERIC SUPPLY

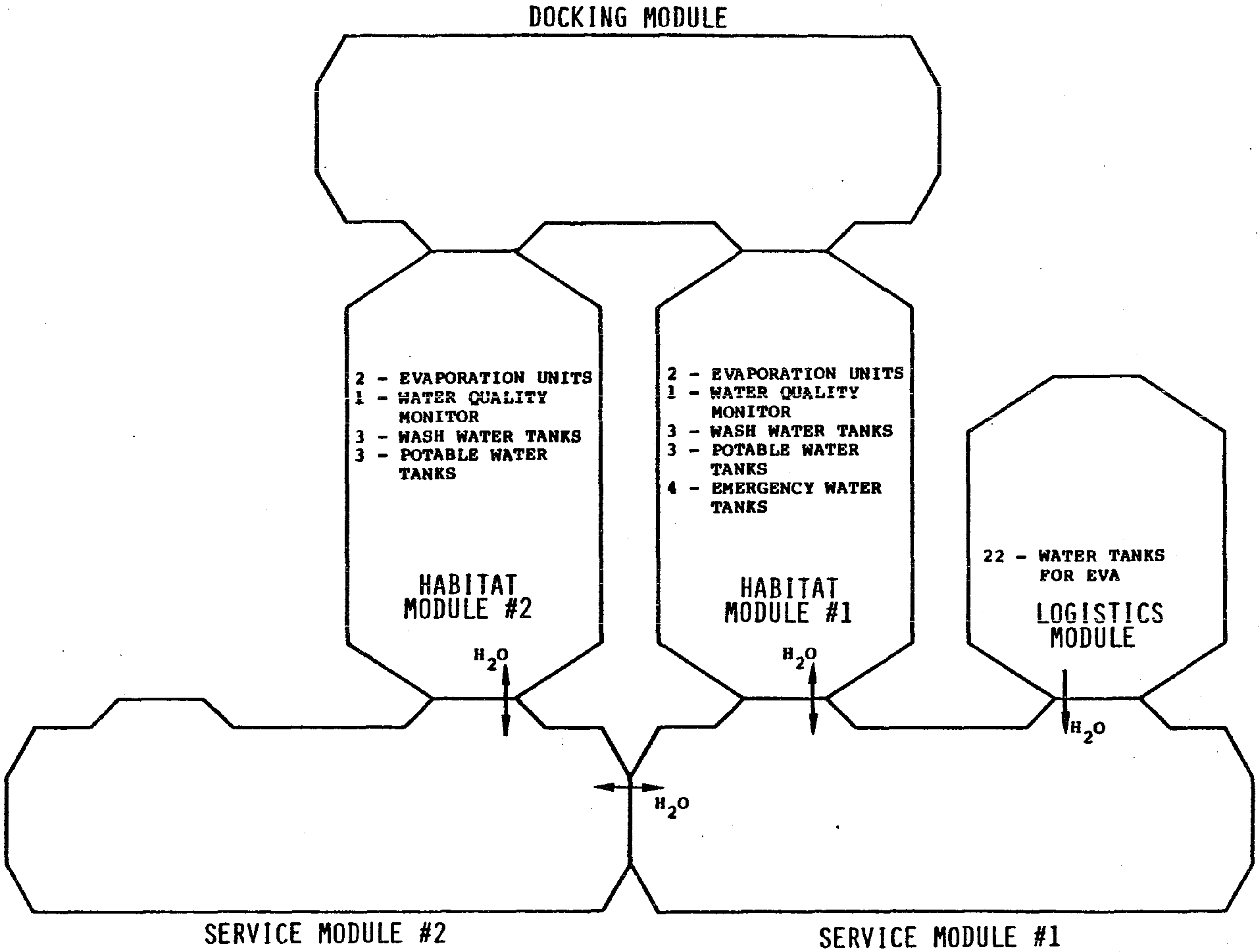


FIGURE H
WATER PROCESSING AND MANAGEMENT

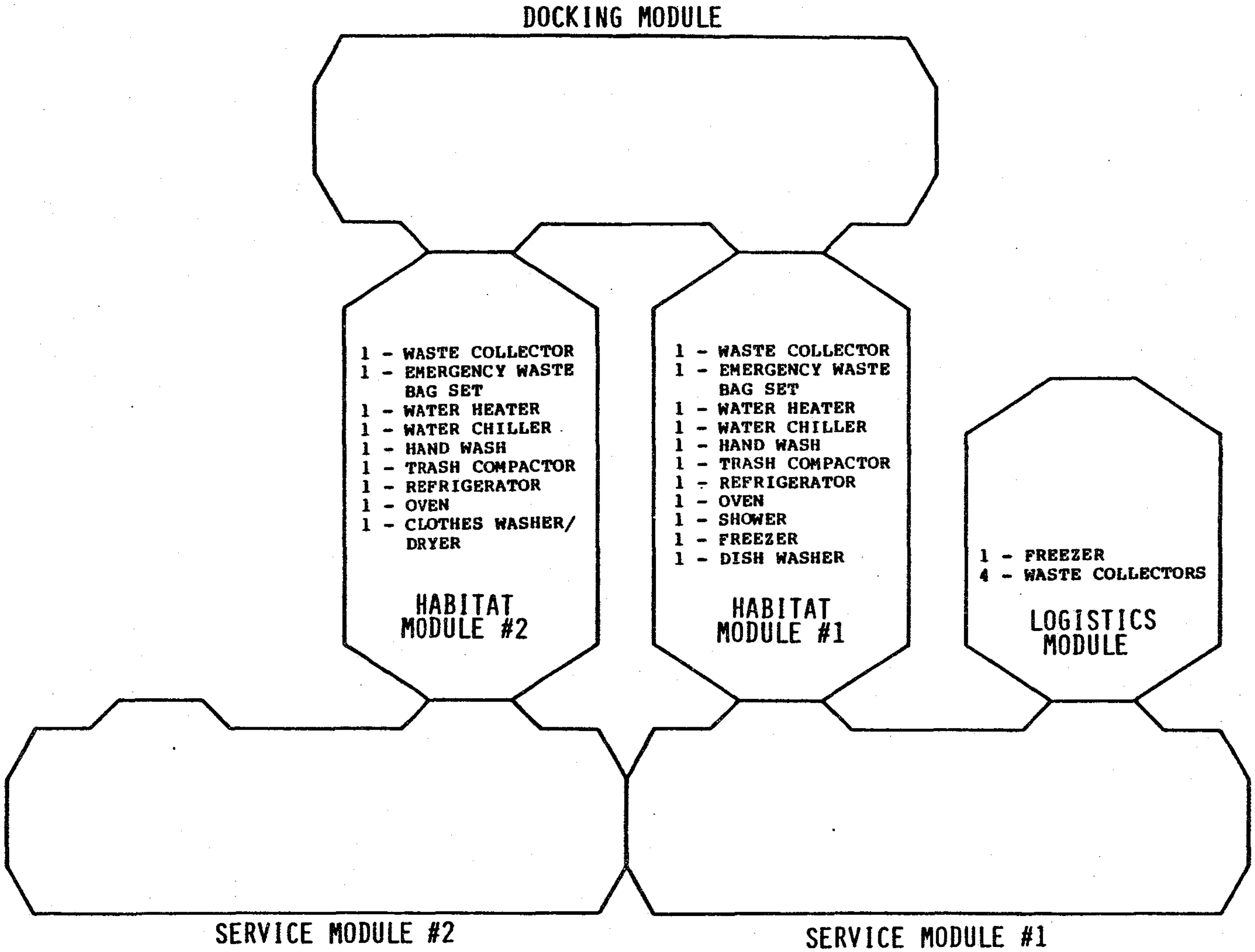


FIGURE I
HEALTH AND HYGIENE

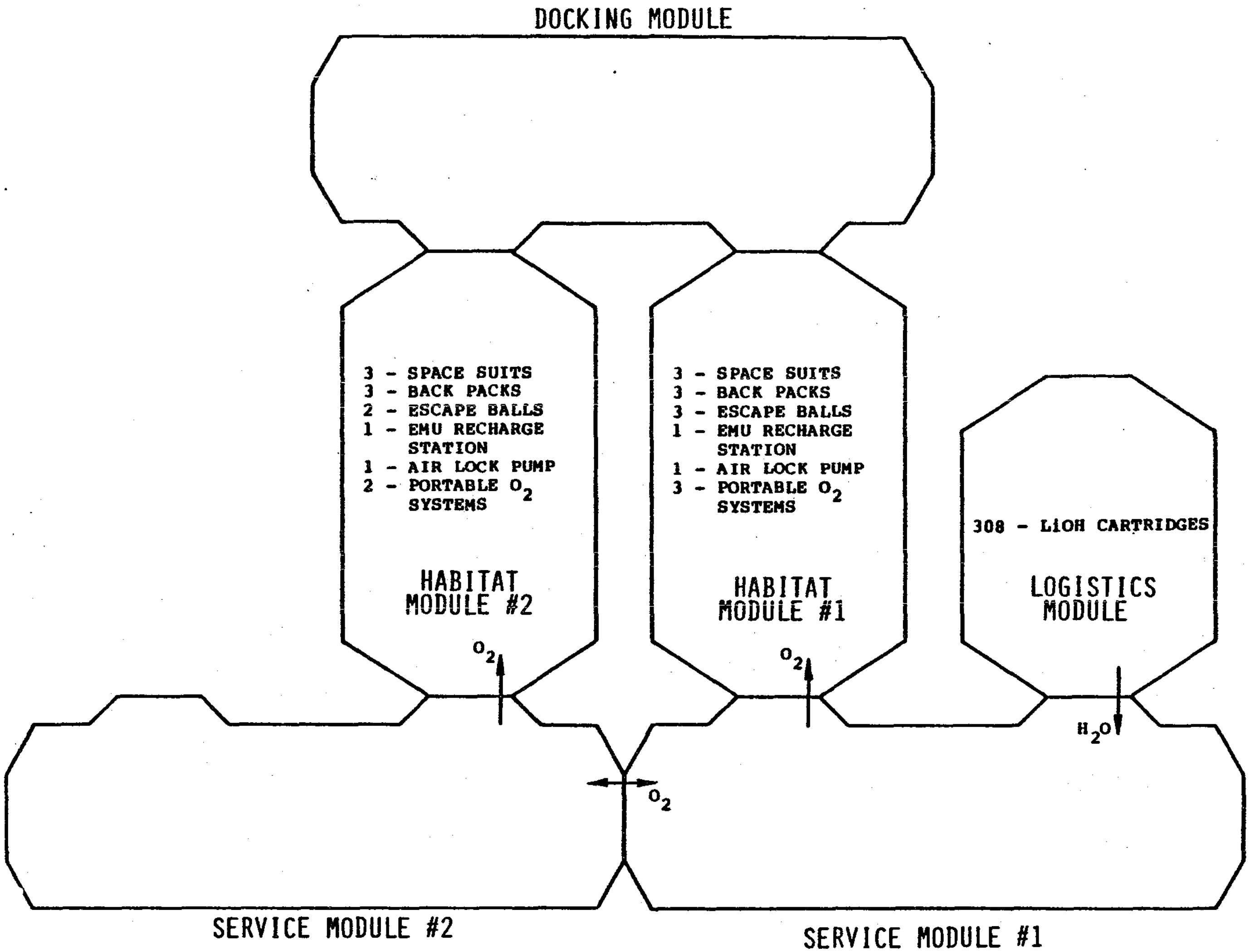


FIGURE J
EVA / IVA SUPPORT

These non-duplications of equipment are permissible since they will not jeopardize the design philosophy of going from normal operational to fail operational (90 day degraded) to fail safe (300 hr. emergency) modes of degradation.

3.0 Design Basis

SOC mission success and the health and safety of the SOC crew are dependent on the continuing reliable performance of the SOC ECLS equipment. A fail operational/fail safe philosophy has been established as the minimum acceptable design criteria for the ECLS equipment. Because of the SOC two habitat configuration, the total SOC crew can take refuge in one of the habitats if a major failure in the other habitat occurs such as an excessive vehicle atmosphere leak, a fire or other atmosphere contamination. However, the ECLS has been designed so that no single failure of ECLS equipment will force the crew to evacuate a habitat. The ECLS performance requirements, Boeing-18, and the above safety criteria have a major impact on the ECLS system design.

The full significance of these performance requirements is manifested in their influence on reliability and redundancy considerations, which in turn dictate the number of primary systems that SOC must carry. Non-maintainable equipment such as main distribution tubing, major wiring distribution bundles and equipment support structure can be assumed to have a reliability of nearly "one". All equipment with a reliability less than "one" which can be practically maintained in space will be designed for replacement and an appropriate complement of spares will be provided.

In order to minimize the spares complement on-board the SOC, commonality is a design requirement. By proper systems engineering common valves, fans, pumps, instruments, controllers, etc. can be designed so that one spare can be used in many different places.

4.0 Mass

Table B is a detailed breakdown of the weight, power, package size and volume of the ECLS equipment for the complete SOC.

On the left-hand portion of the table are listed all ECLS functions followed by a major equipment breakdown. Following this is an itemization of the number and location of major equipment packages.

Next is an itemization of total weight and volume of in-place ECLS equipment, based on total SOC configuration. This is followed by a complete breakdown of total ECLS equipment required power. The power, in which a distinction is made between AC and regulated DC, is separated into light side, dark side and intermittent.

TABLE B
SOC ECLS SYSTEM
TECHNICAL DATA SUMMARY

ECLS FUNCTION	MAJOR EQUIPMENT	Number of Packages and Location						Total SOC ECLS Packages	Total Weight	Total Volume	Package Size
		HAB 1	HAB 2	SM 1	SM 2	LM	DM		lbs	ft³	ft x ft x ft
Cabin Ventilation and Thermal Control	Ventilation Fans	4	4	2	2	—	2	12 PACK'S + 2 FANS	600 PACK'S + 20 FANS	54 PACK'S + 2 FANS	1 x 1 x 1
	Air Cooling Heat Exchangers	4	4	2	2	—	—		—	—	1 x 1.5 x 3
	Cold Plates	10	10	26	26	—	—	40 N.S. + 32 STRUCT.	2600	N/A	2 x 2 x 1" Non Struct. 3 x 3 x 2" Struct.
	Subtotals								3220	56	
Air Revitalization	Dehumidification	2	2	—	—	—	—	4	346	20	1 x 1.5 x 3.5
	CO_2 Removal	2	2	—	—	—	—	4	472	25	1 x 2.5 x 2.5
	Catalytic Oxidizer	2	2	—	—	—	—	4	216	25	1 x 2.5 x 2.5
	CO_2 Reduction	—	—	1	1	—	—	2	214	19	1.5 x 2.5 x 2.5
	Odor Control	2	2	—	—	—	—	4	80	4	1 x 1 x 1
	Atmosphere Monitoring	1	1	—	—	—	—	2	100	5	1 x 1.5 x 1.5
	Subtotals								1428	98	
Heat Transport and Rejection	Radiators	2	2	—	—	—	—	4	N/A	N/A	—
	Freon Coolant Pump Packages	2	2	1	1	—	—	6	225	23	1 x 1.5 x 2.5
	Freon To Water Heat Exchangers	2	2	—	—	—	—	4	125	4	1 x 1 x 1
	Water Coolant Pump Packages	2	2	—	—	—	—	4	128	6	1 x 1 x 1.5
	Subtotals								478	33	
Atmospheric Supply	O_2 Generation	—	—	1	1	—	—	2	750	52	2 x 2 x 6.5
	Hydrazine Decomposition-N_2 Supply	—	—	1	1	—	—	2	320	20	1 x 2.5 x 4
	Hydrazine Storage	—	—	—	—	5	—	5	—	—	1.5 x 1.5 x 3
	Emergency O_2 Storage	—	—	4	3	—	—	7	850	189	3 x 3 x 3
	Emergency N_2 Storage	—	—	7	—	—	—	7	800	189	3 x 3 x 3
	Subtotals								2720	450	
Water Processing And Management	Evaporation Purification Units	2	2	—	—	—	—	4	1660	148	2.5 x 2.5 x 6
	Water Quality Monitoring	1	1	—	—	—	—	2	120	8	1 x 1.5 x 2.5
	Wastewater Storage	3	3	—	—	—	—	6	303	40	1.5 x 1.5 x 3
	Potable Water Storage	3	3	—	—	—	—	6	303	40	1.5 x 1.5 x 3
	Emergency Water Storage /EVA Water	4	—	—	—	22	—	26	850 HAB	27 HAB	1.5 x 1.5 x 3
	Subtotals								3236	263	
Health And Hygiene	Waste Collection And Storage	1	1	—	—	—	—	2	180	26	2.3 x 2.3 x 2.3
	Emergency Waste Collection	1	1	—	—	—	—	2	30	2	1 x 1 x 1
	Hot Water Supply	1	1	—	—	—	—	2	60	3	1 x 1 x 1.5
	Cold Water Supply	1	1	—	—	—	—	2	40	2	1 x 1 x 1
	Shower	1	—	—	—	—	—	1	120	44	2.5 x 2.5 x 7
	Hand Wash	1	1	—	—	—	—	2	50	7	1.5 x 1.5 x 1.5
	Clothes Washer/Dryer	—	1	—	—	—	—	1	90	6	1.5 x 2 x 2
	Trash Compactor	1	1	—	—	—	—	2	80	15	1.5 x 2 x 2.5
	Food Refrigerator	1	1	—	—	—	—	2	100	20	2 x 2 x 2.5
	Food Freezer	1	—	—	—	1	—	1	60 HAB	13 HAB	2 x 2 x 3.3 4 x 5 x 2 LM
	Oven	1	1	—	—	—	—	2	75	5	1.3 x 1.3 x 1.5
	Dishwasher	1	—	—	—	—	—	1	30	8	1.8 x 1.8 x 2.5
	Subtotals								915	151	
EVA/IVA Support	Suits And Backpacks	3	3	—	—	—	—	6	744 SUIT + 459 B.P.	116 SUIT + 19 B.P.	6 x 2.7 x 1.2 2.7 x 2 x 0.6
	Recharge Stations	1	1	—	—	—	—	2	120	8	1 x 1.5 x 2.5
	Air Lock Support	1	1	—	—	—	—	2	80	3	1 x 1 x 1.5
	Emergency Escape System	3	2	—	—	—	—	5	90 POS + 150 BALL	5 POS + 4 BALL	1.2 x 1.7 x 0.5 1.5 x 0.7 x 0.8
	Subtotals								1643	155	
System Control	ECLS Central Control/Display	1	1	—	—	—	—	2	100	7	1.5 x 1.5 x 1.5
	Portable Maintenance Control Display	1	1	—	—	—	—	2	50	4	1.5 x 1.5 x 1
	Subtotals								150	11	
	GRAND TOTAL								13790	1217	

ECLS FUNCTION	MAJOR EQUIPMENT	Total Light Side Power		Total Dark Side Power		Total Intermittent Power		Initial Spares Weight	Initial Spares Volume	90 Day Resupply Weight	90 Day Resupply Volume
		AC Watts	DC Watts	AC Watts	DC Watts	AC Watts	DC Watts	lbs	ft³	lbs	ft³
Cabin Ventilation and Thermal Control	Ventilation Fans	2600	180	2600	180	—	—	26 Filters	2.3 Filters	24 Filters	2.5 Filters/Valves
	Air Cooling Heat Exchangers	—	—	—	—	—	—	0	0	—	—
	Cold Plates	—	—	—	—	—	—	0	0	—	—
	Subtotals	2600	180	2600	180	0	0	26	2.3	24	2.5
Air Revitalization	Dehumidification	410	50	410	60	—	2460	6	0.2	.7	.1
	CO_2 Removal	180	1216	180	60	—	—	56	2.0	17.4	.8
	Catalytic Oxidizer	140	622	—	60	—	—	54	1.5	6.5	.2
	CO_2 Reduction	190	30	—	30	250 Light Side	200 Light Side	44	3.8	26	.2
	Odor Control	—	—	—	—	—	—	146	7.5	146.0	7.5
	Atmosphere Monitoring	—	200	—	—	—	—	100	5.0	6.0	.3
	Subtotals	920	2128	590	210	250	2660	406	20.0	179.2	9.1
Heat Transport and Rejection	Radiators	—	—	—	—	—	—	—	—	—	—
	Freon Coolant Pump Packages	1875	75	1875	75	—	—	45	3.8	8.1	.7
	Freon To Water Heat Exchangers	—	—	—	—	—	—	—	—	—	—
	Water Coolant Pump Packages	1500	60	1500	60	—	—	32	1.5	3.8	.2
	Subtotals	3375	135	3375	135	0	0	77	5.3	11.9	.9
Atmospheric Supply	O_2 Generation	90	3980	—	30	—	—	72	3.0	22.5	1.7
	Hydrazine Decomposition-N_2 Supply	134	130	—	30	—	—	36	.8	9.6	.6
	Hydrazine Storage	—	15	—	15	—	—	543	—	1005.0	34.0
	Emergency O_2 Storage	—	} 15	—	} 15	—	—	—	—	25.5	5.7
	Emergency N_2 Storage	—		—		—	—	—	—	24.0	5.7
	Subtotals	224	4140	0	90	0	0	651	3.8	1086.6	47.7
Water Processing And Management	Evaporation Purification Units	—	1440	—	1440	—	—	267 Chem/Tanks	11.2 Chem/Tanks	246.8 Chem/Tanks	11.7 Chem/Tanks
	Water Quality Monitoring	—	80	—	80	—	—	60	4.0	3.6	.2
	Wastewater Storage	—	20	—	20	—	—	—	—	9.1	1.2
	Potable Water Storage	—	20	—	20	—	—	—	—	9.1	1.2
	Emergency Water Storage /EVA Water	—	20	—	20	—	—	—	—	4675.0	148.5
	Subtotals	0	1580	0	1580	0	0	327	15.2	4943.6	162.8
Health And Hygiene	Waste Collection And Storage	—	—	—	—	240	30	180	26.0	360	52.0
	Emergency Waste Collection	—	—	—	—	—	—	—	—	—	—
	Hot Water Supply	—	400	—	30	—	—	25	.3	1.8	.1
	Cold Water Supply	—	—	—	—	—	—	25	.2	1.2	.1
	Shower	—	—	—	—	250	15	120	.5	36	1.3
	Hand Wash	—	—	—	—	200	30	50	.4	1.5	.2
	Clothes Washer/Dryer	—	—	—	—	340	15	90	.5	2.7	.2
	Trash Compactor	—	—	—	—	240	30	80	.7	2.4	.5
	Food Refrigerator	—	146	—	30	—	—	100	1.0	30	.9
	Food Freezer	—	360 HAB 815 LM	—	15 HAB 15 LM	—	—	240	7.4	1800	40.0
	Oven	—	—	—	—	90	740	75	.5	23	.2
	Dishwasher	—	—	—	—	240	15	30	.8	9	.3
	Subtotals	0	1721	0	90	1600	875	2635	38.4	5594	95.8
EVA/IVA Support	Suits And Backpacks	—	—	—	—	—	—	120.3	13.5	2998.1 LiOH	103.8 LiOH
	Recharge Stations	—	125	—	125	—	—	12	.8	3.5	.2
	Air Lock Support	—	—	—	—	2000	15	8	.3	2.4	.9
	Emergency Escape System	—	—	—	—	—	—	46	1.8	7.2	.3
	Subtotals	0	125	0	125	2000	15	186.3	16.4	3011.3	105.2
System Control	ECLS Central Control/Display	—	200	—	200	—	—	10.0	.7	3.0	.2
	Portable Maintenance Control Display	—	—	—	—	—	200	5.0	.4	1.5	.1
	Subtotals	0	200	0	200	0	200	15.0	1.1	4.5	.3
	GRAND TOTAL	7119	10209	6565	2610	3850	3750	1951.8	102.5	9820.5	424.3
		17328		9175							

NOTES:

This Page Intentionally Left Blank

Because of the large penalty in battery weight for powering equipment on the dark side of an orbit, where feasible ECLS equipment will be operated only in the sun portion of the orbit. Where cyclic operation is not feasible, power will be required, as shown, to operate ECLS equipment during the dark side.

The intermittent category is for that ECLS equipment which might operate for short periods of time or at any random time during an orbit. In some instances it may be feasible to schedule intermittent power usage for times when SOC power demand is lower.

Initial spares weights and volumes shown on the table are for those items which must be carried as spares to ensure that a mission duration of 90 days is possible, assuming a Shuttle resupply mission could not be affected for that time. On some items such as pump packages and ventilation fans, one spare has been deemed adequate. On other items, such as the clothes washer and dishwasher, where one entire unit as a spare is impractical, 10 percent of the in-place hardware weight and volume have been assumed for spare components.

Spares for 90 day resupply generally fall under two categories. The first is consumables such as EVA water and LiOH, which must be replaced 100 percent each 90 days. The other is hardware replacement assumed to be 3 percent of initial installation weight and volume. With the full complement of resupply spares a 90 day mission fully operational SOC, with full EVA activity, is possible and could continue for an additional 90 days if necessary, however, only minimal EVA activity is available.

WBS 1.2.1.1.13.1 CABIN VENTILATION AND THERMAL CONTROL SYSTEM

1.0 WBS Dictionary

The Cabin Ventilation and Temperature Control System provides a uniformly mixed atmosphere and removes the airborne sensible heat load from the cabin environment.

2.0 Description

The following are descriptive items of the operation of the Ventilation and Temperature Control System: (Refer to Figure A).

1) Air is supplied to the cabin from a ceiling plenum. Anemostats in the ceiling induce approximately 4 times the air flow for additional mixing of the air. The air is returned through slots along the intersection of the vehicle shell and floor. Air is returned via ducts from the under floor plenum to above the ceiling.

2) Cabin air is drawn into the two double packages. Each package contains a filter, silencers, a constant volume fan, a heat exchanger, and an exit airflow silencer.

3) Coolant water is fed into the heat exchangers from two separate loops, A and B. Separate loops are used in order to ensure that temperature control capability to the habitats or service module is not completely lost in the event of one coolant loop failure. The coolant temperature is controlled to 60°F by a temperature control valve located in the heat transport loop discussed in WBS 1.2.1.1.13.3. After coolant leaves the heat exchangers it flows through the internal habitat and service module cold plates, picking up waste heat for ultimate rejection to space.

The open plenum, ceiling ventilation concept allows great flexibility in preferentially directing airflow to any area of the cabin, as well as assuring that every area is adequately ventilated. This flexibility will ensure, for example, that areas with heavy concentrations of electrical equipment will receive enough extra ventilation to adequately cool the equipment and keep the local atmosphere as comfortable for the crew as other areas of the cabin.

The following are the major elements of the Cabin Ventilation and Temperature Control System and the function of each element:

Filter

A filter is installed over the air return openings to the under floor plenum. These openings run along the intersection of the vehicle shell and the cabin floor. The filters will be disposable and will normally be replaced every 90 days. The filtration level is approximately 300 micron. Locating the filters at the edge of the floor will make them readily accessible for replacement and will protect downstream ducts and equipment from damage or clogging.

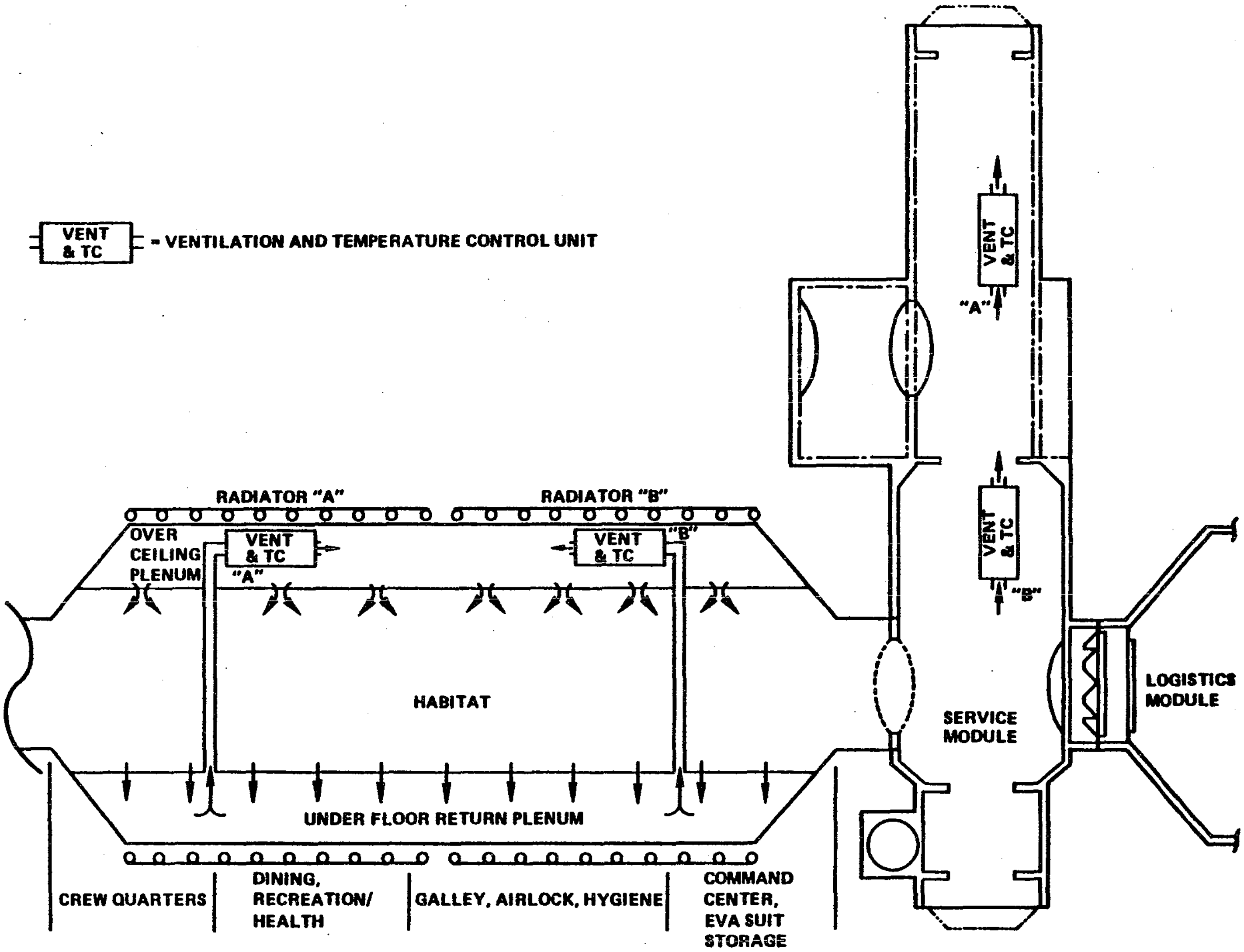


FIGURE A

VENTILATION AND TEMPERATURE CONTROL SYSTEM

Fan

Habitation cabin air or service module air is drawn, via constant volumetric flow fans, through the ventilation system. The fans are an axial flow design with cylindrical aluminum housings and impellers.

Heat Exchangers

The habitat and service module heat exchangers remove sensible heat from the habitat and service modules. The heat exchanger, an all stainless steel plate fin design, would use ruffled fins in the single pass gas side and serrated fins on the two-pass water coolant side. There are four identically sized ventilation and temperature control heat exchanger units in each habitation module, two in the living end, two in the activity end, and two single units installed in the service module. Each set of two in the habitats is packaged together to minimize required packaging volume and for ease of ducting.

Silencer

The noise silencer will be an annular, thick walled design with airflow in the annular passage. The walls will be perforated and will be filled with an acoustically deadening material.

Cold Plates

The cold plates internal to the habitat and service modules are used to remove waste heat from electronic components via contact with a surface of the component. These plates of stainless steel construction, are designed to support the equipment attached to them as well as provide thermal control for the equipment.

It is estimated that ten cold plates will be needed in each habitat and ten cold plates in each service module.

The remaining cold plates are located on the outside of the service modules and are used to remove waste heat from batteries and other power generating equipment. They are designed to sustain heavy masses. Since the cold plates will be used external to the service module, the fluid used is Freon 21, therefore, the cold plates will be aluminum.

It is estimated that 16 cold plates will be required external to each service module.

Performance and Design Data

	Temperature	- Operational (°F)	65-75
		- 90 Day Degraded (°F)	60-85
A		- 21 Day Emergency (°F)	60-90
	Ventilation	- Operational (ft/min.)	15-40
		- 90 Day Degraded (ft/min.)	10-100
A		- 21 Day Emergency (ft/min.)	5-200

Fans:

Number in Operation/Hab. Module - normal	4
Number in Operation/Service Module - normal	2
Design Airflow Rate (cfm/fan)	610
Design Pressure Rise @ 610 cfm (in H_2O)	1.5
Nominal Power Consumption (watts/unit)	217

Heat Exchanger:

Temperature Control Range (°F) (Selectable within cooling capacity of system)	65-80
Temperature Control Tolerance (°F)	$\pm$2
Design Air Side Flow (cfm/unit)	610
Design Coolant Side Flow (lb/hr/unit)	
a) Habitat Module	520
b) Service Module	360
Design Heat Loads (btu/hr/unit)	
a) Habitat Module	13184
b) Service Module	9181

Cabin Ventilation and Temperature Control Package:

Estimated Flight Volume (including fan assembly) (ft^3/unit)	4.5
Package Estimated Flight Weight (lbm/unit)	50

Mechanical

Figure B is an isometric of the Cabin Ventilation and Temperature Control System packaging arrangement. As shown in the figure, in keeping with the requirement for independent redundant systems, heat exchangers in one end of the habitat module are fed by coolant loop "A", while the other similar set of heat exchangers at the other end of the module are supplied by coolant loop "B".

The Cabin Ventilation and Temperature Control System individual package size is 1 ft X 1.5 ft X 3 ft. The cold plates used internal to the habitat and service module are estimated to be 2 ft X 2 ft X 1 in and those external to the service module are estimated to be 3 ft X 3 ft X 2 in.

Electrical

The power requirements for the Ventilation, Temperature Control System are shown in the previous section. The fans will be driven by axial flow 3-phase, 400 Hz, 115 volts/phase induction type electric motors.

Command and Control Functions

Central Control

The Central ECLS Control will give the following mode commands to each Ventilation, Temperature Control System local controller:

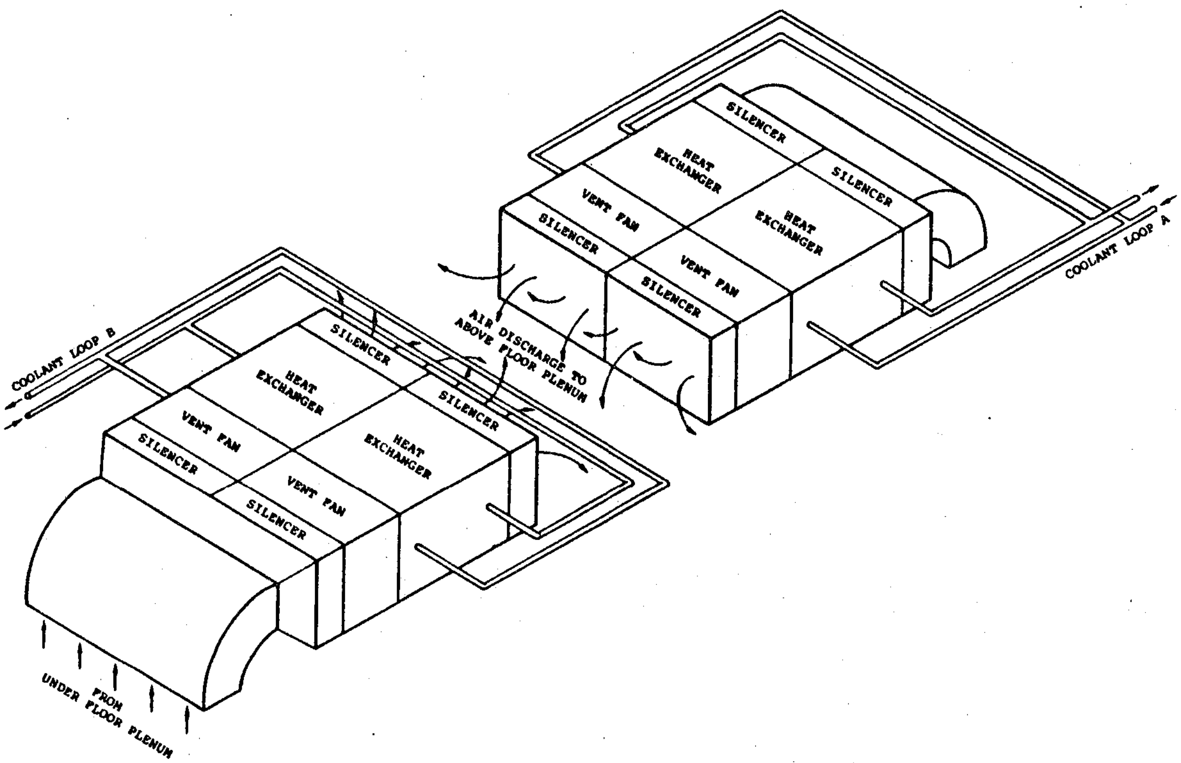


FIGURE B

VENTILATION AND TEMPERATURE CONTROL EQUIPMENT
(HABITAT MODULE)

Loop A Fan #1 (Hab.) On
Loop A Fan #1 (Hab.) Off
Loop A Fan #2 (Hab.) On
Loop A Fan #2 (Hab.) Off
Loop A Fan (Serv-Mod) On
Loop A Fan (Serv-Mod) Off
Loop B Fan #1 (Hab.) On
Loop B Fan #1 (Hab.) Off
Loop B Fan #2 (Hab.) On
Loop B Fan #2 (Hab.) Off
Loop B Fan (Serv-Mod) On
Loop B Fan (Serv-Mod) Off

Local Controller

The two local controllers per habitat and the two local controllers in each service module will perform the necessary control functions for each loop automatically upon a mode selection command from the central control. The following instrumentation will be used for performing this control as well as for performing the other local and central controller functions defined in WBS 1.2.1.1.13.7.

Fans:
a) Speed (rpm)
b) Delta pressure
c) Current

Heat Exchangers:
a) Air inlet temperature
b) Air exit temperature
c) Coolant inlet temperature
d) Coolant exit temperature

Maintenance

1) Routine

a) Replacement or cleaning of debris filters/equipment layout will allow for easy access of high maintenance equipment.

2) Failure

a) Fans - malfunctioning unit will be removed and replaced. The replacement unit, since all habitat fans will be identical, will be fit in any of the packages. Simiarly, the service module fans are interchangeable with the habitat fans.

b) Instrumentation - all types of measurement equipment (temperature, pressure, current, etc.) will have identical hardware so that failed hardware can be replaced from a common generic spares contingent, thereby minimizing spares of each type.

c) Heat Exchanger and Cold Plates - since heat exchangers and cold plates are extremely high reliability items, removal of a unit is not anticipated, and permanent welded interface connections and mounting are expected.

Note: Spares for one habitat will be adequate and usable for the second habitat.

The initial complement of spare hardware for Ventilation, Temperature Control equipment will occupy approximately 2.3 ft^3 and weigh approximately 26 pounds.

Ninety day resupplies will occupy approximately 2.5 ft^3 and weigh 24 pounds.

3.0 Design Basis

The ventilation concept was based upon analyses reported in Boeing-20.

4.0 Mass

See WBS 1.2.1.1.13 mass statement.

WBS 1.2.1.1.13.2 AIR REVITALIZATION SYSTEM

1.0 WBS Dictionary

The Air Revitalization System (ARS) removes carbon dioxide, humidity and atmospheric trace contaminants from the habitation and service modules. The carbon dioxide is reduced in the Sabatier Reactor to reclaim oxygen in the form of water vapor.

2.0 Description

The following are descriptive items of the operation of ARS: (Refer to Figures A and B).

1) Stale air is drawn by constant cfm fans from sources with the highest expected contaminant level.

2) Some air is drawn off into the CO_2 removal solid amine beds, where it is scrubbed of CO_2, then returned to the main air flow stream. This maintains CO_2 concentration at a normal level of less than 3.8 mmHg partial pressures.

3) A small amount of air is also drawn into the catalytic oxidizer. Here combustible and/or toxic gases (CO, H_2, CH_4, benzene, etc.) are burned to maintain acceptable atmospheric levels.

4) Once every other orbit, one of the amine beds is purged of CO_2 by passing a wave of steam through the bed. The steam generator is an integral part of the amine canister. Water is supplied to the steam generator from the water management system.

5) The CO_2 is held in an accumulator, where, during the light side of the orbit, it is sent to the Sabatier Reactor and burned with hydrogen from the electrolysis system to produce CH_4 and water vapor.

6) The water vapor is condensed in the dehumidifier and returned to the water processing system, while the CH_4 is vented overboard through a non-propulsive nozzel.

7) The main ARS air flow stream is passed through a dehumidifier where moisture is removed to maintain a dew point of between 40 to 60°F.

8) The processed air is then passed through a packed charcoal bed for odor removal before being returned to the air plenum in the ceiling for distribution to the cabin.

9) Air samples are taken from selected areas of the cabin to determine atmospheric make-up and the existence of trace contaminants.

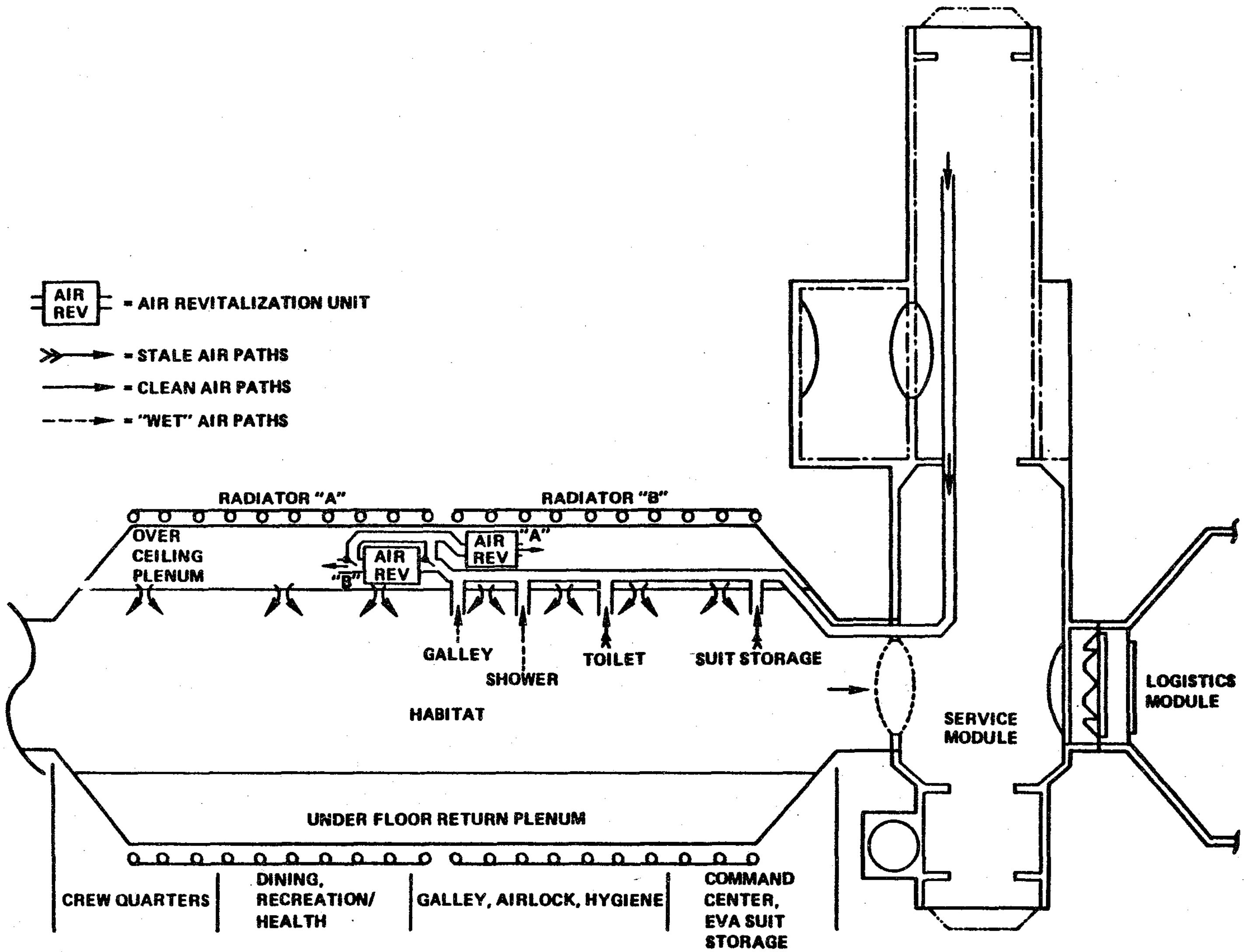


FIGURE A
AIR REVITALIZATION SYSTEM

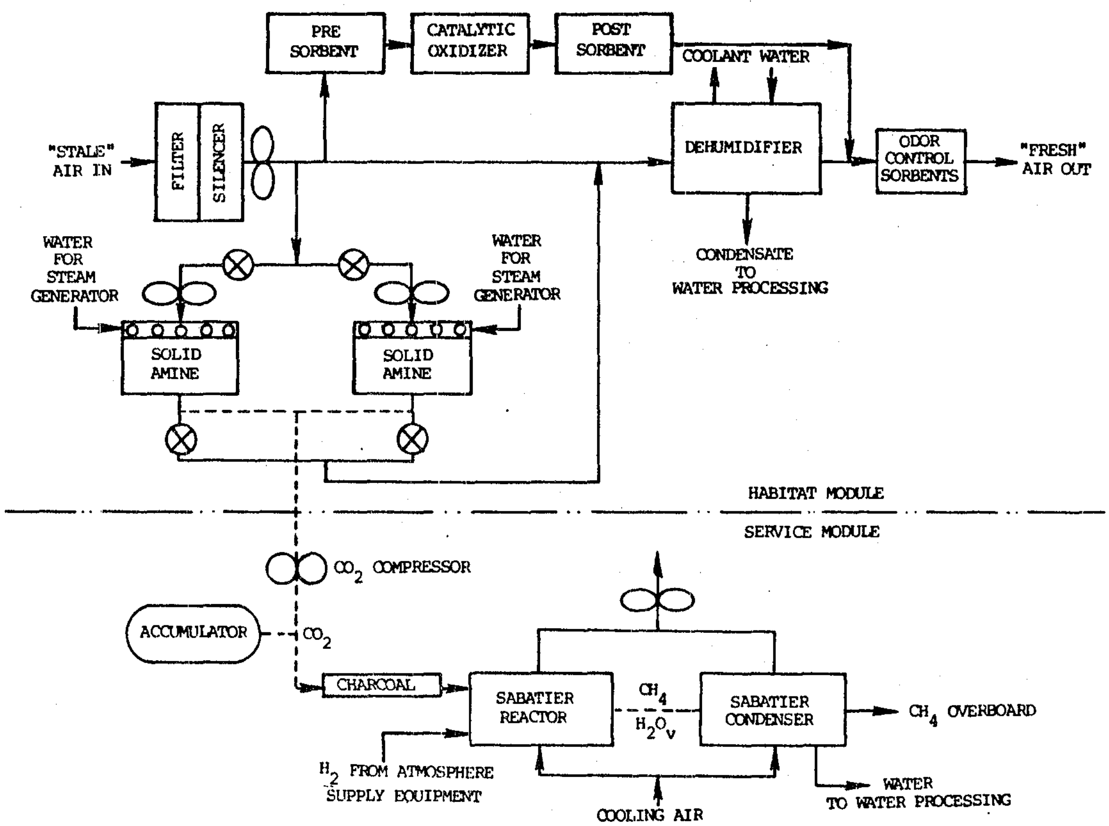


FIGURE B

AIR REVITALIZATION SYSTEM SCHEMATIC

Major Element Descriptions

The following are the major elements of the ARS and the function(s) each performs:

Dehumidification

As shown in Figure B, stale cabin air is drawn, via constant volumetric flow fans, through a debris filter and noise silencer. The fans are an axial flow design.

