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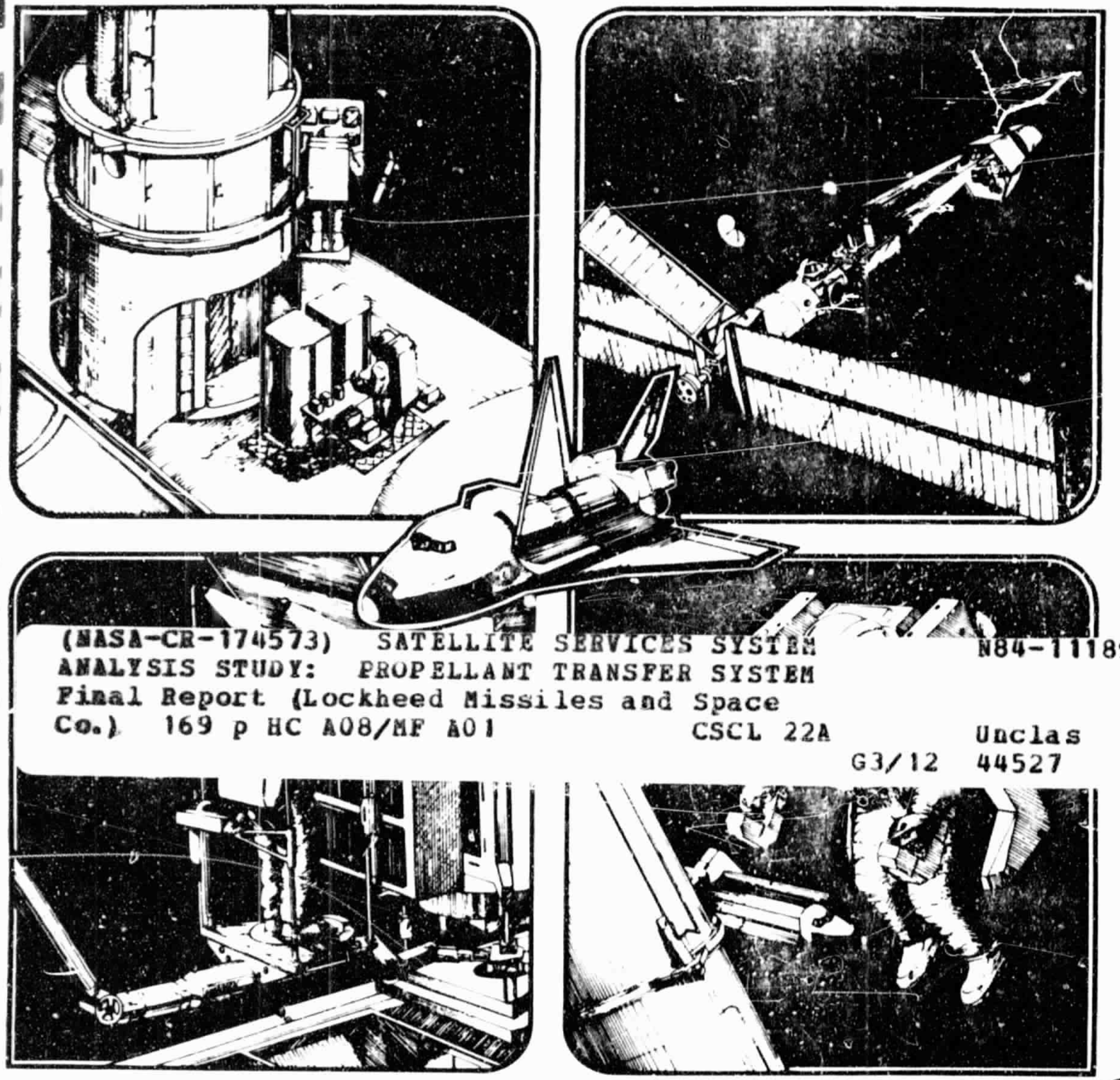

(NASA-CR-174573) SATELLITE SERVICES SYSTEM ANALYSIS STUDY: PROPELLANT TRANSFER SYSTEM Final Report (Lockheed Missiles and Space Co.) 169 p HC A08/MF A01 CSCL 22A

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SATELLITE SERVICES SYSTEM ANALYSIS STUDY

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FINAL REPORT

PROPELLANT TRANSFER SYSTEM

CONTRACT NAS 9-16121

AUGUST 1982

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NASA JOHNSON SPACE CENTER

Lockheed

LOCKHEED MISSILES & SPACE COMPANY, INC. SUNNYVALE, CALIFORNIA

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SATELLITE SERVICES SYSTEM ANALYSIS STUDY

FINAL REPORT
PROPELLANT TRANSFER SYSTEM

PRESENTED BY
LOCKHEED MISSILES & SPACE COMPANY, INC.
SUNNYVALE, CALIFORNIA

FOR

JOHNSON SPACE CENTER
HOUSTON, TEXAS

CONTRACT NAS 9-16121
AUGUST 1982

FOREWORD

THE FINAL REPORT ON THE PROPELLANT TRANSFER SYSTEM OF THE SATELLITE SERVICES SYSTEM ANALYSIS STUDY, NAS 9-16121 WILL BE FOUND IN TWO PARTS.

THIS UNCLASSIFIED REPORT CONTAINS THE ANALYSIS, TRADEOFFS, DESIGN GUIDE AND WORK BREAKDOWN STRUCTURE.

THE SECRET APPENDIX CONTAINS THE SELECTED BASELINE PTS, SPECIFICATION, WEIGHT STATEMENT, AND SERVICING MISSION SCENARIO.

TABLE OF CONTENTS

SECTION 1.0

INTRODUCTION

INTRODUCTION

THE FOUR STUDY TASKS OF PART IV OF THE SATELLITE SERVICES SYSTEM ANALYSIS STUDY, SATELLITE ON-ORBIT SERVICES, ARE:

1. SERVICING MISSION ANALYSIS
   - IDENTIFY GENERAL SERVICING REQUIREMENTS
   - PREPARE A SERVICING MISSION CONCEPT AND SCENARIO
   - IDENTIFY OVERALL SERVICING NEEDS
   - IDENTIFY BASIC SERVICING EQUIPMENT
   - PREPARE A GENERAL SERVICING MISSION CONFIGURATION LAYOUT
2. PROPELLANT TRANSFER SYSTEM
   - DEFINE SERVICING NEEDS
   - SELECT EQUIPMENT CONCEPTS
   - DEFINE SYSTEM REQUIREMENTS
   - DEFINE EQUIPMENT SPECIFICATIONS
   - DEVELOP PRELIMINARY DESIGNS
   - DEFINE RESOURCE REQUIREMENTS FOR FLIGHT HARDWARE
3. SERVICING DESIGN GUIDE
4. WORK BREAKDOWN STRUCTURE AND DICTIONARY

THESE TASKS ARE FOR A SPECIFIC SATELLITE DESIGNATED BY THE CUSTOMER, ALTHOUGH THE DESIGN IS TO BE USEFUL TO AS MANY SATELLITES AS PRACTICAL.

THE PROPELLANT TRANSFER SYSTEM (PTS) WILL BE CAPABLE OF RESUPPLY X* LBS OF HYDRAZINE AND REPRESSURIZING THE SATELLITE VEHICLE. THIS IS THE PRIMARY TASK.

THE SERVICE DESIGN GUIDE IS COMPILATION OF MODULE AND INTERFACE REQUIREMENTS THAT HAVE BEEN DEVELOPED BY LMSC IN STUDIES AND THE FABRICATION OF HARDWARE FOR OTHER PROGRAMS.

THE WORK BREAKDOWN STRUCTURE FOR THE PROGRAM IS TAILORED FOR THE CUSTOMER'S ON-ORBIT SERVICING SYSTEM THRU LEVEL 4 AND WILL BE ACCOMPANIED BY A WBS DICTIONARY. THE PROPELLANT TRANSFER SYSTEM WBS IS THROUGH LEVEL 7.

* SEE CLASSIFIED APPENDIX

OBJECTIVES AND GUIDELINES

THE PTS WILL BE DESIGNED FOR MAXIMUM FLEXIBILITY AND LOW COST. TO THIS END THE DESIGN OBJECTIVES/GUIDELINES ARE:

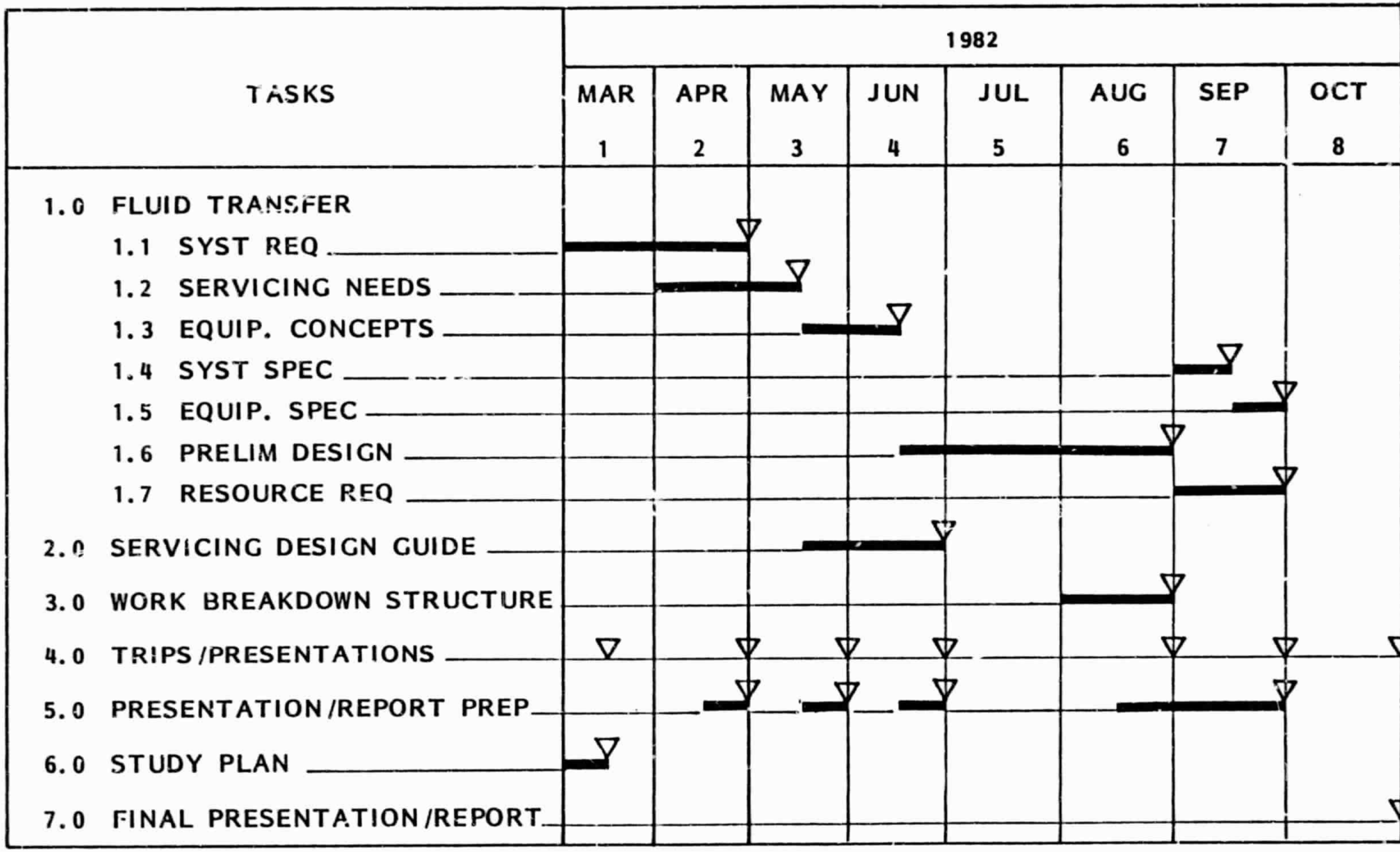
- RESUPPLY OF BI-PROPELLANTS AS WELL AS HYDRAZINE
- WILL BE INCORPORATED INTO A CRADLE THAT CAN SUPPORT THE SV
- USE AS MUCH OFF-THE-SHELF HARDWARE AS POSSIBLE
- HAVE AS LITTLE IMPACT ON THE SV AS POSSIBLE
- MATE/DEMATE FLUID UMBILICAL BY EVA
- SV WILL BE HARD BERTHED TO THE ORBITER
- CREW AND ORBITER SAFETY IS OF PARAMOUNT IMPORTANCE
- THE IDEAL SINGLE LAUNCH SERVICING MISSION WILL BE
    - DEPLOY A SV
    - SERVICE A SV
    - EARTH RETURN OF A SV
- THE COST WILL BE BASED ON A PROTO FLIGHT CONCEPT, ONE SHIP SET IN 1982 DOLLARS, NO PRIME FEE
- TRAINING WILL BE IDENTIFIED BUT NOT COSTED
- HARDWARE GO-AHEAD OCT 1984 WITH DELIVERY OF FLIGHT HARDWARE, 1ST QUARTER OF 1990
- TWO-TWO MAN EVA'S OF 6 HRS EACH

SCHEDULE

THE SATELLITE ON-ORBIT SERVICES STUDY SCHEDULE IS SHOWN ON FACING PAGE.