The filter removes airborne particles from the circulating air stream, thus protecting the fan and succeeding downstream component from damage or clogging. The filter element is a 300 micron level filter.

The noise silencer shown will be a thick walled duct design with airflow in the annular passages. The inner tube walls will be perforated and will be filled with an acoustically deadening material.

A dehumidifier removes sensible and latent heat from the ARS process stream. Following each solid amine bed steam desorption, airflow to the bed is resumed. This causes an increase in the humidity of the air entering the condenser. The condenser is sized to accommodate this peak without allowing the cabin dew point to exceed 60°F.

A thermoelectric regenerator, by electrically transferring heat, assists the dehumidifier in regulating humidity during a period of degraded heat rejection by maintaining dehumidifier inlet coolant temperature below levels which would be obtainable by simply using the degraded heat transfer loop.

Solid Amine CO_2 Removal Subsystem

As seen in Figure B, a portion of the ARS flow is diverted to the CO_2 removal subsystem. The CO_2 removal subsystem consists of constant volume flow fans which forces air, in parallel, through two canisters filled with a solid amine. The amine is produced in spherical pellet form and is kept in place in the canisters by a stainless steel mesh.

During this portion of the cycle, CO_2 is scrubbed from the air passing through the beds by absorption into the amine. Once every other orbit one of the amine beds is desorbed of CO_2 by passing atmospheric pressure steam through them sequentially. The steam is generated by a zero "g" electrical element AC powered steam generator which is integral to each beds' air inlet header.

The CO_2 is "pushed off" the bed by the wave of steam and passed, via a compressor, into an accumulator until it is needed for the operation of the Sabatier reactor subsystem.

Catalytic Oxidizer Subsystems

Figure B shows that a portion of the ARS flow is diverted through the Catalytic Oxidizer Subsystem. This system removes CO, H_2, CH_4, benzene and other trace gases by oxidation at high temperature (580°F).

LiOH is used as a protective pre- and post-sorbent material. As a pre-sorbent, the LiOH will remove such compounds as SO_2, H_2S, HCl and HF. As a post-sorbent, it will also remove acid gases such as HCl and HF which may be created in the oxidation process.

The oxidizer contains a regenerative heat exchanger, an electrical air heater and a catalyst bed, all in an insulated stainless steel housing. Small constant volumetric flow AC powered fans draw air through the oxidizer system.

CO_2 Reduction Subsystem

An important part of the ARS is the CO_2 Reduction Subsystem, the integral component of which is the Sabatier Reactor. In this subsystem, shown schematically in Figure B, hydrogen from electrolysis and hydrazine decomposition mixes with CO_2 accumulated from the CO_2 removal system.

The high temperature (approximately 1000°F) catalyzed reaction converts the constituents into methane and water vapor. The water vapor is condensed out and separated from the process stream in a condensing heat exchanger.

Methane and any unreacted gases are vented overboard. On non-EVA days, the unreacted gas will be CO_2, while on EVA days, since CO_2 production would be less, the unreacted gas would be hydrogen.

Odor Control

At the exit of the ARS, as shown in Figure B, is a packed charcoal bed to control odors by adsorption. The granular charcoal particles are held in place by fine wire mesh screens. The beds will require regularly scheduled replacement.

Atmospheric Monitoring

The habitat atmosphere must be continually monitored to determine atmospheric makeup and the existence of trace contaminants.

This monitoring function can be performed by a space flight version of the Continuous Atmospheric Monitoring System (CAMS) used aboard Navy submarines. The CAMS is a mass spectrometer, built by Perkin-Elmer. As configured for submarine uses, the CAMS detects the presence of hydrogen, oxygen, nitrogen, water vapor, carbon dioxide, Freons 11, 12 and 14 and determines carbon monoxide by ionization detection.

Gas samples are passed, using a positive displacement pump, through the spectrometer. Molecular weights are determined, and the output is presented in digital form, in torrs. Sample points can be judiciously placed in various locations throughout the habitation and service modules to most readily detect any leakages or excessive buildup of gases.

The unit would be tied into the central ECLS controller. Warnings would be indicated on the display console and would be accompanied by an audible signal. The warning system would compare each measured gas level with its allowable range, and issue the alarms if tolerances are exceeded.

In order to take pre-emptive measures, it may be desirable to have low level alarms, as well as emergency alarms; the lower level being triggered by a smaller deviation from a nominal pre-set value.

The CAMS unit aboard submarines needs minimum maintenance, with a simple monthly calibration required. Expected power requirements would be approximately 200-300 watts.

<u>Performance And Design Data</u>

	CO_2 Partial Pressure	- Operational (mmHg)	3.8 max
		- 90 Day Degraded (mmHg)	7.6 max
A|		- 21 Day Emergency (mmHg)	12.0 max
	Dew Point Temperature	- Operational (°F)	40-60
		- 90 Day Degraded (°F)	35-70
A|		- 21 Day Emergency (°F)	30-75
	Trace Contaminants	- Operational - 24 Hr. Ind. Std.	
		- 90 Day Degraded - 8 Hr. Ind. Std.	
A|		- 21 Day Emergency - 8 Hr. Ind. Std.	

<u>Dehumidification</u>:

Number of units/hab. module	2
Nominal airflow rate (cfm/unit)	130
Nominal inlet air temperature (°F)	65-75
Nominal exit air dew point	40-60
Coolant side pressure drop (psi)	1.5
Air side pressure drop (in H_2O)	1.0
Estimated flight weight (lbm) (2 units)	173
Estimated flight volume (ft^3) (2 units)	10
Fan pressure rise (in H_2O)	5.0
Nominal power consumption (watts) (2 units)	205

CO_2 Control:

	Number of beds/hab. module	4
	Airflow rate thru bed (cfm/bed)	35
	Pounds of dry amine/bed (lbm)	13.0
A	Estimated flight weight (2 units) (lbm)	236
A	Estimated flight volume (2 units) (ft^3)	12.6
A	Nominal power consumption (watts) (2 units)	
	Steam generator	578
	Fans	90
	Controller	30

Catalytic Contaminant Burner:

	Number of burners/hab. module	2
	Flow rate thru burner (cfm/burner)	10
A	Estimated flight weight (lbm) (2 units)	108
A	Estimated flight volume (ft^3) (2 units)	12.5
A	Nominal power consumption (watts) (2 units)	381

A | Sabatier/CO_2 Reduction:

	Number of units serving each hab. module	1
	Estimated cooling airflow rate (cfm)	67
A	Estimated flight weight (lbm)	107
A	Estimated flight volume (ft^3)	12.5
	Start-up heater power (watts)	200
	Nominal power consumption (watts)	95
	CO_2 compressor power (watts)	250

Atmospheric Monitor

	Number of units/hab. module	1
	Estimated flight weight (lbm)	50
	Estimated flight volume (ft^3)	2.5
A	Nominal power consumption	100

Vehicle Requirements

Mechanical

Figure C is an isometric of the Air Revitalization System suggested packaging arrangement. Shown in the figure is the required piping arrangement to allow for a change from the normal ARS series flow arrangement to a parallel flow arrangement, in the event that there was a malfunction in one of the systems.

With this arrangement, one ARS can be isolated and shut down for repair while the other system can still maintain a reduced level of air revitalization to all areas of the habitat module. This level of maintained revitalization would keep all required parameters within 90 day degraded specifications.

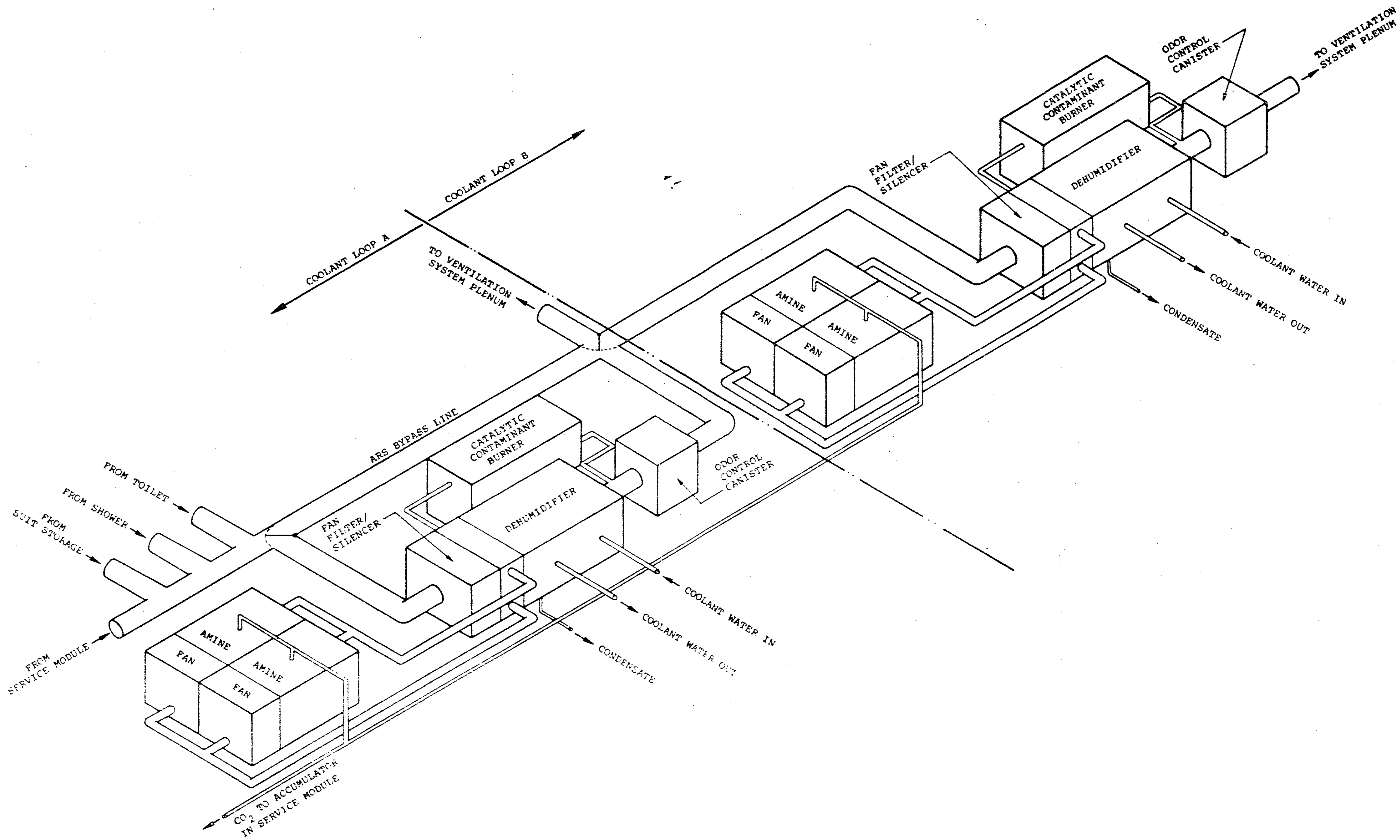


FIGURE C
AIR REVITALIZATION SYSTEM

This Page Intentionally Left Blank

All the ARS equipment will be located in the space above the habitat module ceilings and in service module racks. Air inlet ducting can be routed from areas such as the toilet, lab, shower, wash, food preparation and suit storage. In keeping with the policy of independent redundant systems, the dehumidifiers will receive coolant water from separate liquid coolant loops, thereby preventing the complete loss of dehumidification capability in the event of a loss of a coolant loop.

Electrical

The power requirements for the Air Revitaliztion System are shown in the previous section. The fans and motors will be driven by 3 phase, 400 Hz, 115 volts/phase induction type electric motor. Heaters and steam generators will use regulated 28 VDC for power.

Command and Control Functions

Central Control

Central Control will give the following mode commands to each ARS local controller:

ARS Dehumidifier	Loop A Dehumidifier on Loop A Dehumidifier off Loop B Dehumidifier on Loop B Dehumidifier off
Solid Amine	Loop A Subsystem on Loop B Sybsystem on Loop B Subsystem off Loop A Subsystem single bed mode #1 canister on Loop A Subsystem single bed mode #2 canister on Loop B Subsystem single bed mode #1 canister on Loop B Subsystem single bed mode #2 canister on
Canister Burner	Loop A Subsystem on Loop A Subsystem off Loop B Subsystem on Loop B Subsystem off
Sabatier	Subsystem on Subsystem off Subsystem at standby
Atmospheric Monitor	Subsystem on Subsystem off

Local Controller

The seven local controllers per habitat will perform the necessary control functions for such subsystem automatically upon a mode selection command from the central control. The following instrumentation will be used for performing this control as well as for performing the other local and central controller functions discussed in WBS 1.2.1.1. 13.7.

Dehumidifer

a) Air inlet temperature
b) Air inlet dew point
c) Air exit temperature
d) Fan speed
e) Fan pressure
f) Fan current

CO_2 Control

a) Fan speed (RPM)
b) Fan pressure
c) Fan current
d) Bed exit temperature
e) CO_2 flow switch
f) Steam temperature (each bed)
g) Water pump speed
h) Water pump current

Sabatier (CO_2 reduction)

a) CO_2 accumulator pressure
b) Electrolysis current (for H_2 flow)
c) Coolant outlet temperature
d) Catalyst bed temperature
e) Catalyst bed overtemperature
f) Sabatier condenser process gas exit temperature
g) Water pump current
h) Water accumulator quantity
i) Compressor speed (RPM)
j) Compressor current

Catalytic Contaminant Burner

a) Fan speed (RPM)
b) Fan current
c) Reactor temperature
d) Reactor overtemperature
e) Coolant inlet temperature
f) Coolant exit temperature
g) Coolant flow
h) Condensate flow
i) Water separator current

Odor Control

No instrumentation is required on the odor control canister. The ECLS atmosphere monitoring instrumentation will determine if a charcoal canister should be replaced before its scheduled maintenance period.

Atmospheric Monitor

a) CO_2 partial pressure
b) Water vapor partial pressure
c) Oxygen partial pressure
d) Nitrogen partial pressure
e) Hydrogen partial pressure
f) Tracing of mass numbers up to 110

Maintenance

1) Routine

a) Replacement or cleaning of debris filters/equipment layout should allow for easy access of high maintenance equipment.

2) Failure

a) Fans - malfunctioning units will be removed and replaced. The main ARS fans will all be identical, therefore, a replacement unit will be common for all 4 SOC ARS packages. The same will be true for the solid amine bed fans and catalytic burner fans.

b) Amine Beds - While the amine bed and material have very high reliability, the steam generator integral to the inlet header may not have the same level of reliability. A spare bed, because of commonality, should be adequate in any of the eight SOC locations.

c) Catalytic Burner - Catalyst will be subject to degradation in performance, therefore, replacement must be allowed for. Probably the catalytic burner will be replaced as a unit. Heaters and sensors will be maintainable.

d) Dehumidifier - While the units themselves are of such high reliability that replacement should not be necessary, condensate pump repair or replacement will be required.

e) Instrumentation - All types of measurement equipment (temperature, pressure, current, etc.) should have identical hardware so that failed hardware can be replaced from a common generic spares contingent, thereby minimizing spares of each type.

Logistics

The initial complement of spare hardware for Air Revitalization System equipment will occupy approximately 17.5 ft^3 and weigh approximately 356.0 pounds.

90 day resupplies will occupy approximately 9.1 ft^3 and weigh 179.2 pounds.

3.0 Design Basis

The Air Revitalization System design is based both upon technology used on past manned spacecraft and upon technology resulting from NASA sponsored research and development activity which has been pursued anticipating that new concepts will be required for a SOC type spacecraft. The old technology applies to humidity control and odor control. The new technology applies to CO_2 removal and reduction, trace gas catalytic oxidation and atmospheric monitoring. Boeing document 20 provides more detail on design rationale for the CO_2 removal system.

4.0 Mass

Refer to WBS 1.2.1.1.13 mass statement.

WBS 1.2.1.1.13.3 HEAT TRANSPORT AND REJECTION SYSTEM

1.0 WBS Dictionary

The Heat Transport and Rejection System takes heat removed from the cabin atmosphere and cold plates and transports the heat, via water/freon heat exchangers, to radiators for rejection to space.

2.0 Description

The following are descriptive items of the operation of the Heat Transport and Rejection System: (Refer to Figure A).

Coolant water flows through the condensing heat exchanger, picking up sensible and latent heat of cabin cooling and air dehumidification. It then mixes with a recycle stream, the mixed stream is then used to supply coolant for the main cabin heat exchangers. A thermally controlled flow diverter valve regulates the amount of cooling to the cabin heat exchanger flow in order to avoid condensing in the cabin heat exchangers.

After leaving the heat exchangers, the coolant again splits, some remaining in the recycle loop, the other loop picking up heat loads from cold plates. This loop is then pumped to the freon to water heat exchanger where waste heat is transferred to a freon coolant loop for dissipation to space via radiators.

Freon is circulated through the space radiator as required to provide flow, which is slightly above the freezing point of water to the freon to water heat exchanger. A thermally controlled flow diverter valve located downstream of the freon pump controls the amount of flow to the radiator or bypassing the radiator in order to avoid freezing in the freon to water heat exchanger.

In the event of a failed radiator loop or poor radiator performance, a thermoelectric regenerator would be used to ensure proper dehumidification by lowering the condensing heat exchanger inlet temperature. There are two separate parallel freon and water loops, "A" and "B" in each habitat.

The space radiators are an integral part of the meteorite bumper shield which completely surrounds the two SOC habitat modules. The radiators are plumbed so that there are two independent flow loops on each habitat. The specific design of the radiators is Boeing's responsibility for this phase of the SOC study.

Major Element Description

The following are the major components and the function of each component in the freon and water loops.

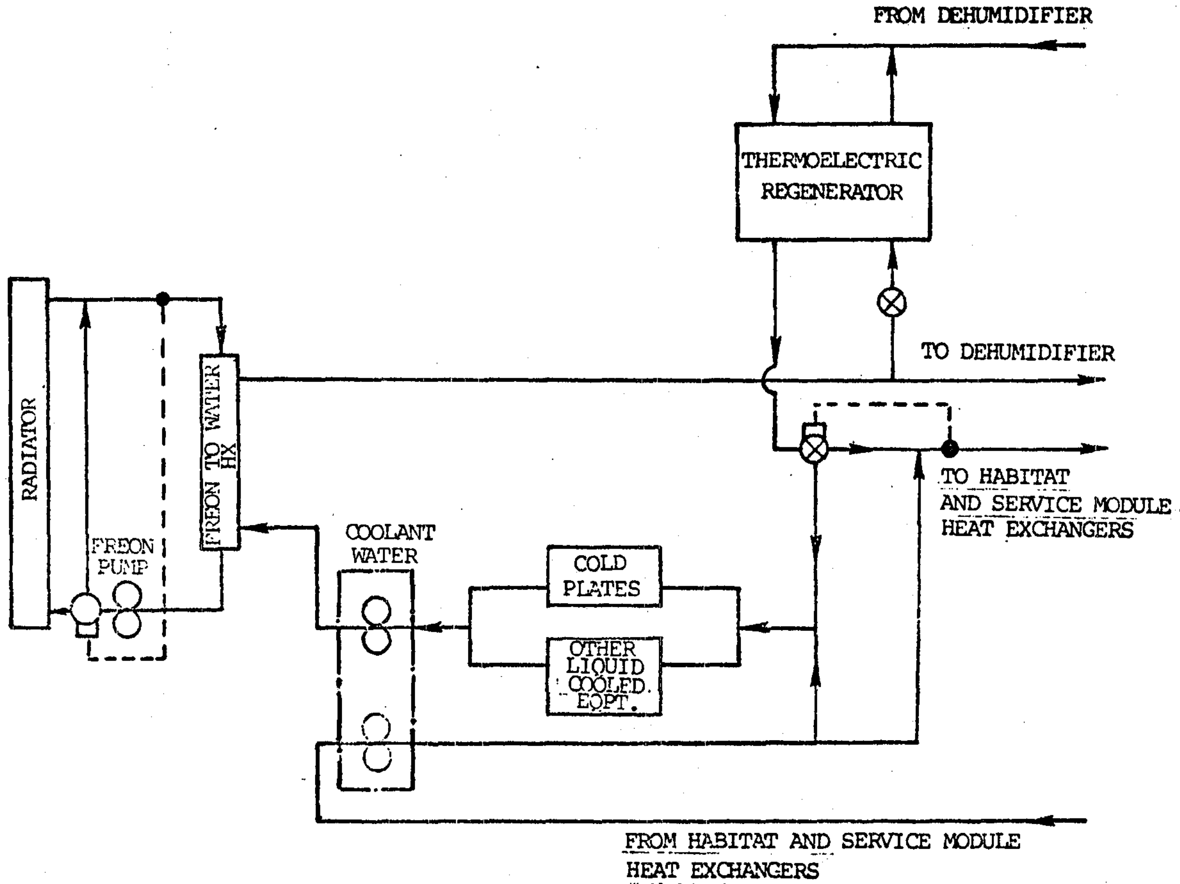


FIGURE A

RADIATOR, HEAT TRANSPORT LOOPS

Coolant Water Pump Package

The water coolant pump package, which includes two pumps and an accumulator, circulates coolant water through the liquid heat transport loop, maintains system pressure, and compensates for leakage and thermally induced volumetric changes by flow in and out of the accumulator.

Freon Pump Package

The freon pump package, which includes two pumps and an accumulator, provides coolant flow in the freon coolant loop, maintains fluid pressure, and compensates for leakage and thermally induced volumetric changes by flow in and out of the accumulator.

Water to Freon (Interface) Heat Exchanger

The freon to water heat exchanger transfer heat from the water loop to the freon loop. The heat exchanger is a stainless steel plate fin unit.

Thermally Controlled Valves

The two thermally controlled bypass valves, one in the water loop and one in the freon loop, are motor driven valves which electronically sense a mixed flow temperature and modulate a cold and a warm flow supply to provide a proper mixed temperature.

Habitat Space Radiators

A | Each habitation module has a radiator containing two integral freon coolant loops, which together are capable of rejecting the maximum amount of heat which can be generated inside one habitat module and its associated service module.

It is currently expected that the power module will deliver 78 kw to the entire SOC during sunlight operation. About 30 kw of this goes to charge the batteries. Battery heat rejection during the recharge is not directed to the habitat module radiators, but rather to a separate radiator on the solar panel boom. Thus, the 78 kw total solar array power results in the need for 78-30 = 48 kw of electrical heat rejection per full SOC, during sunlight.

There are other smaller heat loads, in addition to the above 48 kw electrical load, which must also be rejected by the radiators. The crew metabolic load, together with heat released by the N_2 generator for cabin atmosphere, result in another 1.3 kw of heat input. This added to the 48 kw electrical load results in a 49.3 kw total heat rejection requirement. Some of the total electrical load will go to electrical transmission losses, and rejected before the power enters the service module. Also some power will be radiated from antennas. These external losses will not appear in the habitat module radiators heat rejection requirement. Considering these external losses, a 50 kw total radiator capacity will provide some margin and is a reasonable design criteria at this point in the SOC study. The derivation of this radiator heat rejection requirement is summarized below:

Habitat Module Radiator Heat Rejection Requirement Per Full SOC

Load	Light Side Electric Load (kw)	Light Side Habitat Radiator Load (kw)
ECLS Electrical	17.3	17.3
Crew Metabolic Plus N_2 Generator	N/A	1.3
Heat Conduction Through Spacecraft Walls	Zero	Zero
Non-ECLS Electric Loads	30.8	*27.0
Battery Charge	30.0	Zero
Margin	N/A	4.4
Total	78.1	50.0

*Heat load on habitat radiators assumed to be 90% electrical load.

A| Because of variation of the angle with calendar time and the daily nodal regression, there are several periods each year when radiator heat rejection performance is significantly increased for several days at a time. During these periods, up to a maximum of an additional 12.5 kw of heat can be rejected from the full SOC. Judicious scheduling of high power using activities can take advantage of this extra cooling capability.

Performance and Design Data

Water Coolant Pump Package

Number of pumps/hab. module	4
Pump rated flow (lb/hr/pump)	955 ± 20
Pump rated pressure rise (psi)	53.5
Accumulator usable volume (in^3)	50
Nominal power consumption (watts/hab. module)	750
Estimated flight weight (lbm/package)	32
Estimated flight volume (ft^3/package)	1.5

Freon Pump Package

Number of pumps/hab. module	4 (2 are backups)
Pump rated flow (lb/hr/pump)	2540 ± 40
Pump rated pressure rise (psi)	56
Nominal power consumption (watts/hab. module)	750
Estimated flight weight (lbm/package)	37.5
Estimated flight volume (ft^3/package)	3.8

Freon to Water Interchanger Package

Number of units required/hab. module	2
Water outlet temperature (°F)	39 ± 2
Freon inlet temperature (°F)	34 ± 2
Heat transfer (BTU/hr/unit)	TBD
Water inlet flow (lb/hr)	955 ± 20
Freon inlet flow (lb/hr)	2540 ± 40
Estimated flight weight (lbm/hab. mod)	62.4
Estimated flight volume (ft^3/hab. mod)	2.0

Habitat Space-Radiators

A Heat rejection capacity (per Hab)(kw)	24-30
Freon flow (each loop two pumps)(lb/hr)	5000
Inlet temperature (max. load)(°F)	89
Outlet temperature (max. load)(°F)	36
Pressure drop two pumps operating (psi)	56

Vehicle Requirements

Mechanical

Figure A is a schematic of the Heat Transport and Rejection equipment. Not shown, for purposes of clarity, is the redundant coolant loop which would be located in the other end of the habitat module. This loop would have its own interfaces with the other ventilation pack located in the service module and with the other water/freon heat exchanger.

The water coolant loop main supply and return lines will be located above the habitat ceiling. The two separate loops will be separated as much as possible to avoid accidental damage of both loops from a single incident. The water to freon heat exchangers will be located outside the pressurized volume and these heat exchangers as well as the freon pump packages and radiators will be located on opposite ends of the habitat. Both water loops will be supplied to the service module through the docking port interface.

With the exception of the radiators, the Heat Transport and Rejection System package envelopes are shown below:

Freon coolant pump package (ft)	1 X 1.5 X 2.5
Freon to water heat exchanger (ft)	1 X 1 X 1
Water coolant pump package (ft)	1 X 1 X 1.5

The water loop main lines are 0.75 in. O.D. and the freon main lines are 1.0 in. O.D.

Electrical

Electrical power requirements for Heat Transport and Rejection Loop equipment are given in WBS 1.2.1.1.13.2. The coolant pumps will be driven by 115 VAC, 400 Hz, 3 phase induction motors.

Command and Control Functions

Central Control

Central Control will give the following mode commands to each Heat Transport and Rejection System local controllers:

Coolant Water Pump Packages -	Loop A Pumps	On
	Loop A Pumps	Off
	Loop B Pumps	On
	Loop B Pumps	Off
Freon Pump Packages -	Loop A Pumps	On
	Loop A Pumps	Off
	Loop B Pumps	On
	Loop B Pumps	Off

Local Controllers

The local controllers will perform the necessary control functions for each subsystem automatically upon a mode selection command from the central control.

The following instrumentation will be used for performing this control as well as for performing the other local and central controller functions discussed in WBS 1.2.1.1.13.7.

Coolant Water Pump Package

a) Pump flow
b) Pump delta pressure
c) Pump inlet pressure
d) Pump current
e) Coolant inlet temperature
f) Water accumulator quantity

Freon Pump Package

a) Pump flow
b) Pump delta pressure
c) Pump inlet pressure
d) Pump current
e) Coolant inlet temperature
f) Freon accumulator quantity

Freon Modulating Valve

a) Mixed flow temperature
b) Valve position

Water Modulating Valve

a) Mixed flow temperature
b) Valve position

Maintenance

1) Routine - none of the equipment in the Heat Transport and Rejection System will require regularly scheduled routine maintenance.

2) Failure

a) Pump Packages - All coolant water pump packages and all freon pump packages will be identical to minimize the number of spare packages required.

b) Instrumentation - all types of measurement equipment (temperature, pressure, current, etc.) should have identical hardware so that failed hardware can be replaced from a common generic spare contingent, thereby minimizing spares of each type.

c) Heat exchanger - Because of its extremely high reliability, it is not anticipated that the Interface Heat Exchanger would need replacement. Because of this, line connections and mounting arrangements can be permanent in design.

d) Spare Valves

e) Spare Controllers

Logistics

In order to afford Heat Transport Loop reliability, an appropriate complement of spares must be carried on an initial SOC launch and brought to the SOC during normal 90 day resupplies.

The initial spare complement, not including radiator hardware, will occupy approximately 5.3 ft^3 and weigh approximately 77 pounds.

The 90 resupply spare complement will occupy, on the average, .9 ft^3, and weigh on the average 11.9 pounds.

3.0 Design Basis

The Heat Transport and Rejection System design is based on previous manned spacecraft experience. It is anticipated that several Shuttle Orbiter components can be used in the SOC Heat Transport and Rejection System such as liquid pumps, freon and water accumulators and some valves and quick disconnects.

4.0 Mass

Refer to WBS 1.2.1.1.13 mass statement.

WBS 1.2.1.1.13.4 ATMOSPHERE SUPPLY SYSTEM

1.0 WBS Dictionary

The Atmospheric Supply System supplies oxygen for metabolic consumption and cabin leakage by water electrolysis and nitrogen for cabin leakage by hydrazine decomposition. Emergency oxygen and nitrogen supplies are maintained in pressurized storage tanks.

2.0 Description

Schematic Discussion

The following are descriptive items of the operation of the Atmosphere Supply System (refer to Figure A):

Hydrazine is reduced, via a hydrazine reactor, H_2 separator and catalytic oxidizer into hydrogen and nitrogen. The product nitrogen is vented into the service module. The product hydrogen is directed to the Sabatier reactor.

A liquid water electrolysis cell stack, using a solid polymer electrolyte, provides oxygen for cabin use and hydrogen for use in the Sabatier reactor. The hydrazine reduction and liquid electrolysis processes are performed only during the sunlit portion of the orbit.

In the event of a malfunction causing the shutdown of the electrolysis or hydrazine reduction systems, emergency storage tanks of oxygen and nitrogen would be used to maintain a proper cabin environment until repairs can be made or a rescue mission can be performed.

Major Element Descriptions

The following are the major elements of the Atmospheric Supply System and the function(s) each performs:

Liquid Water Electrolysis

The Liquid Water Electrolysis Subsystem provides oxygen (O_2) for metabolic consumption and leakage makeup and hydrogen (H_2) for use in the Sabatier reactor. The subsystem consists, primarily, of an electrolysis cell stack using a solid polymer for electrolyte, a H_2/H_2O Regenerator heat exchanger which preheats water entering the cell stack and a H_2/H_2O Phase Separator which directs the H_2 flow to the Sabatier and returns the water to the cell stack feed. Oxygen produced in the electrolysis reaction is supplied to the cabin. The cell stack is sized and constructed to operate at 1,000 psia, so that O_2 can be supplied for EVA backpack recharging.

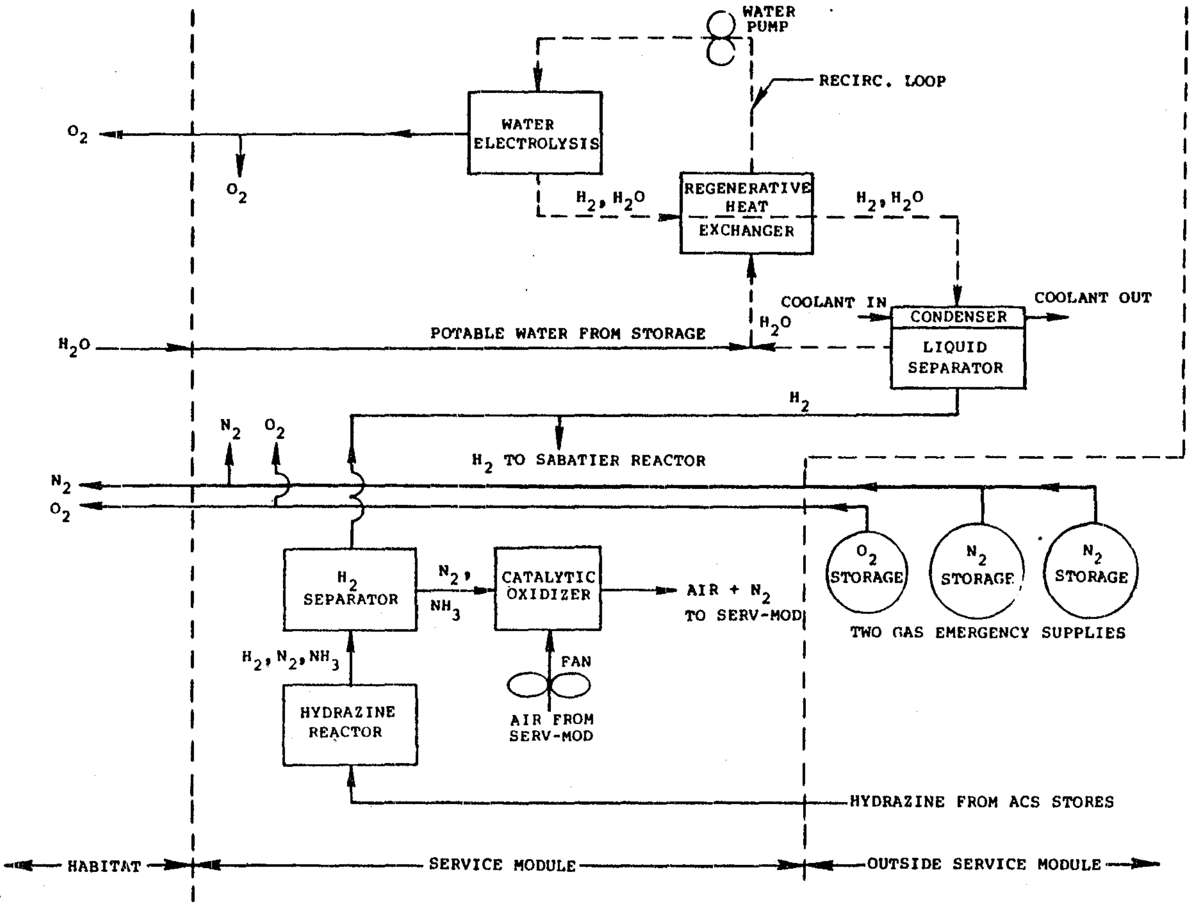


FIGURE A

ATMOSPHERE SUPPLY SYSTEM

Nitrogen Generation Subsystem

The Nitrogen Generation Subsystem provides makeup nitrogen for cabin leakage and hydrogen for the Sabatier Reactor. Nitrogen is provided by the dissociation of liquid hydrazine (N_2H_4) into nitrogen (N_2), hydrogen (H_2) and trace amounts of ammonia (NH_3) in a reactor chamber patterned after an altitude control thruster. These gases flow to a hydrogen separator where 94 percent of the hydrogen is removed for use in the Sabatier reactor. The "raw" nitrogen leaving the hydrogen separator is mixed with cabin air and directed to a catalytic oxidizer where ammonia is dissociated and the remaining hydrogen is oxidized to form nitrogen and water vapor.

Oxygen/Nitrogen Emergency Storage Tanks

The Emergency Oxygen and Nitrogen Storage Tanks are used for emergency metabolic consumption (O_2) and leakage ($N_2 + O_2$). The stored O_2 and N_2 supplies must be sufficient for at least one habitat module complete atmospheric repressurization. In addition, O_2 must be adequate for a 21 day emergency metabolic use.

The O_2 and N_2 storage tanks are each supplied with a check valve installed downstream so that in the event that one tank leaks, the total supply is not lost. All O_2 tanks are charged through fill valves. Shut-off valves are placed between the fill valves and tanks so that the fill and vent can be cycled without a need for disconnecting during resupply.

Performance and Design Data

O_2 Partial Pressure - Operational (psia)	2.73 - 2.93
- 90 Day Acceptable (psia)	2.66 - 3.05
- 21 Day Emergency (psia)	2.3 - 3.05
Total Pressure (psia)	11.8 $\pm$ 0.2

Electrolysis

Number of units/habitat module	1
O_2 Production Rate (lbm/hr):	
EVA Day	1.235
Non-EVA Day	1.090
H_2 Production Rate (lbm/hr):	
EVA Day	.154
Non-EVA Day	.136
Operating Pressure (psia)	
EVA Mode	1000
Non-EVA Mode	300
Nominal Power Consumption (watts)	
EVA Day	3980
Non-EVA Day	3530
Subsystem Estimated Flight Weight (lbs)	375
Subsystem Estimated Flight Volume (ft^3)	26

N_2 Generator

Number of units/habit module	1
N_2H_4 Feed Rates (lbm/hr):	
EVA Day	.641
Non-EVA Day	.310
Oxidizer Reactant Airflow (cfm)	.17
Subsystem Estimated Flight Weight (lbs/unit)	160
Subsystem Estimated Flight Volume (ft^3/unit)	10
Nominal Power Consumption (watts)	
115 VAC	33
28 VDC	25

O_2/N_2 Emergency Storage

O_2 Initial Charge Pressure (psia)	3,000
Initial O_2 Mass Per Tank (lbm)	198
N_2 Initial Charge Pressure (psia)	4000
Initial N_2 Mass Per Tank (lbm)	296
Estimated Flight Weight (lbm, O_2 + N_2 + Tankage)	1430
Estimated Flight Volume (ft^3)	113

Vehicle Requirements

Mechanical

The Atmosphere Supply System is located primarily in the service module. The electrolysis and hydrazine decomposition subsystems are located inside the service module. The emergency oxygen and nitrogen tanks are located outside the service module. Both SOC service modules will each have one electrolysis and hydrazine decomposition units installed, however emergency oxygen and nitrogen supplies are needed only outside one service module. All the plumbing lines supplying oxygen and nitrogen are 1/4 in. stainless steel lines. Oxygen and nitrogen passthroughs are required through all docking and berthing ports. Within each pressurized volume will be a small two gas control module which is used for pressurization of the volume and emergency supplies. Normal supplies will come directly from the electrolysis and hydrazine decomposition units. The packaging envelopes for the major equipment in the Atmosphere Supply System are shown below (emergency oxygen and nitrogen gas tanks are spherical but rectangular envelopes are shown):

Electrolysis Subsystem (one/SM)	2' X 2' X 6.5'
Hydrazine Subsystem (one/SM)	1' X 2.5' X 4'
Emergency Oxygen (one/SOC)	3' X 3' X 3'
Emergency Nitrogen (two/SOC)	3.5' X 3.5' X 3.5'

Electrical

The power requirements for the Atmospheric Supply System are shown in the previous section. The pumps and fans will be driven by 3 phase, 400 hz, 115 volts/phase induction type electrical motors. Sensors, heaters and controllers will use regulated 28 VDC power.

The electrolysis cell stack will use a TBD higher regulated VDC power.

Command and Control Functions

Central Control

Central control will give the following mode commands to each Atmosphere Supply Systems local controller:

N_2 Generator	Subsystem On Subsystem Off
Electrolysis	Subsystem On - Low Press. Subsystem at Standby - Low Press. Subsystem On - High Press. Subsystem at Standby - High Press. Subsystem off
O_2N_2 Emergency Storage	O_2 Supply On O_2 Supply Off N_2 Supply On N_2 Supply Off

Local Controllers

The local controllers will perform the necessary control functions for each subsystem automatically upon a mode selection command from the central control.

The following instrumentation will be used for performing this control as well as for performing the other local and central controller functions defined in WBS 1.2.1.1.13.7.

N_2 Generator

a) Hydrazine Tank Pressure
b) Hydrazine Reactor Outlet Temperature
c) H_2 Separator pre-heater Current
d) H_2 Separator Inlet Temperature
e) H_2 Separator H_2 Side Outlet Pressure
f) H_2 Separator N_2 Side Outlet Pressure
g) Oxidizer Air Fan Speed (RPM)
h) Oxidizer Air Fan Current
i) Oxidizer Inlet Temperature
j) Oxidizer Outlet Temperature
k) Oxidizer Post Mix Exit Temperature

Electrolysis

a) Electrolysis Module Current
b) Cell Voltages
c) Cell Stack Voltage
d) O_2 Side Pressure
e) H_2 Side Pressure
f) Chamber Nitrogen Pressure
g) Coolant Water Inlet Temperature
h) Coolant Water (Makeup) Pump Current
i) Coolant Water (Makeup) Pump Pressure
j) Process Side - Regenerator Inlet Temperature
k) Process Side - Regenerator Exit Temperature
l) H_2/H_2O Separator Current
m) H_2/H_2O Separator Speed
n) H_2/H_2O Separator H_2 Side Pressure
o) Water Accumulator Quantity

O_2/N_2 Emergency Storage

a) O_2 Tank Pressure
b) N_2 Tank Pressure (Each Tank)

Maintenance

1) Routine - none of the equipment in the Atmosphere Supply System will require regularly scheduled routine maintenances.

2) Failure

a) Electrolysis - any defective components of the electrolysis unit would be replaced by an onboard spare.

b) N_2 Generator - any defective components of the generation unit would be replaced by an onboard spare. Periodic replacement of the hydrazine reactor and oxidizer will be required.

c) Instrumentation - all types of measurement equipment (temperature, processes, current, etc.) should have identical hardware so that failed hardware can be replaced from a common genetic spare contingent, thereby minimizing spares of each type.

d) Spare Valves

e) Spare Controllers

Logistics

The initial complement of spare hardware for Atmosphere Supply equipment will occupy approximately 22.2 ft^3 and weigh approximately 651 pounds. (18.4 ft^3 and 543 pounds of this is for an emergency 90 days supply of hydrazine for N_2 makeup).

Ninety day resupplies will occupy approximately 47.7 ft^3 and weigh approximately 1086.6 pounds. (34.0 ft^3 and 1005 pounds of this is for hydrazine which will be consumed to replace N_2 lost by leakage and EVA's during normal 90 day operation. These members include tankage weight and volume).

3.0 Design Basis

The normal Atmospheric Supply System design is based on NASA sponsored research and development activity which has anticipated a SOC type spacecraft. The water electrolysis subsystem concept deviates from the NASA developed technology only in that a high pressure oxygen supply capability is required for EVA backpack recharging. This high pressure technology, however, has been developed by the Navy. The emergency oxygen and nitrogen supply technology uses technology employed by NASA on previous manned spacecraft. It is anticipated that the high pressure emergency gas tanks will use Shuttle Orbiter designs and some orbiter gas valve designs can also be used.

4.0 Mass

Refer to WBS 1.2.1.1.13 mass statement.

WBS 1.2.1.1.13.5 WATER PROCESSING AND MANAGEMENT SYSTEM

1.0 WBS Dictionary

The Water Processing and Management System collects chemically pretreats and stores wastewater from the showers, hand washers, clothes washer, urinals and humidity condensers. The system then processes all of the wastewater by an energy efficient phase change process where the latent heat of condensation is used to evaporate the water. Finally the system post-treats the water and stores the now potable water for reuse.

2.0 Description

Schematic Discussion

The following are descriptive items of the operation of the Water Processing and Management System (refer to Figure A):

Wastewater from all sources is fed into a waste tank where it is pretreated with a sulfuric acid/chromium trioxide solution in order to keep urea from decomposing to ammonia and to maintain sterility. The fluid is then fed, through preheaters, into the processing units. Purified water is produced through phase separation by evaporation and condensation, and passed through a conductivity sensor and, if acceptable, through a post filtration module and into potable water storage tanks.

The potable water supplies for the two habitat modules will be connected, so that in the event that one system suffers a non-maintainable failure, that potable water from the functioning processing system may still be provided.

In the unlikely event of non-maintainable malfunction or required shutdown of all four sets of water processing equipment, water for metabolic consumption can be taken from emergency water storage tanks. Since, in this emergency mode, the showers, diswasher, clothes washer, and hand washer will not be used, the wastewater generated will mainly be condensate from metabolic latent loads and urine. These will be vented overboard after the waste tanks re filled.

Major Element Descriptions

The following are the major elements of the Water Processing and Management System and the function(s) each performs:

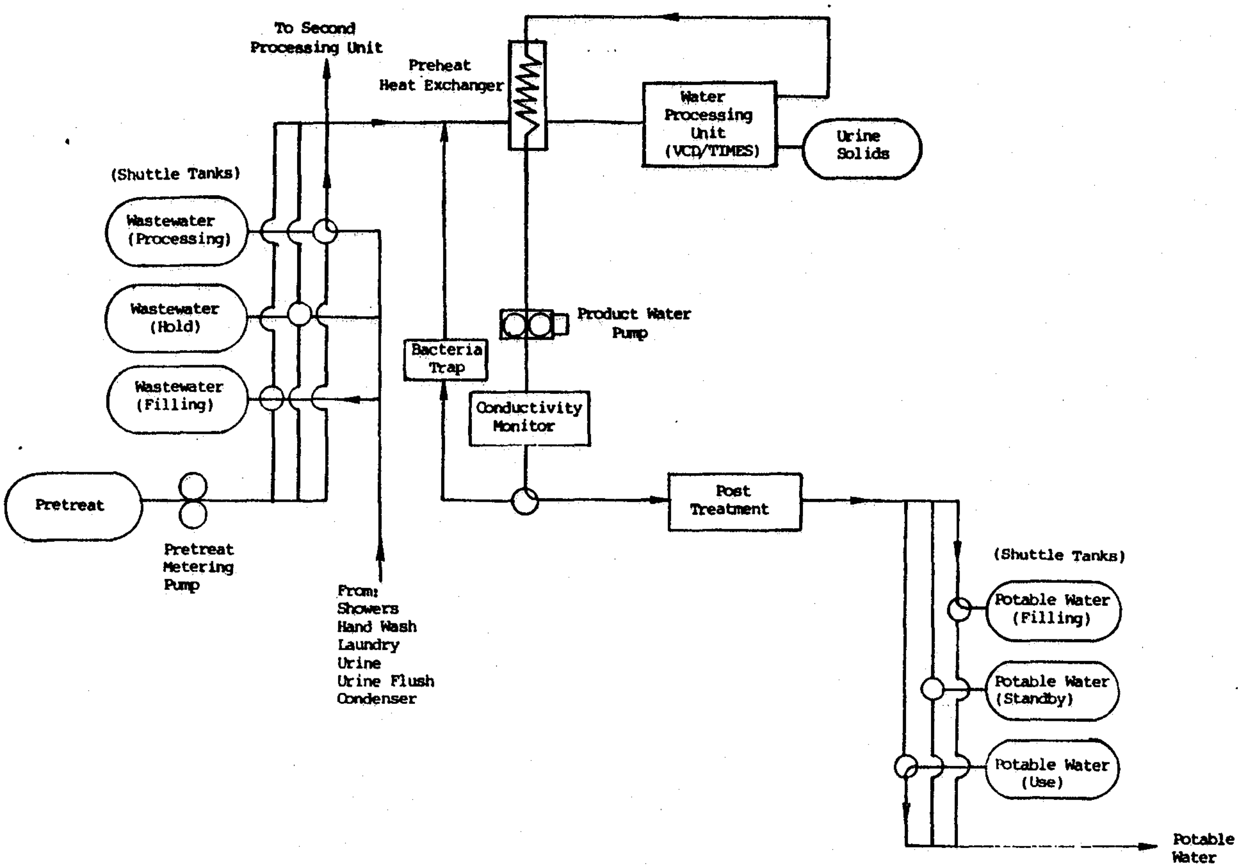


FIGURE A

WATER PROCESSING AND MANAGEMENT SYSTEM

Pretreat and Wastewater Storage Tanks

The pretreat is added to a waste tank which then is filled with incoming wastewater.