ALL MAJOR MILESTONES HAVE BEEN MET DURING THIS STUDY.

STUDY SCHEDULE



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SECTION 2.0

ASSUMPTIONS & REQUIREMENTS DEFINITION

ASSUMPTIONS

THE FACING PAGE PRESENTS THE BASIC LIST OF ASSUMPTIONS MADE DURING THE COURSE OF THE STUDY. CLOSE PROXIMITY OF THE SPACECRAFT TO THE PROPELLANT TRANSFER SYSTEM IS HIGHLY DESIRABLE AND, AS SUCH, IT WAS ASSUMED THAT THE X_o STATION LOCATION COULD BE MET. CREW OPERATIONAL ASSUMPTIONS APPEAR TO BE IN-LINE WITH STATED ORBITER CREW GUIDELINES. LOCATION OF SPACECRAFT UMBILICAL INTERFACES AT THE AFT END OF THE SPACECRAFT SIGNIFICANTLY SIMPLIFIES THE UMBILICAL MATE/DEMATE EFFORT AND INTERFACE. THE ABILITY TO CONDUCT THE BASIC TRANSFER OPERATION FROM THE AFT FLIGHT DECK IS CERTAINLY KEY TO OVERALL SPACECRAFT STATUS MONITORING AS WELL AS PTS STATUS DETERMINATION.

ASSUMPTIONS

A. HPA POSITIONS S/C AT ORBITER COORDINATE X_O 947.5 (NEAR FWD CRADLE) AND VARIATIONS CAN BE MINIMIZED IN S/C RELATIONSHIP TO ORBITER X, Y, & Z COORDINATES

B. A PORTION OF ONE EVA SORTIE (2 CREWMEN EV) CAN BE ALLOCATED TO PTS OPS & I/F WITH S/C

C. CONTINGENCY SITUATION REQUIRING 30 MIN (MAX) FOR PTS EVA 'CLOSEOUT'

D. A MINIMUM OF TWO 2-MAN EVA SORTIES (UP TO 6 HOURS EACH) AVAILABLE

E. ALL S/C UMBILICALS (PROPELLANT) ARE S/C AFT END (TANK AREA) LOCATED

F. PRIMARY PROPELLANT XFER OPS ARE CONDUCTED (IV) FROM THE AFT FLT. DECK

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GENERAL REQUIREMENTS - HIGHLIGHTS

THE FACING PAGE PRESENTS THE GENERAL REQUIREMENTS IN A SYNOPSIZED FORM WITH THE MORE DETAILED REQUIREMENTS PRESENTED IN FOLLOWING PAGES. ADDITIONALLY, A TOP-TIER PTS SPECIFICATION HAS BEEN DEVELOPED WHICH APPEARS IN THE CLASSIFIED APPENDICE TO THIS DOCUMENT.

THE BASIC MISSION OF THE PROPELLANT TRANSFER SYSTEM (PTS) IS TO BE ABLE TO TRANSFER SEVERAL THOUSAND POUNDS OF PROPELLANT FROM THE SERVICE TANKS INTO THE SATELLITE TANKS WHILE ASSURING THERE IS A 350 PSI MINIMUM ULLAGE PRESSURE FOR THE BLOW-DOWN FEED SYSTEM. (SEE ITEM A)

THE PTS IS DESIGNED AS A REMOVABLE MODULE FOR PLACEMENT IN THE FORWARD CARGO BAY OF THE ORBITER. AS SUCH, IT MUST MEET STS SAFETY AND INTERFACE REQUIREMENTS AND NORMAL OPERATING PROCEDURES. (SEE ITEMS B, C, D, H, AND J)

THE SYSTEM MUST BE FLEXIBLE ENOUGH TO SERVICE BOTH MONOPROPELLANT AND BIPROPELLANT SATELLITES WITHOUT MAJOR SYSTEM CHANGES. (SEE ITEMS E AND F)

THE SYSTEM IS DESIGNED WITH A DEFINITE OPERATING SCENARIO IN MIND: THE SATELLITE IS DOCKED AND THE INTERCONNECTS MADE BY AN ASTRONAUT DURING EVA. ONCE CONNECTED, ALL TRANSFER OPERATIONS ARE CONDUCTED FROM THE ORBITER AFT CONTROL PANEL. DISCONNECT HAS TO BE DONE BY AN ASTRONAUT DURING A SUBSEQUENT EVA. (SEE ITEM G)

THE PTS IS CHECKED OUT BEFORE FLIGHT AND REMOVED FOR SERVICING AFTER FLIGHT. THERE ARE NO IN-FLIGHT SERVICEABLE ITEMS. IT CAN BE CLEANED AND REUSED INDEFINITELY. (SEE ITEM I)

PTS REQUIREMENTS

THE FOLLOWING SIX (6) PAGES PRESENT A SYNTHESIZED SET OF BASIC PTS REQUIREMENTS USED IN THE CONDUCT OF THE STUDY. FURTHER, THESE REQUIREMENTS ALSO WERE USED AS THE BASIS FOR DEVELOPMENT OF THE PTS TOP-TIER SPECIFICATION CONTAINED IN THE CLASSIFIED APPENDICE OF THIS DOCUMENT. REQUIREMENTS WERE CATEGORIZED AS FOLLOWS:

A. FORWARD CRADLE WITH PTS

B. SPACECRAFT POSITIONING VIA HPA

C. SPACECRAFT HOLDING

D. PROPELLANT LINE & SIGNAL/POWER UMBILICALS MATE/DEMATE

E. UMBILICAL MOUNTING ON SPACECRAFT - GUIDELINES

F. CREW IVA SUPPORT FROM THE AFT FLIGHT DECK

G. CREW EVA INTERACTION WITH THE PTS

H. CREW WORK STATION GUIDELINES

I. SAFETY

PTS REQUIREMENTS

A. FWD CRADLE WITH PTS

1. AREA ABOVE CRADLE REQD FOR PTS OPS & I/F
    - AFTER S/C DEPLOYMENT
    - DURING SERVICING
    - PRIOR TO S/C INSERTION

2. CRADLE SHALL PROVIDE THE FOLLOWING SUPPORT
    - S/C SUPPORT
    - PTS INSTALLATION
    - CREW WORK STATION SUPPORT
    - PROPELLANT LINE STOWAGE/MGMT
    - PTS EQUIP BAY
    - PLUMBING/CABLING

B. S/C POSITIONING VIA HPA

1. PROVIDES S/C POSITIONING ADJACENT TO STARBOARD ORBITER SILL NEAR FWD CRADLE WITH SOME SLIGHT Z_o ADJUSTMENT

2. PROVIDES S/C ROTATION TO BRING UMBILICAL WORK SITE TO RESTRAINED CREW-MAN

C. S/C HOLDING

1. HFA-S/C WILL TAKE CREW EVA INDUCED LOADS OF ~100 LBS AT A POINT I/F

2. HPA MAINTAINS S/C TO WITHIN A ±3 INCHES SPHERICAL ENVELOPE IN X, Y, &Z COOR-DINATES

PTS REQUIREMENTS (Cont'd)

D. PROPELLANT LINE & SIGNAL/POWER UMBILICALS MATE/DEMATE

1. CREW EVA MANUAL MATE/DEMATE OF UMBILICALS - PROPELLANT/PRESSURANT
   - FOUR (4) UMBILICALS

2. CREW EVA MANUAL MATE/DEMATE OF SIGNAL/POWER UMBILICAL
   - CREWMAN MATES SIGNAL/POWER UMBILICAL ON 1ST EVA
   - CREWMAN DEMATES SIGNAL/POWER UMBILICAL AT END OF 2ND EVA

3. MATE/DEMATE SEQUENCE
   - CREWMAN MATES & DEMATES UMBILICALS ON 1ST EVA
     √PROPELLANT XFER PLANNED FOR 1ST EVA
   - EMERGENCY DEMATE ACCOMPLISHED BY EVA CREWMAN PRIOR TO A/L INGRESS
     √AUTO (ELECTRO/MECHANICAL) KEMATE IS OPTION (KIT)

E. UMBILICAL MOUNTING ON S/C-GUIDELINES

1. AT ONE OF TWO CANDIDATE LOCATIONS
   - BETWEEN TANKS AT MID-LINE
   - AT/ADJACENT TO NOZZLE MOUNT STANDOFF

2. FOUR (4) UMBILICALS AT CANDIDATE LOCATION(S)
   - ADEQUATE INSTALLATION AREA
   - ADEQUATE CREW ACCESS
     √ANTHROPOMETRIC USE/ACCESS ENVELOPES
     √SWEPT TOOL VOLUME ENVELOPE
   - INSTALLATION AREA REQD FOR UMBILICAL ENGAGE, GUIDE & 'MECHANICAL ADVANTAGE' DEVICE

PTS REQUIREMENTS (Cont'd)

F. CREW IVA SUPPORT FROM AFT FLIGHT DECK
   1. PROPELLANT XFER OPS/MANAGEMENT
   2. OVERRIDE AND/OR RECONFIGURATION
   3. CRITICAL/UNSCHEDULED EVENT DECISION MAKING

G. CREW EVA INTERACTION WITH PTS
   1. PROPELLANT LINE MGMT
   2. ELECTRICAL/SIGNAL CABLE LINE MGMT
   3. UMBILICAL MATE/DEMATE - PROPELLANT & SIGNAL/PWR
   4. VALVE OVERRIDE
   5. PRESSURE/TEMP INDICATOR OBSERVATION
   6. CREW WORK STATION SET-UP/TEAR-DOWN
   7. EMERGENCY LEAK FIX
   8. AID IN CONTINGENCY JETTISON
   9. MONITOR PRESSURANT/FUEL VENT

PTS REQUIREMENTS (Cont'd)

H. CREW WORK STATION GUIDELINES

1. CREW WORK STATION SHALL INCORPORATE THE FOLLOWING CAPABILITY:
   - FOOT RESTRAINT INTERFACES
   - PROPELLANT/PRESSURANT LINE MGMT I/F & HANDLING FEATURES
   - PERSONNEL & EQUIPMENT TETHERING
   - TOOL MGMT & STOWAGE
2. CREW WORK STATION LOCATION
   - DESIGN & LAYOUT SHALL BE COMPATIBLE WITH 2 CANDIDATE LOCATIONS
     - √BRIDGE FITTING MTD TO ORBITER SILL
     - √FITTINGS ON FWD CRADLE
3. CREW WORK STATION SHALL BE COMPATIBLE WITH:
   - 5TH TO 95TH %TILE ASTRONAUT/MSE MALE POPULATION
   - ANTHROPOMETRIC LIMB/BODY MOTIONS
   - CREW LIMB (ARM/HAND) & TOOL SWEPT MOTION ENVELOPES
4. WHEREVER PRACTICAL, MINIMUM ORBITER INTERFACES SHALL BE REQD

PTS REQUIREMENTS (Cont'd)

I. SAFETY

1. LEAK DETECTION SHALL BE INCORPORATED IN BOTH THE PTS & S/C
2. VENT & /OR RELIEF DEVICES SHALL BE INCORPORATED IN BOTH THE PTS & S/C SUBSYSTEMS TO PRECLUDE POTENTIAL TANK EXPLOSION OR EXCESSIVE PRESSURE BUILD-UP
3. ALL CONTAMINANT & CHEMICALLY DANGEROUS (CREW/ORBITER/SPACECRAFT) FLOW LINES, VALVES, SOURCES, VENTS, RELIEF VALVES, ETC. SHALL BE CODED, LABELED, FLAGED, ETC.
4. EVA CREW OPERATED CRITICAL OVERRIDE VALVES, VENTS, OR OTHER DEVICES SHALL BE PROVIDED ON PTS SYSTEM
5. DESIGN OF THE PTS SHALL PRECLUDE POTENTIAL FOR TWO SEPARATE FUELS COMING INTO CONTACT THEREBY POSSIBLY CREATING A HYPERGOLIC REACTION
6. VENTING OF LIQUIDS (e.g., FUEL) & PRESSURANTS, IF NOMINALLY REQD, SHALL:
   - BE OUTBOARD OF THE CARGO BAY
   - ANY VENTING IMPULSES SHALL BE MINIMIZED
   - PRECLUDE POTENTIAL ASSOCIATED CLOSE PROXIMITY OF FUELS WHICH COULD BE HYPERGOLIC
   - NOT BE IN THE DIRECTION OF ANY CREW ACTIVITY AREA
     - √DIRECTLY ON SUITED CREWMEMBER
     - √ON SURFACES WITH WHICH THE CREW MEMBER MAY CONTACT