Three Shuttle water storage tanks are believed to be adequate for storage of peak wastewater discharge from showers and the clothes washer. The tanks are a positive deplacement aluminum pressure vessel containing stainless steel welded bellows separating the stored water which is inside the bellows from the nitrogen expulsion gas. Water is pumped into the purification units from these tanks. Particulate filtration is provided locally at the various sources of wastewater.

Evaporation Purification Units

Either of the following processes provides the required processing of the wastewater and integrate into the SOC in an identical manner.

1) Thermoelectric Integrated Membrane Evaporation Subsystem (TIMES) This system purifies water in a continuous process by diffusion of preheated wastewater through hollow fiber tubes. Once diffused through the tubes, the water is exposed to a lower pressure and vaporizes. The vapor is recondensed in a condenser which is in contact with the cold terminal of a thermoelectric heat pump. The latent heat given up in condensation is thereby transmitted to a heater which serves to heat the wastewater prior to entering the hollow fiber membranes.

   The condensed purified water is checked for conductivity and, if acceptable, is passed through a final post-treatment and into potable water storage. The post-treatment removes trace odors and adds silver ions or iodine to the water to maintain sterility.

2) Vapor Compression Distillation Subsystem (VCD) This system purifies water by exposing wastewater to a lower pressure and evaporating a portion of this wastewater at the inside surface of a rotating drum. The vapor is centrifugally separated from the unevaporated wastewater, compressed and passed over the outside of the rotating drum. The vapor recondenses on the drum's outer surface, releasing its latent heat to the drum, thereby supplying energy by heat transfer for the evaporation process.

   The quality of the condensed water is checked by a conductivity sensor, and if found acceptable, is passed through a post-treatment and into potable water storage.

Water Quality Monitors

Either of the following provides the necessary analysis to monitor the potability of the purification units product water.

1) Electrochemical Cell
   This Water Quality Monitor is based on an electrochemical cell which uses a linear potential sweep technique to detect oxidizable or reducible species present in purified wastewater. In this method the potential of the sensing electrode with respect to a reference electrode is programmed to vary as a triangular wave with time over the potential stability range for water. The minimum potential starts just above the point where molecular hydrogen evolution begins and the maximum potential is slightly less than that at which molecular oxygen evolution begins. The water to be tested is presaturated with calcium sulfate (2200 ppm) in order to obtain sufficient ionic conductivity. The current response is measured as a function of potential sweep time and a characteristic curve for pure water shows regions due to atomic hydrogen adsorption desorption, double layer charging, and electrode surface oxidation-reduction. Any impurities in the water will modify this characteristic current response curve depending on their ability to be absorbed on the electrode surface or on their electrochemical activity toward oxidation reduction. Therefore, the difference between the current response curves for pure water and water containing active impurities will give an indication of the kind and amount of the impurity.

2) Wet-Chemical Analysis
   The wet-chemical analysis monitor continuously measures samples of product water for pH, specific conductance, ammonia content and total organic carbon (TOC). To test for ammonia and TOC, reagents potassium monopersulfate, sodium hydroxide and sulfuric acid are used. The NaOH removes ammonium ions to prevent interference with the NH_3 gas sensor electrode. The other reagents serve to oxidize organic compounds, most notably acetic acid, in the presence of UV light, to yield CO_2 which is measured by a gas sensing electrode.

Potable Water Storage Tanks

It is believed that a group of three Shuttle-type potable water storage tanks are adequate to provide peak water needs for showers and clothes washing.

Emergency Water Storage Tanks

Emergency water storage tanks are also Shuttle type tanks. Four will be stored in habitat #1, while 22 will be installed in the logistics module. Water from these tanks will be used for EVA, therefore, must be replenished during each resupply.

Performance And Design Data

Wash water processed - operational (lb/man day) - 40 min.
A| - 90 Day Acceptable (lb/man day) - 20 min.
A| - 21 Day emergency (lb/man day) - 0

Pretreat/Mixing And Dirty Water Storage Tanks

Number of pretreat tanks/habitat module	1
Water capacity per tank (lbm)	162
Number of dirty water storage tanks/habitat module	3
Estimated flight weight (dry)/habitat module (lbm)	151.5
Estimated flight volume/habitat module (ft^3)	20
Nominal power consumption/habitat module (watts)	10

Evaporation Purification Units

Processed water flow rate (lb/hr-EVA day/unit)	3.9
Processed water flow rate (lb/hr-non-EVA day/unit)	4.1
Number of units per habitat module	2
Estimated flight weight (dry)/habitat module (lbm)	830
Estimated flight volume/habitat module (ft^3)	74
Nominal power consumption/habitat module (watts)	360

Water Quality Monitors

Number of units per habitat module	1
Estimated flight weight/habitat module (lbm)	60
Estimated flight volume/habitat module (ft^3)	3.8
Nominal power consumption/habitat module (watts)	40

Potable Water Storage Tanks

Number of tanks per habitat module	3
Water capacity per tank (lbm)	162
Estimated dry weight/habitat module (3 tanks)(lbm)	151.5
Estimated volume/habitat module (3 tanks)(ft^3)	20
Nominal power consumption/habitat module (watts)	10

Emergency Water Storage Tanks

Number of tanks in habitat #1	4
Number of tanks in logistics module	22
Water capacity per tank (lbm)	162
Estimated dry weight per tank (lbm)	50.5
Estimated total weight in habitat #1 (lbm tanks & water)	850
Estimated total weight in logistics module (lbm tanks & water)	4675
Estimated total volume in habitat #1 (ft^3)	27
Estimated total volume in logistics module (ft^3)	148.5
Nominal power consumption in habitat #1 (watts)	10
Nominal power consumption in logistics module (watts)	10

Vehicle Requirements

Mechanical

All Water Processing and Management processing equipment is located below the habitat module floors. Emergency water storage tanks are located only in habitat module #1. Water for EVA cooling is stored in the logisticis module.

All tanks (wastewater recycle, pretreat and potable water) are the Shuttle water tanks size. The tanks are cylindrical, however, a rectangular envelope of 1.5 ft X 1.5 ft X 3 ft should be used for packaging. Each water processing package size is 2.5 ft X 2.5 ft X 6 ft. The water quality monitor package is 1 ft X 1.5 ft X 2.5 ft.

Electrical

The power requirements for the Water Processing and Management System are shown in the previous section. The equipment will use regulated 28 VDC power.

Command and Control Functions

ECLS Central Control

Central control will give the following mode commands to each local controller:

Pretreat and Wastewater Storage Tanks

Wastewater storage subsystem	On
Wastewater storage subsystem	Off

Evaporation Purification Units

(Each habitat)	Unit #1	On
	Unit #1	Off
	Unit #1	Standby
	Unit #2	On
	Unit #2	Off
	Unit #2	Standby
Water Quality Monitor		On
		Off
		Standby

Potable Water Storage Tanks

Potable water storage subsystem	On
Potable water storage subsystem	Off

Emergency Water Storage Tanks

(Habitat #1 and Logistics Module)

Outlet valves	Open
Outlet valves	Closed

Local Controllers

The local controllers will perform the necessary control functions for each subsystem automatically upon a mode selection command from the central control.

The following instrumentation will be used for performing this control as well as for performing the other local and central controller functions in WBS 1.2.1.1.13.7.

Pretreat and Wastewater Storage Tanks

a) Pretreat tank quantity
b) Wastewater tank quantities (3)
c) Wastewater tank inlet valve positions (3)
d) Wastewater tank outlet valve positions (3)

Evaporation Purification Units

TIMES

a) Regenerative preheater exit temperature
b) Recycle pump delta pressure
c) Recycle pump inlet pressure
d) Recycle pump current
e) Heater inlet temperature
f) Heater exit temperature
g) Evaporator pressure
h) Condenser temperature
i) Recycle filter delta pressure
j) Valve position indicators
k) Condensate pump current
l) TER current
m) Condensate accumulator quantity
n) Condensate accumulator pressure
o) Cooling pump current
p) Product water conductivity

VCD

a) Condenser pressure
b) Compressor delta pressure
c) Recycle filter tank delta pressure
d) Condenser temperature
e) Recycle fluid temperature
f) Evaporator temperature
g) Product water conductivity
h) Evaporator liquid level
i) Product water flow
j) Valve position indicators
k) Still motor speed
l) Still motor current
m) Centrifuge speed
n) Purge pump speed
o) Purge pump current
p) Fluid pump speed
q) Fluid pump current

Water Quality Monitor

a) Current
b) Cell voltage

Potable Water Storage Tanks

a) Water quantity
b) Inlet valve positions (3)
c) Outlet valve positions (3)

Emergency Water Storage Tanks

a) Outlet valve positions (4)

Maintenance

1) Routine

a) Pretreat Tanks - The tanks must be replaced in each habitat once each 90 days.

b) Recycle Tanks - Require regular periodic replacement when concentration reaches approximately 40 percent solids. This replacement is required approximately once in each habitat each 90 days.

c) Bacteria Traps and Filters - require periodic replacement (TIMES & VDC).

e) Water Quality Monitor - a small amount of calcium sulfate is used, and will need to be infrequently replaced.

2) Failure

a) TIMES - Failures will occur in the purification unit (TER, heater, HFM) or in any of the condensate or recycle pumps and are designed for replacement.

b) VCD - Pumps, compressor instruments, valves and still motors will fail and are designed for replacement.

c) Storage Tanks - It is assumed that storage tanks would have a high reliability. However, they are sized for convenient replacement.

Logistics

The initial spares and consumables for the Water Processing and Management System would weigh 327 pounds and occupy 15.2 cubic feet.

Resupply spares would weigh 4943.6 pounds (includes 4675 pounds of EVA water resupply) and occupies 162.8 cubic feet (148.5 of which EVA water resupply).

3.0 Design Basis

Except for potable and wastewater storage tanks and some water valves, which are Shuttle Orbiter designs, the Water Processing and Management System uses concepts developed by NASA sponsored research and development activity. The processing of wastewater to provide potable water has not been needed on previous manned spacecraft because of the abundant water provided from the fuel cell reaction. An analysis of processing wash water, humidity condensate and urine each by separate concepts vs. processing all wastewater by one concept is included in Boeing-20.

4.0 Mass

Refer to WBS 1.2.1.1.13 mass statement.

WBS 1.2.1.1.13.6 HEALTH AND HYGIENE SYSTEM

1.0 WBS Dictionary

The Health and Hygiene System functions discussed herein are food freezers and refrigerators, galley oven, waste collector, trash compactor, hand wash, whole body shower, clothes washer/dryer, dishwasher, and hot and cold water supplies.

2.0 Description

The following are descriptive items of the operation of the Health and Hygiene System.

Food Freezers

These items provide for the storage of all the frozen food and medical supplies on board the vehicle. Medical samples can be stored as food supplies are removed. The vehicle coolant loop is used as the basic heat sink and thermoelectrics are used for maintaining freezer temperatures.

Food Refrigerator

This item provides for keeping unfrozen or unpackaged food on a temporary basis until they are consumed. Refrigeration is obtained in the same manner as used for the freezers.

Oven

This item provides the means to heat food to the proper temperature for thawing, cooking and eating. The oven is an electrically heated forced air convection device.

Waste Collection and Storage

The Waste Collection and Storage consist of the waste collector. The waste collector is an integrated zero-gravity device utilized to collect and process biowastes from the crew members. The waste collector commode is exposed to space vacuum for drying of the waste when it is not in use. Cabin air is utilized to direct the wastes into the commode and urinal, it is then separated from the waste material, filtered and returned to the cabin. Urine is pumped to the Water Processing and Management System.

Trash Compactor

Trash, consisting of wet wipes, tissues, expended food, etc., are deposited into a trash compactor which compresses the waste material to reduce storage volume. The unit is vented to the waste collector for odor control.

Emergency Waste Collection

In the event that the commode fails, feces can be collected in fecal bags which can be inserted and vacuum dried and stored in the commode. Urine can also be collected in bags and then transferred directly to the waste storage tanks.

Hand Wash

Hand washing or wash cloth wetting is accomplished inside a clear plastic enclosure with access holes. Elbow operated controls and the access hole sleeves minimizes water loss. Water from the central water heaters is temperature controlled via a mixing valve and is discharged through a nozzle. Water is removed by suction and pumped to the Water Processing and Management System.

Whole Body Shower

Whole body washing is accomplished in the shower which utilizes air and water flow to direct the water over the body and into a vacuum pick-up for phase separation. Water is supplied from and returned for reprocessing to the Water Processing and Management System. Vehicle electrical power is used to heat water in a central water heater and is used to power the fan and the liquid/gas separator.

Clothes Washer/Dryer

Clothes and other washable items are washed in a combination washer/dryer. Water is supplied from and returned for reprocessing to the Water Processing and Management System. Airflow is used to dry the items.

Dishwasher

Most of the food for the crew will be individually packaged and consumed directly from the disposable package. However, some food preparation and consumption will result in having dirty dishes and utensils. These dishes and utensils are washed in a dishwasher. Water is supplied from and returned for reprocessing to the Water Processing and Management System.

Water Heater

A central water heater is installed in each habitat. The water is heated electrically and a sufficient quantity of water is available for use in the galley, shower or hand wash stations.

Water Chiller

A central water chiller is installed in each habitat. The chiller is cooled by interfacing with the coolant water heat transport loop. Cold water is provided to the galley, shower and hand wash stations.

Major Element Description

The following is a description of the major elements of the Health and Hygiene System and functions of each subsystem.

Food Freezers

A food freezer is installed in the #1 habitat module and a freezer for food is located in the logistics module. Each freezer contains a refrigeration unit consisting of thermoelectric elements which interface directly with the storage compartment and at separate locations on the unit interface with both water coolant loops to enhance reliability. Cooling water must be supplied to the logistics module on the ground when the freezer is operated to reject heat.

The storage volume consists of two stainless steel boxes, one inside the other and thermally insulated from each other except for the thermoelectric interfaces. Fasteners which attach the freezer to the module structure are located on the outer box. The inner box is separated within the other box by foam insulation. Sufficient insulation is provided to minimize heat leaks and to maintain a freezer temperature of -10°F. Every 90 days food is brought up in the logistics module freezer.

Refrigerator

The refrigerator is identical to the freezer described above except the compartment temperature is maintained at about 34°F.

One refrigerator will be located in the habitat #1 module for storing unconsumed, thawed food temporarily.

Oven

The oven is provided for heating and maintaining food items at temperatures suitable for hot meals. It is an electrically heated forced air convection device with the internal shape optimized for the food packages to be heated and to aid the air circulation pattern.

Waste Collection and Storage The waste collection and storage subsystem provides facilities for fecal, urine, vomitus collection and processing in each habitability module.

The waste collector for each habitability module collects and processes biowastes from crewmembers and is designed to operate in zero-gravity. A simplified schematic is shown in Figure A and described below.

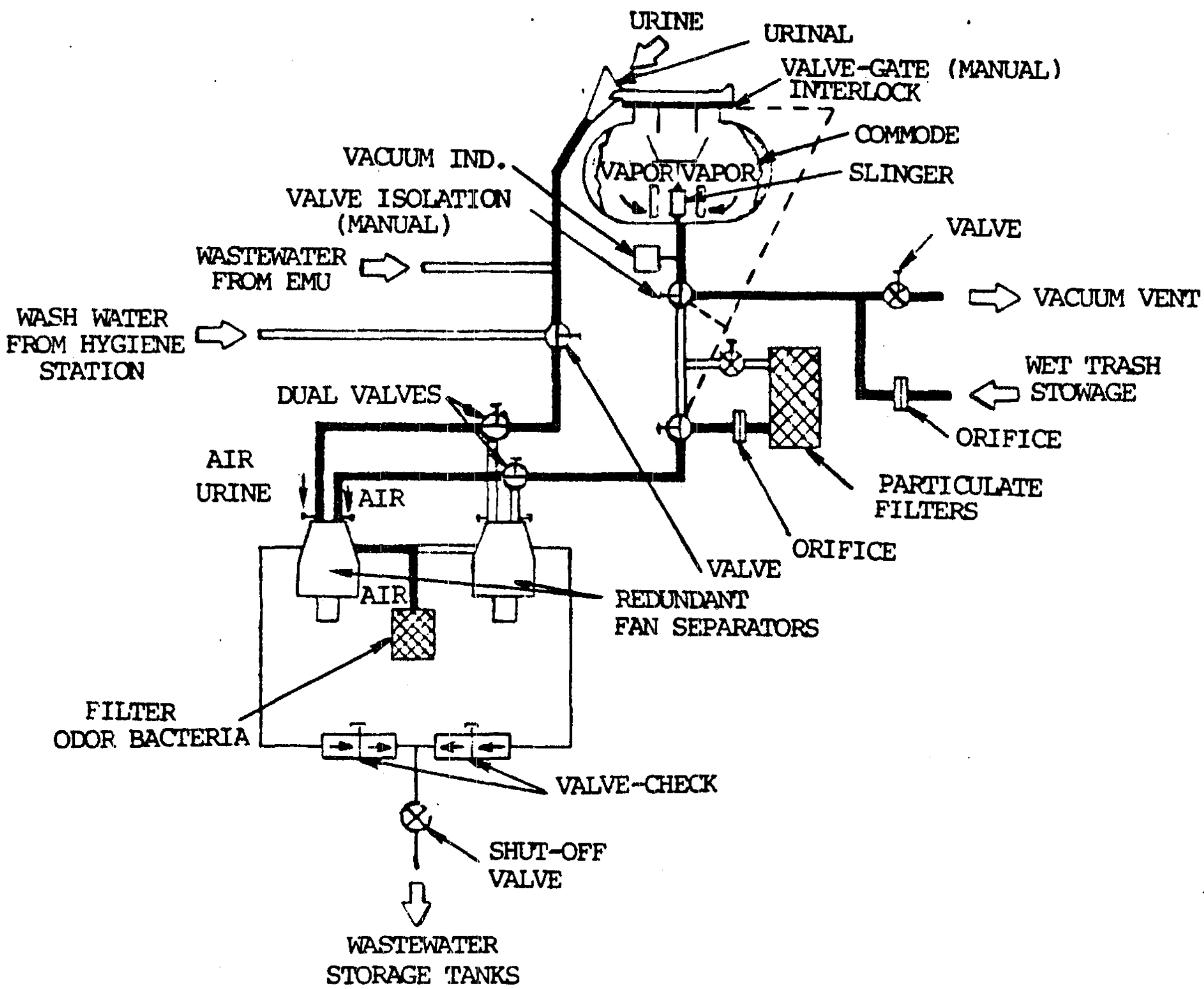


FIGURE A
WCS FUNCTIONAL DIAGRAM-URINE COLLECTION MODE OF OPERATION

Normal System Operation

- Urine Collection - The system can be used in either standing or seated position. Urine is conveyed into the system by airflow (8 scfm) generated by the fan separator. As the liquid air mixture reaches the fan separator, it is centrifugally separated. The liquid is then pumped out while the air exits through the fan into an odor bacteria filter.

- Urine and Feces Collection - The user positions ones self on the seat using seat and foot restraints. The urinal can be positioned for male or female use. Tissue wipes are used after releasing ones self from the seat restraint. The urine is processed as described above. Feces and tissues are brought into the waste collection system (see Figure B) using an airflow of about 30 scfm. Solid wastes are moved into a rotating slinger where tines shred the feces and deposit it evenly around the periphery of the bowl. Tissues slide over the rotating tines into the storage volume. The transport airflow leaves the commode through a bacteria filter and through valves into the fan separator. Commode valves are interlocked for proper sequencing. A control timer continues slinger operation while commode is evacuated so that debris is not introduced into the bacteria filter. Closing the commode handle opens the commode to space vacuum for drying.

Trash Compactor

Wet trash such as used containers, wet towels, tissues, personal hygiene items, etc. are deposited in a container accessible through an opening. The container consists of a compactor with a disposable bag liner mounted in a rigid structure. After trash is inserted into the container, it is closed and a button pressed which compacts the waste into the bottom of the bag and withdraws the same so the compactor is ready for additional trash. When the bag is full, it is removed and sealed for storage, and a new bag liner installed.

Emergency Waste Collection

In case of failure of the waste collection or shower system, the following are provided:

Contingency Fecal Bags
Emesis Bag Storage
Wet Wipes
Urine Collection Bags

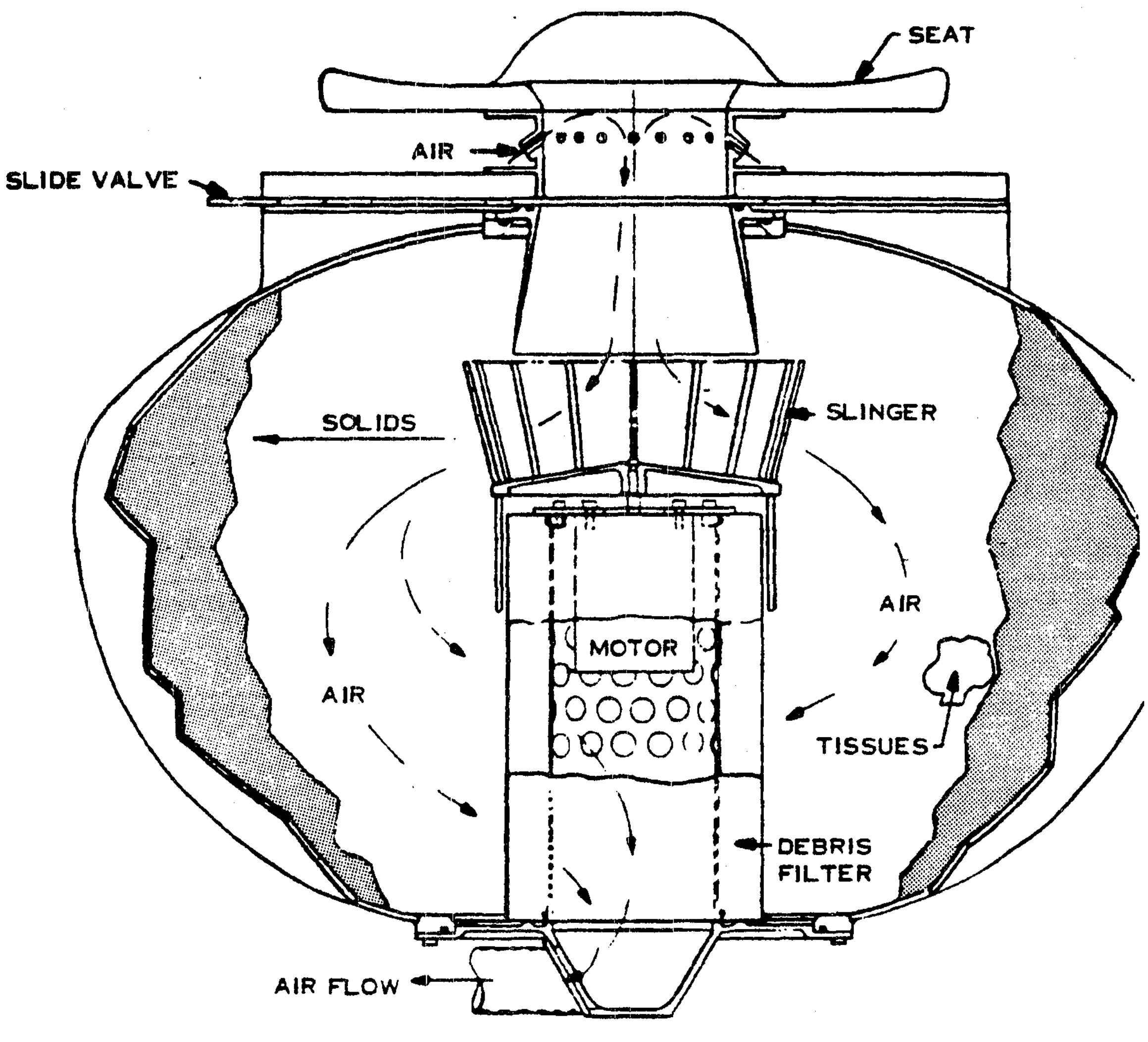


FIGURE B
FECES COLLECTOR ASSEMBLY

The clothes are placed in a basket in the unit which rotates continuously while a water jet is directed at the clothes to provide washing and tumbling action. Daily clothes washing is done in one or two loads. The wash water has a 0.1 percent concentration of detergent and is sprayed over the clothes during the washing cycle. Spinning the clothes at high rpm extracts the water detergent solution. Rinse water with a bactericide is then sprayed on the clothes. After the rinse cycle, the clothes are spun dry and can be subsequently air dried by using ambient air. This air is returned to the Atmosphere Revitalization System.

The primary interfaces of the clothing system are with the Water Processing and Management System and Air Revitalization System. In the event of washer/dryer failure, clothing could be worn for a longer time period with some increase of crew discomfort. It is also possible to wash some clothing in the shower or hand wash facilities.

Dishwasher

The dishwasher is used to wash reusable dishes and eating utensils to keep them hygienic.

An automatic dishwasher is used for this function: Items are placed in trays and enclosed in a cabinet where rotating water jets are directed on the items. A detergent is dispensed during the wash cycle to clean the items. Reused water is then directed on the items to remove the detergent. After the reuse cycle warm air is blown over the items to dry them. The wastewater is pumped to the Water Processing and Management System.

In the event of a dishwasher failure, items can be washed manually in the hand wash or shower.

Water Heater

Water is heated electrically in a heater/accumulator which stores sufficient hot water (140°F) for all short term needs. When dispensing hot water it is discharged from the accumulator while makeup water enters the unit and is heated at a predetermined rate as it is fed into the accumulator section. With this design, the hot and cold water is not mixed together thereby maintaining the hot water temperature. A central heater used to serve all hot water needs (food preparation, hand wash, dishwasher and shower) is located in each habitat.

Water Chiller

Potable water is cooled in a stainless steel coolant water to potable water heat exchanger. Cooled water for drinking and food preparation is cooled on demand as it passes through the water chiller. The water flow rate is controlled by the cold water dispenser.

A central water chiller to provide cool water is located in each habitat.

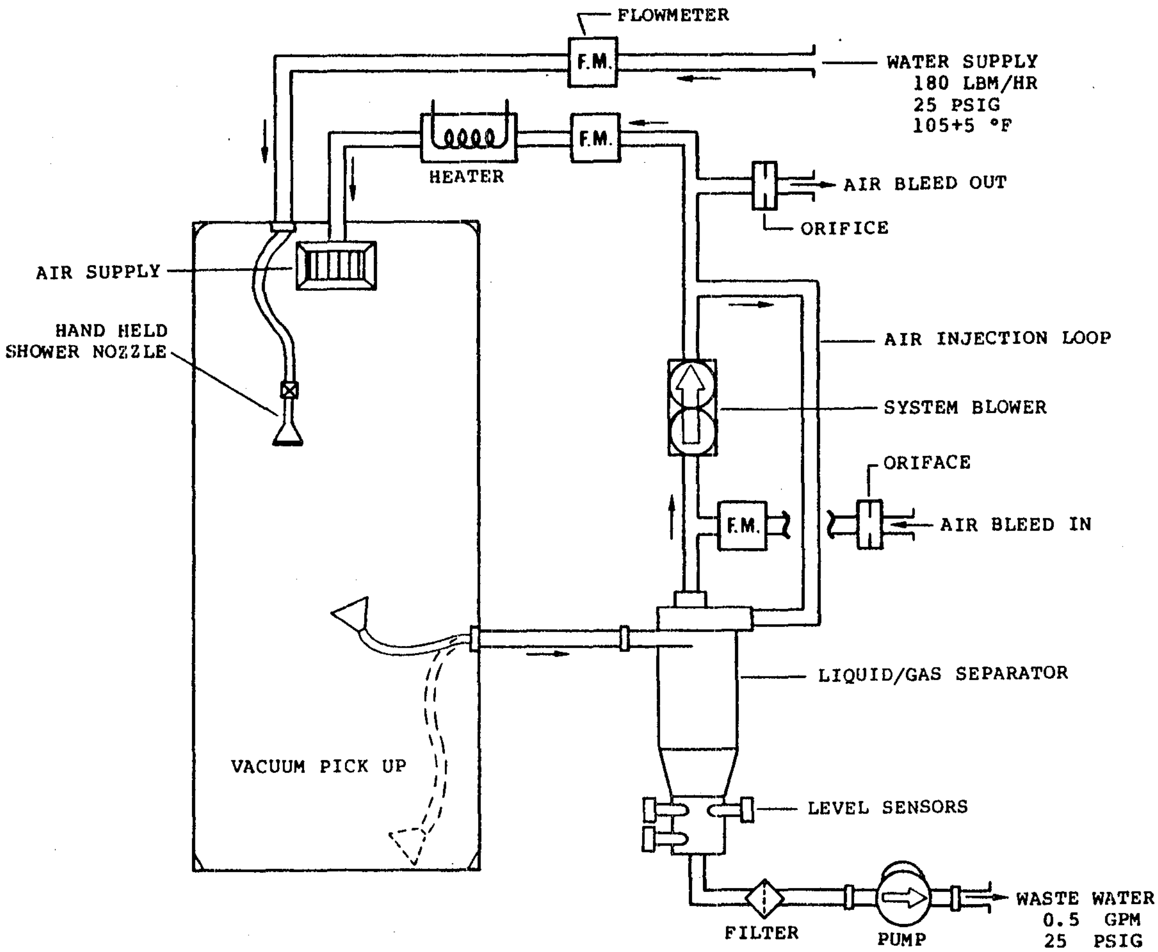


FIGURE C

SHOWER SCHEMATIC

Performance and Design Data

Performance and Design Data for each of the major subsystems in the Health and Hygiene System are described below:

Freezer

Volume and Location - 13.2 ft^3 in habitat #1
40 ft^3 in logistics module
Temperature - -10°F
Cooling sink - water loop (45°F)
Cooling device - thermoelectric
Insulation - 2 inches (all outside surfaces)
Power - 360 watts DC cyclic, 15 DC cont. watts - habitat #1
815 watts cyclic, 15 watts DC cont. - logistics module
Weight- 60 pounds in habitat #1
180 pounds in logistics module

Refrigerator

Volume and location - 10 ft^3 in habitat #1 & #2
Temperature - 30°F
Cooling sink - water loop (45°F)
Cooling device - thermoelectric
Insulation - 2 inches (all outside surfaces)
A1 Power - 73 watts DC cyclic, 15 watts DC cont.
Weight - 50 pounds

Oven

Location - 1 per habitat
Oven temperature - 145 - 500°F (Selectable)
Oven size - 8 meals at a time
Oven power - 370 watts DC intermittent, 45 watts AC intermittent
Oven type - forced air convection
Oven volume - 2.5 ft^3
A1 Oven weight - 37.5 pounds

Waste Collector
(Commode)

Location - 1 unit each habitat module
2 units in logistics module
Crew - .27 lbs. feces and wipes/man day
Capacity - 210 man days/unit
Number required - 4 units/90 days
Emergency - use reserve capacity, backup with bags
Power - 120 watts intermittent, 15 watts DC intermittent
Volume - 12.2 ft^3 per unit
Vent - space vacuum
Odor filter volume - .8 ft^3 each (4 units required/90 days)
Weight - 90 pounds per unit

THIS PAGE IS INTENTIONALLY LEFT BLANK

Trash Compactor

Location - 1 unit each habitat module
90 replacement bags in logistics module
Trash - .1 ft^3/man day compacted
Storage volume - 72 ft^3 (compacted) total
Capacity - .7 ft^3/unit (bag)
Vent - to commode
Emergency - 2 extra replacement bags
Power - 120 watts AC intermittent, 15 watts DC intermittent
External volume - 7 ft^3/unit
Weight - 40 pounds per unit

Shower

Location - habitat #1
Frequency/crewman - 1 per day
Shower time - 15 minutes
Water/shower - 7 lbs.
Water temperature - 90 to 125°F
Power - 250 watts AC intermittent, 15 watts DC intermittent
Water heater - use central water heater
Volume - 44 ft^3
Water removal - pump to Water Processing and Management System
Weight - 120 pounds

Hand Wash

Location - 1 per habitat (hygiene area)
Water flow - 12 lbs./hr.
Temperature - 90 to 125°F
Power - 100 watts AC intermittent, 15 watts DC intermittent
Volume - 3.5 ft^3
Water removal - suction, 30 cfm to waste commode water separator
Weight - 25 pounds

Clothes Washer/Dryer

Location - habitat #2
Wash - one or two loads per day
Power - 340 watts AC intermittent, 15 watts DC intermittent
Volume - 6 ft^3
Water quantity - 110 lbs./wash - room temperature
Water removal - pump to Water Processing and Management System
Weight - 90 pounds

Dishwasher

Location - habitat #2
Wash - one or two loads per day
Power - 240 watts AC intermittent, 15 watts DC intermittent
Volume - 8 ft^3
Water quantity - 16 lbs./wash
Water removal - pump to Water Processing and System
Weight - 30 pounds

Water Heater

Location - 1 per habitat
Temperature - 140°F
Water Discharge Rate - 2 lbs/min
Water Heating Rate - 8 lbs/hr (heating)
Power - 200 watts AC cyclic, 15 watts DC continuous
Volume - 1.5 ft^3
Weight - 30 pounds

Water Chiller

Location - 1 per habitat
Temperature - 45°F
Water Discharge Rate - 12 lbs/hr
Water Storage Volume - zero
Volume - 1.0 ft^3
Weight - 20 pounds

Mechanical

Table A shows the location and package sizes for the Health and Hygiene System. Table B shows the major subsystem interfaces in the Health and Hygiene System.

Electrical

The quantity and type of power required by the Health and Hygiene System hardware was defined in the previous paragraphs. All power is either three phase, 400 cycle, 115 VAC or 28 volts DC regulated.

Command and Control Functions

Central Control

No central control is required on most of the Health and Hygiene equipment due to the nature of the subsystem equipment involved. Only the refrigerator, freezer, water heater, and water chiller temperature is monitored by central control.

TABLE A

HEALTH AND HYGIENE COMPONENT LOCATION AND SIZE

COMPONENT	LOCATION			EXTERNAL DIMENSIONS	EXTERNAL VOLUME
	HAB #1	HAB #2	LM	L X W X H (FEET)	VOL (FT^3)
Food Freezer	X	-	-	2 X 2 X 3.3	13.2
Food Freezer	-	-	x	4 X 5 X 2	40.0
Refrigerator	x	x	-	2 X 2 X 2.5	10.0
Galley Oven	x	x	-	1.3 X 1.3 X 1.5	5
Hand Wash/Food Prep.	x	x	-	1.5 X 1.5 X 1.5	3.5
Commode	x	x	-	2.3 X 2.3 X 2.3	12.2
Trash Compactor	x	x	-	1.5 X 2 X 2.5	7.5
Shower	x	-	-	2.5 X 2.5 X 7	44.0
Hand Wash	x	x	-	1.5 X 1.5 X 1.5	3.5
Clothes Washer/Dryer	-	x	-	1.5 X 2 X 2	6.0
Dish Washer	-	x	-	1.8 X 1.8 X 2.5	8.0

TABLE B

HEALTH & HYGIENE – VEHICLE INTERFACES

Vehicle Interfaces	Power	Coolant Loop 45°F	Vac. Vent	Potable Water Supply	Cabin Air In	Heat Rejection Cabin Air	Heat Rejection Latent	To Water Processing System	Resupply	Location
Hand Wash/Food Prep.	x	x		x		x		x	D	H_1 H_2
Oven	x				x	x	x			H_1 H_2
Freezer/Refrigerator	x	x								H_1
Clothes Washer/Dryer	x			x	x	x	x	x	D	H_1 H_2
Shower/Heater	x			x	x	x	x	x		H_1 H_2
Hand Wash	x			x		x				H_1 H_2
Waste Collector	x		x		x	x		x	x	H_1 H_2
Trash Compactor	x				x	x			x	H_1 H_2
Dish Washer	x			x	x	x	x	x	x	H_1 H_2
Freezer – Logistics Module	x	x								LM

NOTES: D – Detergent Only

H_1 – Hatitat Module #1
H_2 – Habitat Module #2
LM – Logistics Module

TABLE C

CONTROL FUNCTIONS

Item	Subsystem	Automatic	Manual
	Hand Wash/Food Preparation	x	x
	Oven	x	x
	Freezer & Refrigerator	x	-
	Clothes Washer/Dryer	x	-
	Shower	x	x
	Waste Collector	x	x
	Trash Compactor	x	x
	Dish Washer	x	-
	Hand Wash	x	x
	Water Heater	x	-
	Water Chiller	x	-

TABLE D

SPARES WEIGHT AND VOLUME

MAJOR EQUIPMENT	INITIAL SPARES WT. LBS.	INITIAL SPARES VOL. FT^3	90 DAY RESUPPLY WT. LBS.	90 DAY RESUPPLY VOL. FT^3
Waste Collection And Storage	180.0	26.0	360.0	52.0
Emergency Waste Collection	—	—	—	—
Hot Water Supply	2.5	.3	1.8	.1
Cold Water Supply	2.5	.2	1.2	.1
Shower	12.0	.5	3.6	1.3
Hand Wash	5.0	.4	1.5	.2
Clothes Washer/Dryer	9.0	.6	2.7	.2
Trash Compactor	8.0	.7	2.4	.5
Food Refrigerator	10.0	1.0	3.0	.9
Food Freezer	24.0	7.4	180.0*	40.0
Oven	7.5	.5	2.3	.2
Dishwasher	3.0	.8	.9	.3
Total	263.5	38.4	559.4	95.8

*Weight of freezer in logistics module.

Local Control

Each subsystem has its own control which is automatic or under the direction of the crewmember using the subsystem. Table C defines the type of control for each subsystem.

Logistics

Scheduled maintenance is required on the following subsystems.

Trash collector - every day or when bag is full, replace compactor bag with new bag
Galley hand wash - replacement detergent supply
Hand wash - replacement detergent supply
Shower - replacement detergent supply
Dishwasher - replacement detergent supply
Clothes washer - replacement detergent supply
Waste collector - every 90 days or when commode is full, replace commode and bacteria filter.

Each wastewater supplying system will have a particulate filter which must be changed.

Unscheduled maintenance resulting from equipment malfunctions can be accomplished in general with no impact on other subsystems or systems. Adequate space between elements should be allowed to facilitate maintenance.

Spares should be carried only for those items that do not have an acceptably high reliability. Examples of those are:

1) Shower Air Fan
2) Urine/Air Separator
3) Water Pumps

Note: Spares for one habitat will be adequate and usable for the second habitat.

Table D is a tabulation of the spare weights and volumes for the initial launch and the 90 day resupply for the major equipment in the Health and Hygiene System.

3.0 Design Basis

The SOC, because of its long duration mission, will require some Health and Hygiene System technology not previously used in manned spacecraft. Specifically, the SOC freezer's, refrigerator, trash compactor, clothes washer/dryer and dishwasher are in this category. The waste collection and storage units, hand wash, galley oven, whole body shower, water heater and chiller have all been demonstrated in previous manned spacecraft to some extent and some items (waste collector and storage units, hand wash, water heater and galley oven) will be identical or nearby identical to Shuttle Orbiter designs. The new technology hardware is patterned after related commercial technology.

4.0 Mass

Refer to WBS 1.2.1.1.13 mass statement.

WBS 1.2.1.1.13.7 ECLS CONTROL AND DISPLAY SYSTEM

1.0 WBS Dictionary

This element includes the controls and displays dedicated to the EC/LSS system. These are to integrated into the WBS 1.2.1.1.10.1.3 control/display system.

2.0 Description

The ECLS control and display system performs the following functions:

* Control of subsystem function(s) required
  Mode command, on, off, standby, etc.
* Instrumentation, signal conditioning, multiplexing, etc.
* Fault detection and isolation to maintenance level
  Maintenance instruction
  Training instruction
* Caution/warning
  Up link/down link information
  Display
* Data storage/trend information

The asterisked functions are performed in a microprocessor controller which is part of each ECLS subsystem or package. The checked functions are performed in a central ECLS control which is located in the SOC command center. The functions with both an asterisk and check are done by both for reliability reasons. The subsystem controller will store data for a short term and the central system will store long term data for trend analysis.

Instrumentation will be installed on the subsystems to provide the necessary information in order to perform the above list of functions. In general, two instruments will be provided to measure the same parameter. If there is disagreement between the two instruments, the system will automatically shut down for sensor maintenance. When inference logic can be used to check a sensor, only one sensor may be required. The above approach provides maximum safety and a minimum quantity of instrumentation. Shutdown of the subsystem is allowable, since all subsystems are either backed up with another subsystem which will satisfactorily perform the necessary function (possibility with some degradation or the time required to perform maintenance is short enough that the subsystem function is not required during the maintenance period).

All ECLS subsystems will be designed to monitor their own interfaces both vehicle interfaces and interfaces with other subsystems. Information can be provided from interfacing subsystems to meet this requirement as long as unacceptable cascading failures are not introduced. Subsystems will shut down safely due to a failure including an electrical power failure and will retain the necessary data in a non-volatile memory required for fault isolation and to allow a safe subsystem restart. As a goal, all ECLS subsystem microprocessor controllers will be identical. When a controller is installed on a subsystem, it will have an address. By this address it will perform the appropriate control for that subsystem. This technique will allow a single spare controller to be used as any ECLS subsystem controller.

The ECLS control and display station will provide all the information necessary for the crewman to operate the ECLS system. Instrumentation will be powered and available for readout without requiring a subsystem to be operating. The central display will provide all the information required for the crewman to normally operate and maintain the ECLS subsystems as well as provide training for a detailed understanding of the ECLS. For maintenance convenience a portable display capability will be provided which can be connected to or near the ECLS subsystem being maintained.

Each of the ECLS functional areas in WBS 1.2.1.1.13 include a preliminary listing of command functions required from the ECLS system central control and a preliminary instrumentation list which will provide subsystem information for control caution and warning, trend analysis and fault detection and isolation to the maintenance level. It is planned that one ECLS system central controller will be installed in each habitat. Both of these central controllers will be able to run the entire SOC ECLS system, thus providing redundancy. All communication between ECLS system central controllers, local subsystem controllers and the SOC main computers will be by data bus.

3.0 Design Basis

The many interrelated and complex ECLS system functions necessary for the SOC requires more advanced control techniques than those used on previous spacecraft ECLS systems. The design concept of using distribution microprocessor based controls interfacing with a central command and display unit is based on studies sponsored by NASA such as the Space Station Prototype program and is now generally accepted as the best concept for complex industrial processes.

4.0 Mass

Refer to WBS 1.2.1.1.13 mass statement.

WBS 1.2.1.1.13.8 EVA WORK SYSTEM

1.0 WBS Dictionary

The EVA work system includes all equipment and consumables required to support anticipated extravehicular activity (EVA) and unpresssurized intavehicular activity (IVA). This section includes a discussion of the general capability requirements of the SOC EVA work system, and a description of the major elements of this system, which are: the Extravehicular Mobility Unit (EMU), Emergency Escape Gear, and Manned Maneuvering Unit (MMU). (The Airlock Module (WBS 1.2.2.4) is also an essential element of the EVA work system.)

2.0 Description

Extravehicular Mobility Unit (EMU)

The existing Shuttle EMU consists of a Life Support System (LSS) and a modular Space Suit Assembly (SSA). The LSS and SSA modules are designed for individual replacement. An SSA composed of standard modules is fitted to a particular crewmember prior to EVA. Once these standard modules are assembled to form a complete SSA for any particular crewmember, the complete assembly is as a result customized to be one size. New crew-members coming from earth will bring with them their own customized SSA. However, only three suits per four crewmembers is the preferred suit complement for SOC. It is believed reasonable that this sharing of the SSA complement is feasible because there are limited adjustments on each SSA such as about 1" adjustment on spinal length and shoulder width. Salient characteristics of the Shuttle EMU, which is considered baseline for SOC, are:

- o 7 hour EVA capability, (8 hours with SOC expected loads)
- o Reduced front to back dimensions of suited astronaut for improved mobility (20.25 inches front to back in extra large HUT, and approximately 30 inches maximum shoulder width)
- o heat sink using expendable H_2O
- o CO_2 removal using expendable LiOH cartridge,

The suit must be upgraded to a pressure consistent with SOC cabin pressure in order to eliminate prebreathe.