PTS REQUIREMENTS (Cont'd)

I. SAFETY (CONTINUED)

7. PTS & S/C TO ORBITER ELECTRICAL GROUNDING SHALL BE ACHIEVED PRIOR TO PTS OPS

8. POWER SOURCE INPUTS TO THE PTS & S/C FROM THE ORBITER OR ASE SHALL BE DESIGNED OR INCORPORATE FEATURES TO PRECLUDE POWER SURGES

9. PTS OPERATIONS

   - AFT FLIGHT DECK OR CARGO BAY LOCATED 'CRITICAL' CONTROLS (e.g., VALVES) SHALL:
     - √BE CODED WITH A MINIMUM OF 2 TECHNIQUES
     - √INCORPORATE 'LOCK-OUT' PROVISIONS FOR POTENTIAL HAZARDOUS SEQUENCING
   - PROPELLANT XFER SHALL NOT BE CONDUCTED WITHOUT A CREW EV OR IN-SUITS (STANDBY)
   - PROPELLANT XFER SHALL NOT BE CONDUCTED WITHOUT AN OPERABLE RMS
   - PROPELLANT XFER SHALL NOT BE CONDUCTED WITHOUT A MINIMALLY REQD STATUS OF S/C PROP SYSTEM
   - EVA CREWMEMBERS SHALL HAVE A DIRECT & UNOBSTRUCTED PATH TO/FROM PTS - S/C DURING PROPELLANT TRANSFER

PTS UMBILICAL DERIVED REQUIREMENTS

THE FOLLOWING 3 PAGES PRESENT THE DERIVED REQUIREMENTS FOR THE PTS UMBILICAL - ASE & S/C SIDES. PRIMARY DRIVERS ARE ASSOCIATED WITH AN UMBILICAL THAT WOULD BE MANUALLY MATED/DEMATED IN THE EVA MODE. ADDITIONALLY, MINIMUM LEAKAGE ALSO BECAME A MAJOR DRIVER.

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DERIVED REQUIREMENTS

1. UTILIZE OFF-SHELF HDWR. IF PRACTICAL
2. EMPLOY EXISTING TECHNOLOGY WHERE APPLICABLE
3. SAFETY SHALL BE A PRIME CONSIDERATION
4. REMOTE UMBILICAL MATE/DEMATE OPERATIONS WOULD INCLUDE (IF SELECTED) SUPPORT OF:
   - INITIAL S/C BERTHING AND UMBILICAL MATE
   - NOMINAL UMBILICAL DEMATE AFTER PTS FUEL TRANSFER
   - CONTINGENCY DEMATE
5. MANUAL EVA UMBILICAL MATE/DEMATE WOULD INCLUDE (IF SELECTED) SUPPORT OF:
   - INITIAL S/C BERTHING AND SUBSEQUENT UMBILICAL MATE
   - NOMINAL UMBILICAL DEMATE AFTER PTS FUEL TRANSFER
   - CONTINGENCY DEMATE
6. MANUAL EVA UMBILICAL MATE/DEMATE WOULD INCLUDE PROVISIONS FOR:
   - 5TH %TILE TO 95TH %TILE FLIGHT CREW RANGE
     - √MALE AND FEMALE (?)
     - √ANTHROPOMETRICS
     - √FORCE APPLICATION

DERIVED REQUIREMENTS (CONTINUED)

7. UMBILICAL UNIT SHALL BE LOCATED/POSITIONED TO PERMIT EVA ACCESS
8. AFT FLT. DECK CMD/MONITOR PANEL (OR SUB-PANEL) PROVIDED FOR IVA REMOTE MATE/DEMATE OF UMBILICAL
   - LEAK INTEGRITY VERIFICATION OF I/F SEAL BETWEEN THE 2 DISCONNECT HALVES
   - FUEL LEAKAGE WARNING
   - BITE AND ASSOCIATED CONTROLS/CIRCUITRY TO CORRECT HAZARDOUS SITUATION
9. PROVISIONS FOR PREVENTING AND/OR MINIMIZING 'SIGNIFICANT' FUEL OR GAS LEAKAGE INTO CARGO-BAY OR CONTACTING SUITED CREWPERSON
10. MATE/DEMATE MECHANISM SHALL BE DESIGNED TO MINIMIZE/ELIMINATE JAMMING DURING NOMINAL MATE/DEMATE ACTUATIONS
11. MAXIMUM REQUIRED MATE/DEMATE MECHANISM STROKE SHALL BE ~3 IN.
12. FINAL MAXIMUM ALLOWABLE OFF-SET SHALL BE ±0.0675
13. MAXIMUM ENGAGE (MATE) AND DISENGAGE (DEMATE) FORCE SHALL BE 260 LB_F AT ~300 PSI
14. MAXIMUM ALLOWABLE ANGULAR MISALIGNMENT SHALL BE ±5°

DERIVED REQUIREMENTS (CONTINUED)

15. INITIAL ALIGNMENT
    - MAXIMUM OFF-SET = 0.75 IN.
    - MAXIMUM ANGULAR MISALIGNMENT = ±6° CONICAL
16. BURST PRESSURES (MINIMUM) SHALL BE AS FOLLOWS:
    - MATED = 1200 PSIG
    - UNMATED = 1200 PSIG
17. LEAKAGE (MAXIMUM) SHALL BE AS FOLLOWS:
    - MATED = 1×10^{-3} CCS GH_e
    - DEMATED = 1×10^{-3} CCS GH_e
18. DEMATE METHOD
    - BREAK-AWAY
    - SELF-SEALING
19. S/C PROPULSTION SYSTEM SIGNALS REQUIRED FOR PTS OPS TO BE SUPPLIED THRU S/C UMBILICAL

DISPLAY AND CONTROL REQUIREMENTS

1. The baseline for operation of the system is to use the Orbiter Aft Control Panel (OPWS). Once the satellite is mated to the Orbiter, the umbilical connections are made, and the vent masts deployed by the astronaut, all subsequent operations are conducted at the Aft Control Panel, except for umbilical demate and vent mast storage.

2. The Service Module Control Panel will have some critical pressure and temperature readouts. It will have a circuit breaker panel providing protection for all valves and control devices.

3. Status lights will be of the type that illuminate an "open" or a "closed" segment. Lights will be on anytime there is power to the PTS, the aft control panel is connected to the PTS, and the respective circuit breaker is in.

4. Emergency operation termination can be provided at the Service Moduel Control Panel by including a single button or guarded switch that could be activated by an astronaut during EVA. Actuation of this switch would remove power from all valves. Since valves return to the closed position when unpowered the system would effectively be shut down but all instrument readings would still be available.

DISPLAY AND CONTROL REQUIREMENTS

I. DISPLAY ITEM	ORBITER AFT CONTROL PANEL		SERVICE MODULE CONTROL PANEL
	REQUIRED	DESIRABLE	
1. Satellite and Transfer System Propellant Tank Pressures, A & B Circuits (1 ea system)	Digital Readouts		'Gauge', Both Circuits
2. Satellite and Transfer System Propellant Tank Temperatures A & B Circuits (1 ea system)		Digital Readouts	
3. Propellant Mass Transfer			
A. "A" Circuit, primary	Digital Readout		
B. "A" Circuit, Secondary		Digital Readout	
C. "B" Circuit, Primary	Digital Readout		
D. "B" Circuit, Secondary		Digital Readout	
4. Propellant Shut-Off Valve Position Indicator			
A. "A" Circuit	Status Light		
B. "B" Circuit	" "		
5. Propellant Connector			
A. "A" Circuit	Status Light		
B. "B" Circuit	" "		
6. Pressurant Tank Pressure	Digital Readout		'Gauge'
7. Pressurant Tank Temperature	Digital Readout		'Gauge'
8. Pressurant Regulator Outlet Pressure			
A. "A" Circuit	Digital Readout		
B. "B" Circuit	" "		

DISPLAY AND CONTROL REQUIREMENTS (Cont'd.)

Interconnect Position - The final design of the interconnect will determine the number and kind of status lights needed. The assumption is that a "connected" or "open" status light will suffice. This may be backed up with a leak check system which would fill the lines with pressurant gas, hold to check pressure stability, and then vent the lines to vacuum before propellant transfer.

Satellite Valve Position - The number of satellite valves that need to be statused is eight for the baseline satellite system. Additional valve and instrumentation indicator space should be included on the control board to accommodate other satellites and later changes.

DISPLAY AND CONTROL REQUIREMENTS (Cont'd.)

I. DISPLAY ITEM	ORBITER AFT CONTROL PANEL		SERVICE MODULE CONTROL PANEL
	REQUIRED	DESIRABLE	
9. Pressurant Vent Valve Position Indicators			
A. "A" Circuit		Status Light	
B. "B" Circuit		" "	
10. Pressurant Shut-Off Valve Position Indicators			
A. "A" Circuit	Status Light		
B. "B" Circuit	" "		
11. Pressurant Isolation Valve Position Indicators			
A. "A" Circuit		Status Light	
B. "B" Circuit		" "	
12. Pressurant Connector			
A. "A" Circuit	Status Light		
B. "B" Circuit	" "		
13. Relief Valve Position			
A. "A" Circuit		Status Light	
B. "B" Circuit		" "	
14. Interconnect Position			
A. "A" Circuit	Status Light		
B. "B" Circuit	Status Light		
15. Satellite Valve Position	Status Lights		

DISPLAY AND CONTROL REQUIREMENTS (Cont'd.)

Valve Types - Isolation valves and shut-off valves will be solenoid or spring loaded ball valves that close by spring force when power is interrupted. This is a necessary safety feature since propellant and pressurant transfer require valve closure to stop transfer. The valves also must relieve upstream when all are closed. (To avoid excessive pressure between two closed valves).

Relief valves are automatically resetting type valves that close when pressure is reduced to a value below their operating range. All valves except the manually operated valves and relief valves have a control circuit wired into the Orbiter Aft Control Panel. Power for valve actuation is taken from the PTS Electrical Distribution Bus. Each valve has its own circuit protection in the form of a resettable circuit breaker on the Service Module Control Panel.

DISPLAY AND CONTROL REQUIREMENTS (Cont'd.)

II. CONTROL ITEM	ORBITER AFT CONTROL PANEL		SERVICE MODULE CONTROL PANEL
	REQUIRED	DESIRABLE	
1. Propellant Isolation Valves Control (A&B Circuits)	Switch-Open/Closed Powered Open (2)		
2. Propellant Shut-Off Valves Control (A&B Circuits)	Switch-Open/Closed Powered Open (2)		
3. Propellant Ullage Valves (Total of Seven)			Manually Operated Valves (Closed on Ground)
4. Pressurant Isolation Valves Control (A&B Circuits)	Switch-Open/Closed Powered Open (2)		
5. Pressurant System Inter-connect Valve			Manually Operated Valve (Closed on Ground for Bipropell-ant Otherwise Open)
6. Pressurant Shut-Off Valves Valves (A&B Circuits)	Switch-Open/Closed Powered Open (2)		
7. Vent Line Shut-Off Valve Control (A&B Circuits)	Switch-Open/Closed Powered Open		
8. Satellite Ullage Valve Control (A&B Tanks)	Switch-Open/Closed (8)	pulse to open/pulse to close	
9. Satellite Propellant Valve Control (A&B Tanks)	Switch-Open/Closed (6)	pulse to open/pulse to close	
10. Control Circuit Power	Resettable Circuit Breaker		

DISPLAY AND CONTROL REQUIREMENTS (Cont'd.)

Satellite Valve Controls - The control panel will have a satellite status and control section. Satellite valves will be powered by a separate orbiter electrical bus. Control power is routed to the Orbiter Aft Control Panel.

DISPLAY AND CONTROL REQUIREMENTS (Cont'd.)

II. CONTROL ITEM	ORBITER AFT CONTROL PANEL		SERVICE MODULE CONTROL PANEL
	REQUIRED	DESIRABLE	
11. Panel Lights	Manual Rheostat		
12. Circuit Breaker Panel			Breakers for each Valve, Flowmeter, and Light

SECTION 3.0

ANALYSES & TRADE STUDIES

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CANDIDATE SERVICE SYSTEMS

1. Adiabatic Compression: The satellite propellant tank is refilled through a line to the fluid side of its propellant management device (PMD). The expanded satellite tank ullage bubble is gradually compressed by the incoming propellant until the original pressure is attained (at equilibrium).