The major EMU elements are shown on Figure A. A more complete listing of EMU elements is as follows:

- o Primary Life Support Subsystem (PLSS)
- o Displays and Control Module (DCM)
- o EMU Electrical Harness (EEH)
- o Contaminant Control Cartridge (CCC)
- o Battery
- o Secondary Oxygen Pack (SOP)
- o Extravehicular Communications System (EVC)
- o EMU antenna

Elements comprising the SSA are identified:

- o Hard Upper Torso (HUT)
- o Lower Torso Assembly (LTA)
- o Arms - right and left
- o N_2 Purge Cuff
- o Helmet
- o Extravehicular Visor Assembly (EVVA)
- o Communications Carrier Assembly (CCA)
- o Liquid Cooling and Vent Garment (LCVG)
- o Insuit Drink Bag (IDB)
- o Urine Collection Device (UCD)
- o Operational Bioinstrumentation System (OBS)

Baseline EMU support equipment elements are:

- o Service and Cooling Umbilical (SCU)
- o Suit Adapter Plate (SAP)
- o EMU Maintenance Kit

The following is a brief summary description of each of the baseline EMU elements which together form the Life Support Subsystem (LSS):

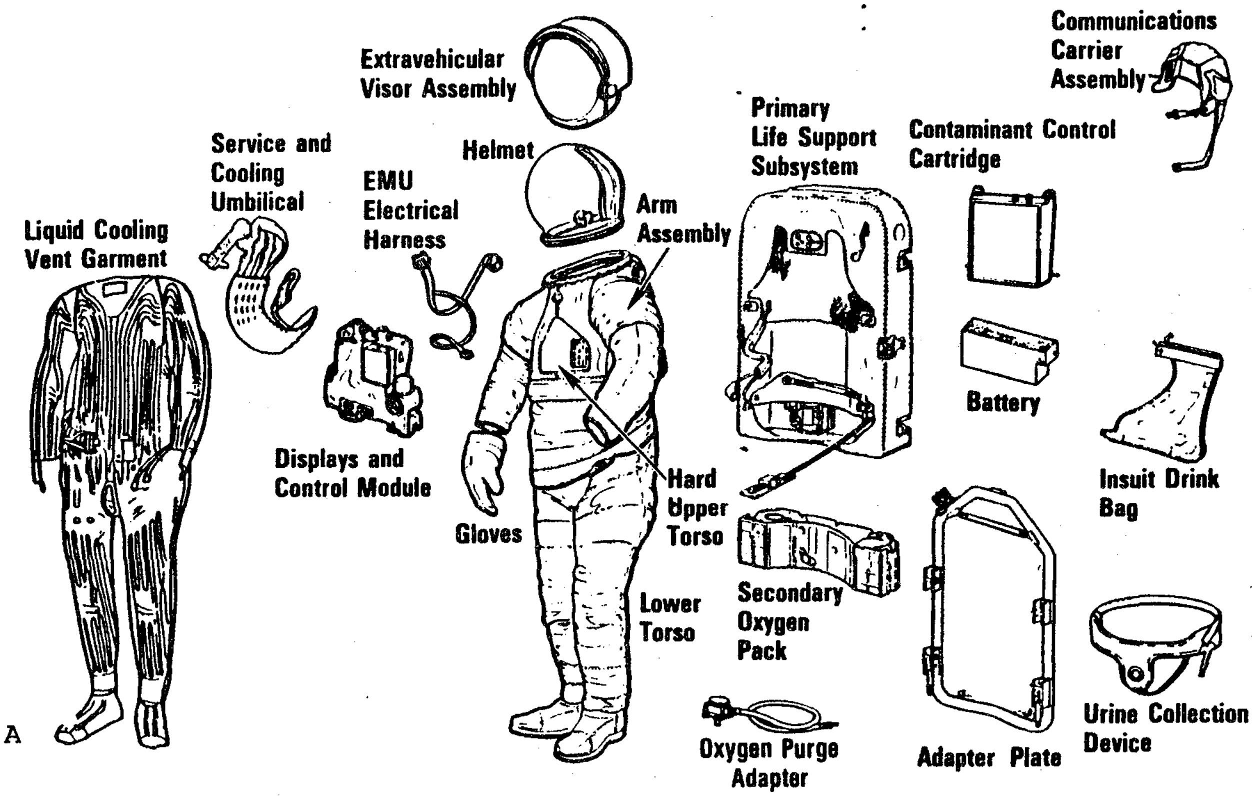


FIGURE A

BASELINE EMU ELEMENTS

Primary Life Support Subsystem (PLSS)

The PLSS is a self-contained, portable life support system. It is attached to the back of the HUT. The PLSS performs the following functions during an EVA:

A. Provides breathing oxygen and controls the pressure within the crewmember's suit.

B. Provides thermal control by recirculating and reconditioning both the oxygen in the suit and the water in the LCVG.

C. Removes humidity, carbon dioxide, odors, and other contaminants for the recirculating oxygen.

D. Provides mounting facilities for the EVC and EMU antenna.

Displays and Control Module (DCM)

The DCM contains the visual displays and electrical and mechanical controls required for operation of the EMU by the EVA crewmember. Contained in the DCM are the cooling control valve, suit pressure gauge, purge valve, the SCU interface connector, a significant portion of the EMU electrical system, controls and switches, and the remote actuation module for oxygen regulators. The DCM mounts directly to the front of the HUT.

EMU Electrical Harness (EEH)

The EEH is a communications harness located within the HUT. It is used to connect the CCA an the OBS to the EMU electrical system.

Contaminant Control Cartridge (CCC)

The CCC contains an activated charcoal bed for trace gas removal, a LiOh bed for CO_2 removal, and a particulate filter to remove solid particles and prevent the migration of LiOH dust. The CCC is installed in the PLSS and is in-flight replaceable for EMU recharge.

Battery

The battery stores and provides the electrical power for operation of all the electronic components of the EMU. The battery mounts into the PLSS, is in-flight replaceable, and can be recharged either installed within or removed from the PLSS.

Secondary Oxygen Pack (SOP)

The SOP is a functionally independent life support system, providing the EMU with an emergency backup for a minimum of 30 min. It provides oxygen for suit loop backup pressure regulation and an open loop oxygen purge for removal of heat, CO_2, and humidity in the event of a PLSS malfunction or failure. The SOP is mounted to the bottom of the PLSS.

Extravehicular Communication System (EVC)

The EVC is an electronic package installed within the PLSS. It provides the following basic capabilities:

- Duplex voice commuications between Earth and one or both of the two extravehicular crewmembers
- Uninterruptable noice communcations between the crewmembers
- A backup communications mode
- Separate subcarrier frequencies for continously monitoring each crewmember's ECG during EVA
- Audible caution and warning tones to alert the crewmember in the event of abnormal or unsafe conditions
- An audible thruster cue signal, identifying MMU thruster activity

EMU Antenna

The EMU antenna, used with the EVC, provides the capability of radiating of signals to space. The antenna mounts on top of the PLSS.

Space Suit Assembly

The SSA end items are described in the following paragraphs:

Hard Upper Torso (HUT)

The HUT comprise the upper torso of the SSA. It includes provisions for the attachment of the helmet, arms, LTA, PLSS, and DCM. The HUT consists of a hard torso section, an upper half of an LTA closure, a lower half of a helmet neck ring, and an integrated thermal/micrometeroid garment (ITMG).

Lower Torso Assembly (LTA)

The LTA provides the crewmember coverage from the waist down. It includes a waist bearing, brief, legs, boots, boot soles, fabric restraint, bladder, and ITMG. The top of the LTA is the lower half of the HUT closure, which provides SSA separation for donning, and support for the fabric brief and hip joints.

Arms - right and left

Each arm right and left, consists of an upper arm and a lower arm connected by the arm bearing. The upper arm includes the HUT - interfacing scye bearing, a shoulder joint, a conformal bladder, and an ITMG. The lower arm includes the glove-interfacing wrist disconnect, an elbow joint, a conform bladder, and an ITMG.

Gloves - right and left

The gloves right and left, provide crewmember hand protection during EVA. The fabric restraint includes wrist and finger joints. Each glove incorporates an optional hot pad for use when extreme touch temperatures are encountered.

Helmet

The helmet is a detachable, hard, pressure-retaining vessel encompassing the head of pressure garment enclosure and providing the crewmember with visibility. It is a rigid, one-piece shell fabricated from an ultraviolet (UV) stabilized polycarbonate material.

Extravehicular Visor Assembly (EVVA)

The EVVA protects the crewmember and the helmet from the EVA thermal and solar radiation environments. It consists of visors, pivot and latch mechanisms, center and side eyeshades, and supporting devices. Th EVVA visors are fabricated from UV stabilized polycarbonate material with thermal/optical coatings applied on the inner surface. The Skylab Extravehicular Visor Assembly (SEVA) design is used for SOC.

Communications Carrier Assembly (CCA)

The CCA is a head-fitted, soft goods assembly contining encapsulated microphone and earphone electronic modules mounted in a fabric skull cap.

Liquid Cooling and VEnt Garment (LCVG)

The LCVG is a form-fitting elastic garment worn against the crewmember's body. The garment supports a network of tubing which circulates the cooling water over the body. The garment also supports a network of ducting which draws the ventilating gas from the suit extremities to complete the oxygen loop. Connections to the HUT are via the multiple connector.

Insuit Drink Bag (IDB)

The IDB is a sealed bag holding 21 fluid ounces (621 cm^3) minimum of potable water. It allows crewmember drinking by mouth activation of the drink valve. The bag is attached to the front inner wall of the HUT, below the helmet disconnect. The IDB design used on the Apollo and Skylab programs is also used for SOC.

Urine Collection Device (UCD)

The UCD consists of a 32 fluid ounce (950 cm^3) capacity container worn inside the SSA, a replaceable adapter to be employed at the crewmember interface, and a transfer hose for emptying into the SOC Waste Management System.

Operational Bioinstrumentation System (OBS)

The OBS is contained within the SSA and provides for the measurement of the crewmember's electrocardiogram (ECG). The ECG signal is then carried via the EEH to the PLS and sent to the Space Shuttle Orbiter by the EVC.

Support Equipment

Items which interface with SOC are described in the following paragraphs.

Service and Cooling Umbilical (SCU)

The SCU (Figure B) is a 12-ft (3.7 m) umbilical, consisting of three water hoses, a high pressure oxygen hose, electrical wiring, bacteria filter, and a strain relief tether. The SCU is used to interconnect the EMU and the SOC airlock for two major functions which provide:

- o Electrical power, hardline communications, biomedical data transmission, oxygen supply, waste water drainage, during IVA operating.
- o Recharge capability for th PLSS oxygen tanks, water reservoir, and battery.

Suit Adapter Plate (SAP)

The SAP (Figure C) provides a mechanical interface between the EMU and EVA Suit Storage Closet wall for EMU stowage. The adapter attaches to the backside of the PLSS and engages with a fixture on the wall of the closet. The adapter is also used to maintain the EMU in a fixed position on orbit for EMU donning and doffing operations.

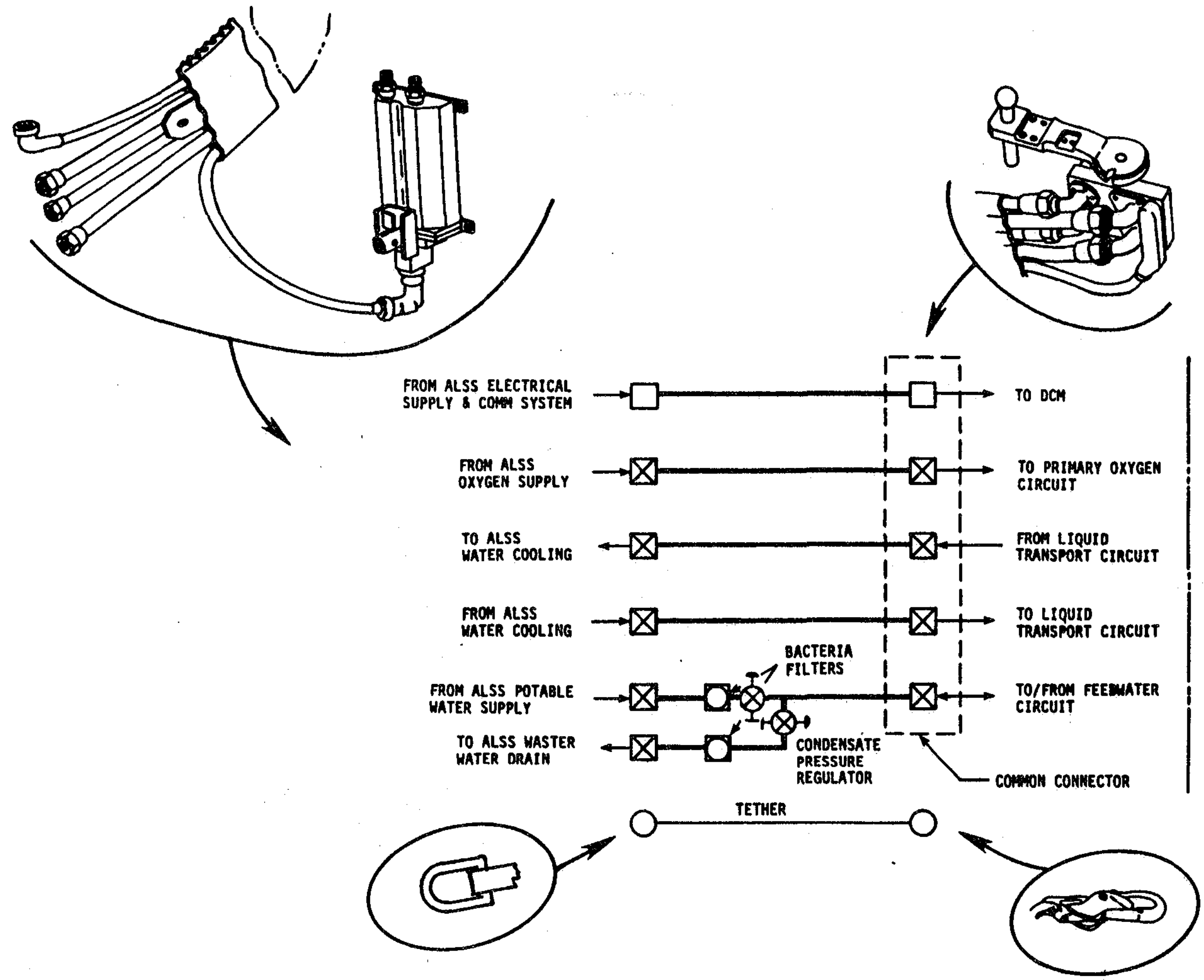


FIGURE B

SERVICE AND COOLING UMBILICAL (SCU)

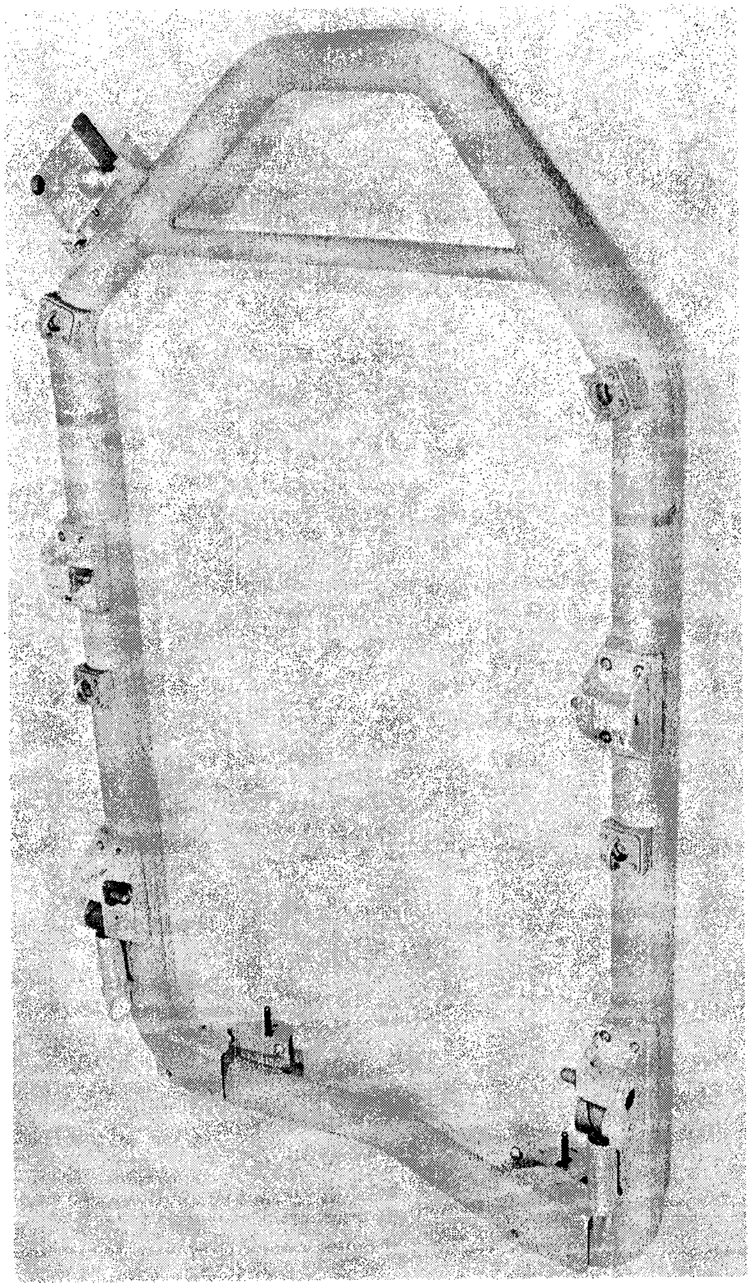


FIGURE C
SUIT ADAPTER PLATE (AAP)

SERVICE AND COOLING UMBILICAL REQUIREMENTS:

System	Parameter	Requirements
Oxygen delivery	Pressure	900 ± 50 psia (6.21 ± 0.34 x 10^6 N/M^2)
	Temperature	40°F to 90°F (4.4°C to 32.2°C)
	Flow rate	20 lb/hr (9 kg/hr) maximum at 900 psig (6.21 x 10^oN/m^2) and 65°F (18.3°C)
	Leakage	0.06 in^3/hr (1 cm^3/hr) 0_2 at 1050 psia (7.24 x 10^6 N/m^2) and 70°F (21.1°C)
Portable water delivery	Pressure	8 - 17 psig (0.55 - 1.17 x 10^5 N/m^2)
	Temperature	40°-100°F (4.4° = 37.8°C)
	Flow rate	50 lb/hr maximum (22.7 kg/hr)
	Pressure drop	1.0 psid (6.89 x 10^3 N/M^2) at 10 psi (6.89 x 10^4 N/M^2) and 50 lb/hr (22.7 kg/hr)
	Leakage	0.006 in^3/min (0.1$_5$cm^3/min) H_2O at 32 psid (2.21 x 10^5 N/m^2)
Condensate drain	Pressure	8 to 32 psid (0.55 to 2.21 x 10^5 N/M^2)
	Flow rate	50 lb/hr 22.7 kg/hr
	Temperature	40° to 100°F range (4.4° to 37.8°C)
Cooling water supply	Pressure	8 - 30 psid (0.55 to 2.07 x 10^5 N/m^2)
	Flow rate	240 lb/hr (108.8 kg/hr)

System	Parameter	Requirements
	Temperature range	45°F to 100 ° F (7.2°C to 37.8°C)
	Pressure drop	1.17 psid (8.07 x 10^3 N/m^2) at 2.5 psid (1.72 x 10^4 N/m^2) in each line
	Leakage	0.006 in^3/hr (0.1 cm^3hr) H_2O at 30 psid (2.07 x 10^5 N/m^2) from each line
Bacteria filtration	Absolute filtration	20 parts/million (20 mg/liter) solid
	Micrometer rating	0.005-10 micrometer particle size
	Pressure	30 - 32 psid (2.07 to 2.21 x 10^5 N/m^2)
Bacteria	Pressure drop	5psid(3.45x10^4N/m^2)at302/hr(13.6kg/hr)H_2O
	Flow rate	50 lb/hr (22.7 kg/hr)
	Temperature	40° - 90° F (4.4° - 32.2° C)
	Leakage	TBD
Electrical supply	Battery Charging	21.5 V dc maximum
	Battery bypass	17.0 ± 0.3 V dc ; 0 - 6.0 A

Emergency Escape Gear, MMU, and WRV Interfaces

The Personnel Rescue System (PRS) is a flexible, folded, ball. When pressurized, the ball produces an EVA rescue capability for passengers and non-EVA crewmembers for whom EMU's have not been provided. The EMU interfaces with the PRS to effect a free space transfer of the PRS from the disabled vehicle to a rescue vehicle.

The Portable Oxygen System (POS) interfaces with the EMU during EVA preparation activities when it provides EVA remember prebreathing. In this case, it interfaces with the EMU while the crewmember is donning the LCVG, CCA, LTA and HUT, helmet, gloves and harness connections. Another major function of the POS is to act as an emergency oxygen supply inside SOC whenever the SOC atmosphere is contaminated. In this role the POS interfaces directly with the unsuited crewmember. The manned maneuvering unit (MMU) is stationed on the outside of the HAB/MOD near the airlock external hatch. It is a modular, self-contained propulsive backpack designed to attach to the Extravehicular Mobility Unit (EMU) and to be donned and doffed by one unassisted crewmember. Gaseous nitrogen (GN_2) is used as the propellant with redundant design to insure that no single credible failure can disable the unit. The MMU is designed to increase the SOC crew's EVA mobility by extending the range of their activities to remove portions of the spacecraft, to appendages of payloads, or to other spacecraft entirely. Some examples of MMU use include the following:

- construct tasks
- inspection and checkout of satellite systems
- repair and adjustment of satellite systems
- detumbling, stabilization, and general manipulation of satellites
- transfer of crewmembers from disabled Orbiter
- only feasible method with tumbing spacecraft involved
  access to all portions of SOC
- cargo transfer.

The MMU has complete six degree-of-freedom control authority with spacecraft type piloting logic, enabling it to perform a full range of translation or rotation maneuvers, either singly or in combination. Control inputs are via two hand controllers; the left-hand controller handling three degree-of-freedrom translation inputs and the right-hand controller handling three degree-of-reduction rotational inputs.

The MMU also has the capability to perform automatic attitude hold on command. This capability is typically sufficient to damp out the effects of the user's limb motion, but it is usually not adequate for tool use loads and similar activity.

The MMU possesses a total impulse of 1392 lb-sec, yielding a V capability of 70 ft/sec when a total weight of 737 lb is assumed.

Electrical power is provided by two batteries capable of supplying 752 W-hr of energy, sufficient for one nominal 6-hr EVA between changes.

A general view of the interfaces between, SOC, the MMU and WRU as shown on Figure E.

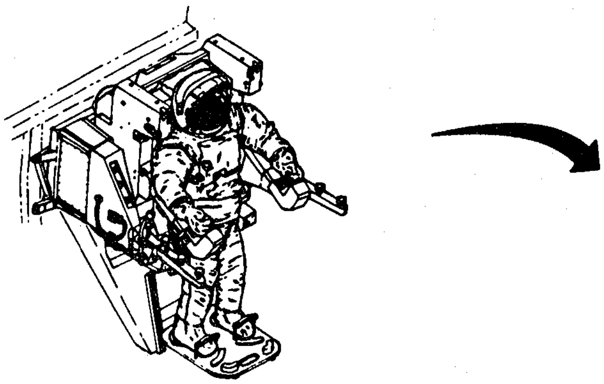
EVA Work System Impact on SOC Design

In the previous portions of this section, the baseline EVA work system for SOC was described, together with interface requirements to support its operation. Table A has been constructed to summarize the impact on SOC of this baseline EVA work system. Table A is arranged in the form of a scenario of a typical EVA mission. As the chronological elements of the EVA mission are described, a parallel evaluation of its impact on the SOC design is made.

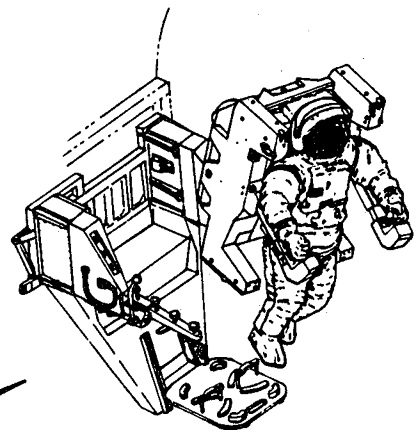
3.0 Design Basis

Design basis

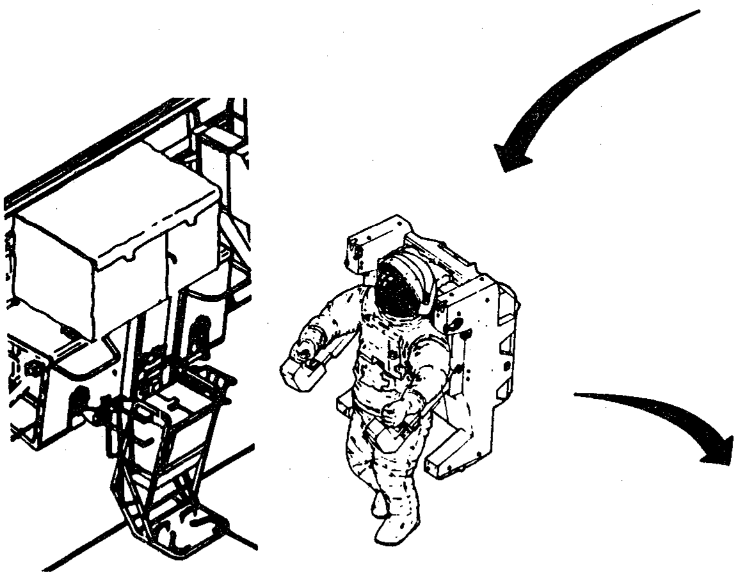
Increased complexity of SOC vehicle equipment, together with its long mission duration result in a high statistical probability that limited life components will wear out or fail if not maintained or periodically replaced. Primary reliance on redundant components, which is the approach used in Apollo, Skylab, and STS programs, leads to impractical design requirements for the SOC 10 to 20 year mission. Long life space system reliability can be practically achieved, however,



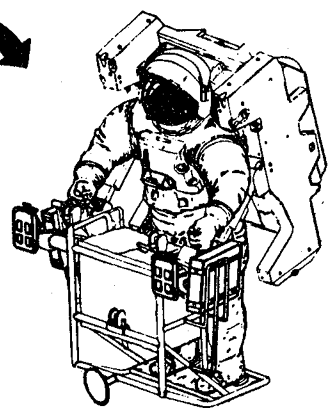
MMU DONNING CONFIGURATION ON SIDE OF SOC HABITAT MODULE



EGRESS/INGRESS



CONFIGURE MMU AND WRU FOR SOC EVA MISSION



THE MMU/WRU FREE FLIGHT CONFIGURATION

FIGURE E

SOC - EMU - MMU - WRU INTERFACES

TABLE A.

EVA WORK SYSTEM IMPACT ON SOC DESIGN

EVA WORK SYSTEM ACTIVITY	IMPACT ON SOC DESIGN
Initial Preparations:	
1. Transfer needed EMU items into airlock from lockers adjacent to airlock. Such items include: a) tools stored in tool caddy b) work aids c) TV, lights, mini-work-station	1. Provide required storage locker space adjacent to airlock for EMU items.
2. Transfer personal support items from storage lockers to EMU stow bags in the airlock. Such items include: a) foodstocks b) valsalva c) prep kit d) cue cards, cuff cards, cuff mirror e) watch	2. Provide required storage locker space adjacent to airlock for personal EMU items and space in the airlock for transferred storage items.
3. Replenish drinking water by taking insuit drink bag from adjacent storage locker to galley and return filled bag to EMU airlock.	3. None, utilizes available galley water drink gun.
DON EMU:	
4. Remove waste collection devices from locker adjacent to airlock, and don in private area.	4. Storage space provided in #1 above.
5. Remove biomed harness from locker and don in private area.	5. Storage space provided in #1 above.
6. Remove wristlet pads from maintenance kit and liquid cooled vent garment (LCVG) from locker, and don in private area.	6. Storage space provided in #1 above.

TABLE A.

EVA WORK SYSTEM IMPACT ON SOC DESIGN

(Continued)

EVA WORK SYSTEM ACTIVITY	IMPACT ON SOC DESIGN
7. All activity outside suit donning area complete. Apply antifog from prep kit to helmet visor. Don EMU prescription glasses if required. Don EMU at EMU donning station mounted to Suit Adapter Plate (SAP).	7. Suit donning area sized to allow two astronauts to engage simultaneously in required pre-EVA activities, as well as provide required storage space for two EMU's and support equipment.
Checkout EMU:	
8. After suited in suit donning area, enter airlock, check out EMU systems, including the following, which have an interface impact on the airlock: a) communications b) fan operation c) suit leakage d) emergency O_2 pack e) sublimator water	8. Supply and Cooling Umbilical (SCU) interface with EMU must be provided in the airlock for: a) wire and radio communication b) electrical power (28 V) c) oxygen d) water Also controls and readout of above supplied items as well as airlock pressure must be provided.
Egress:	
9. Pump down airlock	9. Provide a positive displacement airlock pump with capacity to pump the airlock pressure down to 2 psia, in order to save the charge of pressurizing atmosphere which would otherwise be vented overboard.
10. Egress Airlock	10. Provide fixed hand holds, translation rails, lights, and tether attachment points. Provide window for IVA astronaut observation of egressing EVA astronaut.
EVA Operations:	
11. Don-Doff-Service MMU	11. Provide area for a Shuttle MMU Flight Support Station FSS for each MMU. FSS facility provides MMU service capability (nitrogen, recharge batteries), restraints, mounting bracket, etc.

TABLE A.

EVA WORK SYSTEM IMPACT ON SOC DESIGN

(Continued)

EVA WORK SYSTEM ACTIVITY	IMPACT ON SOC DESIGN
12. Translate to SOC work site and perform work.	12. Provide fixed SOC hand holds, translation rails, lights, and tether attachment points to support EVA work at SOC work sites. Use EMU glove/tool compatible fasteners, connectors and fittings on all SOC equipment to be maintained by EVA astronaut.
Ingress and Doff EMU:	
13. Ingress Airlock.	13. Provisions provided in #10 above.
14. Connect supply and cooling umbilical (SCU).	14. Provision provided in unit #8 above.
15. Repressurize airlock.	15. None, pressurization source is SOC cabin atmosphere. Pressurization controls per Shuttle.
16. Enter suit storage area, doff EMU.	16. Doff EMU at doffing station mounted to Suit Adapter Plate (SAP).
17. Store work aids, tools, mini-work-station, TV, lights, and personal items.	17. Storage space provided in #2 above.
Post EVA, Sanitize & Dry EMU:	
18. Dump waste collection devices.	18. Use head for urine disposal, provide sanitary storage for solid waste.
19. Towel dry EMU.	19. Provide towel storage and laundry deposit.
20. Sanitize liquid cooling & vent garment (LCVG) and stow in locker.	20. Provide storage for disinfectant towels.

TABLE A.

EVA WORK SYSTEM IMPACT ON SOC DESIGN

(Continued)

EVA WORK SYSTEM ACTIVITY	IMPACT ON SOC DESIGN
Inspect, Recharge and Replenish EMU Consumables:	
21. Position EMU on Suit Adapter Plate (SAP) for access to PLSS to replace LiOH cartridge. Inspect EMU for damage/wear.	21. Provide LiOH storage lockers convenient to suit storage area. Spares storage LiOH, spares, batteries.
22. Refill PLSS with H_2O, O_2 and charge battery.	22. Use supply and cooling umbilical (SCU). Provide capability for recharging batteries used with portable lights and power tools.
23. Restow EMU	23. Use Airlock Adapter Plate (AAP).
24. Store work aids and personal support items.	24. Storage space provided in #1 above.
Periodic Planned EMU Maintenance:	
25. Inspect EMU for wear/damage and replace modules (e.g., gloves) as required.	25. Provide storage for EMU spares. Make use of existing SOC work area and tools.
26. Clean and polish helmet, visor, and eye glasses.	26. Make use of SOC work area and tools.
27. Launder LCVG and wrist cuff pads.	27. Use SOC laundry facilities.
28. Lubricate helmet, waist, glove, etc. disconnect rings.	28. Lubrication pouch provided. Perform in airlock with EMU mounted on Airlock Adapter Plate (AAP). Make use of SOC work area and tools.
Contingency Procedures:	
29. Denitrogenate by prebreathe of pure O_2	29. Portable Oxygen Systems (POS) provided. Provide O_2 outlets in airlock and adjacent SOC area.

TABLE A.

EVA WORK SYSTEM IMPACT ON SOC DESIGN

(Continued)

EVA WORK SYSTEM ACTIVITY	IMPACT ON SOC DESIGN
30. Hyperbaric decompression.	30. Provide capability in airlock, pump, and controls. Alternately make use of hyperbaric emergency escape ball.
31. Unscheduled maintenance done by replacing complete: Secondary O_2 Pack (SOP) Display and Control Module (DCM) Primary Life Support System (PLSS) Hard Upper Torso (HUT) Lower Torso Assy (LTA) Arms, Gloves	31. Make use of existing SOC work area and tools. Provide storage for spare EMU components.
32. EMU check out	32. Airlock provides checkout capability via SCU and EMU computer and display and controls module (DCM).
33. Conduct unpressurized IVA.	33. Provide adequate volume to accommodate EMU in internal SOC areas where contingency unpressurized intravehicular maintenance could occur. Use EMU glove/tool compatible fasteners, fittings and connectors on critical internal SOC equipment.
<u>Effect of New Technology Items</u>:	
34. Install EMU overgarment hazards protection.	34. Provide storage area for hazards protection overgarments.
35. Service EMU no-vent regenerable heat sink.	35. Provide airlock capability for regenerating (e.g., refrigeration) no-vent heat sink.
36. Decontaminate EVA astronaut and airlock atmosphere (e.g. hydrazine, freon).	36. Provide airlock interface/volume to accommodate decontamination filter unit.
37. Connect EMU to SOC life support system while on EVA.	37. Provide LSS umbilicals and connectors (communication, H_2O, O_2, electrical power) on SOC in the vicinity of planned extravehicular work sites.

by use of maintainable hardware with a provision for in-flight spares. Maintenance of certain SOC equipment will require the use of EVA for the refurbishment of solar arrays, antennae, and radiators, and repair of orbital transfer vehicles or of the SOC vehicle itself. Also, contingency unpressurized IVA could be required to repair the interior of a depressurized SOC module. Therefore, SOC must include work system capability for conducting EVA and unpressurized IVA in support of maintenance operations.

Future SOC operation will involve use of EVA in the final assembly and installation in-orbit of satellite or SOC appendages such as antennae, radiators, instrumentation booms, and solar arrays. Cost savings and reliability advantage will be realized by avoiding the complexities of conventional self-deployment mechanisms designed to deploy under remote control the various appendage elements in-orbit. In-orbit final assembly can also take better advantage of shuttle payload capacity, which will tend to be volume rather than weight limited for the case of irregular shaped payloads. Also, the capability to assemble structures in-orbit from multiple shuttle payloads offers potential for orbiting large scale structures and satellite systems that would not otherwise be possible.

Large space construction projects will require EVA crews working full shifts at remote sites. Beam building facilities are currently under study, which when developed would be transported to orbit by Space Shuttle for fabrication in space of structural beams. SOC is presumed to be the logical construction center for such activity. EVA could be used for crew transfer to and from beam builder assembly facilities, visual inspection and surveillance of beam fabrication, and work assistance in assembly of beams to form final structures. EVA could prove particularly cost effective in performing tasks such as installing subsystems and sensors on structures, connecting electrical cables, and interconnecting beams where the infrequent occurrence of these activities would not justify the complexity and high cost of automated mechanisms.

It is projected that EVA will be required to support SOC satellite service operations. A SOC orbital satellite service capability would permit a variety of service tasks such as fluid system repair and subsystem diagnosis and checkout. Fluid system repairs are expected to involve leak detection, replacing seals within fittings, pump replacement, and repair of tubing sections where future satellites would be expected to include valves for isolating fluids during normal service. With relatively simple but specialized EVA service tools other important service tasks could be performed. EVA could be essential in activities such as defueling satellites and removing structural debris from a damaged satellite prior to transport to a SOC berthing platform for repair.

EVA may become important in handling what otherwise could become a significant future problem in space, namely, space debris. An EVA crewmember could utilize MMU for free-flying contingency retrieval of small debris. A debris basket, mounted to the mini-work-debris. A debris basket, mounted to the mini-work-system could be used to stow pieces of debris gathered by hand, generated inadvertently in SOC operations. It could become important to avoid generating space debris in SOC operations, since such debris would represent a hazard to Shuttle logistics resupply flights.

The space suits, backpacks, emergency escape systems, maneuvering unit airlock equipment except for the airlock pumping system are the Shuttle orbiter program designs. The orbiter program design are satisfactory for initial SOC activities. The numerous air lock operations expected of SOC made incorporation of an airlock pump necessary to save the airlock atmosphere. The design of this pump will be derived from commercial pump practice (or compressors) which have similar flow and pressure rise characteristics.

4.0 Mass

Refer to WBS 1.2.1.1.13 mass statement.

WBS 1.2.1.1.14 INSULATION, LININGS, AND PARTITIONS

1.0 WBS Dictionary

This element includes the interior cabin wall thermal insulation and interior wall linings and partitions.

2.0 Description

Provisions for 2 inches of insulation have been allowed in the HM configuration drawings (Figures A thru D WBS 1.2.1)

In concept, the interior walls will be composed of decorative linings similar to commercial aircraft interior linings.

3.0 Design Basis

There has been no analysis of these requirements during this study.

4.0 Mass

See WBS 1.2.1 mass statement.

WBS 1.2.1.2 HABITAT MODULE NO. 2

1.0 WBS Dictionary

This element includes the second Habitat Module to be installed on the SOC. It provides one of the primary living and working areas for the crew.

2.0 Description

This HM is virtually identical to HM1 (see WBS 1.2.1.1). The differences are cited in Section 2.0 of WBS 1.2.1.1.

The HM2 Observatory end is berthed to Service Module No. 2 (WBS 1.2.2.2) and the Command Center end is berthed to the Docking Tunnel (WBS 1.2.2.3).

3.0 Design Basis

Refer to WBS 1.2.1, Section 3.0.

The Command Center end is berthed to the Docking Tunnel so that a control center overlooks the exterior operational areas on this end of the SOC.

4.0 Mass

Refer to WBS 1.2.1, Section 4.0.

WBS 1.2.1.3 MINI-HABITAT MODULE

A

1.0 WBS Dictionary

This element is a small crew quarters module.

2.0 Description

The Mini-HM is illustrated in Figure A. It provides sleeping quarters for 4 people. Some additional storage volume is provided. This module has the same body diameter, debris shield/radiator, berthing ports, ventilation and thermal control unit, ARS fan, catalytic oxidizer, CO_2 removal unit, dehumidifier, and odor control unit as used in HM-1 and HM-2. The interior furnishings of the sleeping quarters are also identical to those located in HM-1 and HM-2.

This module berths to the Docking Tunnel (WBS 1.2.2.3) and has an Airlock Module No. 2 (WBS 1.2.2.4.2) attached to the opposite berthing port.

3.0 Design Basis

This module was created to provide additional sleeping quarters when the full-time SOC crew size ranges from 9 to 12 people.

The mission analysis and crew operations analysis in Boeing -33 shows that there will be requirements for this range of crew size. When the crew size required exceeds 12 people, it is probably time to add a second SOC to service the mission requirements.

This module does not provide other ECLS provisions, e.g., water supply, waste management, food service, etc. as the HM-1 and HM-2 systems are adequately sized to handle up to 8 people each.

The Mini-HM is berthed to the DT as this is the only available location. It must be located on one of the berthing ports opposite where the HM's are berthed in order that the Airlock Module/Portable IVA Tunnel (WBS 1.2.2.4.2/1.2.2.4.3) is properly

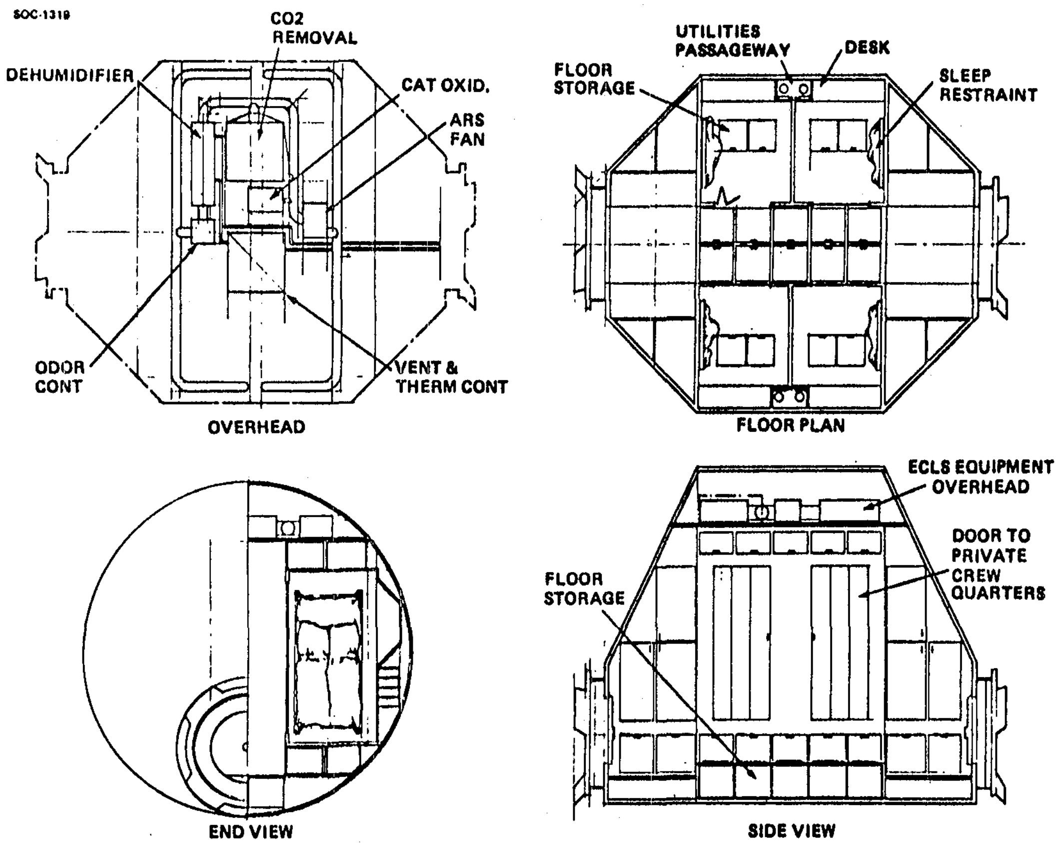


Figure A. Mini-Habitat Module

located for interfacing with the MOTV crew module. The Airlock Module also provides the required second egress path from the Mini-HM.

4.0 Mass

WBS 1.2.2 SERVICE MODULES

1.0 WBS Dictionary

This element includes Service Modules No. 1 and No. 2, the Docking Tunnel, and the Airlock Modules.

2.0 Description

These elements are all pressurizable work areas (the SM1, SM2, and DT are normally pressurized). The SM1, SM2, and DT provide IVA pathways between the two Habitat Modules. Refer to WBS 1.2.2.1 and 1.2.2.2 for more detailed descriptions.

3.0 Design Basis

Refer to Section 3.0 in WBS 1.2.2.1, 1.2.2.2, 1.2.2.3, and 1.2.2.4.

4.0 Mass

The mass estimates for these elements are summarized in Table A.

TABLE A

WBS 1.2.2 SERVICE MODULES
MASS SUMMARY

WBS 1.2.2.1	Service Module No. 1	21798 kg
WBS 1.2.2.2	Service Module No. 2	21409 kg
WBS 1.2.2.3	Docking Tunnel	7950 kg
WBS 1.2.2.4	Airlock Module	545 kg each

WBS 1.2.2.1 SERVICE MODULE NO. 1

1.0 WBS Dictionary

This element includes the first Service Module to be installed in the SOC.

2.0 Description

The Service Module No. 1 (SM1) is shown in its stowed-for-shipping configuration in Figure A. It's deployed configuration is shown in Figures B. The interior arrangement is shown in Figure C. (Alternative SM1 configuration concepts, have been investigated and are reported in Boeing-20.)

This module is the first SOC module delivered to orbit. It's deployment sequence is shown in Section II.

The auxiliary RCS boom is only used until the SM2 is installed. This boom is then removed and is either stowed on-board as a spare or it is returned to Earth.

This module provides one of the primary Orbiter docking locations on the SOC. There are 7 berthing ports that are used to berth this module to other SOC modules, general purpose support equipment, and mission hardware (e.g., spacecraft, teleoperator vehicles, experiment modules, etc.).

This module is provided with some EC/LSS and crew accommodations that are necessary to provide a habitable area for the 4-man crew for 14 days in an emergency mode where the HM1 had to be evacuated (this is a design requirement pertinent only to the Initial SOC Configuration).

3.0 Design Basis

The SM1 has been sized to fill the maximum shuttle cargo bay envelope. The boom diameters shown are design judgments only. The pressure shell diameter was derived after the boom folded configuration was defined and exterior tanks were sized.