2. Shared Ullage: The satellite propellant tank pressurization and outlet ports are connected to the service tank ullage line and the pressure is equalized. Propellant is transferred to the satellite tanks by a pump until the tanks are completely full. Pressurant gas is then transferred to the satellite tanks until the desired mass and pressure are established. Displaced propellant flows back to the service tanks through relief valves pre-set to the desired operating pressure.

3. Vented & Repressurized: The satellite propellant tank ullage gas is vented to space through a vent system. Propellant is transferred to the satellite tanks by the ullage gas pressure in the feed tanks. After the desired quantity is transferred, the satellite ullage is replenished with pressurant from a high pressure storage system to the desired mass and pressure.

4. Drain, Vent, Refill & Repressurize: A variation of the vented and repressurized system to accommodate a satellite propellant tank whose pressurization port may not give access to the ullage bubble. In this case the satellite tank is drained of propellant under its own ullage pressure. The propellant enters a servicing system catch tank. The ullage gas is now vented, and the satellite is serviced using the same procedures as in the vented and repressurized system.

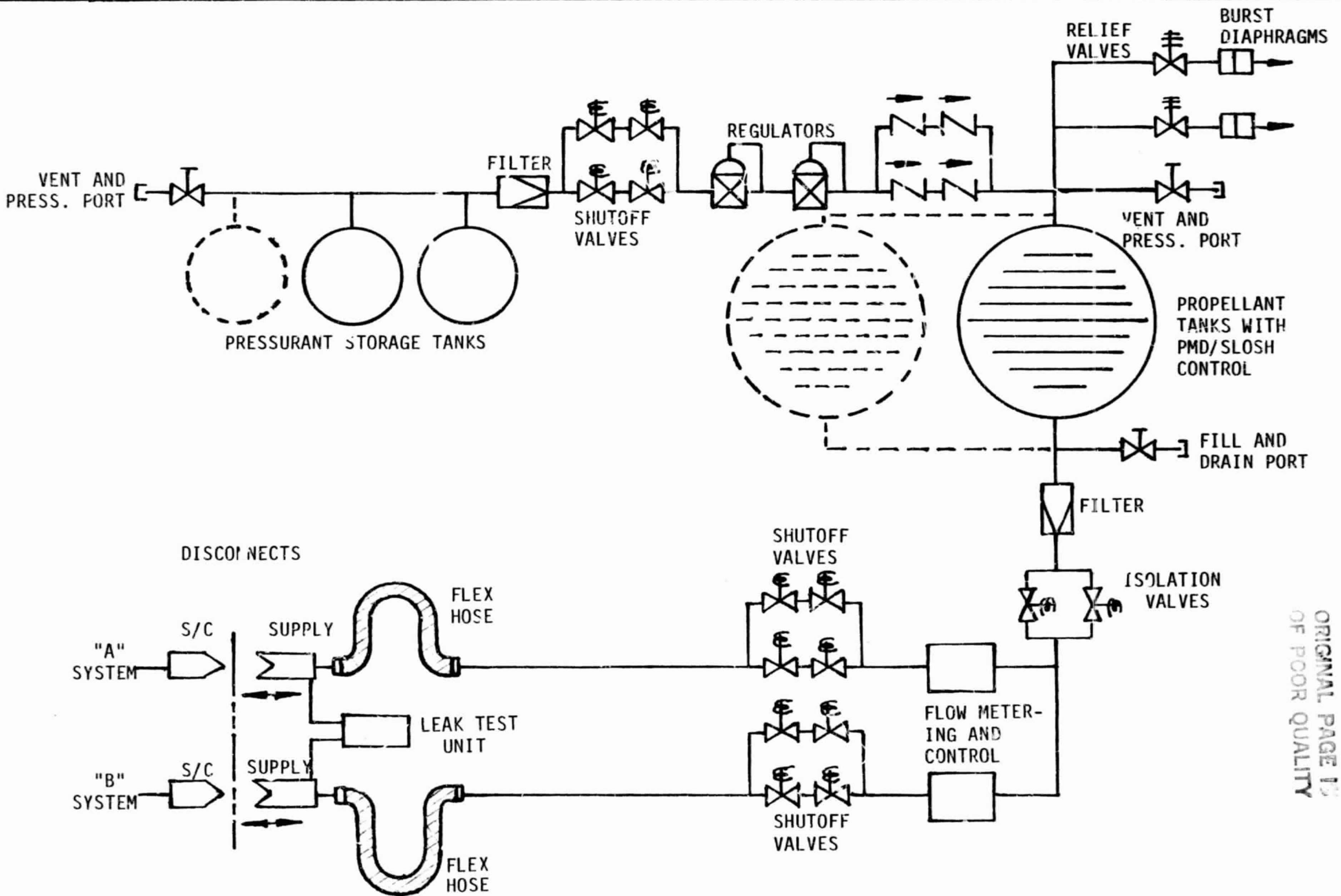
Schematics follow for the candidate systems.

ADIABATIC COMPRESSION SYSTEM

THE ADIABATIC COMPRESSION SYSTEM IS CONNECTED TO THE SATELLITE PROPELLANT TANKS ONLY ON THE PROPELLANT SIDE OF THE TANKS. PROPELLANT IS TRANSFERRED ACROSS THE INTERFACE BY A CONSTANT NITROGEN GAS PRESSURE APPLIED TO THE PROPELLANT TRANSFER SYSTEM TANKS. THE NITROGEN GAS IS STORED IN THE PRESSURANT STORAGE TANKS AT A PRESSURE OF A FEW THOUSAND PSI. THE HIGH PRESSURE NITROGEN IS REGULATED TO APPROXIMATELY 400 PSI BEFORE IT ENTERS THE PROPELLANT TRANSFER SYSTEM TANKS. THE TRANSFER SYSTEM TANKS ARE PROTECTED FROM OVER PRESSURE WITH RELIEF VALVES AND BURST DIAPHRAGMS.

TRANSFER IS ACCOMPLISHED BY CONNECTING THE DISCONNECTS, OPENING THE PRESSURANT SHUTOFF VALVES, OPENING THE PROPELLANT ISOLATION AND SHUTOFF VALVES, AND OPENING THE SATELLITE PROPELLANT SHUTOFF VALVES. ALL VALVES ARE CLOSED WHEN THE DESIRED QUANTITY HAS BEEN TRANSFERRED AND THE DISCONNECTS ARE DISCONNECTED.

ADIABATIC COMPRESSION SYSTEM SCHEMATIC



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I. ADIABATIC COMPRESSION (Notes)

Orbiter Interface - The minimum number of connections beyond the mechanical ones required to dock the satellite is two: a liquid line connection and an electrical connector. A bipropellant satellite will have a minimum of two liquid lines to connect.

Orbiter Operation - Distributing the heat from the compressed ullage gas to the tank walls and propellant may consume several hours. Satellite tank temperature and pressure are monitored while the required propellant load is transferred and the final pressure and temperature obtained.

System Weight - The adiabatic compression system requires high pressure tankage and lines. It also uses the energy of the stored pressurant for the fluid transfer against a constantly increasing satellite ullage pressure. The result is a need for much more stored pressurant gas and heavier components than other candidate systems.

Safety - The concern is with transfer of hydrazine. A Adiabatic compression could heat the nitrogen ullage gas and hydrazine vapor to the decompositon or autoignition point of the hydrazine with consequent failure of the satellite.

I. ADIABATIC COMPRESSION

CRITERIA	PRO	CON
ORBITER INTERFACE	UNCOMPLICATED, FEWEST INTERFACES OF ANY SYSTEM	
ORBITER OPERATION		TIME CONSUMING - SEVERAL HOURS MAY BE REQUIRED FOR TRANSFER.
CREW ACTIVITIES	SIMPLE CONNECTION TO SATELLITE	
OPERATING SIMPLICITY/ COMPLEXITY	SIMPLEST OPERATION OF ALL CANDIDATES	
SYSTEM WEIGHT		REQUIRES MORE NITROGEN THAN OTHER SYSTEMS AND HIGH PRESSURE TANKAGE. HEAVIEST SYSTEM.
SAFETY	FEW CONNECTIONS, UNCOMPLICATED PROCEDURES	HEATING OF ULLAGE GAS UNDER COMPRESSION COULD BE HAZARDOUS.
RELIABILITY	FEWEST CONNECTIONS	MANY VALVE ACTUATIONS

I. ADIABATIC COMPRESSION (Cont'd.)

Development Risk - The adiabatic heating problem could be solved several ways. The simplest is to service the satellite slowly, over a period of several hours, so that the gas temperature stayed near the bulk fluid temperature.

Adaptable to Available Envelope - Additional nitrogen tanks are required for this system compared to the others. This factor, alone, could make this an unacceptable choice.

Flexibility/Redundancy - There is no reasonable back-up for the system if, for instance, the satellite had lost some or all of its pressurant, without adding ullage line connections.

System Unique Factors - The simplicity of the system is its major attraction. It has the fewest connectors and the fewest operations. It is heavier and requires more cargo bay volume beyond that available. It will also be the slowest in operation to control the adiabatic heating problem.

I. ADIABATIC COMPRESSION (CONT'D.)

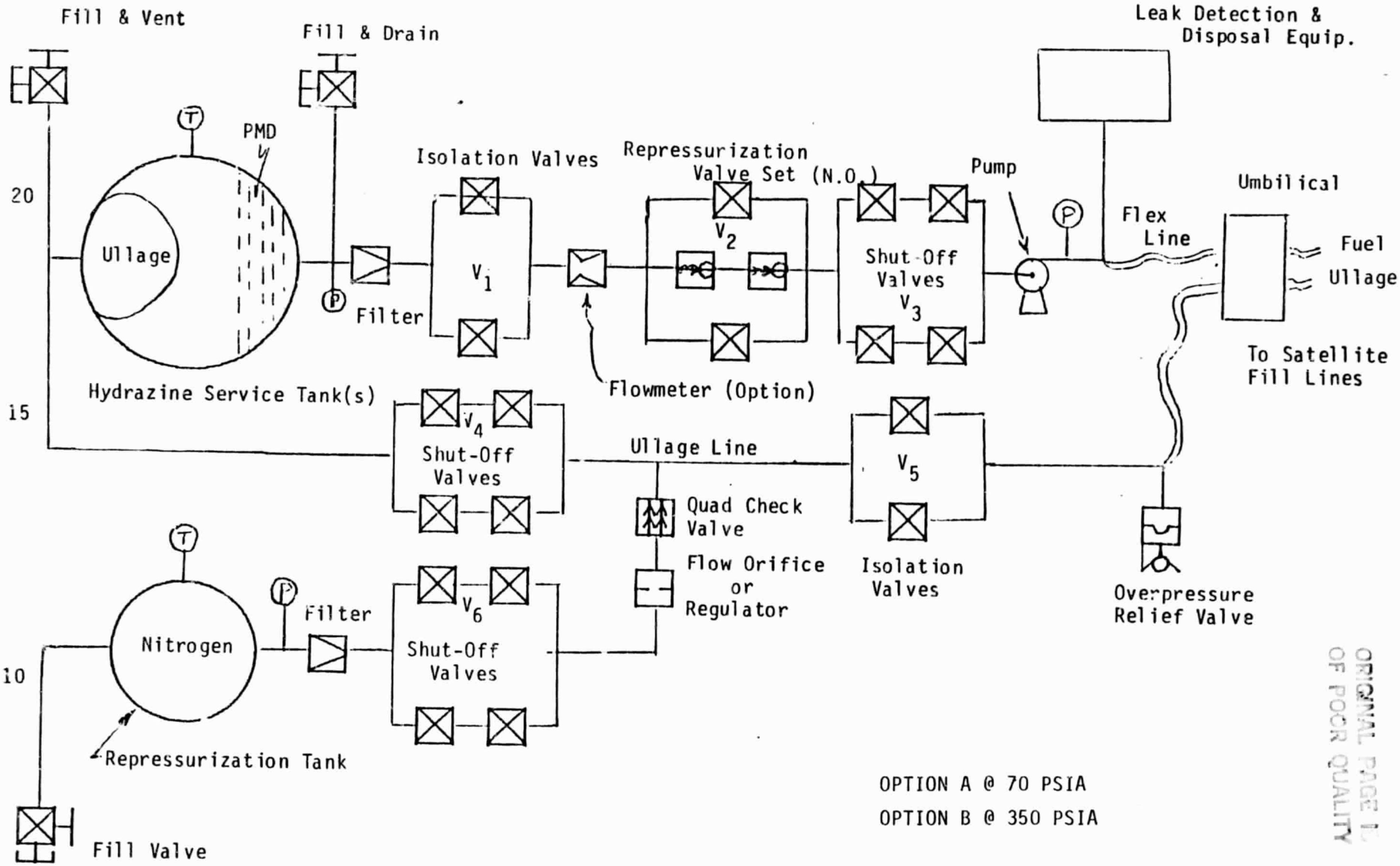
CRITERIA	PRO	CON
DEVELOPMENT RISK		
1. COST	1. LOW RISK	
2. TECHNICAL	2. LOW TO MEDIUM RISK	2. ADIABATIC HEATING PROBLEM MUST BE SOLVED.
3. SCHEDULE	3. LOW RISK	
ADAPTABLE TO AVAILABLE ENVELOPE	SIMPLE PLUMBING REQUIRED	REQUIRES MORE PRESSURANT AND ATTENDANT STORAGE VOLUME THAN THE OTHER SYSTEMS.
POWER REQUIREMENTS	SYSTEM OPERATES ON STORED GAS PRESSURE. MINIMUM CONTROL POWER REQUIRED	
FLEXIBILTY/REDUNDANCY		NO BACKUP TRANSFER METHOD.
SYSTEM UNIQUE FACTORS	NO CONNECTIONS REQUIRED TO SATELLITE ULLAGE	1. SATELLITE MUST HAVE RETAINED NEARLY ALL OF ORIGINAL PRESSURANT. 2. ALL LINES AND TANKS MUST ACCOMMODATE PRESSURE $\geq$ 350 PSI.

SHARED ULLAGE SYSTEM

THE SHARED ULLAGE SYSTEM ELIMINATES ADIALATIC COMPRESSION HEATING OF THE ULLAGE GAS IN THE SATELLITE PROPELLANT TANKS. THE PROPELLANT TRANSFER SYSTEM (PTS) TANKS CAN BE PRESSURIZED PRIOR TO STS LAUNCH TO ANY VALUE BETWEEN THE MINIMUM AND MAXIMUM OPERATING PRESSURE OF THE SATELLITE PROPELLANT TANKS. WHEN THE PROPELLANT OUTLET AND PRESSURANT PORTS OF THE PTS TANKS ARE CONNECTED TO THE RESPECTIVE PORTS ON THE SATELLITE TANKS AND THE VALVES V_1, V_2, V_3, V_4, V_5, PLUS THE SATELLITE VALVES ARE OPEN, THE CONNECTED SYSTEM IS AT A CONSTANT PRESSURE. AT THAT POINT PROPELLANT TRANSFER IS ACCOMPLISHED BY PUMPING THE PROPELLANT FROM THE PTS TANKS TO THE SATELLITE TANKS. IN THIS CONFIGURATION THE PUMP ONLY WORKS AGAINST FRICTION LOSSES IN THE LINES, SO LITTLE PUMPING POWER IS REQUIRED.

PROCEDURALLY, THE PROPELLANT IS PUMPED UNTIL THE SATELLITE TANKS ARE TOTALLY FILLED. THIS PRESUMES THE SATELLITE TANKS ARE CONFIGURED SO ALL OF THE ULLAGE GAS CAN BE TRANSFERRED TO THE PTS TANKS UNDER NEAR-ZERO GRAVITY CONDITIONS. WHEN THE SATELLITE TANKS ARE FILLED, VALVES V_4 AND V_2 ARE CLOSED TO ALLOW REPRESSURIZATION OF THE SATELLITE TANKS TO NOMINAL OPERATING PRESSURE. TO ACCOMPLISH THIS, A PRESCRIBED MASS OF PRESSURANT GAS IS FLOWED THROUGH THE QUAD CHECK VALVE AND VALVES V_5 BY OPENING VALVES V_6 UNTIL THE REPRESSURIZATION TANK PRESSURE DECAYS TO THE APPROPRIATE PREDETERMINED VALUE. THE SERIES RELIEF VALVES IN PARALLEL WITH VALVES V_2 ARE SET TO HOLD THE SATELLITE TANK PRESSURE AT NOMINAL AS THE EXCESS PROPELLANT FROM THE SATELLITE TANKS RETURN TO THE PTS TANKS MAKING ROOM FOR THE REPRESSURIZED ULLAGE SPACE IN THE SATELLITE TANKS.

SHARED ULLAGE SERVICE
SYSTEM SCHEMATIC



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II. SHARED ULLAGE TRANSFER SYSTEM (Cont'd.)

Development Risk - Several pumps have been developed for use with the propellants under consideration, but all can be expected to be less than optimum for this application. A pump development program may be required. The system also requires a pressure relief valve compatible with the propellants and capable of precise operation. This may also require a development program.

Power Requirements - The power required for other systems is control power, transducer amplifier power, and valve actuation power. This system adds a need to power a small pump. Since only a few watts are required, it may be as readily interfaced with the Orbiter as the other power demands.

Flexibility/Redundancy - The system can be readily configured to use its pressurant gas for propellant transfer as in the adiabatic compression system. However, there is not enough gas for a complete transfer so this alternative would only give limited mission success. On a bipropellant system where one of the circuits could not capture the ullage bubble, there would be a possibility of using this ability to make an adiabatic transfer to effectively service both systems. One caution: if the system tanks and lines is designed for low pressure only, then this alternative can't be used.

System Unique Factors - Previous studies have identified liquid/gas transfer based on P, V, T gas law relationships as the most accurate available. This is the basis for the repressurizing transfer. Fluid transfer depends on being able to completely fill the satellite tank then precisely displace fluid with pressurant. The satellite tank ullage bubble must be captured by the ullage vent or the system will "fluid lock" and lead to a loss in filling accuracy.

SYSTEM TRADE STUDY (CONT'D.)

II. SHARED ULLAGE TRANSFER SYSTEM

CRITERIA	PRO	CON
DEVELOPMENT RISK		
1. COST	1. LOW RISK	
2. TECHNICAL	2. LOW TO MEDIUM RISK	2. MAY REQUIRE DEVELOPMENT OF PROPELLANT PUMP AND BACK PRESSURE RELIEF VALVES.
3. SCHEDULE	3. LOW RISK	
ADAPTABLE TO AVAILABLE ENVELOPE	FULLY COMPATIBLE	
POWER REQUIREMENTS	REPRESSURIZATION USES STORED GAS PRESSURE	POWER REQUIRED FOR A SMALL PUMP(S)
FLEXIBILITY/REDUNDANCY	SYSTEM CAN BE CONFIGURED FOR AN ADIABATIC TRANSFER AS A BACKUP MODE	
SYSTEM UNIQUE FACTORS	(1) NO SIGNIFICANT ADIABATIC HEATING	(1) SATELLITE PMD DESIGN CRITICAL FOR REMOVAL OF ULLAGE BUBBLE AND PRECISE PROPELLANT TRANSFER
	(2) POTENTIALLY THE MOST PRECISE PROPELLANT TRANSFER OF ANY SYSTEM	(2) REPRESSURIZATION DEPENDENT ON RELIEF VALVE SETTINGS AND PRESSURE-TEMPERATURE READINGS ON PRESSURANT TANKS.

II. SHARED ULLAGE TRANSFER SYSTEM

Orbiter Interface- This and the adiabatic compression system are the only candidate systems that do not vent gas.

Orbiter Operation - Servicing time is dependent primarily on the pump flowrate. One candidate pump could complete the transfer in less than 30 minutes. With no gravity head loss and only line friction and component pressure drops the pump power requirement is very low. There should be little or no impact on other Orbiter electrical requirements.

Operation Simplicity/Complexity - This is a relatively complex system. Controls logic and operator training are necessary. Success of the transfer depends on the capture of all the satellite tank ullage bubble by the gas outlet line. It would be possible to have an endless fluid loop without removing all of the gas during servicing. This would reduce the certainty of the propellant loading and would reduce subsequent mission life in proportion to the size of the ullage bubble that was left.

System Weight - This is a low pressure system except for the repressurizing gas side. It is also the most efficient in use of pressurant gas. These factors make it the lightest weight of the candidate systems.

Safety - Probably the safest system from an overall standpoint as there is no venting or adiabatic compression.

Reliability - The transfer pump could be made redundant to improve reliability.

II. SHARED ULLAGE TRANSFER SYSTEM

CRITERIA	PRO	CON
ORBITER INTERFACE	NO RELEASE OF GAS DURING OPERATION	REQUIRES 2 LIQUID CONNECTIONS, 2 ULLAGE CONNECTIONS.
ORBITER OPERATION	RAPID TRANSFER OF PROPELLANT	SOME POWER REQUIRED FOR PUMP OPERATION.
CREW ACTIVITIES	ALL REMOTE OPERATION EXCEPT FOR MAKING AND BREAKING CONNECTIONS	
OPERATION SIMPLICITY/ COMPLEXITY	VERY PRECISE PROPELLANT TRANSFER AND REPRESSURIZING IS POSSIBLE	REMOVAL OF ULLAGE GAS IN SATELLITE CRITICAL FOR PRECISE PROPELLANT TRANSFER.
SYSTEM WEIGHT	LIGHEST WEIGHT SYSTEM. USES MINIMUM PRESSURANT	
SAFETY	(1) LOW PRESSURE FOR MOST TRANSFER, STORAGE OPERATIONS (2) NO GAS VENTING	
RELIABILITY	COMPONENTS ARE WELL CHARACTERIZED, STATE-OF-THE-ART EXCEPT FOR THE TRANSFER PUMP AND RELIEF VALVES USED FOR THE REPRESSURIZATION OPERATION.	COMPLEX SYSTEM WITH MANY ACTIVE COMPONENTS. REDUNDANT COMPONENTS MAY BE REQUIRED FOR GOOD RELIABILITY.

III. VENT AND REPRESSURIZE

Orbiter Interface - In addition to the electrical umbilical and fluid transfer connections, this system requires vent mast deployment to avoid cargo bay contamination. This can be done remotely, but adds a system complication. The vent mast is a pipe with a "tee" outlet to reduce any torque input due to the venting of ullage gas. Less than 40 lbm of nitrogen will be vented in a monopropellant system.

Crew Activities - To avoid the complications of a remote deployment system, the baseline plan is to have the vent masts raised up into position by the astronaut. This should be a very simple operation.

System Weight - This system will be somewhat heavier than the shared ullage system but considerably lighter than the other two candidates.

Reliability - The system redundancy in valves should make it more reliable than the satellite propulsion system. The major reliability problem is assuring a leak free fluid connection to the satellite.

III. VENT AND REPRESSURIZE

CRITERIA	PRO	CON
ORBITER INTERFACE		(1) REQUIRES VENTING OF GAS DURING SERVICING (2) REQUIRES 2 LIQUID AND 2 GAS CONNECTIONS AND VENT MAST DEPLOY.
ORBITER OPERATION	RAPID TRANSFER	
CREW ACTIVITIES	ONCE CONNECTED ALL OPERATIONS CAN BE DONE AT AFT CONTROL PANEL	VENT MASTS REQUIRE MANUAL DEPLOYMENT; MUST BE AVOIDED DURING VENT OPERATION
OPERATING SIMPLICITY/ COMPLEXITY	STRAIGHT FORWARD OPERATING PROCEDURES	ELECTRONIC CONTROLS LOGIC REQUIRED TO AVOID OPERATOR ERROR
SYSTEM WEIGHT	NEITHER HEAVIEST NOR LIGHTEST SYSTEM	
SAFETY	SEPARATE GAS AND LIQUID SYSTEMS	
RELIABILITY		
DEVELOPMENT RISK 1. COST 2. TECHNICAL 3. SCHEDULE	 1. LOW RISK 2. LOW RISK 3. LOW RISK	

III. VENT AND PRESSURIZE (Cont'd.)

Adaptable to Envelope - This is the most compact system. The Shared Ullage system requires space for a pump. The other candidates require room for extra tanks.

Flexibility/Redundancy - The system can transfer a small amount of propellant using the ullage pressure in the feed tanks should the ullage gas in the satellite not be vented. The amount transferred this way is not enough to be considered a real back-up. The system lends itself to easy conversion from monopropellant to bipropellant operation with minor configuration changes.

System Unique Factors - System fluid transfer will be rapid once the satellite tanks are vented. Since there is no gas in the satellite tanks there is no danger of adiabatic compression heating. Adiabatic expansion cooling of the pressurant gas may require a waiting period to be sure the temperature and pressure is at thermal equilibrium in the satellite tanks.

III. VENT AND REPRESSURIZE

CRITERIA	PRO	CON
ADAPTABLE TO AVAILABLE ENVELOPE	FULLY COMPATIBLE	
POWER REQUIREMENTS	TRANSFER USES COMPRESSED GAS FOR ENERGY SOURCE	
FLEXIBILITY/REDUNDANCY	READY CONVERSION FROM MONOPROPELLANT TO BIPROPELLANT	NO BACK-UP TRANSFER METHOD.
SYSTEM UNIQUE FACTORS	TRANSFER REQUIRES LITTLE ENERGY	(1) TRANSFER ACCURACY HIGHLY DEPENDENT ON FLOWMETER ACCURACY. (2) REPRESSURIZATION MAY BE DONE IN STEPS DUE TO ADIABATIC COOLING EFFECT ON ULLAGE.