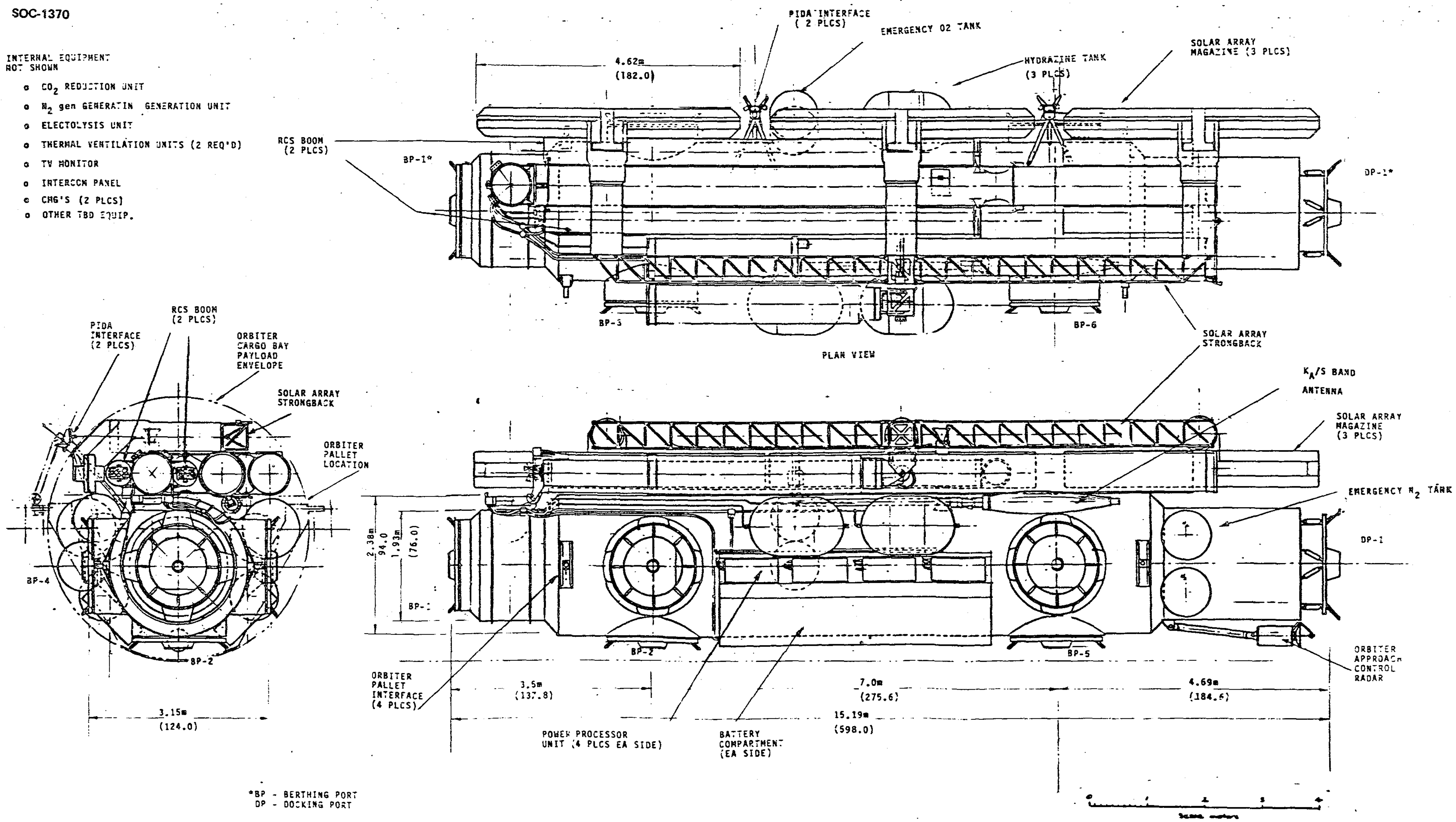
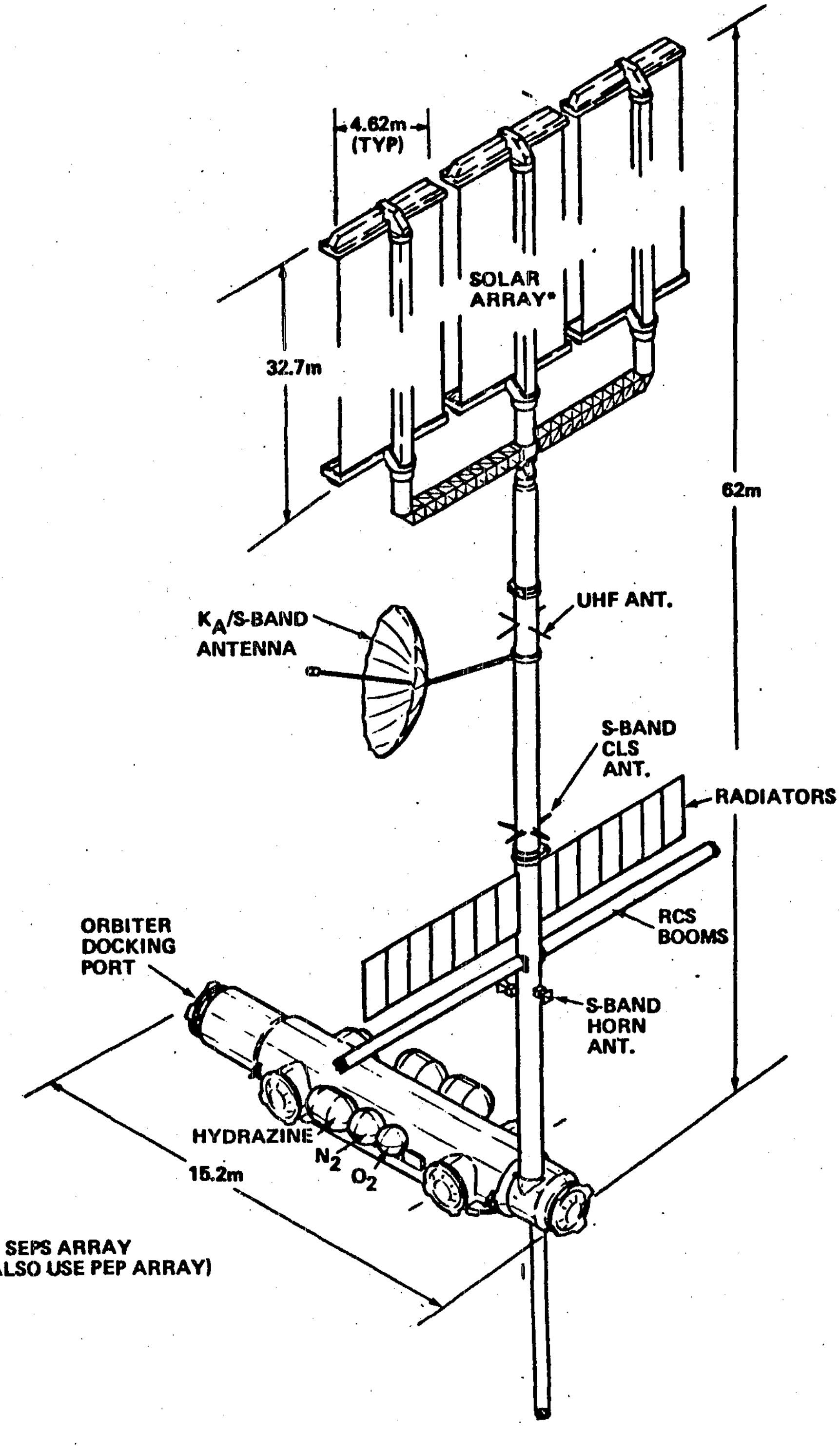


Figure A. Service Module (Packaged Configuration)

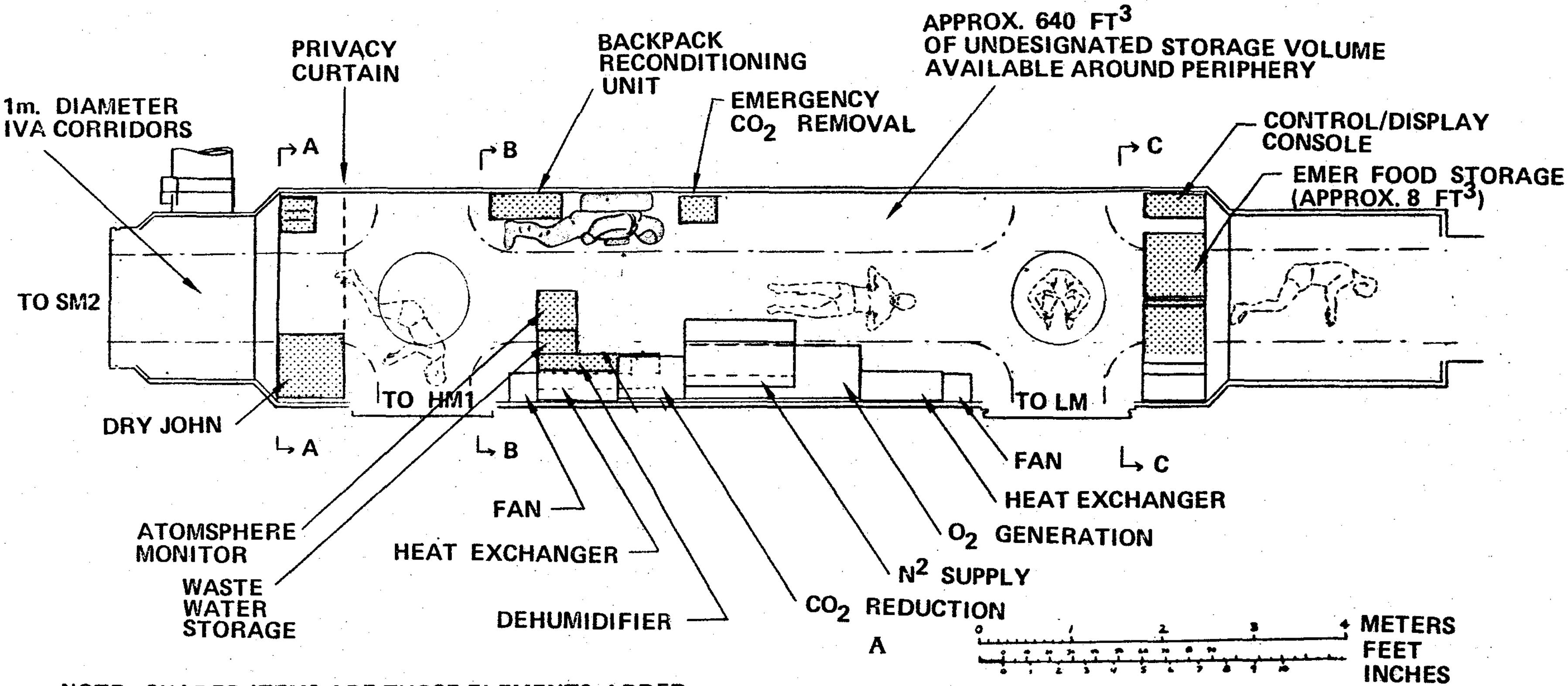
This Page Intentionally Left Blank

SOC-87B



*BASED ON SEPS ARRAY
(COULD ALSO USE PEP ARRAY)

Figure B. Service Module No. 1 Fully Deployed Configuration



A

NOTE: SHADED ITEMS ARE THOSE ELEMENTS ADDED TO MAKE THE SERVICE MODULE HABITABLE FOR A CREW OF 4 FOR ~~14~~ 21 DAYS IN AN EMERGENCY MODE

A

Figure D. Service Module Interior Arrangement for the Initial SOC Configuration

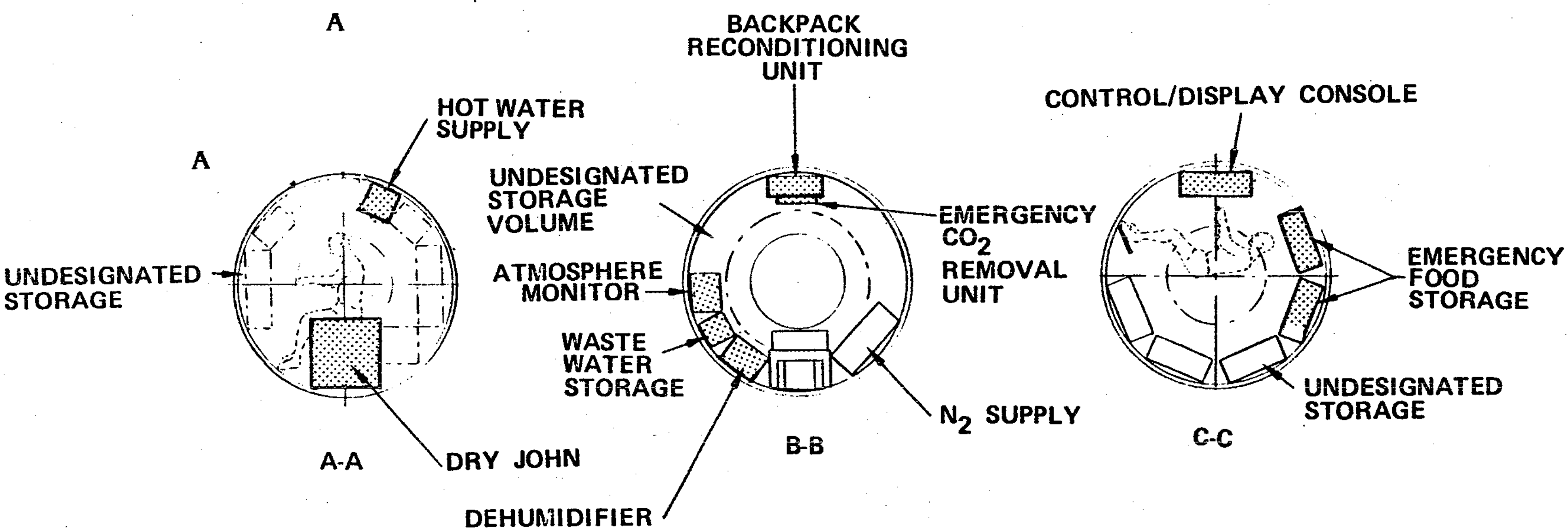


Figure D. (Cont'd) Service Module Interior Arrangement for the Initial SOC Configuration

The SM1 was configured to provide the attitude control, power generation, energy storage and communications necessary to fly it by itself and with the attached HM1 and Logistics Module in the Initial SOC Configuration.

4.0 Mass

The mass estimate for SM1 is given in Table A.

Table A — Service Module Mass Statement

INDEX #	INDENT #	WBS #	TITLE	MASS KG(LB)	OFFSETS,M(FT) X	Y	Z	RATIONALE FOR ESTIMATE
1	1	1.2.2.1	SERVICE MODULE	21798	6.9	0	.1	SUM
				(48058	21.9	0	.3)	
2	2	1.2.2.1.1	STRUCTURES	5483	6.7	0	0	SUM
				(12088	19.1	0	.2)	
3	3	1.2.2.1.1.1	PRESSURE MEMBRAN	3323	6.5	0	-.1	SUM
				(7326	16.3	0	-.2)	
4	4	1.2.2.1.1.1.1	LARGE CYLINDER	1882	5.9	0	0	- D=2.38M - L=10.3M - THICKNESS=1CM - 6 CUTOUTS 1.53M DIA - A CYL-A CUT = 66M2 - 2219 ALUMINUM - 1% FOR WELDS, WELD LANDS, AND TOLERANCES
				(4149	19.5	0	0)	
5	4	1.2.2.1.1.1.2	SMALL CYLINDERS	604	9.4	0	0	- D=1.93M - L FOR THE TWO CYL = 3.5 M - AREA = 21.2M2 TOTAL - ALLOY & ALLOWANCES PER ABOVE
				(1332	2.6	0	0)	
6	4	1.2.2.1.1.1.3	STUB CYLINDERS	55	7	0	0	- D=1.53M - L=0.2M - S=0.96M2 EACH - 2 CYL, ONE EACH END
				(121	22.9	0	0)	
7	4	1.2.2.1.1.1.4	LARGE CONE SEC	129	7	0	0	- DMAX=2.38M - DMIN=1.93M - H = 0.25M - AREA = 2.27M EACH CONE (2 TOTAL)
				(284	22.9	0	0)	

Table A – Service Module Mass Statement (Continued)

INDEX #	INDENT #	WBS #	TITLE	MASS KG(LB)	OFFSETS,M(FT) X	Y	Z	RATIONALE FOR ESTIMATE
8	4	1.2.2.1.1.1.5	SMALL CONE SEC	78	7	0	0	- DMAX=1.93M
				(172	22.9	0	0)	- DMIN=1.53M
								- H = 0.2M
								- AREA = 1.39M2 EACH CONE (2 TOTAL)
9	4	1.2.2.1.1.1.6	SHORT LATERAL EX	57	5.2	0	-1	- DOCKING/BERTHING PORT SUPPORT
				(126	17.2	0	-3.3)	- D=1.53M
								- L = 0.3M
								- AREA = 1.0M2 EACH
								- 2 TOTAL
10	4	1.2.2.1.1.1.7	LONG LATERAL EXT	278	5.2	0	0	- BERTHING PORT SUPPORTS
				(613	17.2	0	0)	- SIMILAR TO SHORT EXT
								- S=2.44M2 EACH
								- 6 TOTAL
11	4	1.2.2.1.1.1.8	PORT PARTIAL CLO	240	5.2	0	-.5	- DMAX=1.53M
				(529	17.2	0	-1.7)	- DMIN=1.0M
								- S=1.05M2
								- 8 TOTAL
12	3	1.2.2.1.1.2	RING FRAMES	50	7.5	0	0	- 8 IN LARGE CYL
				(110	24.6	0	0)	- 2 IN SMALL CYL
								- DEPTH=0.076M
								- X-SEC AREA=2.58CM2
								- 2219 ALUM

Table A — Service Module Mass Statement (Continued)

IN-DEX #	IN-DENT #	WBS #	TITLE	MASS KG(LB)	OFFSETS,M(FT) X	Y	Z	RATIONALE FOR ESTIMATE
13	3	1.2.2.1.1.3	MAIN SUP RINGS	52 (115	7.5 24.6	0 0	0 0)	- DEPTH=0.1M - X-SEC-AREA = 12.9 CM2 - 2219 ALUM
14	3	1.2.2.1.1.4	MAIN SUP TRUNION	45 (99	3 9.8	0 0	0 0)	- 2 SIDE FTGS - 1 KEEL FTG - FWD Y-Z LOADS & - TORSION TITANIUM
15	3	1.2.2.1.1.5	MAIN SUP TRUNION	91 (201	10 32.8	0 0	0 0)	- 2 SIDE FTGS - X LOADS & AFT Y-Z LOADS - TITANIUM
16	3	1.2.2.1.1.6	MAIN SUP SKIN DB	113 (249	10 32.8	0 0	0 0)	INSUFFICIENT SPACE TO LOCATE LONGERONS; MUST HEAVILY REINFORCE MEMBRANE IN REGION OF AFT SUPT TRUNNIONS
17	3	1.2.2.1.1.7	ENTRY HATCH & ME	454 (1001	7 22.9	0 0	0 0)	ORBITER AIRLOCK HATCH & MECHANISM
18	3	1.2.2.1.1.8	ENTRY HATCH FRAM	327 (721	7 22.9	0 0	0 0)	ESTIMATE
19	3	1.2.2.1.1.9	INTERNAL RAILS	45 (99	7 22.9	0 0	0 0)	ESTIMATE
20	3	1.2.2.1.1.10	EXTERNAL RAILS	91 (201	7 22.9	0 0	0 0)	ESTIMATE

Table A — Service Module Mass Statement (Continued)

IN-DEX #	IN-DENT #	WBS #	TITLE	MASS KG(LB)	OFFSETS, M(FT) X	Y	Z	RATIONALE FOR ESTIMATE
21	3	1.2.2.1.1.11	BATTERY COMPARTM	220	7	0	-1	- SURFACE AREA 11.3 M2
				(485	22.9	0	-3.3)	- COMPARTMENT UNIT MASS 9.76 KG/M2 (2 LB/FT2)
22	3	1.2.2.1.1.12	TANKAGE SUPPORT	91	7	0	0	ESTIMATE
				(201	22.9	0	0)	
23	3	1.2.2.1.1.13	ARRAY BOOM	224	7	0	2	- LENGTH 26M
				(494	22.9	0	6.5)	- DIAM 0.66M - TBAR 0.125 CM - GRAPHITE EPOXY @ 1660 KG/M2 - BASIC MASS 4.3 KG/M2 - 100% FACTOR FOR HINGE JOINTS & MECHANISMS
24	3	1.2.2.1.1.14	ARRAY STRONGBACK	43	7	0	0	- LENGTH 10.8M
				(95	22.9	0	0)	- BASIC MASS 2 KG/M - 100% FACTOR FOR CANNISTER ATTACH POINTS
25	3	1.2.2.1.1.15	ARRAY SUPPORT	136	7	0	2	LAUNCH SUPPORT STRUCTURES AND RELEASE MECHANISMS - ESTIMATE
				(300	22.9	0	6.5)	
26	3	1.2.2.1.1.16	RCS BOOMS	65	5.9	0	2	- LENGTH 9M
				(143	19.3	0	6.5)	- DIAM 0.46M - TBAR 0.125M - GR-EP - BASIC MASS 3 KG/M - 20% FACTOR FOR BASE HINGE JOINT & MECHANISM

Table A — Service Module Mass Statement (Continued)

INDEX #	INDENT #	WBS #	TITLE	MASS KG(LB)	OFFSETS, M(FT) X	Y	Z	RATIONALE FOR ESTIMATE
27	3	1.2.2.1.1.17	RCS BOOM SUPT	18	6	0	2	LAUNCH SUPPORT STRUCTURES AND RELEASE MECHANISM
				(40	19.6	0	6.5)	
28	3	1.2.2.1.1.18	EC/LSS DUCTING	27	7	0	0	ESTIMATE
				(60	22.9	0	0)	
29	3	1.2.2.1.1.19	MISC. SEC. STRUC	68	7	0	0	ESTIMATE
				(150	22.9	0	0)	
30	2	1.2.2.1.2	MECHANISMS	544	7	0	-.5	SUM
				(1199	22.9	0	-1.7)	
31	3	1.2.2.1.2.1	UNIV BERTH PORTS	544	7	0	-.5	ESTIMATED AS 60% OF DOCKING PORTS; 8 PORTS TOTAL
				(1199	22.9	0	-1.7)	
32	2	1.2.2.1.3	THERMAL CONTROL	1064	6.2	0	.7	SUM
				(2346	20.5	0	2.4)	
33	3	1.2.2.1.3.1	RADIATOR	390	5	0	2	- 16.245 KW HEAT LOAD - 20 DEG C MEAN TEMP - 3.72 M2/KW (2 SIDES) - 78 M2 @ 5 KG/M2 - 30% MARGIN
				(860	16.4	0	6.5)	
34	3	1.2.2.1.3.2	PLUMBING	31	7	0	0	- EQUIVALENT OF 52 M OF 2 CM DIA X 1 MM WALL CRES TUBING - 20% MARGIN FOR FITTINGS
				(68	22.9	0	0)	
35	3	1.2.2.1.3.3	FLUIDS	23	7	0	0	- FLUID FILL FOR PLUMBING - FREON @ 1458 KG/M3
				(51	22.9	0	0)	

Table A — Service Module Mass Statement (Continued)

IN-DEX #	IN-DENT #	WBS #	TITLE	MASS KG(LB)	OFFSETS,M(FT) X	Y	Z	RATIONALE FOR ESTIMATE
36	3	1.2.2.1.3.4	WATER-FREON HTX	14	7	0	0	ESTIMATE
				(31	22.9	0	0)	
37	3	1.2.2.1.3.5	HEAT PIPE HTX	25	7	0	0	ASSUMES USE OF CONSTRUCTABLE RADIATOR - THIS HTX FROM FREON LOOP TO RADIATOR HEAT PIPES
				(55	22.9	0	0)	
38	3	1.2.2.1.3.6	PUMP PACKS	35	7	0	0	BASED ON HAMILTON STANDARD ESTIMATE
				(77	22.9	0	0)	
39	3	1.2.2.1.3.7	COLD PLATES	477	7	0	0	BASED ON HAMILTON STANDARD ESTIMATES FOR COLD PLATES
				(1052	22.9	0	0)	
40	3	1.2.2.1.3.8	TANKS & PRESSURI	23	7	0	0	ESTIMATE
				(51	22.9	0	0)	
41	3	1.2.2.1.3.9	THERMAL COATINGS	23	7	0	0	ESTIMATE
				(51	22.9	0	0)	
42	3	1.2.2.1.3.10	MISC. ITEMS	23	7	0	0	ESTIMATE
				(51	22.9	0	0)	
43	2	1.2.2.1.4	PRIMARY PROPULSI	0	0	0	0	(NO PRIMARY PROPULSION)
				(0	0	0	0)	
44	2	1.2.2.1.5	AUX PROPULSION	638	7.8	0	.5	SUM
				(1407	25.7	0	1.9)	
45	3	1.2.2.1.4.1	TANKAGE	300	8.4	0	1	- TANKS AND PRESSURE BOTTLES - 50% MORE HYDRAZINE CAPACITY THAN 100-DAY DENSE ATMOSPHERE REQUIREMENT
				(661	27.7	0	3.2)	

Table A — Service Module Mass Statement (Continued)

IN-DEX #	IN-DENT #	WBS #	TITLE	MASS KG(LB)	OFFSETS,M(FT) X	Y	Z	RATIONALE FOR ESTIMATE
46	3	1.2.2.1.4.2	VALVES	45	7	0	0	30 VALVES @ 1.5 KG EACH
				(99	22.9	0	0)	
47	3	1.2.2.1.4.3	FILL & DRAIN	9	7	0	0	6 PORTS @ 1.5 KG EACH
				(20	22.9	0	0)	
48	3	1.2.2.1.4.4	UMBILICAL PLATES	10	7	0	0	2 PLATES @ 5 KG EACH
				(22	22.9	0	0)	
49	3	1.2.2.1.4.5	PORT INTERCONNEC	20	7	0	0	2 PORTS @ 10 KG
				(44	22.9	0	0)	
50	3	1.2.2.1.4.6	LINES	20	7	0	0	0.17 KG/METER X 40 M + 20% FOR INSTL AND 10% FOR FLEX LINES & FITTINGS
				(44	22.9	0	0)	
51	3	1.2.2.1.4.7	AC THRUSTERS	36	7	0	0	18 THRUSTERS @ 2 KG EACH
				(79	22.9	0	0)	
52	3	1.2.2.1.4.8	DEORBIT THRUSTER	80	7	0	0	4 THRUSTERS @ 20 KG EACH (THESE ARE 4000-N THRUSTERS)
				(176	22.9	0	0)	
53	3	1.2.2.1.4.9	INSTRUMENTATION	43	7	0	0	ESTIMATE
				(95	22.9	0	0)	
54	3	1.2.2.1.4.10	UNUSABLE PROPELL	75	8.4	0	1	5% OF CAPACITY
				(165	27.7	0	3.2)	
55	2	1.2.2.1.6	ORDNANCE	10	7	0	0	ESTIMATE FOR DEPLOYMENT RELEASES
				(22	22.9	0	0)	
56	2	1.2.2.1.7	ELECTRICAL POWER	3983	7	0	.2	SUM
				(8781	22.9	0	.7)	
57	3	1.2.2.1.7.1	SOLAR ARRAY	630	7	0	1.5	- SID SILVERMAN ESTIMATE - 65 KW RAW BOL POWER - SIZED FOR 25% DEGRADATION IN TEN YEARS
				(1389	22.9	0	4.9)	

Table A — Service Module Mass Statement (Continued)

IN-DEX #	IN-DENT #	WBS #	TITLE		MASS KG(LB)	OFFSETS,M(FT) X	Y	Z		RATIONALE FOR ESTIMATE
58	3	1.2.2.1.7.2	POWER CONDITIONI		234	7	0	0		SID SILVERMAN
				(	516	22.9	0	0	)	ESTIMATE
59	3	1.2.2.1.7.3	BATTERIES		1941	7	0	0		- SID SILVERMAN ESTIMATE
				(	4279	22.9	0	0	)	- NICKEL HYDROGEN
										- 50% REDUNDANCY
60	3	1.2.2.1.7.4	ARRAY MAIN CABLE		168	7	0	0		SID SILVERMAN
				(	370	22.9	0	0	)	ESTIMATE - SIZED FOR 1
										VOLT DROP
61	3	1.2.2.1.7.5	BUSSING		200	7	0	0		SID SILVERMAN
				(	441	22.9	0	0	)	ESTIMATE
62	3	1.2.2.1.7.6	HARNESSES & APSM		500	7	0	0		SID SILVERMAN
				(	1102	22.9	0	0	)	ESTIMATE
63	3	1.2.2.1.7.7	MISC. EQUIPMENT		200	7	0	0		SID SILVERMAN
				(	441	22.9	0	0	)	ESTIMATE FOR
										SWITCHING, BOXES,ETC.
64	3	1.2.2.1.7.8	INTERIOR LIGHTIN		60	7	0	0		SID SILVERMAN
				(	132	22.9	0	0	)	ESTIMATE
65	3	1.2.2.1.7.9	EMERGENCY BATTER		50	7	0	0		ESTIMATE PER HAB
				(	110	22.9	0	0	)	MODULE
66	2	1.2.2.1.8	GN & C		420	6.1	0	0		SUM
				(	926	20.1	0	0	)	
67	3	1.2.2.1.8.1	CMG'S		300	7	0	0		ALLOWANCE PENDING
				(	661	22.9	0	0	)	FINAL SIZING OF CMG'S

Table A — Service Module Mass Statement (Continued)

IN-DEX #	IN-DENT #	WBS #	TITLE	MASS KG(LB)	OFFSETS,M(FT) X	Y	Z	RATIONALE FOR ESTIMATE
68	3	1.2.2.1.8.2	COMPUTER AND SUP	120	4	0	0	SAME AS HAB MODULE
				(265	13.1	0	0)	
69	2	1.2.2.1.9	TRACKING & COMM	440	7.9	0	0	SUM
				(970	26	0	0)	
70	3	1.2.2.1.9.1	RF EQUIPMENT	357	8.2	0	0	SUM
				(787	27.1	0	0)	
71	4	1.2.2.1.9.1.1	KU AMPS	47	7	0	0	F. KIM ESTIMATE
				(104	22.9	0	0)	
72	4	1.2.2.1.9.1.2	S-BAND AMPS	110	7	0	0	F. KIM ESTIMATE
				(243	22.9	0	0)	
73	4	1.2.2.1.9.1.3	SURVEILL RADAR	65	14	0	0	F. KIM ESTIMATE
				(143	45.9	0	0)	
74	4	1.2.2.1.9.1.4	HI-GAIN ANTENNA	34	7	0	0	- 5.5 M DIAM
				(75	22.9	0	0)	- 1 KG/M2
								- 10 KG FOR FEED
75	4	1.2.2.1.9.1.5	MAST & DRIVE	20	7	0	0	ESTIMATE
				(44	22.9	0	0)	
76	4	1.2.2.1.9.1.6	CLS ANTENNAS	8	7	0	0	4 @ 2 KG EACH
				(18	22.9	0	0)	
77	4	1.2.2.1.9.1.7	L-BAND ANTENNA	4	7	0	0	ESTIMATE
				(9	22.9	0	0)	
78	4	1.2.2.1.9.1.8	UHF ANTENNA	9	7	0	0	ESTIMATE
				(20	22.9	0	0)	
79	4	1.2.2.1.9.1.9	HORNS & DRIVE	10	7	0	0	ESTIMATE
				(22	22.9	0	0)	
80	4	1.2.2.1.9.1.10	RF CABLING	50	7	0	0	ESTIMATE
				(110	22.9	0	0)	
81	3	1.2.2.1.9.2	INTRA-SOC COMM	25	7	0	0	SUM
				(55	22.9	0	0)	
82	4	1.2.2.1.9.2.1	VOICE TERMINALS	5	7	0	0	ESTIMATE
				(11	22.9	0	0)	

Table A — Service Module Mass Statement (Continued)

IN-DEX #	IN-DENT #	WBS #	TITLE	MASS KG(LB)	OFFSETS,M(FT) X	Y	Z	RATIONALE FOR ESTIMATE
83	4	1.2.2.1.9.2.2	C & W EQUIPMENT	20	7	0	0	ESTIMATE
				(44	22.9	0	0)	
84	3	1.2.2.1.9.3	COM & TRACK SUPP	58	6.3	0	0	SUM
				(128	20.7	0	0)	
85	4	1.2.2.1.9.3.1	TV CAMERAS	20	5	0	0	ESTIMATE
				(44	16.4	0	0)	
86	4	1.2.2.1.9.3.2	DIGITAL PROCESSO	23	7	0	0	ESTIMATE
				(51	22.9	0	0)	
87	4	1.2.2.1.9.3.3	AUDIO/DATA CABLE	15	7	0	0	ESTIMATE
				(33	22.9	0	0)	
88	2	1.2.2.1.10	DATA MGMT	175	9.4	0	0	SUM
				(386	30.9	0	0)	
89	3	1.2.2.1.10.1	DISPLAY & CON PA	25	12	0	0	20% OF HAB MODULE
				(55	39.3	0	0)	
90	3	1.2.2.1.10.2	CRT'S	40	12	0	0	2 @ 20 KG EACH
				(88	39.3	0	0)	
91	3	1.2.2.1.10.3	KB & DIG DISPL	20	12	0	0	ESTIMATE
				(44	39.3	0	0)	
92	3	1.2.2.1.10.4	REMOTE TERMINALS	40	7	0	0	2 @ 20 KG
				(88	22.9	0	0)	
93	3	1.2.2.1.10.5	WIRING & DATA BU	50	7	0	0	ESTIMATE
				(110	22.9	0	0)	
94	2	1.2.2.1.11	INSTRUMENTATION	100	7	0	0	COVERS
				(220	22.9	0	0)	INSTRUMENTATION NOT PART OF A SPECIFIC SUBSYSTEM
95	2	1.2.2.1.12	CREW ACCOMMODATI	0	0	0	0	(NONE IN SM)
				(0	0	0	0)	
96	2	1.2.2.1.13	EC/LSS	2158	6.3	0	0	SUM
				(4758	20.8	0	0)	

Table A — Service Module Mass Statement (Continued)

IN-DEX #	IN-DENT #	WBS #	TITLE	MASS KG(LB)	OFFSETS,M(FT) X	Y	Z	RATIONALE FOR ESTIMATE
97	3	1.2.2.1.13.1	NORMAL EQUIPMENT	1762	6.6	0	0	SUM
				(3885	21.8	0	0)	
98	4	1.2.2.1.13.1.1	THERMAL-VENT PAC	91	6	0	0	HAMILTON STANDARD
				(201	19.6	0	0)	ESTIMATE
99	4	1.2.2.1.13.1.2	FLUID LINES	10	7	0	0	ESTIMATE
				(22	22.9	0	0)	
100	4	1.2.2.1.13.1.3	EMERG. O2	120	6	0	0	HAM STANDARD ESTIMATE
				(265	19.6	0	0)	
101	4	1.2.2.1.13.1.4	TANK	102	5.9	0	0	ESTIMATE
				(225	19.3	0	0)	
102	4	1.2.2.1.13.1.5	EMERG. N2	185	7	0	0	ONE REPRESS - HAM
				(408	22.9	0	0)	STANDARD ESTIMATE
103	4	1.2.2.1.13.1.6	TANKS	954	7	0	0	ESTIMATE
				(2103	22.9	0	0)	
104	4	1.2.2.1.13.1.7	ELECTROLYSIS PAC	178	6	0	0	HAMILTON STANDARD
				(392	19.6	0	0)	ESTIMATE
105	4	1.2.2.1.13.1.8	CO2 REDUCTION	49	6	0	0	SAME
				(108	19.6	0	0)	
106	4	1.2.2.1.13.1.9	N2 GENERATION	73	6	0	0	SAME
				(161	19.6	0	0)	
107	3	1.2.2.1.13.2	EMERGENCY EQUIPM	396	5	0	0	SUM
				(873	16.4	0	0)	
108	4	1.2.2.1.13.2.1	DEHUMIDIFIER	39	4	0	0	HAM STANDARD ESTIMATE
				(86	13.1	0	0)	
109	4	1.2.2.1.13.2.2	WASTE WATER TANK	23	4	0	0	SAME
				(51	13.1	0	0)	
110	4	1.2.2.1.13.2.3	ATMOS MONITOR	23	4	0	0	SAME
				(51	13.1	0	0)	

Table A — Service Module Mass Statement (Continued)

IN-DEX #	IN-DENT #	WBS #	TITLE	MASS KG(LB)	OFFSETS,M(FT) X	Y	Z	RATIONALE FOR ESTIMATE
111	4	1.2.2.1.13.2.4	HOT WATER SUPPLY	14	4	0	0	SAME
				(31	13.1	0	0)	
112	4	1.2.2.1.13.2.5	WATER PUMP	15	4	0	0	SAME
				(33	13.1	0	0)	
113	4	1.2.2.1.13.2.6	DRY JOHN	41	2	0	0	SAME
				(90	6.5	0	0)	
114	4	1.2.2.1.13.2.7	BACKPACK RECOND	27	4	0	0	SAME
				(60	13.1	0	0)	
115	4	1.2.2.1.13.2.8	EMERG CO2 REMOVA	23	6	0	0	SAME
				(51	19.6	0	0)	
116	4	1.2.2.1.13.2.9	STORAGE CABINETS	100	7.5	0	0	SAME
				(220	24.6	0	0)	
117	4	1.2.2.1.13.2.10	EVA SUIT	91	5	0	0	SAME
				(201	16.4	0	0)	
118	2	1.2.2.1.17	MISSION EQUIPMEN	2900	7.2	0	0	SUM
				(6394	23.9	0	0)	
119	3	1.2.2.1.17.1	ACS PROPELLANT	1500	8.4	0	0	- 100-DAY SUPPLY
				(3307	27.7	0	0)	- WORST-CASE DENSE ATMOSPHERE - 370 KM ALTITUDE - 50% MARGIN
120	3	1.2.2.1.17.2	ATMOSPHERE	136	7	0	0	DENSITY X VOLUME
				(300	22.9	0	0)	
121	3	1.2.2.1.17.3	SPARES	644	7.5	0	0	ROUGHLY 15% OF
				(1420	24.6	0	0)	SUBSYSTEMS AND EQUIPMENT MASS
122	3	1.2.2.1.17.4	FOOD	200	3	0	0	EMERGENCY SUPPLY
				(441	9.8	0	0)	
123	3	1.2.2.1.17.5	LIOH CARTRIDGES	185	7.5	0	0	EMERGENCY SUPPLY
				(408	24.6	0	0)	

Table A — Service Module Mass Statement (Continued)

IN= DEX #	IN= DENT #	WBS #	TITLE	MASS KG(LB)	OFFSETS,M(FT) X	Y	Z	RATIONALE FOR ESTIMATE
124	3	1.2.2.1.17.6	UTENSILS & TOOLS	235	3	0	0	ESTIMATE
				(518	9.8	0	0)	
125	2	1.2.2.1.18	GROWTH	3883	6.9	0	0	33% OF IDENTIFIED MASS EXCLUSIVE OF PRESSURE MEMBRANE AND CONSUMABLES
				(8560	22.6	0	0)	

WBS 1.2.2.1.1 STRUCTURES

1.0 WBS Dictionary

This element includes the pressure vessel structure, interior structures, the solar array boom and the RCS booms. The solar array deployable structure is included in WBS 1.2.2.1.2. The Ka/S-band antenna structure is included in WBS 1.2.2.1.9. The radiation structure is included in WBS 1.2.2.1.3.

2.0 Description

The SM pressure vessel concept was shown in Figure A of WBS 1.2.2.1. It is conceptually a 1 cm thick aluminum structure. A structural detail drawing has not been done. Manufacturing splices have not been identified.

Interior secondary structures have not been defined.

The solar array boom and RCS booms are shown in Figure A. They are conceptually defined to be made from graphite composite materials.

3.0 Design Basis

A structural design analysis has not been performed during this study. A structural dynamics analysis was performed (see Boeing -20, Section 12.0, for complete details).

The pressure vessel wall thickness was arbitrarily defined to be the same as the HM cabin wall (see WBS 1.2.1.1).

The solar array and RCS boom diameters were sized by engineering judgment. The overall length of the boom was taken from the NASA-JSC reference configuration (NASA-3). The length of the boom segments were defined by packaging constraints. They were sized to be the maximum length possible given the packaging constraints.

4.0 Mass

See WBS 1.2.2.1 mass statement.

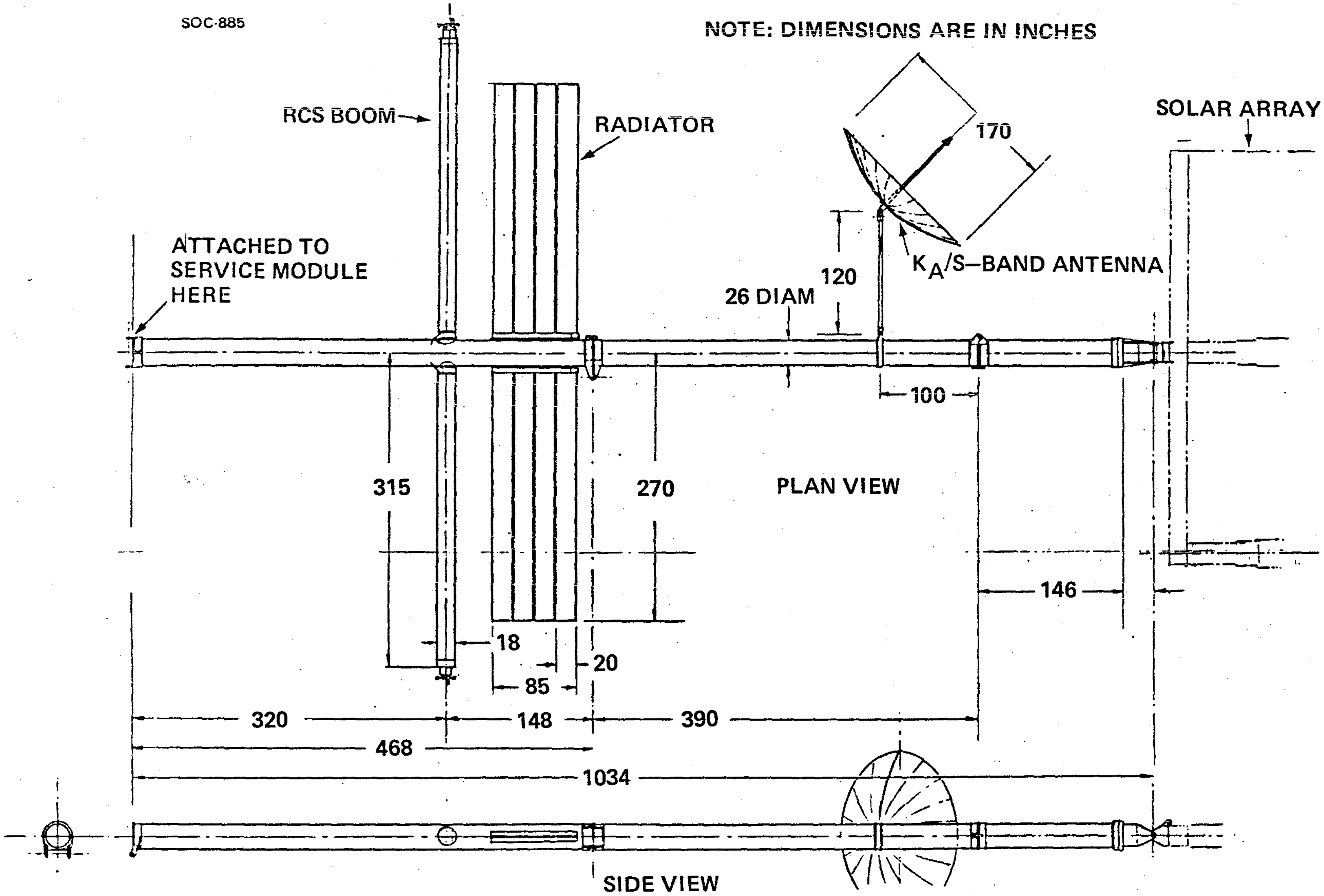


Figure A Solar Array Boom Configuration

WBS 1.2.2.1.2 MECHANISMS

1.0 WBS Dictionary

This element includes the berthing ports, docking port, solar array boom and appendages deployment mechanisms, solar array deployment mechanisms/structure, and umbilical connection actuators.

2.0 Description

Docking Ports - The docking ports concept is shown in Figures A and B (from Rockwell-9). The docking fixture was designed so that the utility interfaces could be maintained from inside as shown in Figure C. The hatch and its latching mechanisms have not been defined. They will probably be similar to the Orbiter airlock hatch hardware.

Berthing Ports - There are 7 berthing ports on the SM. Refer to WBS 1.2.1.1.2 for details.

Boom Deployment Mechanisms - The solar array and RCS boom deployment hinges and actuators are conceptually depicted in Figure A of WBS 1.2.2.1.1. These actuators would be remotely controlled.

Solar Array Deployment Mechanism/Structure - This system concept was depicted in Figure A of WBS 1.2.2.1.1. This deployment is remotely controlled.

Umbilical Connection Acturators - Refer to WBS 1.2.1.1.2.

3.0 Design Basis

The docking port design concept was defined by Rockwell (see Rockwell-3 and -9). The design drivers were Shuttle docking misalignment allowances, multiple docking clock angles, impact energy attenuation, maintainability, and the number of utility interfaces.

SOC-873

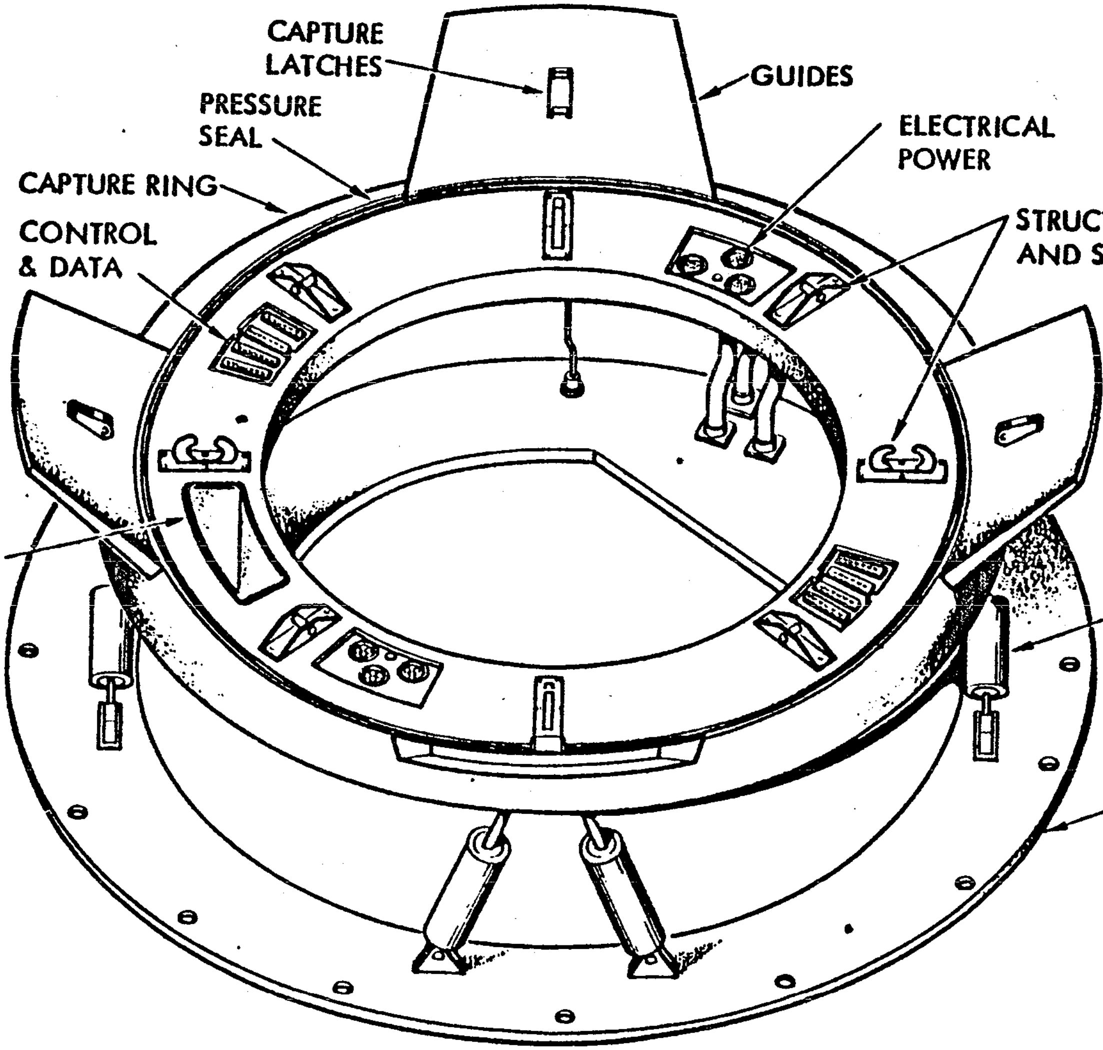


Figure A. Docking Port Concept

SOC-877

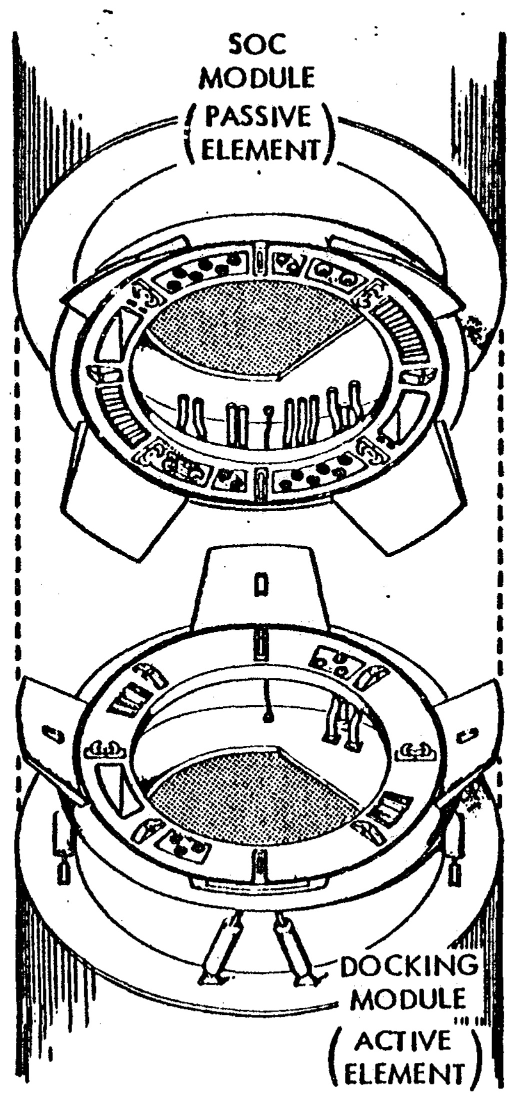


Figure B. Docking Port-to-Berthing Port Mating Concept

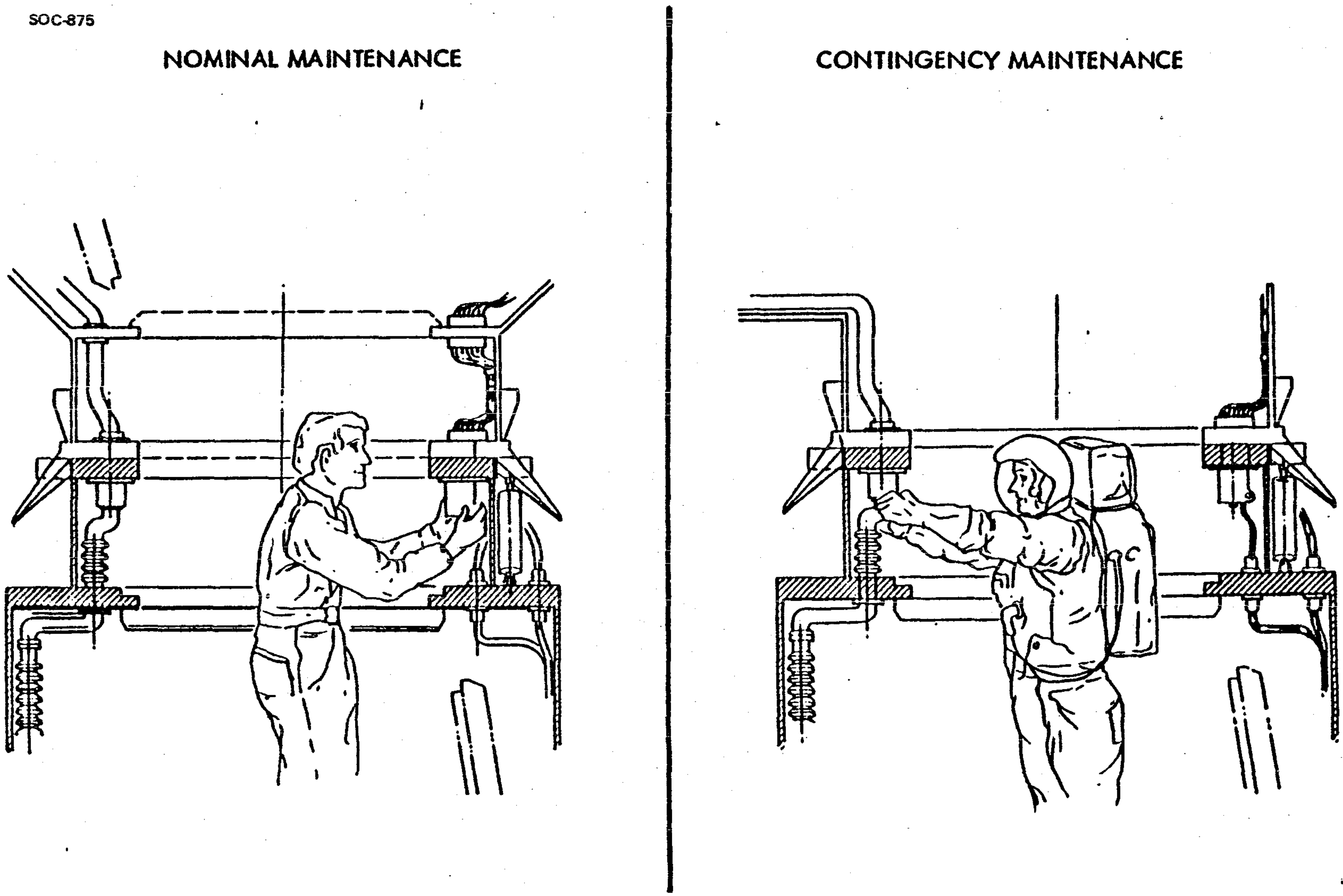


Figure C. Berthing and Docking Port Maintenance Concept

The berthing port design concept was also defined by Rockwell (see the above references).