IV. DRAIN, VENT, REFILL AND REPRESSURIZE

Orbiter Operation - Two additional tanks are required, in the service module, to hold the residual satellite propellants. Initially these residual tanks are vented to space to allow the satellite ullage pressure to empty the satellite tank's propellants as completely as possible. The satellite ullage bubble is next vented off and operation proceeds similar to the previous system.

Crew Activities - Similar to the previous system in requiring vent mast deployment by the astronaut.

System Weight - Low pressure tanks are required to contain the satellite residual propellants. Some increase in system complexity would allow this propellant to be reloaded, but in either case it is the heaviest system.

Reliability - The number of active components and the complexity of the operation would make this the least reliable of the candidate systems.

Adaptable to Envelope - The additional residual propellant tanks make this system too large for the given envelope.

IV. DRAIN, VENT, REFILL & REPRESSURIZE

CRITERIA	PRO	CON
ORBITER INTERFACE		ULLAGE GAS RELEASED DURING OPERATION.
ORBITER OPERATION		TIME CONSUMING - EXTRA OPERATION.
CREW ACTIVITIES		2 LIQUID AND 2 GAS CONNECTIONS, VENT MAST DEPLOY.
OPERATION SIMPLICITY/ COMPLEXITY	VERY PRECISE PROPELLANT TRANSFER AND REPRESSURIZING POSSIBLE	MOST COMPLEX OPERATING PROCEDURES OF ANY SYSTEM.
SYSTEM WEIGHT		REQUIRES EXTRA TANK, HEAVY SYSTEM.
SAFETY	LOW PRESSURE FOR MOST TRANSFER	REQUIRES GAS VENTING.
RELIABILITY		COMPLEX SYSTEM WITH MANY ACTIVE COMPONENTS. MAY HAVE LOWEST RELIABILITY OF ANY SYSTEM.
DEVELOPMENT RISK 1. COST 2. TECHNICAL 3. SCHEDULE	 1. LOW RISK 2. LOW RISK 3. LOW RISK	
ADAPTABLE TO AVAILABLE ENVELOPE		ADDITIONAL PROPELLANT STORAGE VOLUME MAY EXCEED AVAILABLE ENVELOPE.

IV. DRAIN, VENT, REFILL AND PRESSURIZE (Cont'd.)

Flexibility/Redundancy - This system is proposed for a satellite PMD where the ullage bubble cannot reliably be vented. For this situation, this system, or the Adiabatic Compression system, are the only alternatives. It is very similar to the operational Soviet system. Essentially it will work with any satellite that can be connected to the fluid and gas lines.

System Unique Factors - The Vent & Repressurize system requires a satellite where the propellant is substantially depleted, or the size or number of catch tank becomes impractical. It is the system of choice where there is substantial doubt that the ullage bubble in the satellite tank can be vented without significant propellant loss. Use of the vent masts is condidered acceptable where the vent compositon is pressurant gas with only that small amount of propellant due to the vapor pressure of the propellant.

SYSTEM TRADE STUDY (CONT'D.)

IV. DRAIN, VENT, REFILL & REPRESSURIZE

CRITERIA	PRO	CON
POWER REQUIREMENTS	USES STORED GAS PRESSURE FOR ALL TRANSFER	
FLEXIBILITY/REDUNDANCY		NO SIMPLE BACK-UP TRANSFER METHOD
SYSTEM UNIQUE FACTORS	(1) CAN SERVICE A SATELLITE WITH ANY LEVEL OF PROPELLANT REMAINING (2) SHOULD BE INDEPENDENT OF TYPE OF PMD USED	

SYSTEM TRADE STUDY

RANKINGS IN EACH CRITERION - A "one" denotes the system that best satisfies the criterion. A "two" is given the second best system, a "three" the third, and a "four" for the system least satisfactory in meeting that criterion. Where two or more systems seem equally satisfactory they are given the same rating.

TRADE STUDY SCORE - There was no attempt made to assign a greater or lesser weight to particular criterions. Even without weighing, the Vent, Fill & Repressurize system had the best score. There was also no attempt to remove a system from consideration even though it violated a limit, such as available envelope. If this had been done the Adiabatic Compression and Drain, Vent, Fill & Repressurize systems would have been eliminated.

BASELINE SELECTION - The Vent, Fill & Repressurize system was selected as the one most likely to meet the mission requirements while combining light weight and simplicity of operation.

SYSTEM TRADE SUMMARY

CRITERIA	ADIABATIC COMPRESSION	SHARED ULLAGE	VENT, FILL & REPRESSURIZE	DRAIN, VENT, FILL & REPRESSURIZE
ORBITER INTERFACE	1	2	3	3
ORBITER OPERATION	1	2	2	4
CREW ACTIVITIES	1	2	2	2
OPERATION SIMPLICITY/ COMPLEXITY	1	3	2	4
SYSTEM WEIGHT	4	1	2	3
SAFETY	4	2	1	3
RELIABILITY	1	3	2	4
DEVELOPMENT RISK	1	3	2	4
ADAPTABLE TO ENVELOPE	3	1	1	4
POWER REQUIREMENTS	1	4	1	1
FLEXIBILITY/REDUNDANCY	4	1	2	2
SYSTEM UNIQUE FACTORS	3	2	1	4
	25	26	21	38
			BASELINE SELECTION	

MONOPROPELLANT TO BIPROPELLANT

SYSTEM CONVERSION

The Vent, Fill and Repressurize system meets the criteria for system conversion as well as any system.

One possible complication is valve seat and valve seal materials. Materials must be used which are compatible with both propellants.

In normal operation a module could be configured for either monopropellant or bipropellant servicing and would stay in that configuration for its useful life. The proposed system has considerable flexibility in being able to readily convert from one propellant to another by the addition or removal of a propellant manifold connection and the opening or closing of a manual pressurant service valve.

MONOPROPELLANT TO BIPROPELLANT SYSTEM CONVERSION

CRITERIA	DESIGN SOLUTION
• ONE QUALIFICATION PROGRAM FOR A PTS THAT WILL SERVICE EITHER PROPULSION SYSTEM	• BASELINE A BIPROPELLANT SYSTEM THAT CAN BE READILY RECONFIGURED FOR MONOPROPELLANT SERVICING
• MEET ALL BIPROPELLANT SAFETY CRITERIA	• (1) SEPARATE CIRCUITS FOR VENT, PROPELLANT FLOW, AND REPRESSURIZATION (2) CONNECTORS MATE ONLY WITH THEIR OPPOSITE HALF (3) OXIDIZER VENT TIED INTO SEPARATE VENT SYSTEM
• MINIMIZE CONFIGURATION CHANGES	• (1) ADAPTABLE TO EITHER NITROGEN OR HELIUM PRESSURANT (2) NO CHANGE TO ACTIVE COMPONENTS SUCH AS VALVES (3) DESIGN REQUIRES ONLY ONE SHORT LINE ADDITION TO CONFIGURE FOR MONOPROPELLANT OPERATION
• FULLY INSPECTABLE PRIOR TO FILLING	• SYSTEM DIFFERENCES READILY SEEN

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BASELINE SYSTEM SCHEMATIC

The baseline Vent, Fill and Repressurize system is shown as configured for bipropellant operation. For monopropellant operation the following configuration changes would be made:

1. Open pressurant service valve V_{9S}
2. Add line segment to tie propellant feed lines together. This is indicated by a short dashed line between propellant storage tank outlet line manifolds.

This configuration assumes the satellite has "A" and "B" tanks and circuits for the hydrazine supply. For a single tank only the "A" or "B" circuit would be used.

A list of valve names and identifiers is included at the end of the operating procedures section.

REMOTE VS. MANUAL UMBILICAL MATE/DEMATE

THE FACING PAGE PRESENTS THE BASIC OBJECTIVE & GROUNDRULES ASSOCIATED WITH THE TRADE STUDY RELATIVE TO THE PTS UMBILICAL MATE/DEMATE. IT SHOULD BE NOTED THAT THE TRADE IS BETWEEN A REMOTE VS. EVA MANUAL UMBILICAL MATE/DEMATE APPROACH.

REMOTE VS MANUAL UMBILICAL MATE/DEMATE

1. OBJECTIVE
   - CONDUCT A TRADE SUTDY TO DETERMINE THE BEST APPROACH RELATIVE TO PTS UMBILICAL MATE/DEMATE WITH A SPACECRAFT

2. GROUNDRULES
   - UMBILICAL MATE/DEMATE WITH S/C HARD-DOCKED TO ORBITER
   - MATE/DEMATE STATUS PROVIDED TO FLT. CREW
   - MANUAL EVA OVERRIDE IN 'CONTINGENT SITUATION'

UMBILICAL MATE/DEMATE OPS - REMOTE (IVA) VS. EVA

SEVERAL CANDIDATE REASONS FOR IVA VS. EVA UMBILICAL MATE/DEMATE ARE PRESENTED IN THE OPPOSITE CHART. THE LIST, ALTHOUGH NOT EXHAUSTIVE, PRESENTS MANY OF THE MORE PERTINENT FACTORS ASSOCIATED WITH EITHER CASE.

UMBILICAL MATE/DEMATE OPS - REMOTE (IVA) VS EVA

WHY REMOTE (IVA FROM AFT FLT. DECK)	WHY EVA (IN CARGO-BAY)
1. CONDUCTED DURING BERTHING OR ANY TIME THEREAFTER 2. ACCOMPLISHED WHILE VIEWING PANEL Ds & Cs 3. AVAILABLE 'BITE' DIAGNOSTICS Ds & Cs FOR PROBLEM SOLVING 4. PERFORMED WITHIN A BENIGN ENVIRONMENT (CABIN) 5. PERMITS ASSESSMENT OF PROPER MATING PRIOR TO EVA 6. ALLOWS DEMATE ANYTIME DURING MISSION • AFTER OR INBETWEEN EVAs • CONTINGENCIES 7. FACILITATES FUEL XFER WITHOUT EVA CREW IN BAY • SAFETY/CONTAMINATION CONCERNS FOR EVA • INCREASED TIME FOR OTHER EVA SERVICING TASKS 8. OFFERS OPPORTUNITY TO COMBINE WITH S/C BERTHING • LESS IVA TIMELINE IMPACT • 'ASSOCIATED' WITH SIGNAL/PWR UMBILICAL MATE	1. REDUCES ACTUATOR MOTOR (2) COSTS 2. REQUIRES EVA CREW OVERRIDE IN ANY EVENT 3. PERMITS DIRECT (AT WORK SITE) VISUAL INSPECT. 4. ALLOWS MANUAL/TOOL INPUT TO ALIGN/DRIVE/INDEX 5. PERMITS VISUAL INSPECTION FOR GEN. SPILLAGE 6. PERMITS VISUAL INSPECTION FOR SPILLAGE DAMAGE 7. FACILITATES POSSIBLE SPILLAGE CONTAINMENT 8. ALLOWS FOR CREW EVA UMB. MATE/DEMATE EXPERIMT. 9. PERMITS FINAL PTS AND DEMATE 'CLOSEOUT' INSPECTION

UMBILICAL TRADE STUDY EVALUATION FACTORS & CRITERIA

THE FACING PAGE PRESENTS THE NUMERICAL SCORING METHODOLOGY USED IN THE EVALUATION OF THE TRADE STUDY. THE FOLLOWING TWO PAGES LIST THE BASIC TRADE STUDY CRITERIA. CERTAIN CRITERIA (IDENTIFIED OPPOSITE) WERE CONSIDERED MORE 'IMPORTANT' THAN OTHERS, AND WERE THEREFORE, GIVEN A WEIGHTING VALUE.

TRADE STUDY EVALUATION FACTORS

1. A NUMERICAL SCORING RANGE WAS USED
2. SCORING AS FOLLOWS:
   - MAXIMUM POINTS = 10
   - MINIMUM POINTS = 0
3. WEIGHTING FACTOR OF '2 TIMES' APPLIED TO:
   - EMERGENCY DEMATE
   - FUEL SPILLAGE ON EVA SUIT
   - EXPOSURE TO EXPLOSIVE POTENTIAL
   - FLEXIBILITY OF WHEN MATE/DEMATE CAN BE UNDERTAKEN
   - DRIVE MOTOR AND GEAR BOX ASSY
   - COMPLEXITY
   - DEMATE AT ANY TIME UNDER CONTINGENCY MODE
   - REMOTELY OPERATED UNIT MECHANISM (2 CASES)

TRADE STUDY CRITERIA

1. SAFETY
2. COMPLEXITY OF ELECTRO-MECHANICAL DESIGN
3. OFF-SHELF EXISTING AUTO MATE/DEMATE DESIGN
4. EVA OVERRIDABLE (e.g. MECHANICALLY AIDED LOCKING OVER CENTER CRANK DESIGN) WITH SIMPLE TOOL
5. REMOTE (IVA) UMBILICAL DEMATE/MATE
   - REMOTE MEANS TO CORRECTING/OVERRIDING MATE/DEMATE PROBLEM
   - SAVE AN ADDED EVA
6. ELIMINATE EXPOSURE TO STORED ENERGY SOURCES
7. FUEL LEAKAGE (~ 1.0 CC OR LESS CONTAINMENT AT ABOUT 1.0 PSIA (VAPOR PRESSURE) OR LESS

TRADE STUDY CRITERIA

8. METHOD FOR EVA (IVA AID) CHECKOUT OF UMBILICAL STATUS
   - VISUAL CONFIRMATION OF UMBILICAL CONNECTOR PRE-MATE ALIGNMENT
9. NEED FOR CONSTRAINT MONITORING
10. ALIGNMENT AND SEATING 'ADJUSTMENTS'
11. CONTAMINATION
    A. CREW PERSON 'BRINGS' CONTAMINANTS TO UMBILICAL MATE/DEMATE MECHANISM (POPPET SEAT AND THROAT)
    B. CARGO-BAY CONTAMINANT CONTROL
12. COMPLEXITY
13. COST
    - PRIMARY DELTA IS FOR DRIVE ACTUATOR MOTOR (2 FOR REDUNDANCY) AND D&Cs FOR MOTORS
14. RELIABILITY
15. AVAILABILITY

TRADE STUDY & CONCLUSIONS

THE FACING PAGE & SUBSEQUENT FOLLOWING PAGE PRESENT THE SCORING DATA FOR THE SIX (6) MAJOR TRADE CATEGORIES. THE THIRD PAGE INDICATES THE CONCLUSIONS REACHED IN THE BASIC TRADE STUDY. HOWEVER, AT AN TIM MEETING, WHEREIN THIS TRADE STUDY WAS PRESENTED, IT WAS LEARNED THAT THE SPACECRAFT (REFERENCE VEHICLE) WILL NOT HAVE A 'BERTHING SYSTEM' ATTACHED THERETO; CONSEQUENTLY A REMOTELY OPERATED (IVA) UMBILICAL(S) COULD NOT BE INSTALLED ON THE SPACECRAFT SIDE, THEREBY DRIVING THE REFERENCE SYSTEM TO A MANUAL EVA MATE/DEMATE APPROACH.

TRADE STUDY

PAGE 1 OF 2

CANDIDATE OPERATIONAL MODES / CRITERIA	POINT RANGE	REMOTE (IVA) UMBILICAL OPS	CARGO-BAY EVA UMBILICAL OPS	POINT RANGE
1. SAFETY				
A. FUEL SPILLAGE ON EVA SUIT ('SNOW' AND VAPOR)	(2) 20	NONE IF IVA OPS	SOME RISK	(2) 8
B. STOWED ENERGY SOURCE I/F	10	NONE IF IVA OPS	RISK IF SPRING	6
C. BENIGN OPERATING ENVIRONMENT	10	NONE IF IVA OPS	GEN. EVA CONCERN	8
D. EXPOSURE TO EXPLOSIVE POTENTIAL	(2) 16	LIMITED RISK	BASIC RISK	(2) 4
E. EMERGENCY DEMATE	(2) 20	ANY TIME	ONLY IF OUT EV	(2) 0
2. CONTAMINATION				
A. EVA CREWPERSON 'CARRIES' CONTAM. TO UMB. CONNECT I/Fs	10	IF MATE PRE-EVA	SOME POSSIBILITY	7
B. ORB. CARGO-BAY CONTAM. OF 'UNPROTECTED' UMB. CONNECT I/Fs	2	NO CONTROL	POSSIBLE CLEAN	10
C. CONTAM. COVER ACTUATION	3	ADDED HDWR & COST	ADDED HDWR. MIN $	8
D. INSPECTION FOR POSSIBLE CONTAM.	4	POOR (DIRECT OR CCTV)	EXCELLENT	10
3. NEW AND/OR ADDED HDWR. – UMBILICAL				
A. HOLDING BRACKETS – BOTH SIDES	–	REQD	REQD	–
B. DRIVE ACTUATOR MOTOR & ASSOCIATED GEAR BOX ASSEMBLY	(2) 2	HDWR. & SIG. COST	NOT REQD.	(2) 20
C. EVA OVERRIDE DRIVE AND ASSOCIATED GEAR BOX	–	REQD	REQD	–
D. ALIGNMENT/POSITIONING/INDEXING GUIDES	3	MORE COMPLEX/TEST	LESS COMPLEX	8
E. LEAKAGE SPILLAGE COVERS/SHEATHS	4	NON 'FLEXIBLE'	ADJUSTABLE	10
F. DISPLAY/CONTROL PANEL ADDITIONS	5	ADDED D&C/COMPLEX	MIN. D&C	9
4. HARDWARE FACTORS – UMBILICAL				
A. COMPLEXITY	(2) 6	HIGHER WITH 3.8	MODERATE TO MIN.	(2) 16
B. REDUNDANCY	2	2 MOTORS (3.3)	MINIMAL	9
C. OFF SHELF AVAILABILITY	4	SOME ITEMS	MOST ITEMS	7
D. RELIABILITY IMPACT (TEST/VER AND C/O)	(2) 6	CONSIDERABLE	LESSER T/V AND C/O	(2) 14
SUB-TOTAL	127		SUB-TOTAL	154

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TRADE STUDY

PAGE 2 OF 2

CANDIDATE OPERATIONAL MODES / CRITERIA	POINT RANGE	REMOTE (IVA) UMBILICAL OPS	CARGO-BAY EVA UMBILICAL OPS	POINT RANGE
5. OPERATIONS				
A. PROXIMITY TO D&C PANEL DURING MATE/DEMATE OPS	10	EXCELLENT	POOR - COMM REQD	3
B. CLOSE ASSOCIATE WITH 'BITE' AND OVERRIDE CIRCUITRY IF PROBLEM	10	EXCELLENT	POOR - COMM REQD	3
C. DIRECT AND 'CLOSE-UP' VIEW OF BOTH UMBILICAL HALVES	1	VERY POOR	EXCELLENT	10
D. FLEXIBILITY OF WHEN MATE/DEMATE CAN BE UNDERTAKEN	(2) 20	'ANYTIME'	ONLY IF OUT EV	(2) 0
E. DEMATE AT ANY TIME UNDER CONTINGENCY MODE	(2) 20	'ANYTIME'	ONLY IF OUT EV	(2) 0
F. OVERRIDE IF D&C PANEL/SIGNAL OR POWER MALFUNCTION	0	MAY BE IMPOSSIBLE	EXCELLENT IF EV	6
G. SIMULTANEOUS MATING WITH OTHER CONNECTORS (PWR/SIGNAL)	8	VERY POSSIBLE	VERY UNLIKELY	1
H. CREW TIMELINE IMPACT ON EVA	9	VERY LITTLE	HIGH (UP TO 1 HOUR)	2
I. PANEL DISPLAY/CONTROL COMPLEXITY	5	MODERATE	MINIMAL	8
J. TRAINING AND SIMULATION	6	MODERATE	MOD TO SIGNIFICANT	3
6. COSTS				
A. REMOTELY OPERATED UNIT (MATE & DEMATE) - MECHANISM	(2) 4	MAJOR ROT AND E	OVERRIDE ONLY	(2) 14
B. REMOTELY OPERATED UNIT (DEMATE ONLY) - MECHANISM	(2) 8	SIG. ROT AND E	OVERRIDE ONLY	(2) 14
C. EVA OPERATED UNIT (MATE AND DEMATE) - MECHANISM	10	NO HDWR.	OVERRIDE DEVICES	7
D. D&C PANEL (WITH BITE) FOR REMOTE OPS (MATE & DEMATE)	5	SIG. (GEN. PANEL?)	OVERRIDE ONLY	7
E. D&C PANEL (WITH BITE) FOR REMOTE OPS (DEMATE ONLY)	7	MIN. SIC. (GEN. PANEL?)	OVERRIDE ONLY	7
SUB-TOTAL	123		SUB-TOTAL	85
PREVIOUS PAGE SUB-TOTAL	127		SUB-TOTAL	154
TOTAL	250		TOTAL	239

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TRADE STUDY CONCLUSIONS

1. UMBILICAL ENGAGEMENT/DISENGAGEMENT REQUIRES A MECHANICAL ADVANTAGE TO OVERCOME FORCE
   - MAXIMUM FORCE OF 260 LB_F AT 300 PSI
   - SUCH FORCES WAY BEYOND RMS CAPABILITY
   - SUCH FORCES ALSO BEYOND EVA CREWPERSONS CAPABILITY
2. CONTINGENCY OR EMERGENCY UMBILICAL DISENGAGEMENT REQD. (SAFETY)
   - REQUIRES REMOTELY ACTUATED MECHANISM OF SOME TYPE
3. UMBILICAL REQUIRES OTHER MAJOR FEATURES EXCLUSIVE OF MODE OF OPS
   - MTS. BRACKETS
   - ALIGNMENT/POSITIONING GUIDES
   - LEAKAGE/SPILLAGE CONTAINMENT
   - EVA OVERRIDE
4. TRADE STUDY NUMERICAL EVALUATION SLIGHTLY FAVORS REMOTE (CABIN) OPS OF UMBILICAL

THUS

5. REMOTE OPS (IVA) FROM CABIN WITH EVA OVERRIDE CAPABILITY IS RECOMMENDED AS THE APPROACH

EVA DESIGN LOADS

LMSC COORDINATION WITH NASA/MSFC AND WITH NASA/JSC FOR THE SPACE TELESCOPE PROGRAM RESULTED IN CUSTOMER-IMPOSED REQUIREMENTS AS SHOWN IN THE OPPOSITE CHART. SINCE THESE LOADS ARE NOW ACCEPTED AS NASA "STANDARD", THE PTS CONCEPT & DEVELOPMENT PROGRAM WILL UTILIZE THESE LOADS AS MAXIMUM LOADS.

A LOWER LOAD LIMIT WILL APPLY WHERE THE CREW MEMBER IS RESTRAINED (i.e., NOT FLOATING ON A TETHER, MANUEVERING WITH THE MMU, ETC)

EVA DESIGN LOADS *

1. SPACE TELESCOPE PROGRAM IMPOSED A NUMBER OF EVA LOADS REQTS. ON LMSC
2. MAJOR LOAD WAS FOR INDUCED LOAD INPUTS OF SUITED CREWPERSON:

   A. CREWMEMBER INDUCED LOAD ON EV PERSONNEL TETHER POINT AND MTG. STRUCTURE

   B. CREWMEMBER INDUCED LOAD ON EV PERSONNEL TETHER / HOOK ASSEMBLY

   300 LB WORKING LOAD ANY DIRECTION

   574 LB LIMIT LOAD ANY DIRECTION

   900 LB ULTIMATE LOAD ANY DIRECTION

* NASA – MSFC AND JSC CONCURRED UPON EVA LOADS

PTS SERVICING & I/F REQUIREMENTS - CATEGORIZED

THE FACING PAGE SUMMARIZES BY CATEGORY THE SERVICING INTERFACES IDENTIFIED FOR THE PROPELLENT TRANSFER SYSTEM. THESE INTERFACES COMPRISE FOUR BASIC ELEMENTS:

- MECHANICAL
- ELECTRICAL/SIGNAL/FLUID
- PROCEDURAL
- SOFTWARE/FIRMWARE

EACH OF THE INTERFACES ON THE FACING PAGE ARE DISCUSSED AND/OR ILLUSTRATED IN THE BASIC SUBSECTIONS OF THE CORRESPONDING DESIGN AND OPERATIONS PTS ELEMENTS.

PTS SERVICING & I/F REQTS (CATEGORIES)

A. FWD CRADLE WITH PTS

B. S/C POSITIONING VIA HPA

C. S/C HOLDING

D. PROPELLANT LINE & SIGNAL/POWER UMBILICALS MATE/DEMATE

E. UMBILICAL MOUNTING ON S/C - GUIDELINES

F. CREW IVA SUPPORT FROM AFT FLIGHT DECK

G. CREW EVA INTERACTION WITH PTS

H. CREW WORK STATION - GUIDELINES

I. SAFETY

PTS INTERFACE WITH SPACECRAFT AND HPA

THE OPPOSITE PAGE PRESENTS THE BASIC INTERFACES WITH THE SPACECRAFT AND THE HOLDING & POSITIONING AID (HPA). INTERFACE WITH THE SPACECRAFT HAS BEEN MINIMIZED TO REDUCE ANY POTENTIAL IMPACTS WHICH COULD RESULT IN COST, HARDWARE CHANGE, OR SCHEDULE MODIFICATION. NO INTERFACES HAVE BEEN IDENTIFIED FOR THE HPA.