The boom deployment mechanisms were based on engineering judgements.

The solar array deployment mechanism/structure were based on concepts created for the SEPS solar array deployment.

The umbilical connection actuator concepts basis was described in WBS 1.2.1.1.2.

4.0 Mass

See WBS 1.2.2.1 mass statement.

WBS 1.2.2.1.3 THERMAL CONTROL

1.0 WBS Dictionary

This element includes the deployable radiator, the coolant lines, pumps, and cold plates used for thermal control of the interior and exterior avionics. The cabin air thermal control provisions are included in WBS 1.2.2.1.13.

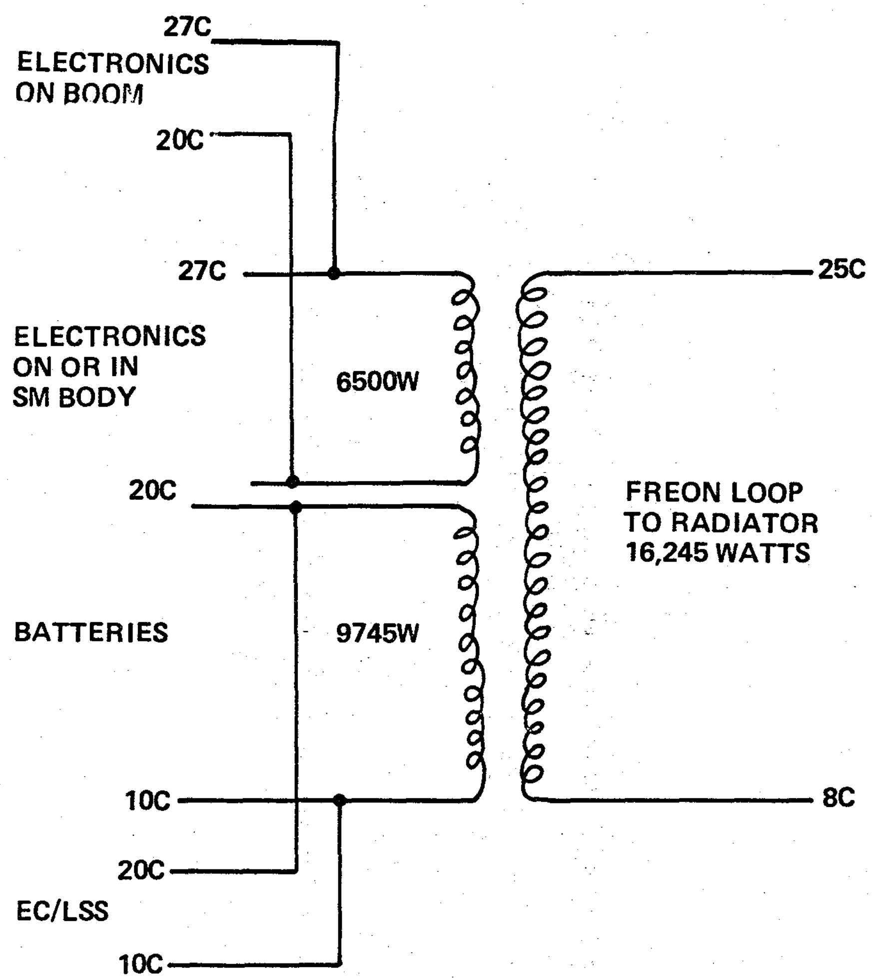
2.0 Description

The service module thermal control system handles the environmental control thermal loads from the service module as well as thermal control of the electrical power system, batteries, and power electronics and the RF power amplifier equipment in the service module. This thermal control system includes four cooling loops—a battery loop, a power electronics loop, RF amplifier loop, and environmental control loop. The battery and environmental control loops share the lower temperature range of the radiator while the others share the higher temperature range. External equipment installed on the service module precludes the use of a radiator like that employed for the habitat module. Consequently the service module utilizes a constructable radiator concept under development at JSC. This radiator concept employs a heat exchanger plug-in area in the service module booms to which heat pipe radiator panels are plugged in after the booms are deployed on orbit. The panels can be replaced in the event of damage or thermal control coating degradation. The radiator panels employ a white paint type selective thermal control coating.

Figure A lists the elements that will require thermal control and their estimated heat rejection requirements. Figure B shows the radiator performance characteristics. A

3.0 Design Basis

The Service Module thermal control system employs a plate-type radiator rather than a radiator integral with the service module external structure. The installation of equipment and structure on the service module is such that little room exists for a wrap-around thermal radiator. The thermal loads on the service



EC/LSS	2245W
METABOLIC	600
EMU RECHARGE	60
WASTE COLLECT	25
HUMIDITY CONTROL	560
AIR-COOLED ELEX	1000
ELECTRONICS ON OR IN SM BODY	6000W
ELECTRONICS ON BOOM	500W
BATTERIES	7500W

Figure A. Service Module Thermal Loads

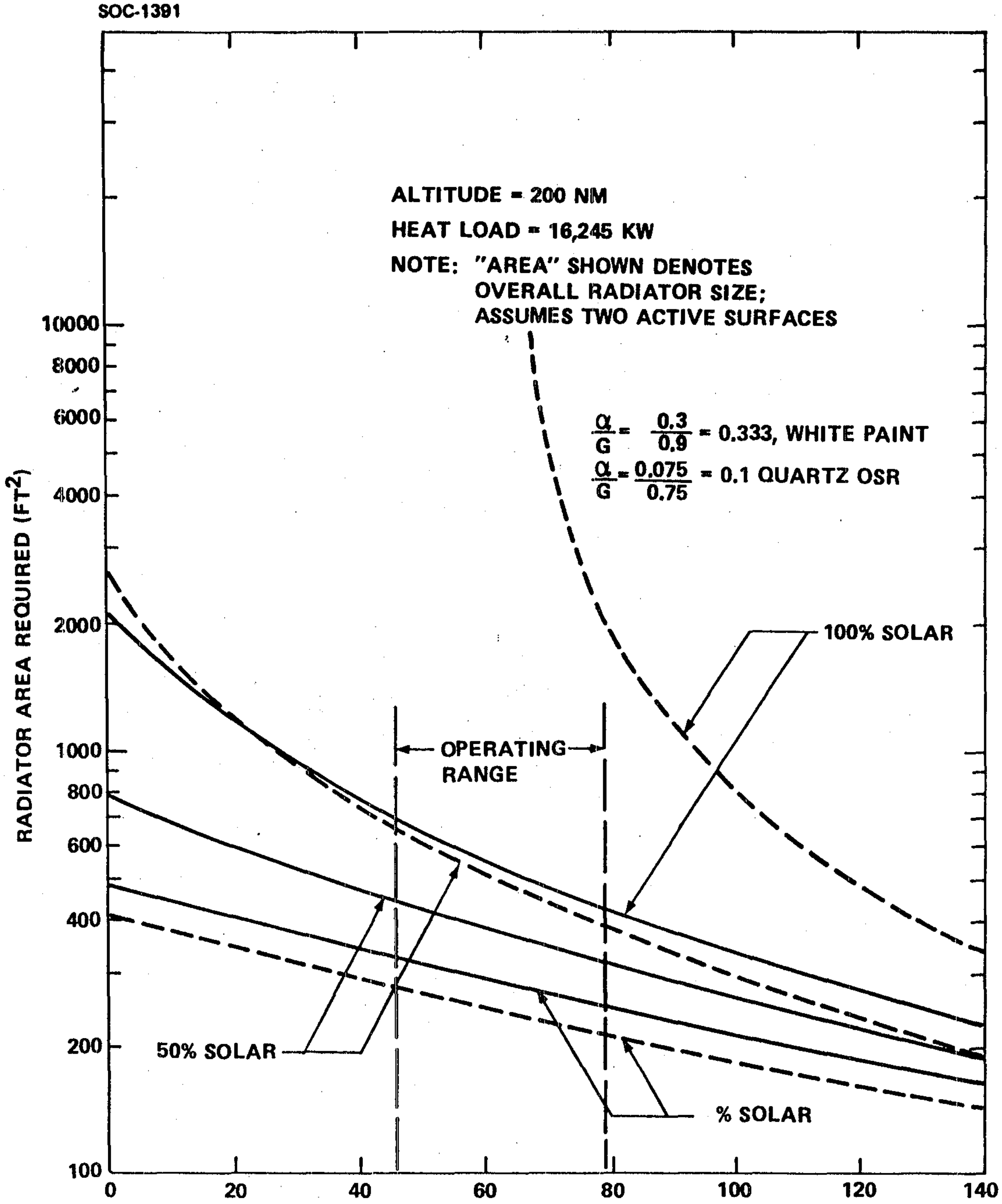


Figure B. SOC Service Module Radiator Performance module are much greater than those that could be handled by an external shell integral radiator.

The reason for selection of a selective coating radiator is the same as that for the habitat module. The same rationale also applies to the use of a water Freon dual loop with a heat exchanger.

Options reviewed for the plate-type radiator included the constructable radiator under technology development for JSC by Grumman, and a deployable radiator concept developed by JSC for earlier programs. Either radiator approach will work for the SOC service module system. The constructable radiator concept offers the significant advantage of relatively straightforward replacement or repair in the event of damage or thermal control degradation. It is a higher risk approach, but technology programs now in being should remove the element of risk prior to any final design commitment.

4.0 Mass

See WBS 1.2.2.1 mass statement.

WBS 1.2.2.1.4 PRIMARY PROPULSION

(There is no primary propulsion on the SOC)

WBS 1.2.2.1.5 ATTITUDE CONTROL PROPULSION

1.0 WBS Dictionary

This element includes the RCS thrusters, propellant delivery lines, propellant storage, and attitude control avionics located on the Service Module. The auxiliary RCS boom is also included. The applicable controls and displays are included in WBS 1.2.1.1.10.

2.0 Description

The SOC attitude control propulsion system installed on the service modules provides attitude control as well as orbit makeup. The attitude control thrusters are mounted on booms as illustrated in Figure B of WBS 1.2.2.1. This provides a sufficient moment arm to always encompass the station center of gravity so that orbit makeup propulsion can be used for attitude control. The propellant for the system is hydrazine stored in blow down type tanks on the service module. Thrusters, see Figure A, for normal attitude control are rated at 130 newtons (30 lbs.) thrust at maximum blow down pressure and will deliver about 60 newtons (14 lbs.) at the minimum blow down pressure.

An option to be evaluated would add a set of 10 to 20 newton thrusters with resistance heater augmentation. These low level thrusters would provide normal attitude control and orbit makeup. The resistance heat augmentation would use excess power from the solar array; thrust timing would be selected during periods of blow power usage. This approach would allow most of the propellant used by the station to deliver a specific impulse of about 300 seconds as compared to approximately 230 seconds without the resistive augmentation. A schematic of the propulsion system is shown in Figure B. This schematic includes control valves and the necessary isolation valves for prohibiting leakage while the system is in the shuttle field of bay for launch.

3.0 Design Basis

The hydrazine attitude control propulsion system was selected on the basis of minimum risk and adequate performance. The particular system configuration

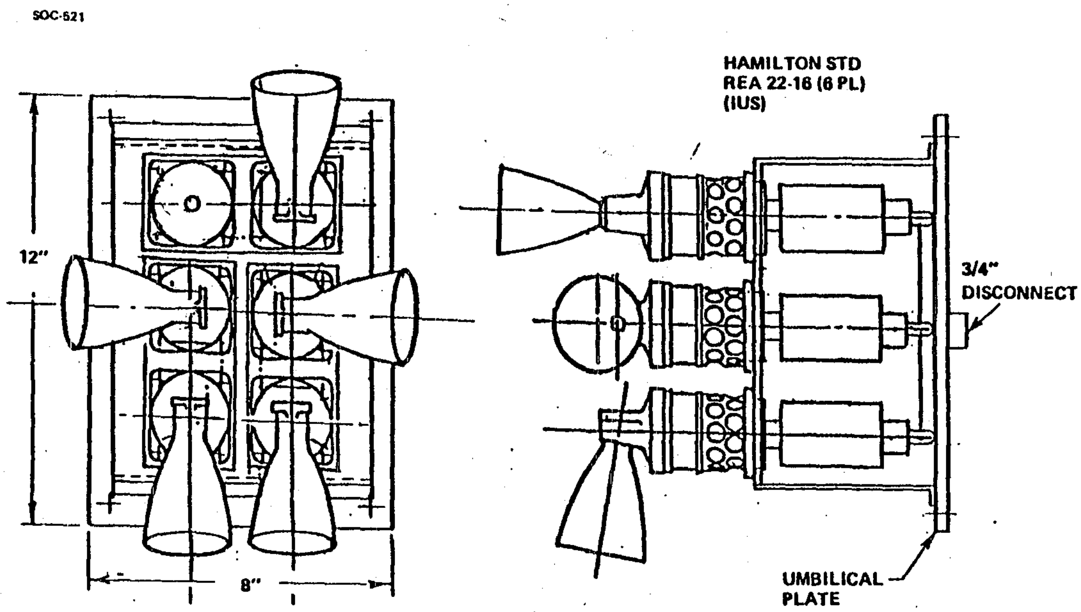


Figure A. SOC Propulsion—Removable RCM Module

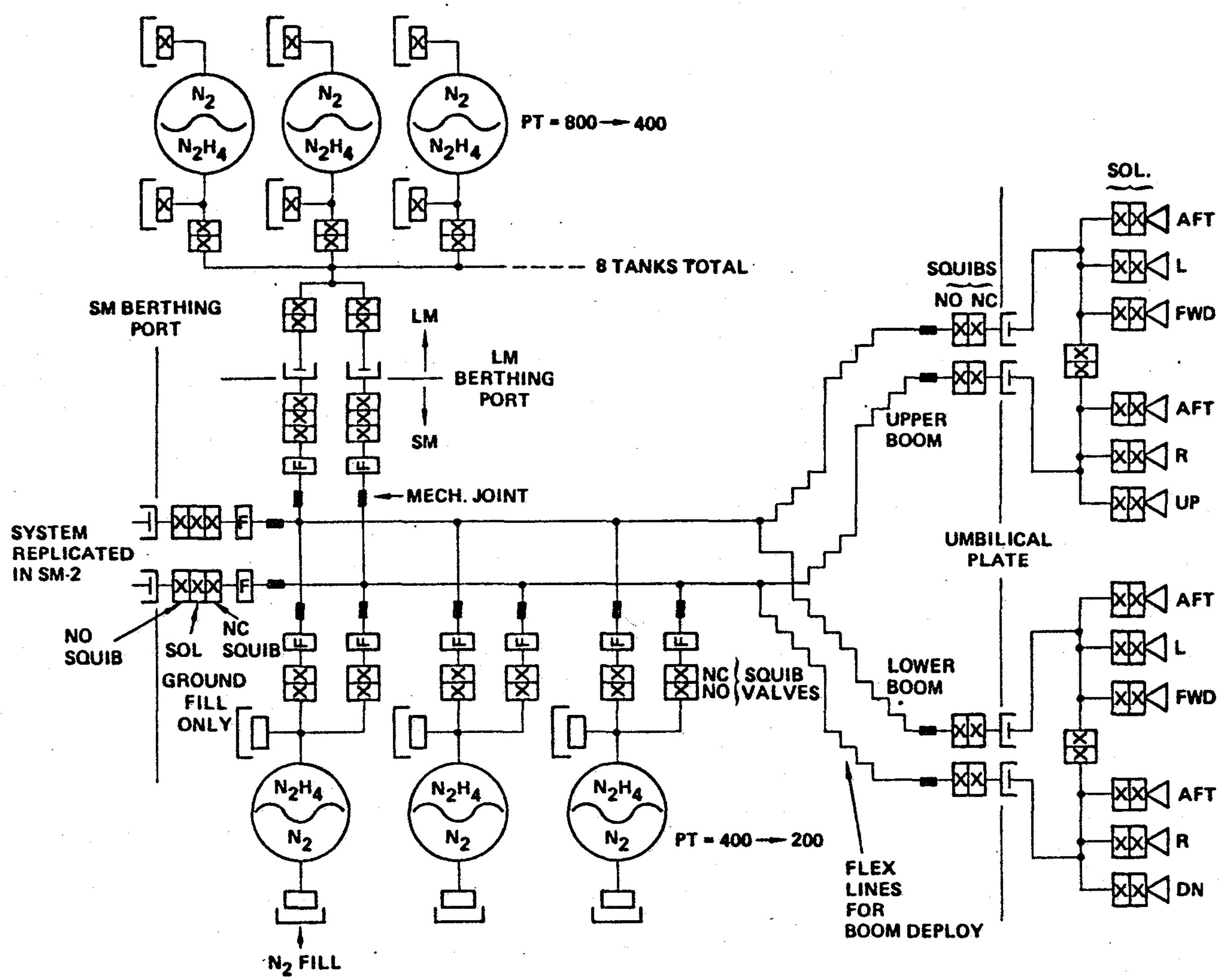


Figure B. SOC Propulsion System Schematic provides sufficient thruster moment arms around the SOC center of gravity so that orbit make-up propulsion can normally also serve the function of attitude control, thus minimizing propellant consumption.

4.0 Mass

Refer to WBS 1.2.2.1 mass statement.

WBS 1.2.2.1.6 ORDNANCE

1.0 WBS Dictionary

This element includes explosive actuated valves and actuators.

2.0 Description

The propellant delivery system will have squib valves. Other explosive actuated devices have not been specifically identified during this study.

WBS 1.2.2.1.7 ELECTRICAL POWER

1.0 WBS Dictionary

This element includes the solar array, power processors, power busses, and electrical power control avionics located on the Service Module. The electrical power system controls and displays are included in WBS 1.2.1.1.10.

2.0 Description

Figure A illustrates a high-level schematic for the SOC electric power system. Power is generated by the solar arrays (see Figure B) at 200 volts and conducted to power conditioning equipment in the service module. The path length is about 30 meters (100 feet). Conditioned power at 28 VDC and 400 HZ AC is provided to busses for distribution to loads. In addition, array power is conditioned and used to recharge nickel-hydrogen batteries. During occulted periods, the batteries provide power to the power conditioners.

The automated power system management system provide reconditioning, fault detection and isolation, load management, battery management, and trend data formatting. The crew will not normally be required to devote attention to power management, but will be able to intervene in power system operation as necessary to manage emergency situations.

The principal design parameters employed in creating the preliminary design of the SOC electric power system are tabulated in Table A. Figure C shows the operational SOC electrical power availability as a function of time. A

It is feasible to get higher levels of power over short periods of time (½ hour or less) under the following conditions: A

A. The batteries can provide some power output to supplement the solar array power output if battery recharge can be accomplished over several orbits. Figures D and E show that high level experiment loads can be accommodated for the load on the battery or on the array within the first 3-4 years for the reference array or the improved array.

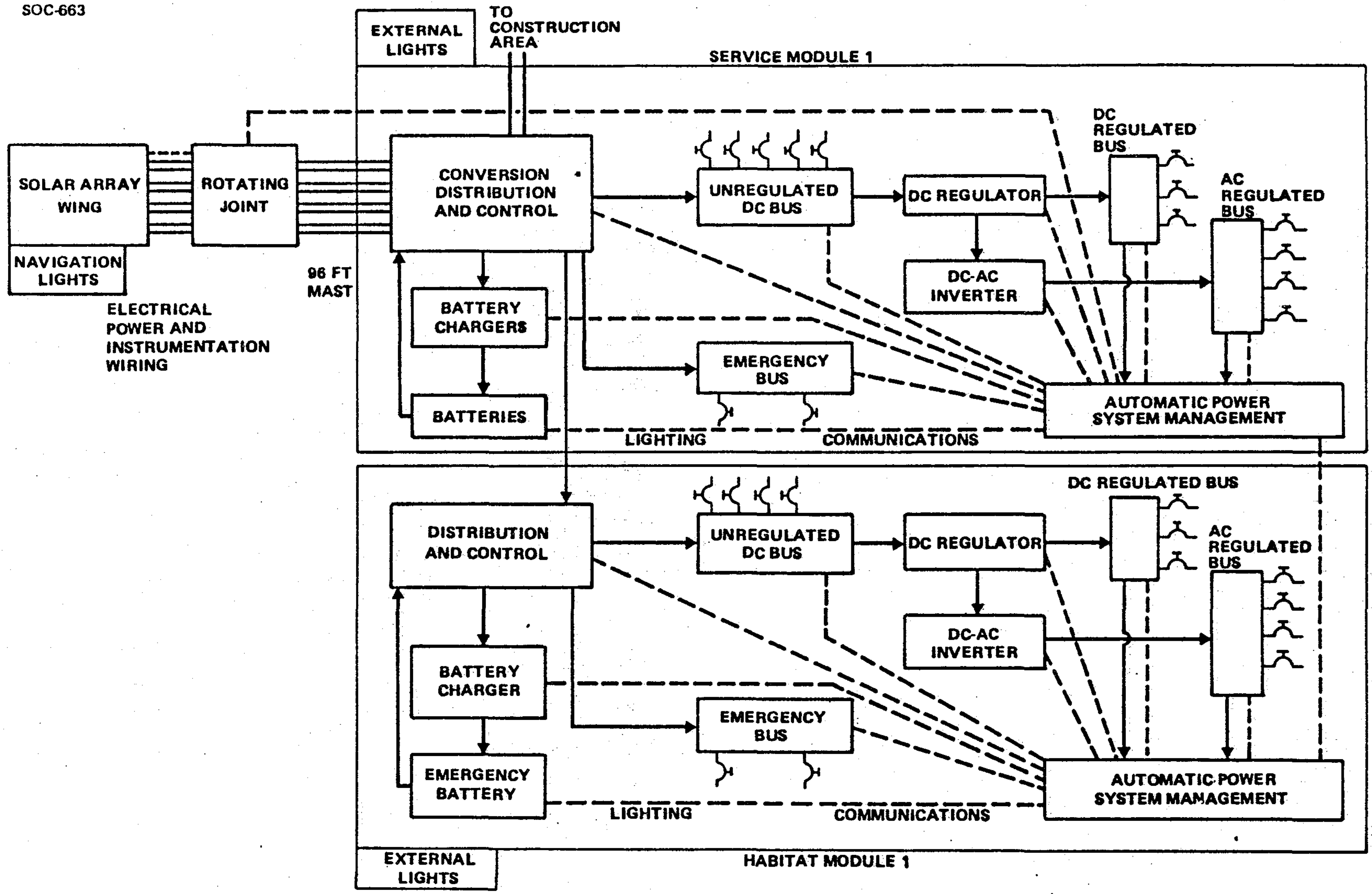


Figure A. Electrical Power System Schematic (Shown for 1/2 SOC)

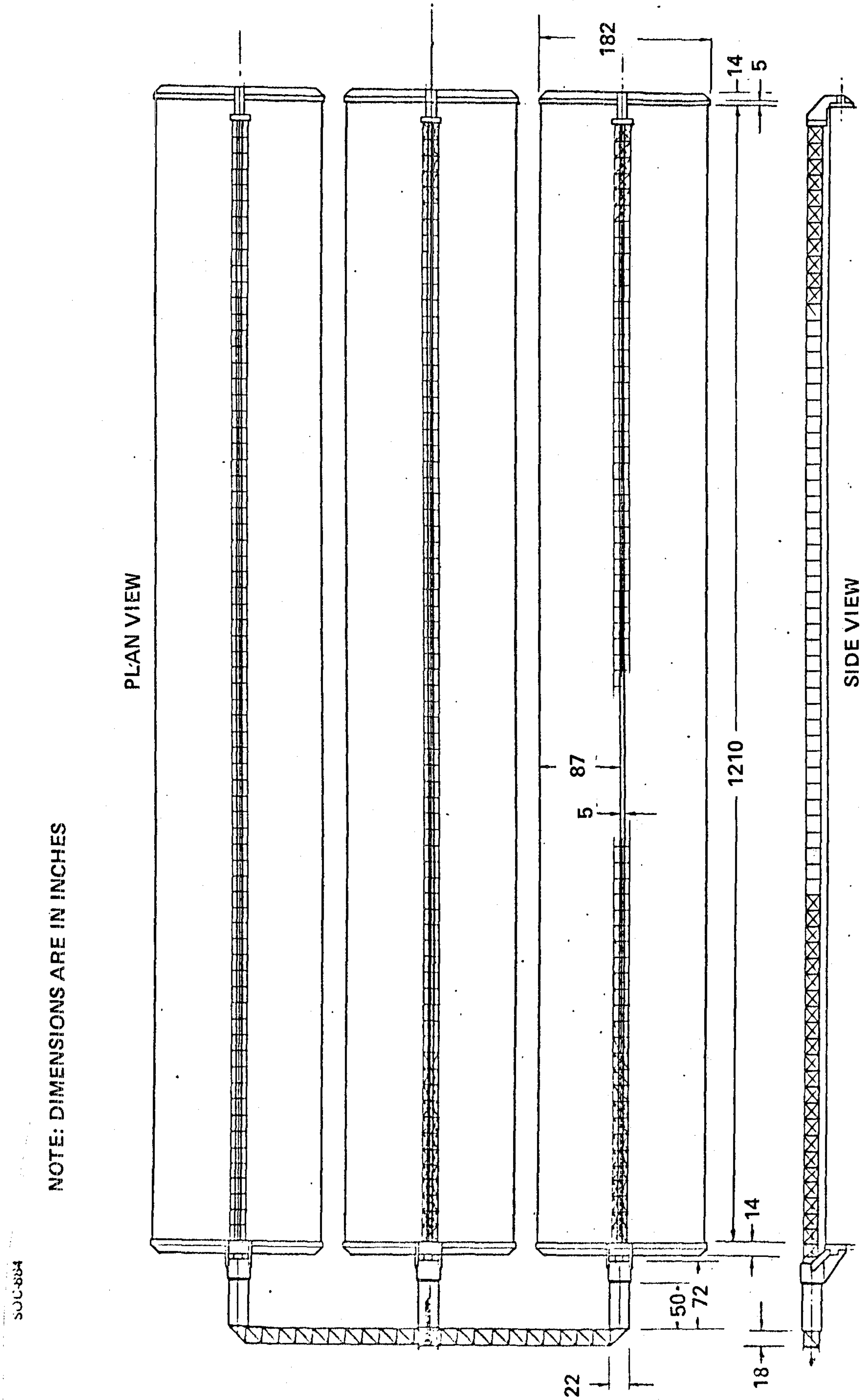


Figure B Solar Array Configuration

SOC-614

SOLAR ARRAY	• 0.32 LBS/SQ. FT (1.56 $\frac{Kg}{m^2}$) S.E.P.S ARRAY TECHNOLOGY	
	• 16 W/SQ. FT (172.05 W/m^2) B.O.L.	A
	• AREA = 8654.3 SQ.FT. (804 m^2) ; WEIGHT = 2769.4 LBS (1258.8 Kg)	A
	• DEGRADATION = 20% IN 10 YEARS	
	• SILICON SOLAR CELLS	
BATTERIES	• NICKEL HYDROGEN	
	• 30% DEPTH -OF-DISCHARGE	
	• WEIGHT = 8,540 LBS (3882 Kg): VOLUME = 249 CU. FT. (7.05 M^3)	INCLUDES 50% REDUNDANCY
	•	
CABLING	• VOLTAGE DROP - 1V IN CABLE ON 96 FT. BOOM	
SYSTEM VOLTAGE	• 200 V DC	
DISTRIBUTION	• 200 V DC TO DC-DC CONVERTER	
	• 28 V DC TO DC LOADS	
	• 115 V AC, 400 HZ TO AC LOADS	
ELECTRICAL LOADS	• SUNLIGHT (ON SOLAR ARRAY) 78,116 W	
	• OCCULTED (ON BATTERIES) 39,231 W_{PK}	

Table A. Electrical Power System Parameters

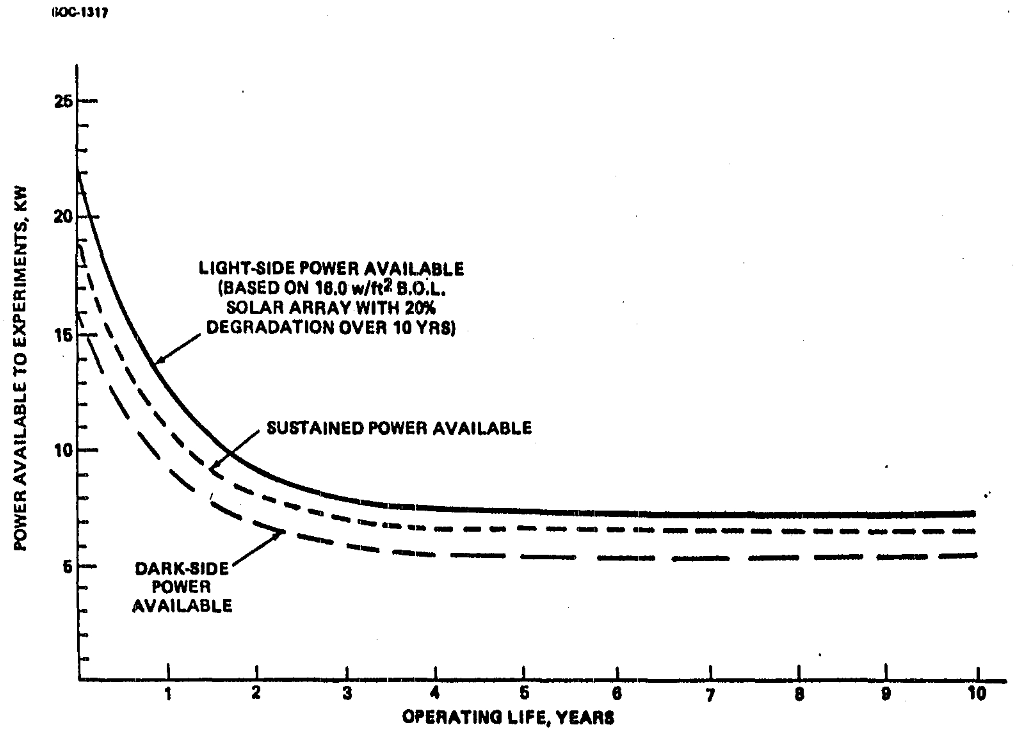


Figure C. Operational SOC Electrical Power with Improved Solar Array

Figure D Experiment Load Accomodation with Peak During Sunlight Portion of Orbit

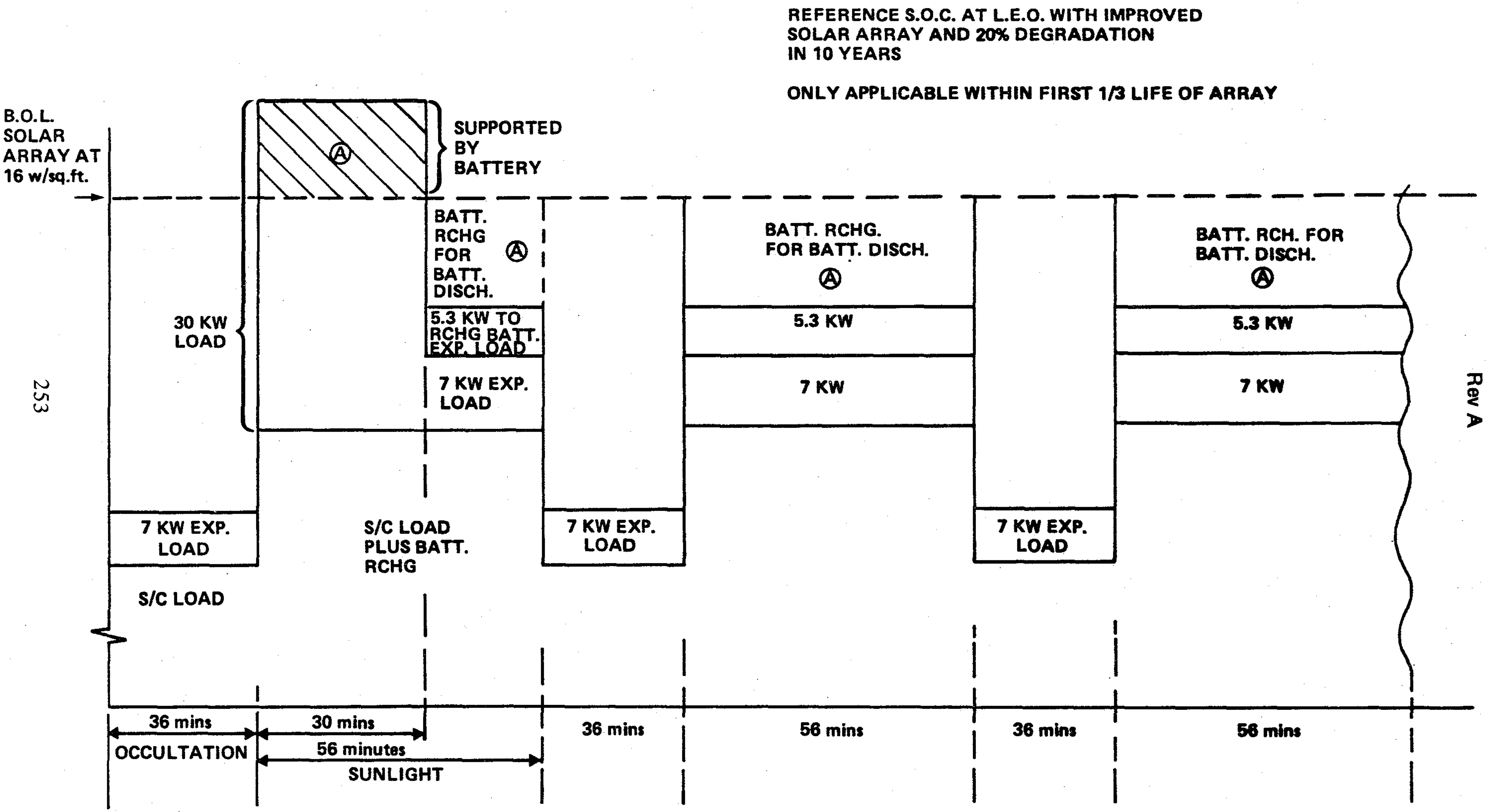
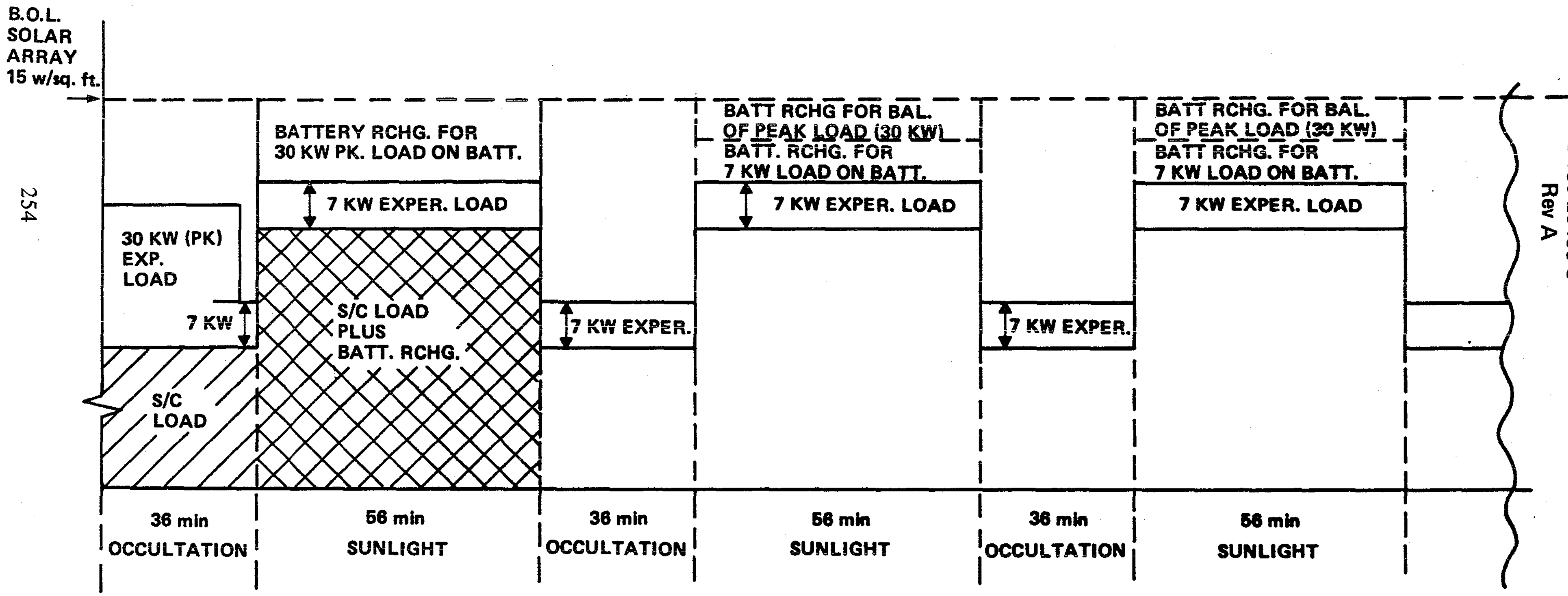


Figure E. Experiment Load Accomodation with Peak During Occultation Portion of Orbit

REFERENCE S.O.C. AT L.E.O. WITH REFERENCE SOLAR ARRAY

ONLY APPLICABLE WITHIN FIRST 1/3 LIFE OF ARRAY

NOTE: CAN ALSO BE APPLIED TO IMPROVED ARRAY, EXCEPT RECHARGE WILL TAKE A SLIGHTLY SHORTER PERIOD.



B. The higher load will not be operated for long periods, or the higher load can be interrupted, or the higher load can be lowered occasionally so that the batteries can be recharged.

C. Wire sizes would have to be increased on additional cables added to accommodate the large currents.

D. The power conditioning equipment would have to be resized for the higher loads.

Table B summarizes the electrical loads.

Figure A in WBS 1.2.2.1.1 illustrated the solar array configuration. The location of the batteries and power processors was illustrated in Figure B in WBS 1.2.2.1.

SOC-648

LOAD	REFERENCE CONFIG.	
	SUNLIGHT	OCCULTED
LIFE SUPPORT	18.096 W	10,211 W_{PK}
COMMUNICATIONS/TELEMETRY	9,370 W	9,270 W_{PK}
DATA MANAGEMENT SYSTEM	1,000 W	1,000 W_{PK}
PROPULSION SYSTEM (HEATERS)	200 W	200 W_{PK}
THERMAL CONTROL SYSTEM	2,300 W	1,300 W_{PK}
ATTITUDE CONTROL SYSTEM	250 W	250 W_{PK}
ELECTRICAL POWER SYSTEM		
LOADS	17,000 W	17,000 W_{PK}
BATTERY RECHARGE	29,900 W	0
TOTAL	78,116 W	39,231 W_{PK}

Table B. Electrical Load Summary

3.0 Design Basis

The electrical power system design was initially sized to serve the reference satellite and occulted modes shown in Figure F at the far right. The principal loads are environmental control and life support which are the bottom increment. The tracking and communications system the next increment and a variety of electric housekeeping loads such as lighting, cooking and construction equipment the next large increment.

The service module in orbit alone and an automated mode during SOC buildup requires relatively little power through its solar array. It can be only partially extended reducing the amount of drag that must be compensated during the buildup period. Further, considerable freedom in selecting a flight attitude for the service module alone is available inasmuch as the solar array need not be efficiently oriented toward the sun.

A single service module and habitat module can be operated in a Shuttle-tended mode. In this mode the required power is somewhat less than half the power required by the reference configuration. If the single solar array available is fully extended and power is augmented by the Shuttle, off miminal flight attitudes could be selected to minimize attitude control problems while sufficient electric power could still be provided by the array.

The next two bars show the operation of the entire SOC in an emergency mode. In this mode, the environmental control and life support system is operated in an open nonregenerative fashion. Only critical voice communications are employed and housekeeping loads are minimized by cutting off all noncritical lighting and shutting down normal operations of construction and flight support equipment. The emergency electric power is under 10 kilowatts, however, since the battery capacity, even at full discharge, is less than 100 kilowatt hours. It is clear that some solar array power is necessary to maintain emergency operations for the required 14 days.

In the event of a partial disabling of the power system the Space Operations Center can be operated in a degraded mode in which loads are reduced by eliminating convenience functions but maintaining operation of the vehicle with regenerative life support and most of the flight operations loads still intact.

SOC 769

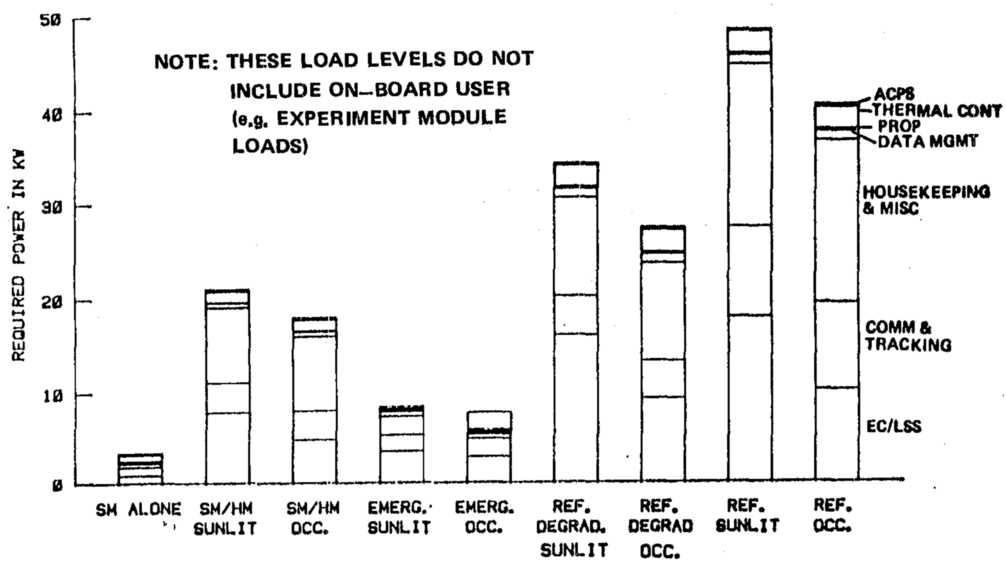


Figure F. SOC Electric Power Requirements

The schematic diagram shown in Figure G illustrates the criteria for sizing batteries and solar arrays. During occulted periods of up to 36 minutes, the SOC loads are fed by stored electric energy in the nickel-hydrogen batteries. During sunlit periods of about 60 minutes, the loads are fed by the solar array. During this time, the solar arrays must also replenish the spent energy from the batteries. This amount of energy to be replenished is about 45% greater than that withdrawn from the batteries because of their inefficiency.

This initial sizing of the solar arrays and batteries did not allot any margin for supporting on-board research/applications equipment. In Section 5.3.2.4 of Boeing -33, this limitation and potential workarounds is discussed. The solar array performance shown in Table A and Figure C, D, and E reflects a more optimistic projection of solar array technology than was originally projected. This additional performance and the load scheduling strategy will provide sufficient power for user equipment during the first 3 or 4 years of solar array design life. During the last 6 to 7 years of design life, the user loads will have to be reduced to an aggregate of approximately 5-7 kw. A

Array current versus power is shown in Figure H. The reference point is the nominal output for one wing of the SOC array. The selected delivery voltage was 200 volts.

Weight penalties are summarized in Table C. These have been used in other subsystems tradeoffs. The penalty for loads on batteries is about ten times that for the array because (a) batteries are much heavier; and, (b) additional array and battery charging equipment must also be added to recharge the batteries.

The crossplot shown in Figure I shows selection of conductor size for a 1-volt conductor drop. This conductor size is for the conductors that bring array power along the boom to the power conditioners on the service module.

4.0 Mass

Table D lists the electrical power system weights.

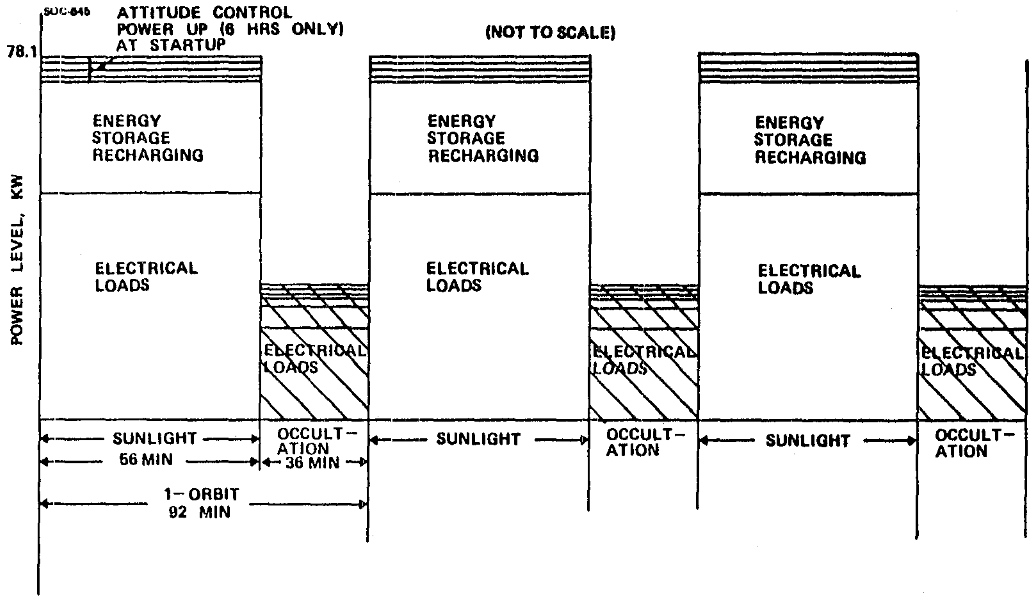


Figure G. Electrical Power Timeline/Load Profile for Reference SOC

SOC-708

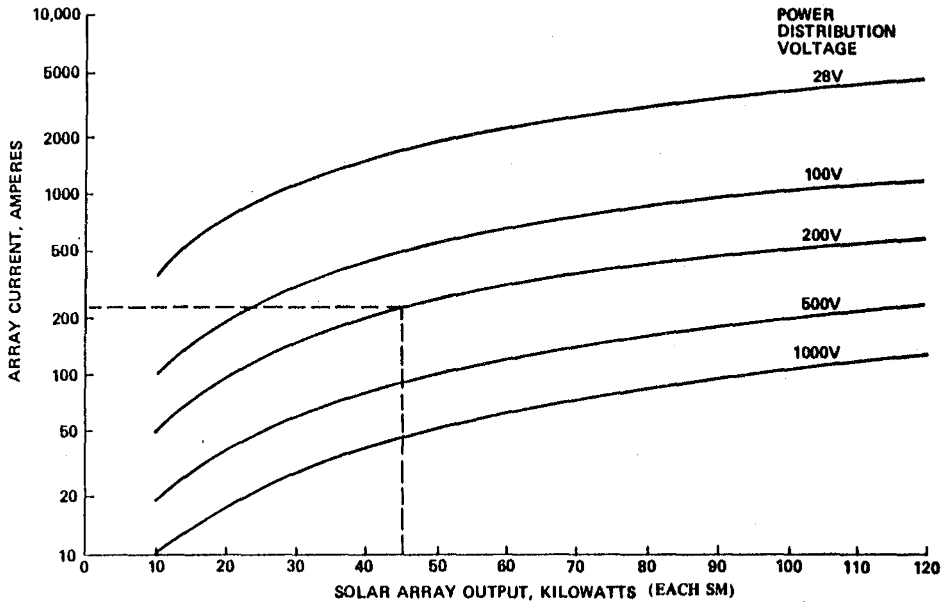


Figure H. SOC Spacecraft Solar Array Power vs Array Current at Different System Voltages

SOC-613

	LOAD ON BATTERIES	LOAD ON SOLAR ARRAY
• AC LOAD	495.6 LBS/KWHR	34.6 LBS/KW
• REGULATED DC LOAD	455.3 LBS/KWHR	32.16 LBS/KW
• UNREGULATED DC LOAD	375.03 LBS/KWHR	30.6 LBS/KW

Table C. Weight Penalties for Loads on Batteries or Solar Array

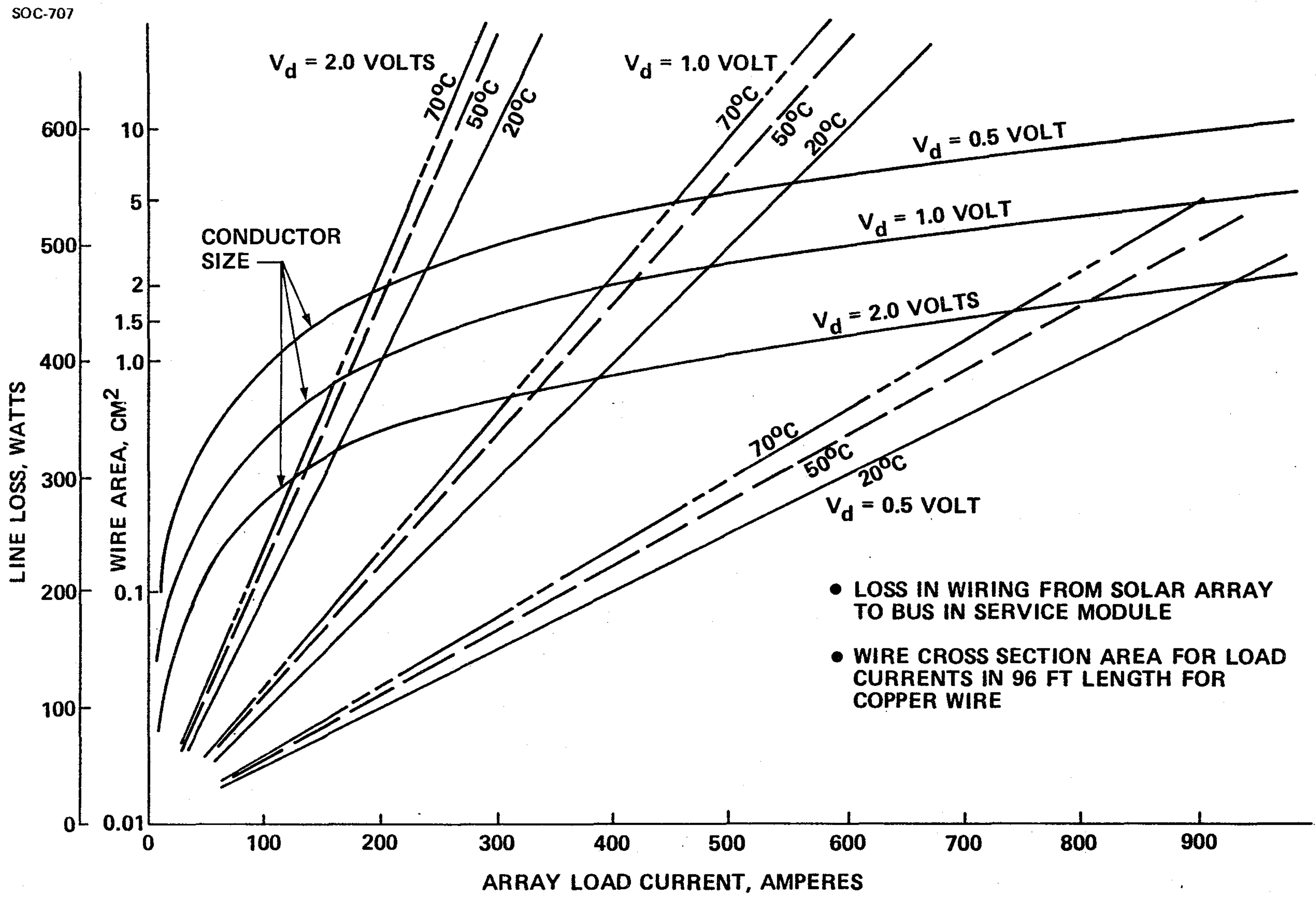


Figure I SOC Spacecraft Solar Array Bus Sizing

	SM 1	SM 2	HM 1	HM 2
● SOLAR ARRAY	630 Kg (1386 LBS)	630 Kg (1386 LBS)	—	—
● POWER CONDITIONING	200 Kg (440 LBS)	200 Kg (440 LBS)	34 Kg (75 LBS)	34 Kg (75 LBS)
● NiH_2 BATTERIES	1941 Kg (4270 LBS)	1941 Kg (4270 LBS)	—	—
● NiH_2 EMERGENCY BATTERIES	50 Kg (110 LBS)	50 Kg (110 LBS)	50 Kg (110 LBS)	50 Kg (110 LBS)
● AUTOMATIC POWER SYSTEM MANAGEMENT	50 Kg (110 LBS)	*50 Kg (110 LBS)	50 Kg (110 LBS)	50 Kg (110 LBS)
● S/A TO SERVICE MODULE - MAIN CABLES	168 Kg (370 LBS)	168 Kg (370 LBS)	—	—
● WIRE HARNESSES AND CONNECTORS	500 Kg (1100 LBS)	500 Kg (1100 LBS)	500 Kg (1100 LBS)	500 Kg (1100 LBS)
● BUSSES	200 Kg (440 LBS)	200 Kg (440 LBS)	25 Kg (55 LBS)	25 Kg (55 LBS)
• SWITCHES • CIRCUIT BREAKERS • TERMINALS • LIGHTS • CONNECTORS • DISTRIBUTION BOXES • LIGHT FIXTURES	200 Kg (440 LBS)	200 Kg (440 LBS)	50 Kg (110 LBS)	50 Kg (110 LBS)
	3939 Kg (8666 LBS)	3939 Kg (8666 LBS)	709 Kg (1560 LBS)	709 Kg (1560 LBS)

Table D. Electrical Power System Weights

Weight estimates for the SOC electric power system were made and values allocated to the habitat and service modules. The estimates were based on levels of technology expected to be available for the SOC design. These include the lightweight deployable solar array designed for SEPS, PEP, or the power system, power electronics in the multi-kilowatt class, and nickel-hydrogen batteries. Generous allowances were made for power bussing and harnesses.

WBS 1.2.2.1.8 GUIDANCE, NAVIGATION, AND CONTROL

1.0 WBS Dictionary

This element includes state vector computers, inertial measurement units, and central moment gyros.

2.0 Description

The SOC Guidance, Navigation, and Control system includes (1) computational equipment to develop state vector data from GPS inputs from the communications system, and other inputs TBD; (2) an inertial measurement unit, and (3) control-moment gyro (CMB) sets to counteract cyclic or transient torques resulting from mutational disturbances and equipment or crew movement. The primary control actuation system is the attitude control and orbit makeup propulsion system. The latter is commanded by the GN & C system.

3.0 Design Basis

Selection of the GN & C concept resulted from the decision to fly the SOC as an Earth-oriented spacecraft. The latter decision is discussed in detail in the Systems Analysis Report (Boeing-20, Section 13).

The flight control strategy is to operate the system in a principal-axis attitude such that gravity gradient control thrust requirements are less than the orbit makeup thrust requirements. Location of the attitude control thrusters then allows orbit makeup thrust to provide the primary attitude control actuation. Subsidiary torques result from inertia distribution anomalies and from crew and equipment motions. It presently appears most practical to provide a nominal CMB capability to deal with these torques, and to use the propulsion system to assist if torques exceed the nominal CMB capability.

The flight control strategy clearly requires an adaptive control software system, with sensing systems to provide the necessary inputs. Presently, it is estimated that tracking the CMB accummulated momentum status, tracking vehicle attidue through the IMU (and probably a horizon sensor), plus determination of orbit parameters through inputs from GPS or TDRSS, will provide the necessary inputs for adaptive control algorithms to effect active control of SOC structural dynamics.

The structural dynamics modes of principal concern are those involving the solar array. If active control of these is needed, accelerometer sensors and possibly small thrusters at the ends of the array wings might be needed. Presently, such a requirement has not been confirmed.

WBS 1.2.2.1.9 TRACKING AND COMMUNICATIONS

1.0 WBS Dictionary

This element includes the communications and tracking antennas and avionics and closed circuit television cameras and avionics located in or on the Service Module.

2.0 Description

The SOC communications links are shown in Figure A. The Tracking and Data Relay Satellite System (TDRSS) has been selected as the relay system.

Communications with close-in satellites will be at S-band using STDN or TDRSS formats with the SOC acting as the interrogator or transponder depending on the other satellites' capabilities. The preferred mode is TDRSS with SOC acting as the interrogator. Four S-band interrogator/transponders will be capable of functioning simultaneously to communicate with Orbiter, MOTV, and free-flyers. The switchable conical log spiral antennas or the steerable/switchable horn antennas will be available for communications, depending on the range. Communications with EVA personnel requires spherical antenna coverage. Further study is required to provide and assure a system free of communication gaps.

Two radars are postulated to provide coverage along the sectors of SOC travel. These are located on the service modules adjacent to the docking ports.

A concept for the processing and transmissison of data for the several links are summarized in Table A. The undefined freeflyers are expected to have either STDN or TDRSS transponders and the linkage are expected to be similar to that involving the Orbiter or the OTV. All transponders are expected to have dual (STDN/TDRSS) mode capability and can operate as an interrogator or a transponder, thus allowing interchangeability of the units.

The voice data rate is tentatively specified to be 16 KBPS Continuous Variable Slope Delta (CVSD) coding algorithm. The algorithm is economical of data rate and circuit complexity, of good quality and is being used by the military. It is recognized that the Orbiter uses the 32 KBPS Delta Modulation, and therefore, an

SOC-351

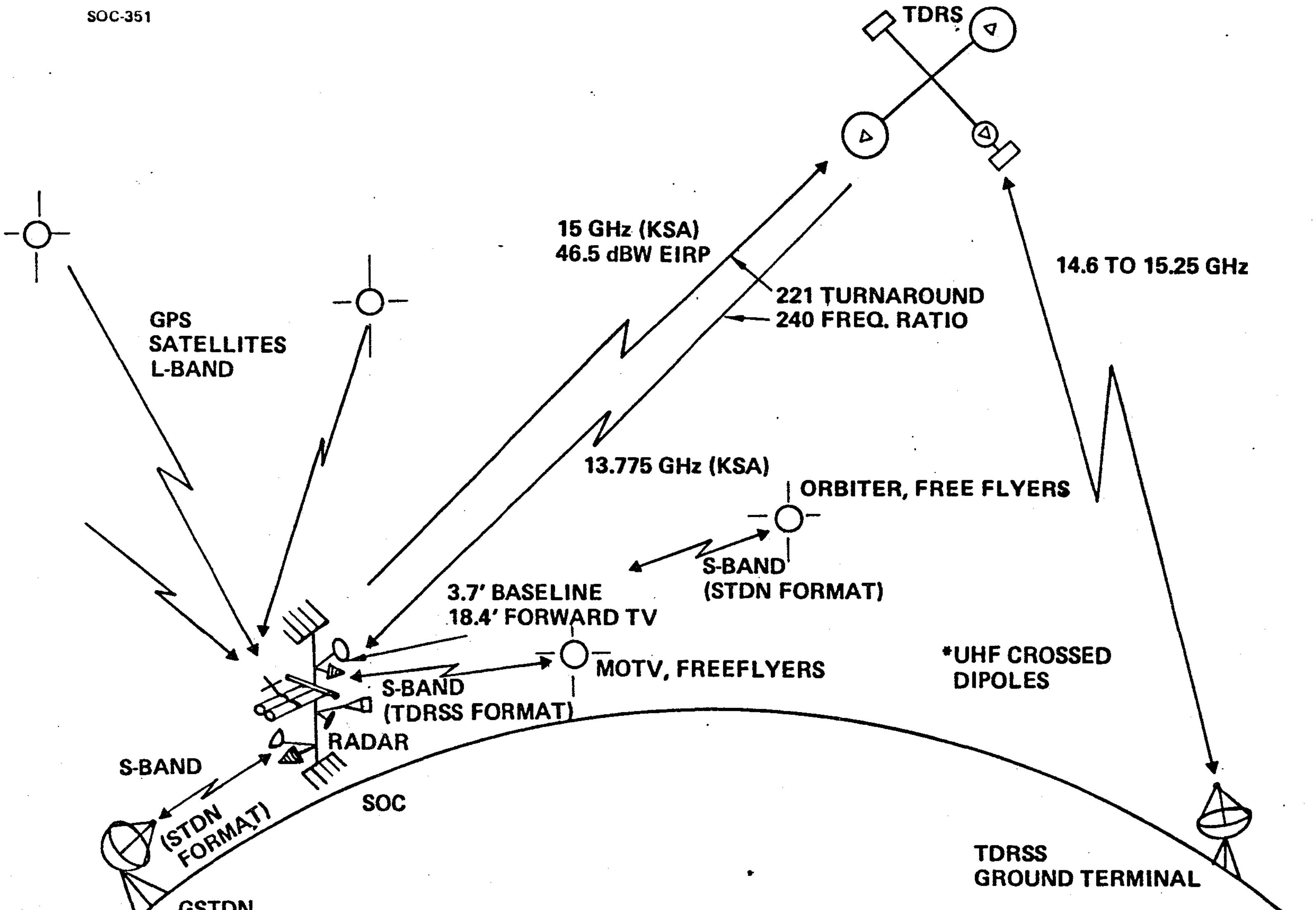


Figure A. SOC Communications Linkages

SOC-344

COMMUNICATION LINK	TYPE R/T	FREQ. BAND	DATA	ENCRYPTION	CODING	FORMAT	MAX RANGE (KM)
SOC-TO-RELAY (RETURN)	NASA STD TDRSS	KU–BAND	TV: 25-50 MBPS DATA: < 1 MBPS VOICE: 16 KBPS	NO DES DES	NO VITERBI	DG-2 I CHANNEL Q CHANNEL	46,000
RELAY-TO-SOC (FORWARD)	NASA STD TDRSS	KU-BAND	TV(OPT): 22 MBPS DATA(CMD): < 1 MBPS VOICE: 16 KBPS PN: ~ 20 MCPS	NO DES DES NO	NO MASSEY MASSEY NO	} I CHANNEL Q CHANNEL	
SOC-TO-OTV (FORWARD)	NASA STD TDRSS	S-BAND	DATA/CMD: 16 KBPS VOICE(MOTV): 16 KBPS PN: ~ 3 MCPS	TBD TBD NO	NO NO NO	} I CHANNEL Q CHANNEL	≤ 600
OTV-TO-SOC (RETURN)	NASA STD TDRSS	S-BAND	DATA/TLM: 64 KBPS VOICE(MOTV): 16 KBPS PN: ~ 3 MCPS	TBD TBD NO	NO NO NO	} DG-1 MODE 1 MODE 2 WITH ABOVE	
SOC-TO-ORBITER (FORWARD)	NASA STD STDN	S-BAND	DATA/CMD: 2 KBPS VOICE: 16 KBPS RANGETONES: 40Hz-500KHz	NO	NO	16 KHz SC 70 KHz SC SIDETONES	≤ 600
ORBITER-TO-SOC (RETURN)	NASA STD STDN	S-BAND	DATA/TLM: 64 KBPS VOICE: 16 KBPS RANGETONES: 40Hz-500KHz	NO	NO	SGLS SC 1.024 MHz SGLS SC 1.7 MHz SIDETONES	

Table A. SOC Communications and Tracking Summary

COMMUNICATION LINK	TYPE R/T	FREQ. BAND	DATA	ENCRYPTION	CODING	FORMAT	MAX RANGE (KM)
SOC-TO-GSTDN (RETURN)	NASA STD STDN	S-BAND	DATA/TLM: 64 KBPS VOICE: 16 KBPS RANGETONES: 40Hz-500KHz	DES DES NO	VITERB: VITERB: NO	SGLS SC 1.024 MHz SGLS SC 1.7 MHz SIDETONES	2800
GSTDN-TO-SOC (FORWARD)	NASA STD STDN	S-BAND	DATA/CMD: 4 KBPS VOICE: 32 KBPS RANGETONES: 1.7 MHz	DES DES NO	NO NO NO	} BASEBAND 1.7 MHz SC	
SOC-TO-SCF	NO REQUIREMENT						
SCF-TO-SOC	NO REQUIREMENT						
EVA		UHF	VOICE: (FULL DUPLEX) ALSO VOICE BW DATA	NO	NO	AM	≤ 1.6
GPS-TO-SOC	GPS	L-BAND	NAV DATA			GPS	18,500
SURVEILLANCE RADAR		MM	MULTIPLE TARGET DATA	N/A	N/A	PULSE CODED	≤ 8 2000 GOAL
SOC-TO/FROM FUTURE SATELLITE	NASA STD TDRSS	S-BAND	TBD				

Table A. SOC Communications and Tracking Summary (Cont'd) interim capability of handling both algorithms is desired. The voice data rate has no significant impact over the bent pipe link; however, it is a factor in the goal of achieving voice/data communcations with the Orbiter at the maximum required range of 600 km. Lower data rates should be considered in future studies. The Adaptive Predictive Coders (APC) and the Linear Predictive Coders (LPC) require eight and four kbps data rate but requires considerably greater processing power than the CVSD algorithm.

The TV digitization algorithm for the forward and return "bent pipe" links presumes the use of adaptive delta modulation (ADM) of NTSC color video signals. The forward data link is restricted to 25 mbps by TDRS whereas the return link is EIRP constrained.

Non-NSA encryption is expected to utilize the Data Encryption Standards established by the NBS. Forward error connection is utilized in the forward "bent pipe" link using Viterbi rate 1/2 constraint length seven convolutional encoding for data and voice. Due to complexity of Viterbi decorder, the return link is not so encoded. However, it is recommended that simple coding algorithms such as Massey's be used in the forward link and possibly for all low data rate links.

The EVA link requires further study to establish best frequency, data processing and modulation techniques. The UHF (FDM) AM system is the initial concept for EVA communications. The Surveillance radar is shown to be a noncoherent Ku-band radar with a goal of coverting to a coherent radar in the 100 - 200 Mhz region in the future.

A preliminary configuration and location of the SOC antennas is shown in the Figure B. The two large Ku/S-band antennas (18.4' diameter baseline) are steerable by command as well as by auto track. The S-band horn antennas are mechanically steerable and the S-band conical-log-spiral antennas are switch-selectable.

The EVA antennas, represented by two UHF crossed dipole sets, require further study/modeling to determine the optimum frequency, antenna type(s), and location to assure spherical coverage.

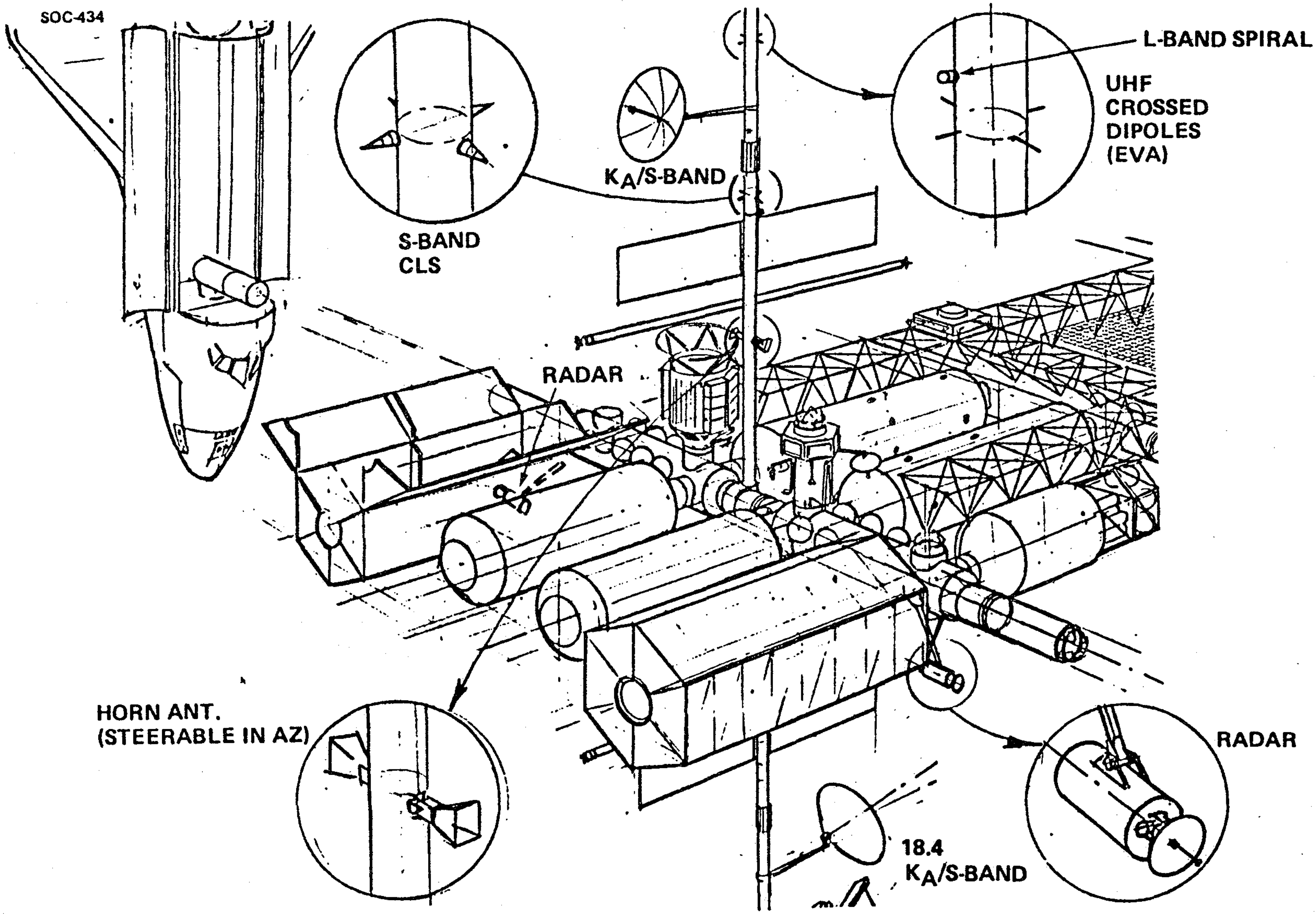


Figure B. Space Operations Center Antenna Locations

The two surveillance radars have scanning antennas with sector coverage along the orbit path. Blockage from the structure restricts the elevation scan and may require relocation for a larger sector coverage. The surveillance radars must meet the following requirements:

- o Track shuttle, upper stages, and free-flyer satellites to at least 100 km range
- o Provide approach path prediction and collision warning
- o Minimum of 2 locations: fore and aft sm docking ports
- o Shuttle blockage of radar view can be minimized by docking to docking module

A flat plate spiral antenna has been selected as the upper-hemisphere-coverage, L-bands, GPS receiving antenna.

A simplified schematic of a dual mode (STDN/TDRSS) transponder is shown in Figure C. The unit operates at S-band, but can be commanded to operate at Ku-band by incorporating the functional blocks shown in dotted lines. This basic transponder shall also be capable of acting as an interrogator through adjustments in the frequency and the base-band input and outputs.

A representative scheme for interfacing the communications and tracking and data management systems is shown in Figure D.

The equipment for a typical non-habitat module is shown in the Figure E. The Caution and Warning System (similar to Orbiter), the data bus I/O and the voice terminals are energized at all times. The TV and TV cameras are remotely controllable from Habitat 1 and 2.

An initial estimate of the SOC Communication and Tracking equipment list along with physical parameters and power requirements are shown in Table B. The size, weight and prime power restraints may eventually reduce the amount of equipment from that shown. A considerable amount of equipment results from the initial concept of letting each habitat have the full capability of the other, although not all equipment in both habitats would be functioning. The number of equipment "on line" refers to those connected up and ready for use, but not necessarily powered

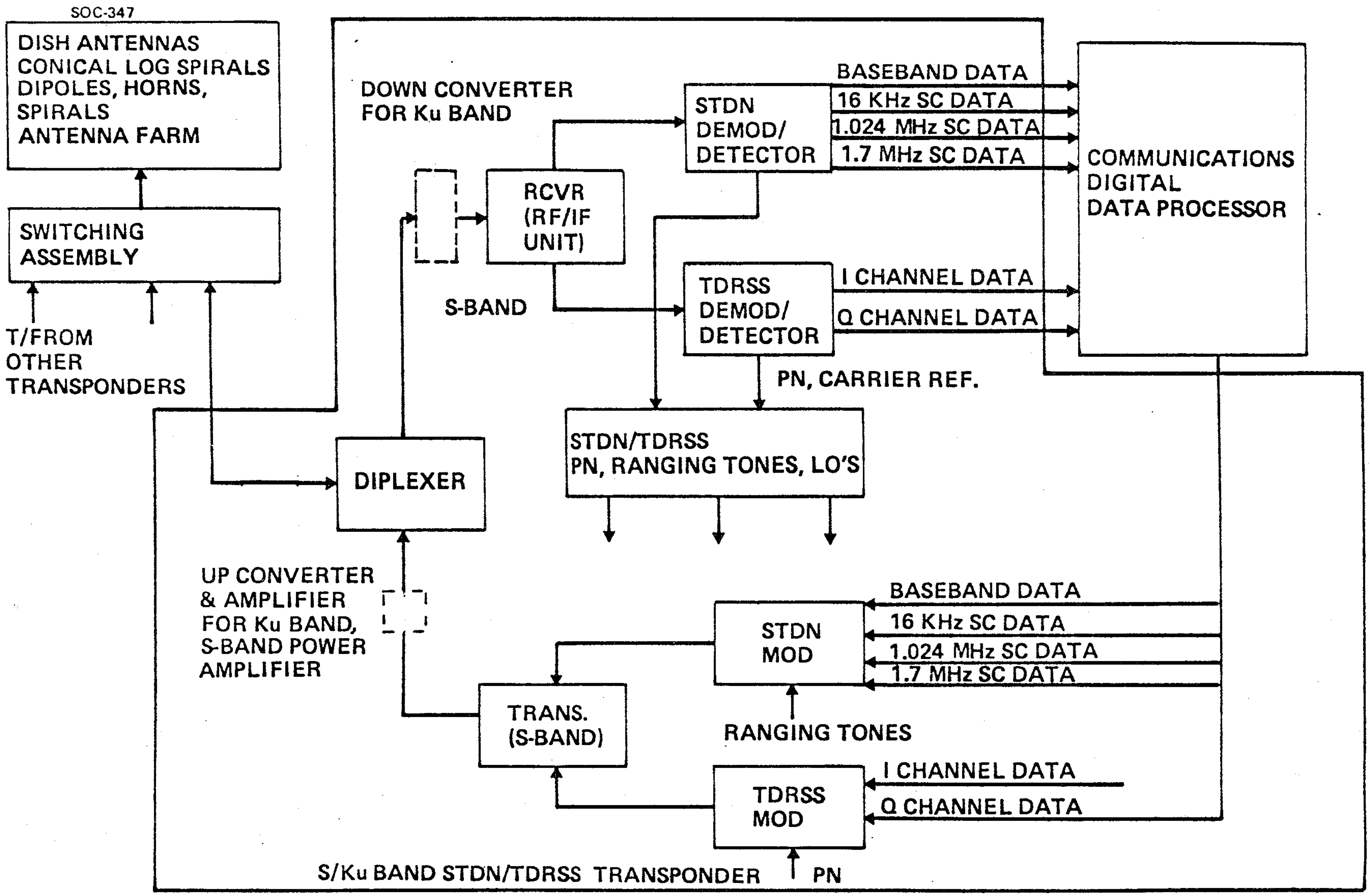


Figure C. Simplified Representation and Interface of S/Ku-Band STDN/TDRSS Transponder

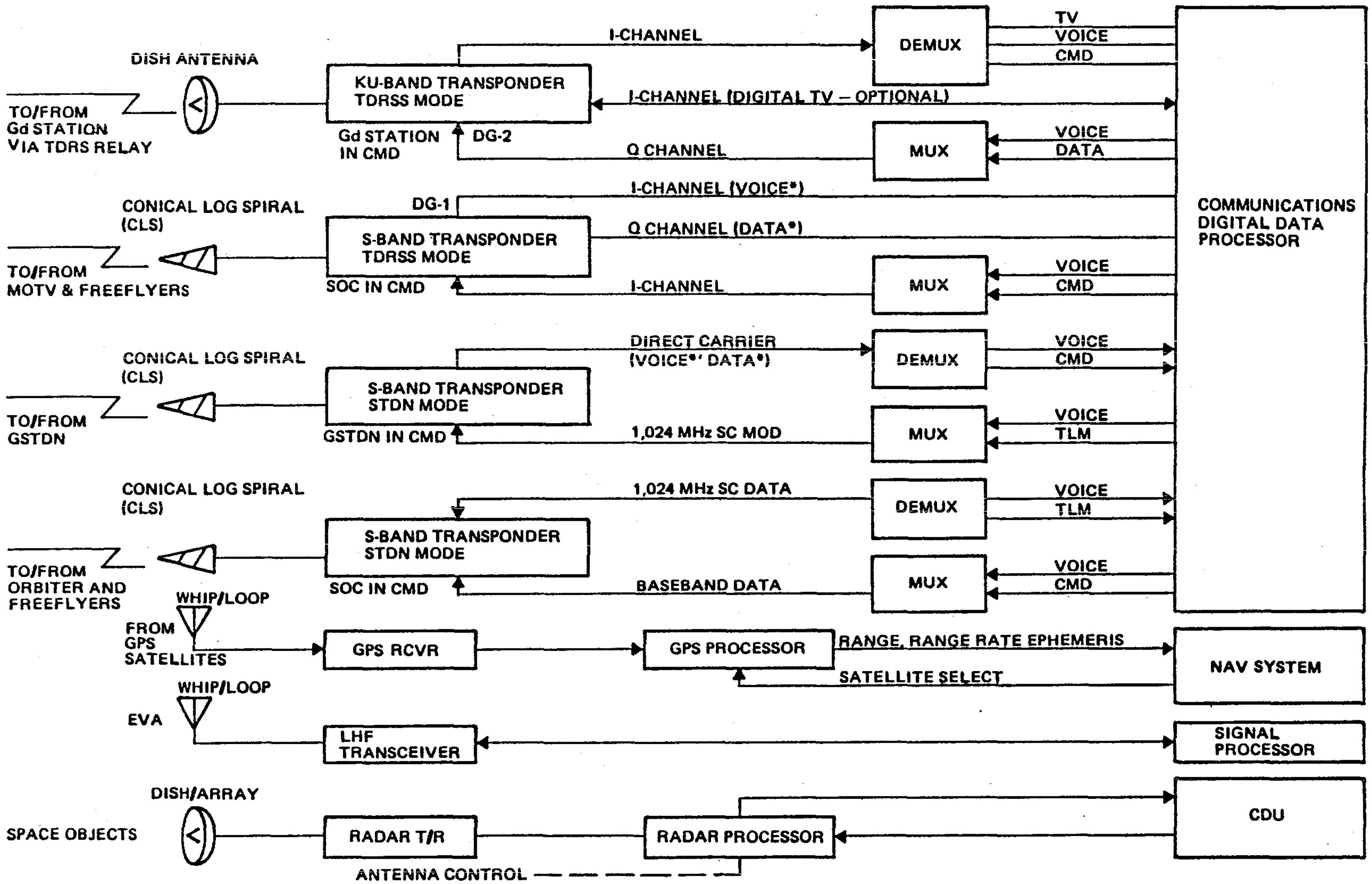
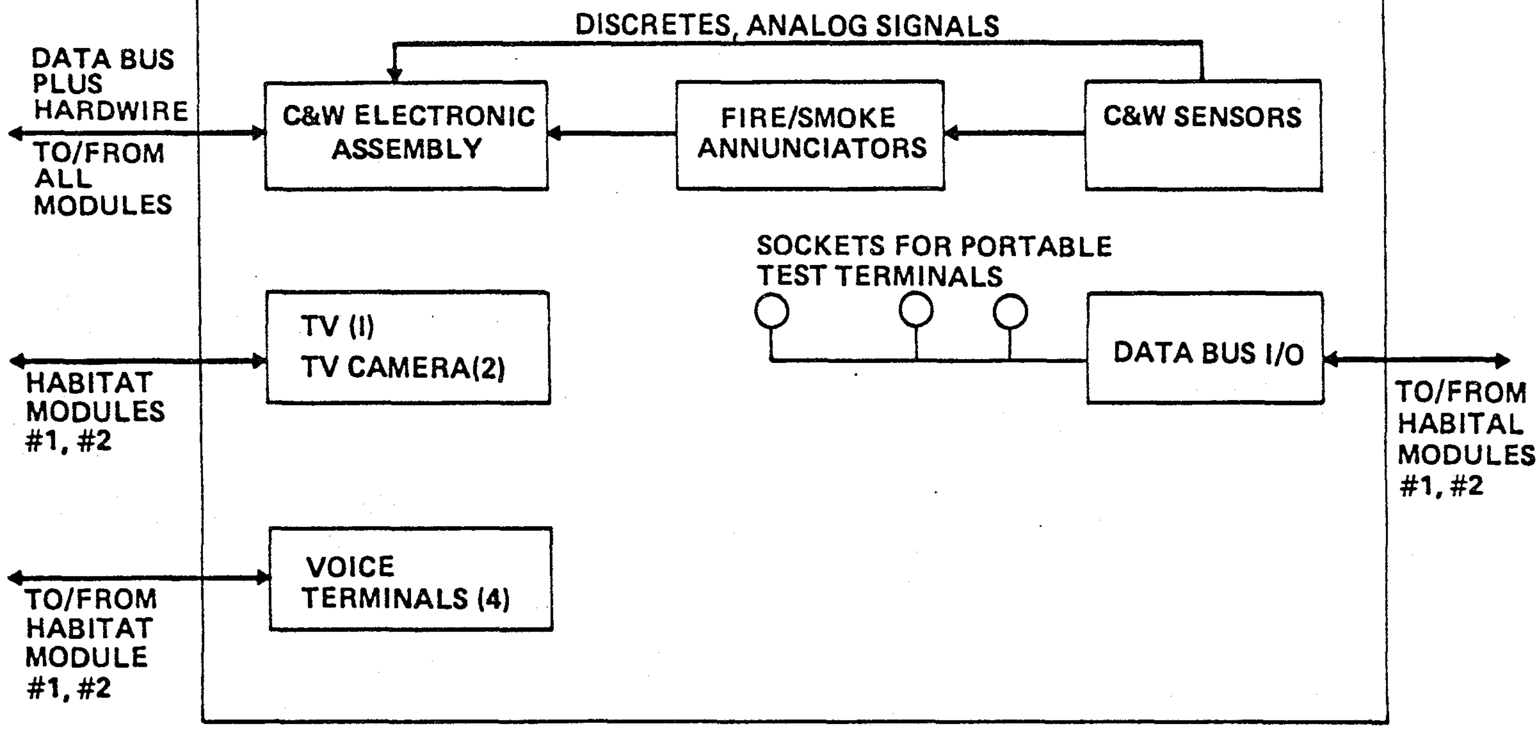


Figure D. SOC Communications/Tracking Modems

SOC-407



*DOCKING ~~MODULE~~ TUNNEL
SERVICE MODULES (2)
LOGISTICS MODULE

*Figure E. SOC Communications and Tracking Module Schematic (Non-Habitat Modules)**

EQUIPMENT	NO. OF UNITS		VOLUME (FT³)		PRIME POWER (W)		WEIGHT (LBS.)		SOURCE
	ON LINE	SPARES	EACH	TOTAL	EACH	TOTAL	EACH	TOTAL	
INTERRO/TRANSPONDER									
KU-BAND TDRS	2	2	0.5	2.0	50	50	20	80	ESTIMATE
KU-BAND PWR AMP (15W)	2	1	1.8	5.4	50	50	8	24	HUGHES TWTA (12454)
S-BAND STDN/TDRSS	8	2	0.5	5.0	50	200	19	190	TRW IUS (SIMILAR)
S-BAND PWR AMP (30W)	4	2	0.4	1.6	125	250	13	52	TRW IUS
EVA									
SOC R/T	4	4	0.1	0.8	20	80	10	80	ESTIMATE
EVA R/T HEADSET	4	10			NEG.	NEG.			
VOICE TERMINALS	24	10	.014	0.5	5	120	1	34	ESTIMATE
GPS RCVR/PROC	1	1			100	100	50	100	ESTIMATE
SURVEILLANCE RADAR	2	2	2.5	10.0	1000 VA	2000 VA	140	560	EQUIV. TO WX50
C&W SYSTEM	6	2	0.5	4.0	200	1200	20	160	ESTIMATE
CRT TERMINAL	2	2	1.0	4.0	500	1000	50	200	ESTIMATE
SIGNAL PROCESSOR	2	1	1.0	3.0	500	1000	50	150	ESTIMATE
DIGITAL PROCESSOR	2	1	1.0	3.0	500	1000	50	150	ESTIMATE
TV 15"	8	2	2.5	25.0	250	1000	35	350	COMMERCIAL
TV CAMERA	12	2	0.5	7.0	10	120	5	70	COMMERCIAL
ANTENNA/ANTENNA CONTROL/MISC.			TBD		TBD				

Table B. SOC C&T Equipment Summary

up. Spares are units that are stowed. The prime power requirement for each line item shows the power required for each unit as well as the power required for all units that are energized, and not necessarily those "on line".

3.0 Design Basis

The TDRSS has been selected over the DSCS III for the following reasons:

- TDRSS can provide SOC with full duplex wideband (TV, data, voice) data capability as opposed to half duplex with DSCS III.

- SOC will practically tie up a DSCS III capability whereas only about half of a TDRS's capability will be engaged.

- Protocols for acquisition and tracking of SOC is established with TDRSS, but not with DSCS III. Also, pointing of antenna beam by DSCS III is by command only, and not by auto track as with TDRS.

- Higher transmitter power required with DSCS III.

The two TDRS (Tracking and Data Relay Satellite) provides nearly continuous geometric coverage for SOC, as shown in Figure F. Flux density restrictions and atmospheric absorption will reduce the effective coverage. Full coverage requirement will necessitate strategically located ground terminals, a supporting satellite or a third relay satellite.

The frequency availability and usability is summarized in Table C.

The antenna type justification is summarized in Table D.

The alternate antenna location considerations are summarized in Table E. The selected antenna location rationale is summarized below:

- The solar array boom has been selected as the site for the communications antennas based on coverage considerations and the availability of the site.

SOC-408

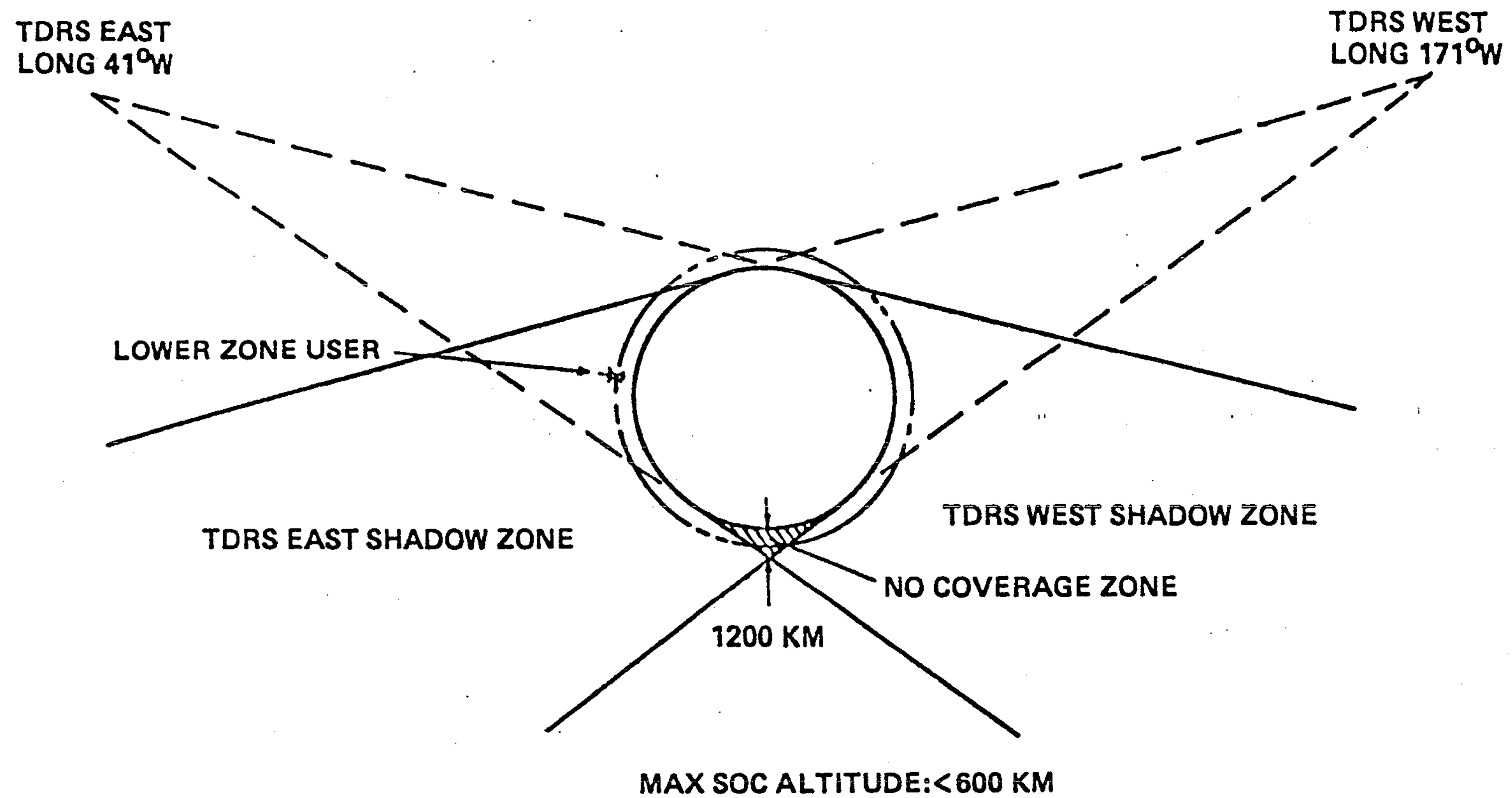


FIGURE SOURCE:
STDN NO. 101.2, REV. 4

Figure F. TDRSS Coverage

FREQUENCY	USABILITY	AVAILABILITY
Ku-BAND (SOC-RELAY LINK)	No other interfering Ku-band signals present onboard SOC. Link analysis shows feasibility of link. There is a potential problem with the Ka-band radar. RFI analysis should be made, particularly for the relay satellite.	Subject to approval of TDRSS management. TDRSS usage in dedicated KSA mode may not be approved. This may require a relay satellite with greater relay capability. TDRSS permits only S-band or Ku-band operation.
S-BAND (SOC-USER SATELLITE LINK)	RFI can be a problem with the multiple simultaneous links at S-band. RFI analysis is required. A number of techniques are available to minimize RFI: o Proper selection of S-band channels o Minimize RF bandwidth o Horn antenna provides limited spatial separation o EIRP control (minimize near/far signal strength problems) o Use code orthogonality (TDRSS Pseudo Noise Code-Code Division As technology develops, MM-wave may surplant S-band for the SOC-user satellite SOC-relay satellite communications.	The NASA standard S-band spectrum (2025-2120 MHz forward link, 2200-2300 MHz return link) are expected to be available to NASA in the foreseeable future. The allocation of channels to SOC and the user-satellites will require coordination with NASA-Goddard.

Table C. Frequency Usability—Availability

FREQUENCY	USABILITY	AVAILABILITY
UHF (EVA)	The UHF band is high enough to enable the use of small, efficient EVA antennas and provide adequate bandwidths (for channel separation and signal bandwidth). The frequency is low enough to enable the use of simple circuits. Interference is expected to be limited to the UHF band users. This can be negated by the proper use of frequency division.	Frequency allocation is not expected to be a problem since the effective radiation volume will be small.
Ka-BAND RADAR	SOC's Ku-band transmission is not expected to be a problem. However, there is a possibility that the Ka-band transmission sidelobes may interfere with the Ku-band signal reception. Further analysis is required.	Availability of this band for high peak power radar operation is not known. Further study is required in this regard.

Table C (Cont'd) Frequency Usability—Availability

FUNCTION	REQUIRED GAIN dB	TYPE SELECTED	RATIONALE
SOC-RELAY LINK Ku-BAND	57 dB	Parabolic Dish (one on each boom)	Planar or conformal array antennas are not considered viable due to their complexity.
SOC-SATELLITE LINK, LONG RANGE (600km) S-BAND	18 dB*	Horn (switchable and steerable in Az	Parabolic dish antenna also viable, however, simpler feed structure with horn antenna leads to its selection.
SOC-SATELLITE LINK, SHORT RANGE S-BAND	6 dB*	Conical Log Spiral (CLS) (switchable)	Set of 4 CLS provides spherical coverage capability (when switched) plus moderate gain (6 dB). Another set of 4 is available to combat blockage. Antenna is simple to fabricate and well proven. Low gain horns may also be used.
EVA UHF	0 dB (omni-directional)	Crossed Dipole Antennas (one at each end of boom)	Antenna is simple and provides good spherical pattern. Blockage is still a problem, so 2 antennas selected. Frequency band of each antenna is offset to minimize interference.

* Value depends on eventual antenna gain, EIRP of user satellite.

Table D. SOC Antenna Type Justification

ANTENNA LOCATION ALTERNATES	ADVANTAGES	DISADVANTAGES
OTV HANGAR	• Good antenna coverage potential (with doors closed)	• Doors cause blockage and antenna installation problems
PROPELLANT TANKS	• Close proximity to crew and supporting electronic equipment	• Safety hazard • Tanks could be replaced
LOGISTICS MODULES	None	• Not a permanent fixture
DOCKING AND SERVICE MODULES	• Good antenna coverage in the absence of vehicles docked or being docked	• Docked S/C creates blockage • Large antennas may impede docking
CONSTRUCTION AREA	• Good antenna coverage in absence of construction work	• Antenna blockage by large S/C being assembled and by cranes • Damage hazard by construction equipment • Long cable runs
HABITAT MODULE	• Very close proximity to supporting electronics (ease of maintenance, low circuit losses)	• Module fabrication problem, there is a cocoon of radiator fluid about the module
SOLAR ARRAY BOOM SELECTED LOCATION	• Very good antenna coverage	• Deployment of boom is more complex • Servicing relatively difficult • Long cable runs

Table E. SOC Antenna Location Considerations

- o Location of antennas at both ends of boom assures good antenna coverage for all SOC orientations.

- o Selection of antenna position on boom is based on the following:

    - o Ku-band antennas -Frequency conversion was deemed a necessity. Therefore, the position was based on coverage only, not cable loss.

    - o S-band horns - No frequency conversion planned. The link is EIRP limited. Hence, the position on boom minimizes cable loss.

    - o S-band conical log spiral antennas - No frequency conversion planned. The link is not EIRP limited. Therefore, the antennas are located further away from the transmitter/receiver than the horn antennas.

    - o UHF-crossed dipoles - No frequency conversion at antenna location. Links not EIRP limited. Position based on antenna coverage.

Additional communications and tracking system analysis data is found in Boeing-14.

4.0 Mass

See Table B.

WBS 1.2.2.1.10 DATA MANAGEMENT AND SOFTWARE

1.0 WBS Dictionary

This element includes the data management system hardware and software for the Service Modules.

2.0 Description

This element has been included in WBS 1.2.1.1.10 et al.

WBS 1.2.2.1.11 INSTRUMENTATION

(Instrumentation has not been specifically identified during this study. An allowance for instrumentation mass was included in the Service Module mass statement.)

WBS 1.2.2.1.12 CREW ACCOMMODATIONS

1.0 WBS Dictionary

This element includes the sleep restraints, food preparation equipment, physical fitness equipment, and health maintenance provisions that are provided to make the SM1 habitable in an emergency mode situation (SM2 does not require these provisions). Also included are stowage and lighting provisions. (Other crew provisions are included in WBS 1.2.2.1.13 -EC/LSS and in WBS 1.2.2.1.10 - Data Management and Software.)

2.0 Description

In the Initial SOC Configuration, it is necessary to equip SM1 with some EC/LSS and crew accommodation provisions to make it habitable for 21 days during an emergency mode where the HM1 had to be evacuated. Table A lists the crew accommodation equipment that is to be included in SM1 (the EC/LSS provisions are included in WBS 1.2.2.1.13). This table notes the provisions required for the emergency mode and those that would be provided for normal operations. A

Sleep Restraints - Provide 3 sleep restraints and attachment hardware for use in the emergency mode. These restraints would be normally stowed in storage lockers.

Exercisers - Provide 1 spring-type exercise device for use in the emergency mode. This would normally be stowed.

Medical Kit - Provide a first aid medical kit for use in the emergency mode.

Food Preparation Fixtures - Provide hot and cold water spigots for use in the emergency mode.

Stowage - There is approximately 640 ft^3 of available stowage volume within SM1.

Table A
Service Module No. 1
Crew Accommodations

ITEM	QTY	EMERGENCY MODE REQM'T	NORMAL MODE REQM'T
Sleep Restraints	3	*	
Spring Exercise Device	1	*	
Medical Kit	1	*	
Food Preparation Fixtures	1 Set	*	
Stowage			*
Lighting			*

Lighting - Figure A illustrates a concept for the location of lighting fixtures in the interior of SM1. The specific types of lighting fixtures have not been defined.

Figure B illustrates a concept for the location of exterior lighting fixtures on the SM. The specific types of lighting fixtures have not been defined.

3.0 Design Basis

Three sleep restraints are provided as it is assumed that one of the four crewmen would have to be on duty at all times during an emergency mode.

Exercise and medical kits are obvious emergency mode requirements.

The water spigots are required so that the food can be rehydrated. The available food during the emergency mode will be both shelf-stable and frozen food stowed in SM1 and in the Logistics Module.

Stowage and lighting are obvious requirements.

4.0 Mass

See WBS 1.2.2.1 mass statement.

SOC-869

NOTE: EACH ZONE HAS INDEPENDENT LIGHT SWITCH CONTROL

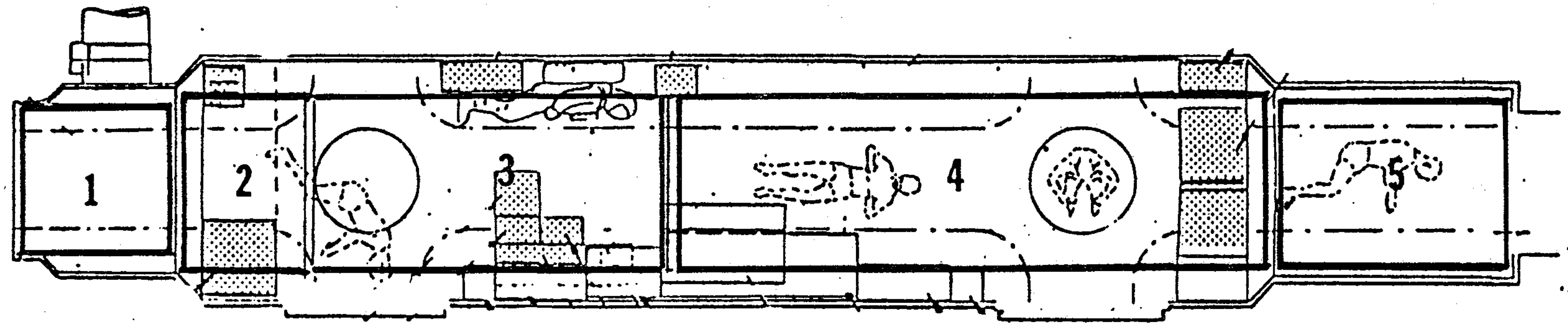


Figure A. Service Module Interior Area Lighting Zones

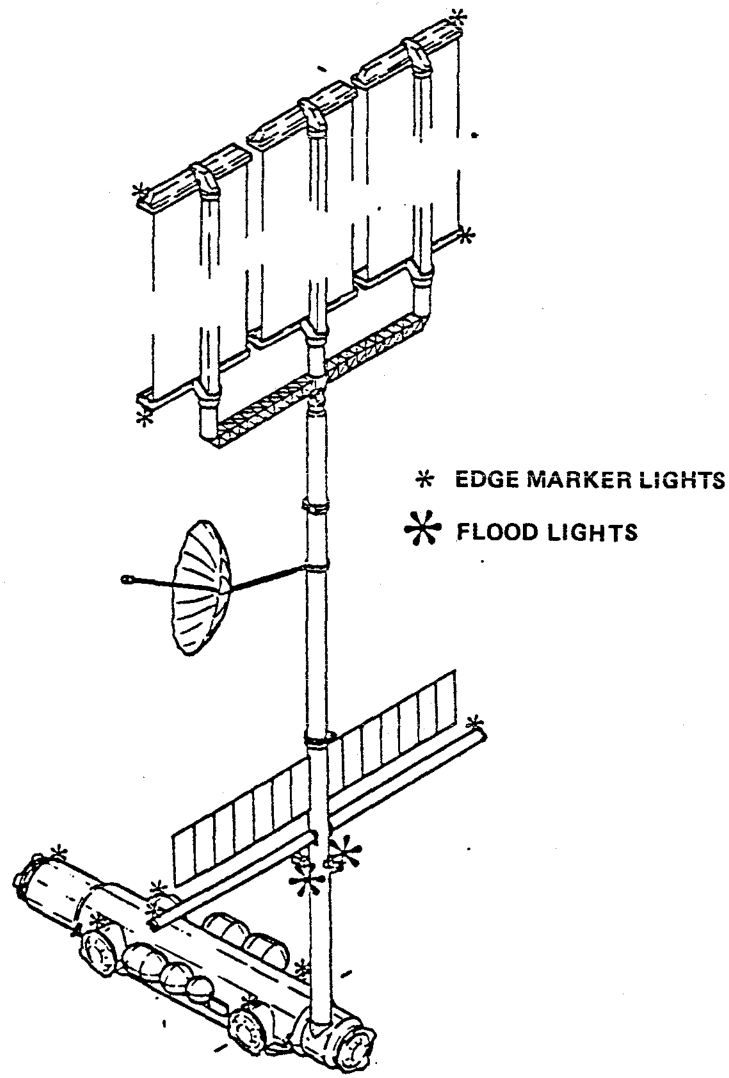


Figure B Service Module Exterior Lighting Concept

WBS 1.2.2.1.13 ENVIRONMENTAL CONTROL/LIFE SUPPORT

(The EC/LSS system elements located in the Service Modules were described in WBS 1.2.1.1.13.)

WBS 1.2.2.2 SERVICE MODULE NO. 2

1.0 WBS Dictionary

This element includes the second Service Module to be installed at the SOC.

2.0 Description

The Service Module No. 2 (SM2) is very similar to SM1. The notable exceptions are 1) it has no auxiliary RCS boom, and 2) it does not include the EC/LSS provisions shown in shading in Figure C of WBS 1.2.2.1.

3.0 Design Basis

This SM2 does not require an auxiliary RCS boom as flight control symmetry is established once this module is attached to the SOC.

The EC/LSS provisions described above are not required in SM2 as they were provided in SM1 only to provide emergency refuge capability in the Initial SOC Configuration. When the Operational SOC Configuration is established, the crew has other places to retreat to in the event a HM has to be evacuated.

4.0 Mass

Refer to Table A.

TABLE A

WBS 1.2.2.2 SERVICE MODULE NO. 2

MASS STATEMENT

o WBS 1.2.2.1 Service Module No. 1		22047 kg	
o Less Special Provisions for Early Habitability			
o Water Pump	15 kg		
o Control/Display Console	175		
o Dehumidifier	39		
o Waste Water Tanks	23		
o Atmosp. Monitor	23		
o Hot/Cold Water Supply	23		
o Dry John	41		
o Backpack Recharge Unit	27		A
o Emer CO2 Removal	23		
	389 kg		
o Net Mass for SM-2		21658 kg	

WBS 1.2.2.3 DOCKING TUNNEL

1.0 WBS Dictionary

This element is a pressurized module that bridges between the 2 Habitat Modules on the ends opposite the Service Modules. (Note—This module may be referred to as the Docking Module (DM) in some places. The preferred nomenclature is the Docking Tunnel.)

2.0 Description

The Docking Tunnel (DT) is shown in Figure A. The DT provides the following:

- Provides IVA path between HAB modules
- Provides 2 Orbiter docking locations
- Provides structural "backbone" for tracks and piers
- Provides 7 Berthing Ports
  - Two for HAB modules
  - Three for mission hardware
  - One for an airlock module
  - One for undesignated functions
- Provides location for IVA bench test facility
- Provides two umbilical attachment stations
- Provides cherrypicker recharge station
- Provides two portable external lighting stations

3.0 Design Basis

The DT design evolved from the tunnel originally shown in the NASA reference SOC concept (refer to NASA-3). As the SOC concept evolved, it became apparent that it would be advantageous to spread out the operational areas (flight support, construction, satellite servicing) as the mission model indicated the requirement to perform many of the missions in parallel. The DT was created to provide another operational work area in addition to that work area provided in and around the SM's.

SOC-918

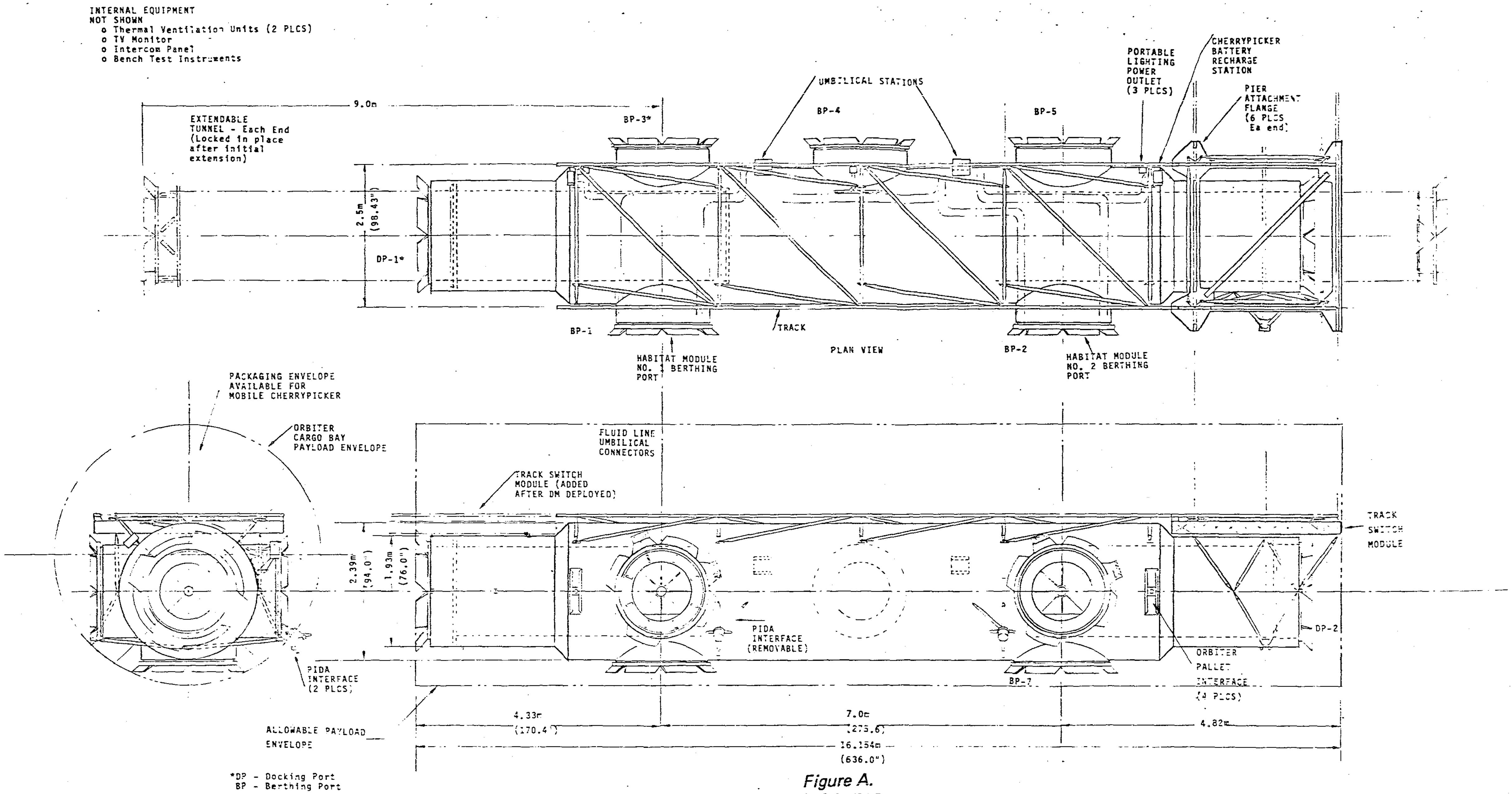


Figure A.
DOCKING MODULE
(PACKAGED CONFIGURATION)

This Page Intentionally Left Blank

The DT is equipped with several berthing ports and 2 more Orbiter docking ports. The berthing ports would be used for mounting mission hardware and support equipment in addition to providing the interfaces to the HM's.

The docking ports are installed on the ends of the telescoping sections. This telescoping was required to configure the DT to fit within the Orbiter cargo bay. The extra length was necessary to get the Orbiter docking interface as far outboard as possible to prevent interference between the SOC elements and the Orbiter.

4.0 Mass

The Docking Tunnel mass statement is given in Table A.

Table A — Docking Tunnel Mass Statement

IN-DEX #	IN-DENT #	WBS #	TITLE	MASS KG(LB)	OFFSETS,M(FT) X	Y	Z	RATIONALE FOR ESTIMATE
1	1	1.2.2.1	DOCKING TUNNEL	7950	6.8	0	-.1	SUM
				(17489	20.3	0	-.2)	
2	2	1.2.2.1.1	STRUCTURES	4686	6.7	0	-.1	SUM
				(10331	18.6	0	-.2)	
3	3	1.2.2.1.1.1	PRESSURE MEMBRAN	3323	6.5	0	-.1	SUM
				(7326	16.3	0	-.2)	
4	4	1.2.2.1.1.1.1	LARGE CYLINDER	1882	5.9	0	0	- D=2.38M - L=10.3M - THICKNESS=1CM - 6 CUTOUTS 1.53M DIA - A CYL-A CUT = 66M2 - 2219 ALUMINUM - 1% FOR WELDS, WELD LANDS, AND TOLERANCES
				(4149	19.5	0	0)	
5	4	1.2.2.1.1.1.2	SMALL CYLINDERS	604	9.4	0	0	- D=1.93M - L FOR THE TWO CYL = 3.5 M - AREA = 21.2M2 TOTAL - ALLOY & ALLOWANCES PER ABOVE
				(1332	2.6	0	0)	
6	4	1.2.2.1.1.1.3	STUB CYLINDERS	55	7	0	0	- D=1.53M - L=0.2M - S=0.96M2 EACH - 2 CYL, ONE EACH END
				(121	22.9	0	0)	
7	4	1.2.2.1.1.1.4	LARGE CONE SEC	129	7	0	0	- DMAX=2.38M - DMIN=1.93M - H = 0.25M - AREA = 2.27M EACH CONE (2 TOTAL)
				(284	22.9	0	0)	

Table A — Docking Tunnel Mass Statement (Continued)

IN-DEX #	IN-DENT #	WBS #	TITLE	MASS KG(LB)	OFFSETS,M(FT) X	Y	Z	RATIONALE FOR ESTIMATE
8	4	1.2.2.1.1.1.5	SMALL CONE SEC	78	7	0	0	- DMAX=1.93M - DMIN=1.53M - H = 0.2M - AREA = 1.39M2 EACH CONE (2 TOTAL)
				(172	22.9	0	0)	
9	4	1.2.2.1.1.1.6	SHORT LATERAL EX	57	5.2	0	-1	- DOCKING/BERTHING PORT SUPPORT - D=1.53M - L = 0.3M - AREA = 1.0M2 EACH - 2 TOTAL
				(126	17.2	0	-3.3)	
10	4	1.2.2.1.1.1.7	LONG LATERAL EXT	278	5.2	0	0	- BERTHING PORT SUPPORTS - SIMILAR TO SHORT EXT - S=2.44M2 EACH - 6 TOTAL
				(613	17.2	0	0)	
11	4	1.2.2.1.1.1.8	PORT PARTIAL CLD	240	5.2	0	-.5	- DMAX=1.53M - DMIN=1.0M - S=1.05M2 - 8 TOTAL
				(529	17.2	0	-1.7)	
12	3	1.2.2.1.1.2	RING FRAMES	50	7.5	0	0	- 8 IN LARGE CYL - 2 IN SMALL CYL - DEPTH=0.076M - X-SEC AREA=2.58CM2 - 2219 ALUM
				(110	24.6	0	0)	

Table A — Docking Tunnel Mass Statement (Continued)

IN-DEX #	IN-DENT #	WBS #	TITLE	MASS KG(LB)	OFFSETS,M(FT) X	Y	Z	RATIONALE FOR ESTIMATE
13	3	1.2.2.1.1.3	MAIN SUP RINGS	52	7.5	0	0	- DEPTH=0.1M - X-SEC-AREA = 12.9 CM2 - 2219 ALUM
			(	115	24.6	0	0)	
14	3	1.2.2.1.1.4	MAIN SUP TRUNION	45	3	0	0	- 2 SIDE FTGS - 1 KEEL FTG - FWD Y-Z LOADS & - TORSION TITANIUM
			(	99	9.8	0	0)	
15	3	1.2.2.1.1.5	MAIN SUP TRUNION	91	10	0	0	- 2 SIDE FTGS - X LOADS & AFT Y-Z LOADS - TITANIUM
			(	201	32.8	0	0)	
16	3	1.2.2.1.1.6	MAIN SUP SKIN DB	113	10	0	0	INSUFFICIENT SPACE TO LOCATE LONGERONS; MUST HEAVILY REINFORCE MEMBRANE IN REGION OF AFT SUPT TRUNNIONS
			(	249	32.8	0	0)	
17	3	1.2.2.1.1.7	ENTRY HATCH & ME	454	7	0	0	ORBITER AIRLOCK HATCH & MECHANISM
			(	1001	22.9	0	0)	
18	3	1.2.2.1.1.8	ENTRY HATCH FRAM	327	7	0	0	ESTIMATE
			(	721	22.9	0	0)	
19	3	1.2.2.1.1.9	INTERNAL RAILS	45	7	0	0	ESTIMATE
			(	99	22.9	0	0)	
20	3	1.2.2.1.1.10	EXTERNAL RAILS	91	7	0	0	ESTIMATE
			(	201	22.9	0	0)	

Table A — Docking Tunnel Mass Statement (Continued)

IN-DEX #	IN-DENT #	WBS #	TITLE	MASS KG(LB)	OFFSETS,M(FT) X	Y	Z	RATIONALE FOR ESTIMATE
21	3	1.2.2.1.1.11	EC/LSS DUCTING	27	7.5	0	0	ESTIMATE
				(60	24.6	0	0)	
22	3	1.2.2.1.1.12	MISC SEC STRUC	68	7.5	0	0	ESTIMATE
				(150	24.6	0	0)	
23	2	1.2.2.1.2	MECHANISMS	544	7	0	-.5	SUM
				(1199	22.9	0	-1.7)	
24	3	1.2.2.1.2.1	UNIV BERTH PORTS	544	7	0	-.5	- ESTIMATED 60% OF DOCKING PORT - 8 PORTS TOTAL
				(1199	22.9	0	-1.7)	
25	2	1.2.2.1.3	THERMAL CONTROL	23	7	0	0	SUM
				(51	22.9	0	0)	
26	3	1.2.2.1.3.1	THERMAL COATINGS	23	7	0	0	ESTIMATE
				(51	22.9	0	0)	
27	2	1.2.2.1.4	ELECTRICAL POWER	610	6.9	0	0	SUM
				(1345	22.6	0	0)	
28	3	1.2.2.1.4.1	BUSSING	100	7	0	0	- HALF OF SERVICE MODULE BUSSING - DOCKING TUNNEL NEEDS BUSSING FOR BERTHING PORT SERVICES
				(220	22.9	0	0)	
29	3	1.2.2.1.4.2	HARNESSES	200	7	0	0	40% OF SERVICE MODULE
				(441	22.9	0	0)	
30	3	1.2.2.1.4.3	LIGHTS	200	7	0	0	THIS IS A ROUGH GUESS FOR MISCELLANEOUS ELECTRICAL EQUIPMENT
				(441	22.9	0	0)	
31	3	1.2.2.1.4.4	INTERIOR LIGHTS	60	7	0	0	SAME AS SERVICE MODULE
				(132	22.9	0	0)	

Table A — Docking Tunnel Mass Statement (Continued)

IN-DEX #	IN-DENT #	WBS #	TITLE	MASS KG(LB)	OFFSETS,M(FT) X	Y	Z	RATIONALE FOR ESTIMATE
32	3	1.2.2.1.4.5	EMERGENCY BATTER	50	6	0	0	EACH MODULE INCLUDES EMERGENCY POWER TO KEEP DATA & LIGHTS RUNNING IF THERE IS A MAIN POWER FAILURE
				(110	19.6	0	0)	
33	2	1.2.2.1.5	TRACKING & COMM	83	7	0	0	SUM
				(183	22.9	0	0)	
34	3	1.2.2.1.5.1	INTRA-SOC COM	25	7	0	0	SUM
				(55	22.9	0	0)	
35	4	1.2.2.1.5.1.1	VOICE TERMINALS	5	7	0	0	SIMILAR TO HAB MODULE
				(11	22.9	0	0)	
36	4	1.2.2.1.5.1.2	C & W SENSORS	20	7	0	0	SIMILAR TO HAB MODULE
				(44	22.9	0	0)	
37	3	1.2.2.1.5.2	C & T SUPPORT	58	7	0	0	SUM
				(128	22.9	0	0)	
38	4	1.2.2.1.5.2.1	TV CAMERAS	20	7	0	0	CONSISTENT WITH HAB MODULE
				(44	22.9	0	0)	
39	4	1.2.2.1.5.2.2	DIGITAL PROC	23	7	0	0	SIMILAR TO HAB MODULE
				(51	22.9	0	0)	
40	4	1.2.2.1.5.2.3	CABLING	15	7	0	0	ESTIMATE
				(33	22.9	0	0)	
41	2	1.2.2.1.6	DATA MGMT	150	7	0	0	SUM
				(331	22.9	0	0)	
42	3	1.2.2.1.6.1	CRT'S	40	7	0	0	SAME AS SERVICE MODULE
				(88	22.9	0	0)	
43	3	1.2.2.1.6.2	KEYBOARDS & DISP	20	7	0	0	SAME AS SERVICE MODULE
				(44	22.9	0	0)	
44	3	1.2.2.1.6.3	COMPUTERS	40	7	0	0	2 AT 20 EACH
				(88	22.9	0	0)	

Table A — Docking Tunnel Mass Statement (Continued)

IN-DEX #	IN-DENT #	WBS #	TITLE	MASS KG(LB)	OFFSETS,M(FT) X	Y	Z	RATIONALE FOR ESTIMATE
45	3	1.2.2.1.6.4	WIRING & BUSSING	50	7	0	0	SAME AS SERVICE
				(110	22.9	0	0)	MODULE
46	2	1.2.2.1.7	INSTRUMENTATION	100	7	0	0	ESTIMATE
				(220	22.9	0	0)	
47	2	1.2.2.1.8	EC/LSS	55	7	0	0	SUM
				(121	22.9	0	0)	
48	3	1.2.2.1.8.1	THERMAL VENT PAC	45	7	0	0	- 2 PACKS
				(99	22.9	0	0)	- SAME AS HAB MODULE
49	3	1.2.2.1.8.2	FLUID LINES	10	7	0	0	- ESTIMATE
				(22	22.9	0	0)	- WATER & FREON
50	2	1.2.2.1.9	MISSION EQUIP	724	7	0	0	SUM
				(1559	22.9	0	0)	
51	3	1.2.2.1.9.1	ATMOSPHERE	80	7	0	0	- 1 ATM PRESSURE
				(139	22.9	0	0)	- BASED ON INTERNAL VOLUME
52	3	1.2.2.1.9.2	SPARES	644	7	0	0	- SAME AS SERVICE MODULE
				(1420	22.9	0	0)	- ASSUMES SPARES FOR OTHER MODULES LAUNCHED WITH DM
53	2	1.2.2.1.10	GROWTH	975	7	0	0	33% OF IDENTIFIED DRY
				(2150	22.9	0	0)	MASS EXCLUDING COLLISION SHIELD

WBS 1.2.2.4 AIRLOCK MODULES

A

1.0 WBS Dictionary

This element includes Airlock Module No. 1, Airlock Module No. 2, and the Portable IVA Tunnel.

2.0 Description

These elements are described in the following WBS sub-element descriptions. These modules are located as shown in Figure A.

3.0 Design Basis

The design basis for each of the modules is described in the following WBS sub-element descriptions.

4.0 Mass

The mass of these elements are summarized in Table A.

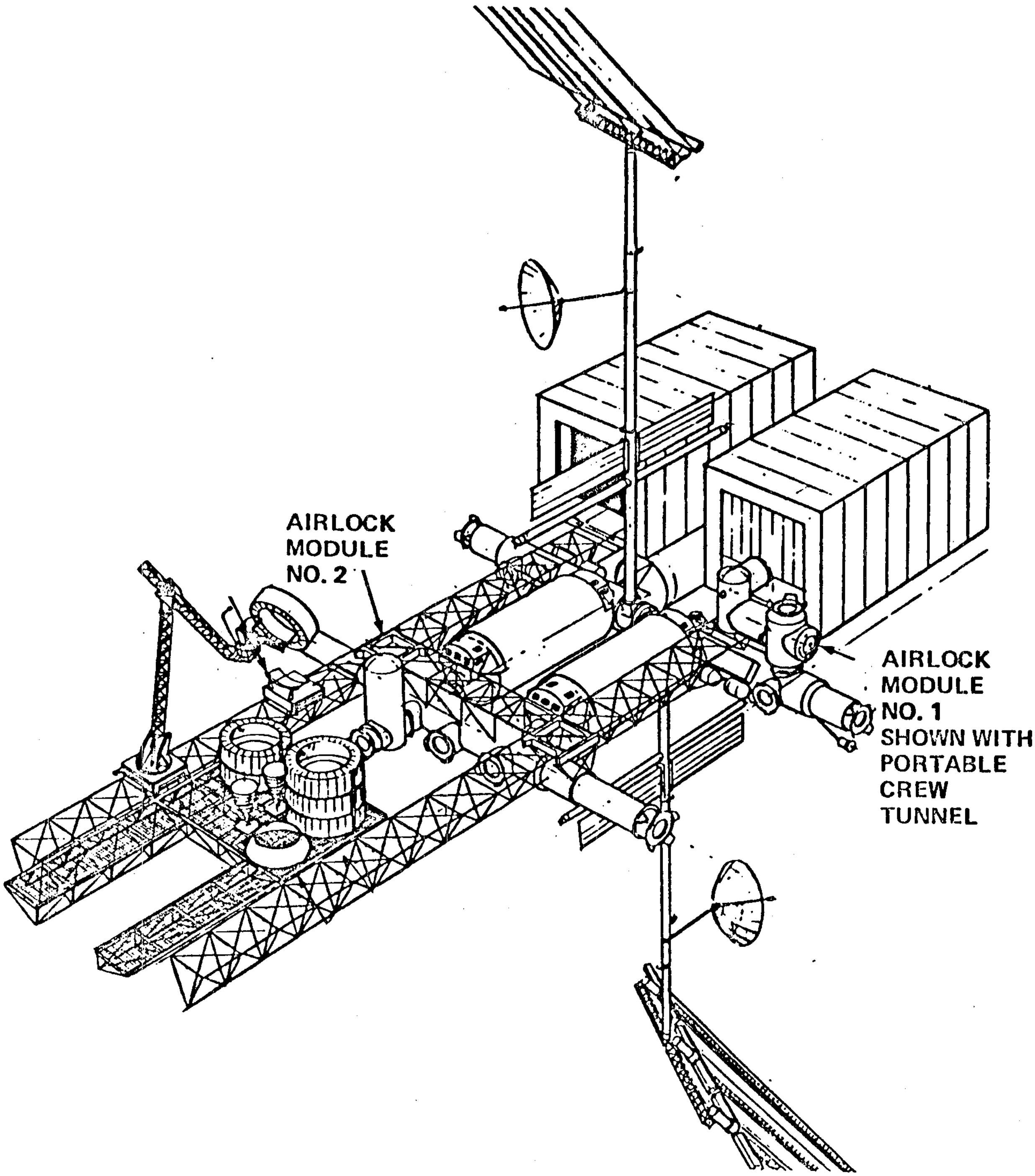


Figure A. Airlock Module Locations on Growth SOC

TABLE A

A

WBS 1.2.2.4 AIRLOCK MODULES MASS SUMMARY

WBS 1.2.2.4.1	Airlock Module No. 1	681 kg each
WBS 1.2.2.4.2	Airlock Module No. 2	920 kg each
WBS 1.2.2.4.3	Portable IVA Tunnel	920 kg each

WBS 1.2.2.4.1 AIRLOCK MODULE NO. 1 A

1.0 WBS Dictionary

This element is an airlock that can be berthed to a Service Module and Habitat A
Module berthing port.

2.0 Description

The Airlock Module No. 1 (AM-1) is shown in Figure A. This airlock has 2 (or 3) A
berthing ports and one docking port. It is sized for occupancy by 2 EVA-suited crewmen. There are airlock pump controls, lighting fixtures and lighting controls, and an intercom located inside the airlock. The pressure vessel is designed for 45 psia so that it can serve as an emergency hypobaric chamber.

There are 2 of the AM-1's in the Initial and Operational SOC configurations. In the A
Initial SOC, one of the AM-1's is berthed to SM-1 and the other to the HM. In the Operational SOC the AM-1's are attached to the SM-1 and to the DT.

In the Growth SOC, only one of these AM-1's is required. It is to be attached to A
the top berthing port on SM-1 as was shown in Figure A in WBS 1.2.2.4.

3.0 Design Basis

In early HM concepts, the airlocks were integral with the HM (an internal airlock). However, for the Initial SOC Configuration, it became necessary to provide an airlock on the SM1 for use in the emergency mode where the HM1 was evacuated. Having created a need for an external airlock, it became advantageous to eliminate the internal airlock, thereby saving considerable interior volume and weight. There was still a requirement for an airlock on the HM1 for use in the event the SM1 were inaccessible. Therefore, a second external airlock was added to the HM1. This airlock will be relocated to one of the DT berthing ports after the DT is installed. The external airlocks can be easily relocated to adapt to changing SOC missions and SOC configurations.

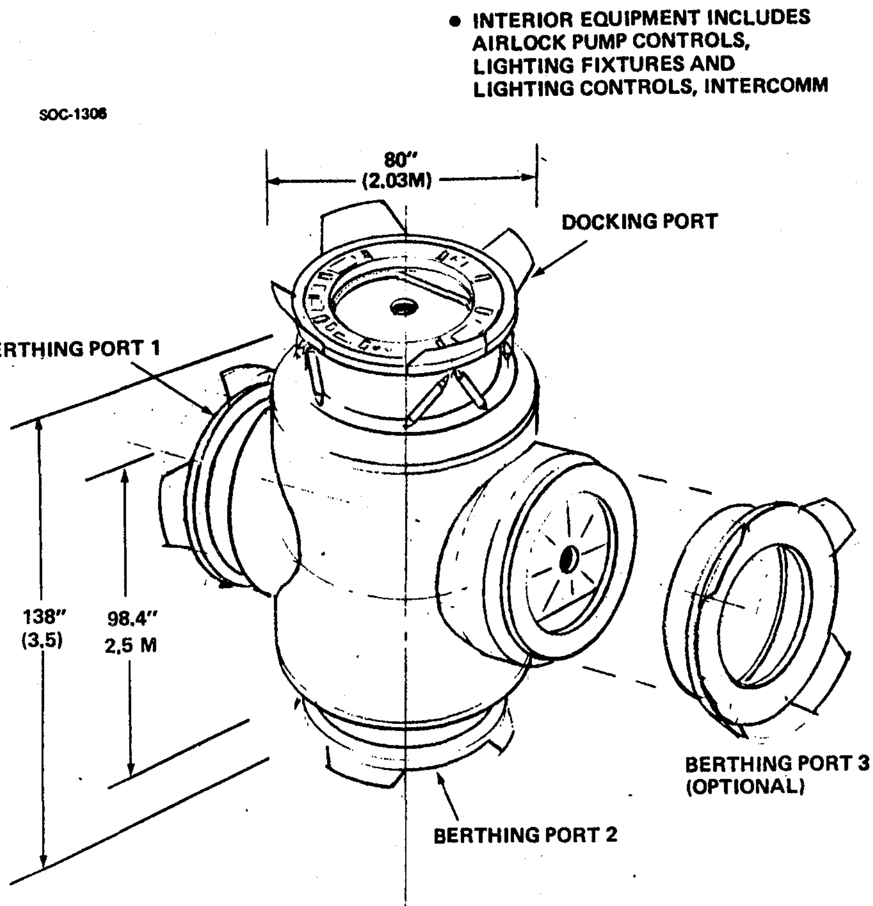


Figure A. Airlock Module No. 1

A docking port was added on the AM so that an alternative Orbiter docking location could be provided in the Initial SOC Configuration. This is required only on the HM1 airlock. It is superfluous on the SM1 airlock but is included to minimize design differences.

This AM-1 is sized in conjunction with the Portable IVA Tunnel (WBS 1.2.2.4.3) to provide the IVA path from SM-1 to the MOTV crew module when the crew module is located in the hangar, see Figure B. A

4.0 Mass

The mass of the AM-1 is estimated to be 681 kg. This is based on 364 kg for Orbiter airlock mass, 113 kg for the docking port, and 68 kg for each of the 3 berthing ports. A

WBS 1.2.2.4.2 AIRLOCK MODULE NO. 2 A

1.0 WBS Dictionary

This element is an airlock module that can be berthed to the Docking Tunnel or Mini-Habitat Module.

2.0 Description

The Airlock Module No. 2 is shown in Figure A. This module has 3 berthing ports. It is sized for occupancy by 2 EVA-suited crewmen. There are airlock pump controls, lighting fixtures and controls, and an intercom located inside the module.

This module is used in the Growth SOC Configuration only. It is located as was shown in Figure A of WBS 1.2.2.4. The Portable IVA Tunnel (WBS 1.2.2.4.3) can be berthed to Berthing Port 1.

3.0 Design Basis

This airlock module configuration resulted from the MOTV operations analysis described in Section 7.4 of Boeing - 33. This module is used in conjunction with the Portable IVA Tunnel to provide a IVA path between the SOC and the MOTV Crew Module when the MOTV is located on the Flight Support Facility pier.

4.0 Mass

The mass of AM-2 is estimated to be 920 kg. This is based on 2 times the Orbiter airlock mass, (2 x 364 kg), and 3 berthing ports (3 x 64 kg).

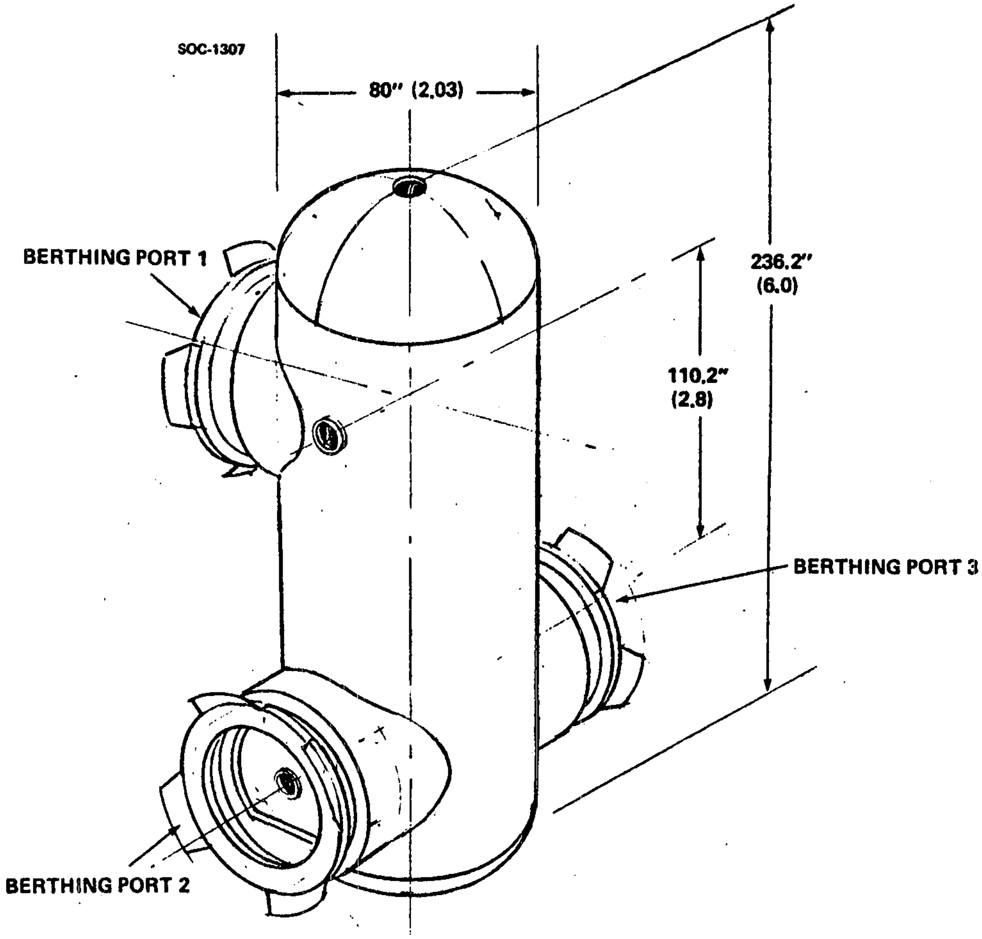


Figure A. Airlock Module No. 2

WBS 1.2.2.4.3 PORTABLE IVA TUNNEL

A

1.0 WBS Dictionary

This element is a portable IVA tunnel that can be berthed to the AM-1 and AM-2.

2.0 Description

The Portable IVA Tunnel (PIT) is shown in Figure A. This PIT can be moved and berthed to AM-1 and AM-2 depending upon the location of the MOTV crew module.

3.0 Design Basis

This module configuration resulted from the MOTV operations analysis described in Section 7.4 of Boeing -33. In conjunction with AM-1 and AM-2, it provides the IVA path to the MOTV crew module when the crew module is located in the Hangar or on the Flight Support facility pier.

This portable tunnel was selected over an option where articulated tunnels would be used. Due to the location of the berthing port on the nose of the MOTV Crew Module, it was necessary to find a way to move the tunnel out of the way so the Crew Module could be moved on the tracks. The articulated tunnel would have required rotary joints that would be potential sources of leakage.

4.0 Mass

The mass of the PIT is estimated to be 920 kg. This is based on its dimensions being similar to the AM-2.

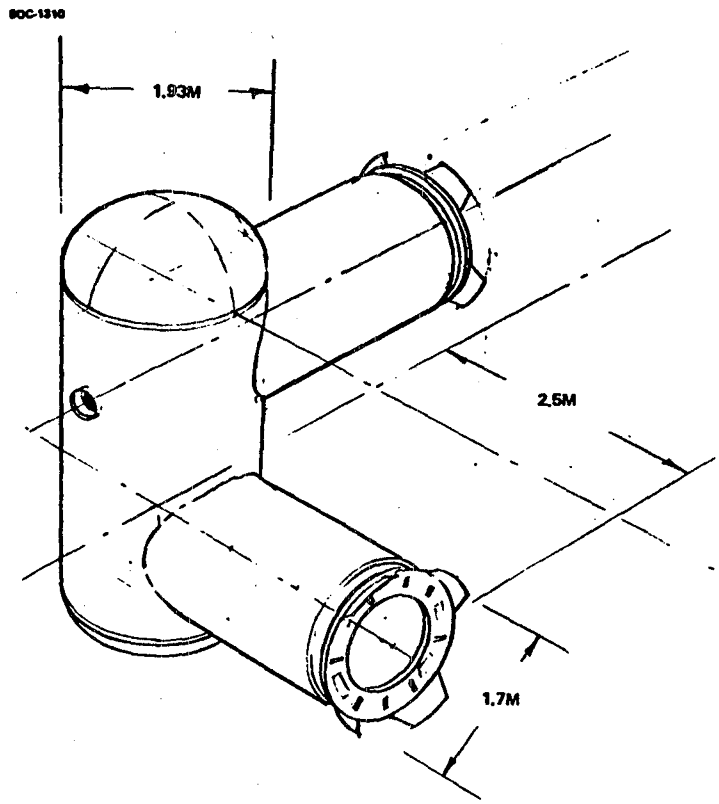


Figure A. Portable IVA Tunnel

End of Document