PTS INTERFACE WITH SPACECRAFT & HPA

SPACECRAFT

A. TWO PROPELLANT FLEX HOSE LINES WITH UMBILICALS (2)

B. TWO PRESSURANT FLEX HOSE LINES WITH UMBILICALS (2)

C. TWO D-RINGS

HPA

A. NONE

FUEL TRANSFER LINE MANAGEMENT

CONSIDERATIONS RELATIVE TO FUEL LINE MANAGEMENT ARE SYNOPSIZED IN THE FACING ;E. WHEREVER PRACTICAL, IT IS MOST DESIRABLE TO REDUCE CREW INVOLVEMENT IN PTS LINE MANAGEMENT. FURTHER, IT IS ALSO HIGHLY DESIRABLE TO ELIMINATE (IF FEASIBLE) ANY SEMI-AUTOMATED 'MECHANISMS' ASSOCIATED WITH LINE MANAGEMENT. THE BASELINE SELECTED SYSTEM PROVIDES A 'MINIMUM MANAGEMENT' TECHNIQUE WELL WITHIN EVA CREW CAPABILITY.

FUEL XFER LINE MANAGEMENT

A. DESIRABLE TO MINIMIZE FUEL LINE MGMT.

   1. REDUCED NO. OF BENDS/ARTICULATION
   2. REDUCED LENGTH
   3. POTENTIALLY MORE SIMPLIFIED LINE
      - 'JOINT' OR 'BEND' TECHNIQUES
   4. POSSIBLE REDUCED COMPLEXITY OR ELIMINATION OF MGMT. DEVICE

B. A SINGLE LESS THAN 360° (90°?) FUEL LINE 'BEND' WOULD BE DESIRABLE

C. LESSER REPEATED 'BENDS' INCREASES RELIABILITY/SAFETY

PROPELLANT TRANSFER SYSTEM PROXIMITY TO THE S/C

THE FACING PAGE CHART ADDRESSES THE ISSUE OF PTS PROXIMITY TO THE SPACECRAFT. IT IS PATENTLY OBVIOUS THAT THE CLOSER THE S/C IS TO THE PTS, THE LESSER THE PROBLEMS. A PRIMARY GOAL IS TO MINIMIZE PTS TO S/C FUEL LINE LENGTH AS INDICATED. THE BASELINE PTS, HOWEVER, CAN ACCOMMODATE SHORT TO LONG (IF NECESSARY) LENGTHS ALTHOUGH SHORTER LENGTHS ARE MORE DESIRABLE.

PROPELLANT TRANSFER SYSTEM PROXIMITY TO SC

DESIRABLE TO HAVE SC VERY NEAR PTS

1. MIN. FUEL XFER LINE LENGTH
   - LESS LINE
   - LESS POTENTIAL 'BENDS'
   - LESS MGMT. OF LINE
   - LESS PRESSURE DROP
   - LESS THERMAL MGMT /CONTROL
   - LESS EXPOSED TO COLLATERAL DAMAGE POTENTIAL

2. POTENTIAL OF PTS & BERTHING DEVICE CRADLE SHARING

3. MORE SIMPLIFIED EVA MONITORING, ACCESS & OVERRIDE

PTS SAFETY CONSIDERATIONS

SAFETY CONSIDERATIONS PLAYED A KEY ROLE IN EVOLVING THE PTS CONCEPT. MAJOR FACTORS ARE ILLUSTRATED ON THE FACING PAGE. ALL SAFETY CONCERNS HAVE BEEN RESOLVED WITH ONLY TWO ITEMS REQUIRING FURTHER STUDY AND/OR GREATER CLARIFICATION: (1) VENTING 'SMALL AMOUNTS' OF FUEL VAPOR OVERBOARD, AND (2) UMBILICAL MATE/DEMATE NOMINAL LEAKAGE (MINUTE QUANTITIES, E.G., ~ 1.0 CC OR LESS AT ~ 1.0 PSIA VAPOR PRESSURE). REPRESENTATIVE SAFETY DOCUMENTATION INCLUDED:

1. NHB 1700.7 (REV. A) SAFETY POLICY AND REQUIREMENTS
2. JSC 11123 STS PAYLOAD SAFETY GUIDELINES HANDBOOK
3. MIL-STD-1522 STANDARD GENERAL REQT. FOR SAFE DESIGN AND OPERATION OF PRESSURIZED MISSILE AND SPACE SYSTEMS
4. NSS/MP-1740.1 NASA AEROSPACE PRESSURE VESSEL SAFETY STANDARD
5. NHB 1700.1 (V1) NASA SAFETY MANUAL
6. SD-REG-127-4 SYSTEM SAFETY CERTIFICATION PROCEDURES AND TECHNICAL REQTS. FOR DoD STS P/Ls
7. MIL-STD-1574 SYSTEM SAFETY PGR FOR SPACE AND MISSILE SYSTEMS
8. SHUTTLE DoD PAYLOAD SAFETY CERTIFICATION, USAF, (NO NUMBER/DATE), LT. COL. J. S. SMITH

PTS SAFETY CONSIDERATIONS

A. TANK EXPLOSION
B. LEAKAGE
C. CONTAMINANTS
D. OVER-PRESSURE
E. POWER SURGE
F. HYPERGOLIC REACTION
G. INCORRECT VALVE SEQUENCE
H. PURGING PROBLEM
I. GROUNDING
J. ADIABATIC COMPRESSION
K. OTHER

1. MISSION & SYSTEM SAFETY
   - GROUND-PAD
   - LAUNCH/ORBIT/LANDING + ABORT
   - ROLL-OUT & SAFEING
2. CREW (IV & EV) SAFETY
3. ORBITER INTEGRITY/SAFETY
4. SC DAMAGE
5. ASE DAMAGE
6. GROUND CREW (FACTORY TO PAD)

EMERGENCY EARTH RETURN

TWO POSSIBLE EMERGENCY EARTH RETURN SCENARIOS WERE DEVELOPED AS SHOWN ON THE FACING PAGE. BOTH SCENARIOS WERE PREDICATED ON AN ASSUMPTION THAT THE ORBITER ENCOUNTERED DIFFICULTY OR THERE WAS AN ENVIRONMENTAL HAZARD POTENTIALLY AFFECTING THE CREW. THE FIRST CASE SUGGESTS THE NEED TO DEMATE THE UMBILICALS TO PERMIT SPACECRAFT RELEASE TO ORBIT. IN THE SECOND CASE, PR[illegible]LENT TRANSFER OPERATIONS MUST BE TERMINATED AND THE UMBILICALS DEMATED PRIOR TO SPACECRAFT RELEASE.

THESE POTENTIAL SCENARIOS WERE POSTULATED TO ASSURE THAT THE PTS AND HPA MECHANICAL INTERFACE DESIGNS TOOK INTO ACCOUNT THE NEED FOR "RAPID RESPONSE" IN THE EVENT OF AN EMERGENCY SITUATION. SUBSEQUENT STUDIES INCORPORATED THIS NEED AS INTEGRAL TO BASIC SYSTEM AND OPERATIONS DESIGN.

EMERGENCY EARTH RETURN
(PTS TO S/C DISCONNECT)

A. ASSUMPTION – ORBITER MUST RETURN TO EARTH WITHIN ~4 TO 6 HOURS

1. PTS PROPELLANT & PRESSURANT UMBILICALS MUST BE DEMATED/DISENGAGED
2. SIGNAL/PWR CONNECTOR MUST BE DEMATED
3. ALL PTS & ASE ITEMS STOWED & SECURED
4. RMS USED TO DEPLOY S/C TO SPACE
5. POSSIBLE EVA TERMINATED & CREW RETURN TO A/L FOR CLOSEOUT & SUIT DOFF
6. CARGO BAY DOORS CLOSED
7. ORBITER & CREW READIED FOR SUBSEQUENT EARTH RETURN

B. ASSUMPTION – EARTH RETURN REQD DURING PTS OPS

1. CREW WILL BE EVA DURING PTS OPS
2. IV CREWMAN TERMINATES PTS OPS FROM AFT FLT DECK
3. EV CREWMAN DEMATES/DISENGAGES & STOWS 4 PTS UMBILICAL/HOSE LINES
4. EV CREWMAN DEMATES SIGNAL/PWR UMBILICAL & STOWS CABLE
5. EV CREWMAN INSPECTS S/C & PTS FOR LEAKAGE
6. EV CREWMAN CLOSES OUT & STOWS PTS WORK STATION
7. EV CREWMAN JOINS 'COMPANION' FOR FINAL ASE CLOSEOUT & STOWAGE
8. EV CREWMEN TRANSLATE TO & INGRESS INTO A/L

SERVICING ABORT - CONCERN

THE FACING PAGE PRESENTS THE CONCERN ASSOCIATED WITH THE POTENTIAL FAILURE OF THE VRCS DURING THE TIME THE SPACECRAFT IS "BERTHED" TO THE HPA, AND IN PARTICULAR, DURING THE TRANSFER OF PROPELLENT. IF A VRCS ENGINE (SUB-SYSTEMS) FAILS OR MUST BE SHUT DOWN, THERE IS NO REDUNDANCY CAPABILITY. THUS, THE ORBITER FLIGHT CREW MUST RELY ON THE LARGER THRUST PRCS ENGINES FOR ORBITER ATTITUDE "ADJUSTMENT." AS INDICATED ON THE OPPOSITE PAGE, NASA-JSC REQUIRES THE PAYLOAD TO BE TIED DOWN DURING MULTI-AXIS FIRINGS OF THE PRCS. THUS, IN THIS POTENTIAL ORBITER ANOMALOUS SITUATION, SOME OPERATIONAL ALTERNATIVE TO HOLDING THE SPACECRAFT (OR RELEASING THE SPACECRAFT FOR SUBSEQUENT RE-CAPTURE) MUST BE CONSIDERED.

SERVICING ABORT - CONCERN

CONCERN IF VRCS FAILS – CAN SERVICING SYSTEM TAKE PRCS LOADS

1. VRCS NOT 'FAULT TOLERANT' – NO REDUNDANCY
2. WITH VRCS 'OUT' PRCS IS PRINCIPAL ATTITUDE CONTROL AUTHORITY
3. NASA-JSC STATES ALL PAYLOADS MUST BE SECURELY TIED-DOWN TO ORBITER DURING MULTI-PRCS ENGINE (870 LB THRUSTERS) FIRINGS

SECTION 4.0

CONCEPTUAL DESIGN & LAYOUT

CANDIDATE PROPELLENT TANKAGE ARRANGEMENT & GROWTH SYSTEMS

PRELIMINARY

THE FOLLOWING FOUR PAGES PRESENT THE EARLY PROPELLANT TRANSFER SYSTEM CONCEPTS WHEREIN LARGE, OFF-SHELF TANKS WERE CONSIDERED. THE INITIAL DRAWING ILLUSTRATES A SINGLE TANK CONCEPT NECESSITATING AN APPROXIMATE 80+ INCH X_O INSTALLATION IN THE ORBITER. THE SECOND FIGURE PRESENTS A TWO TANK CONCEPT USING EXISTING 62 IN. DIAMETER TANKS IN AN OVER AND UNDER CONFIGURATION AND INCORPORATING A POSITIONING PLATFORM (TILT TABLE WITH ROTATION) INTO THE OVERALL CRADLE. THE THIRD FIGURE ILLUSTRATES A LARGE EXISTING 76 INCH TANK DIAMETER DUAL CAPABILITY AGAIN WITH THE OVER AND UNDER CONFIGURATION. IN THIS CASE, THE POSITIONING PLATFORM HAS BEEN OMITTED; HOWEVER, IT COULD BE INTEGRATED IF REQUIRED. THE FOURTH AND FINAL EARLY CONCEPT ILLUSTRATES A FOUR TANK CONFIGURATION WHICH PERMITS SIGNIFICANT GROWTH OF PROPELLENT TO THE 20 TO 25 THOUSAND LB. RANGE.

THESE EARLY CONCEPTS WERE THEN MODIFIED AND A FURTHER SET OF STUDIES CONDUCTED TO PROVIDE ALTERNATIVE ARRANGEMENTS, TANK COMBINATIONS, AND PROPELLENT TRANSFER TECHNIQUES. THESE SUBSEQUENT STUDIES ARE PRESENTED IN THE FOLLOWING PAGES TO ILLUSTRATE THE PTS EVOLUTION SEQUENCE. THE BASELINE PTS IS PRESENTED IN THE CLASSIFIED APPENDIX TO THIS DOCUMENT.

CANDIDATE PROPELLANT TANK INSTALLATION

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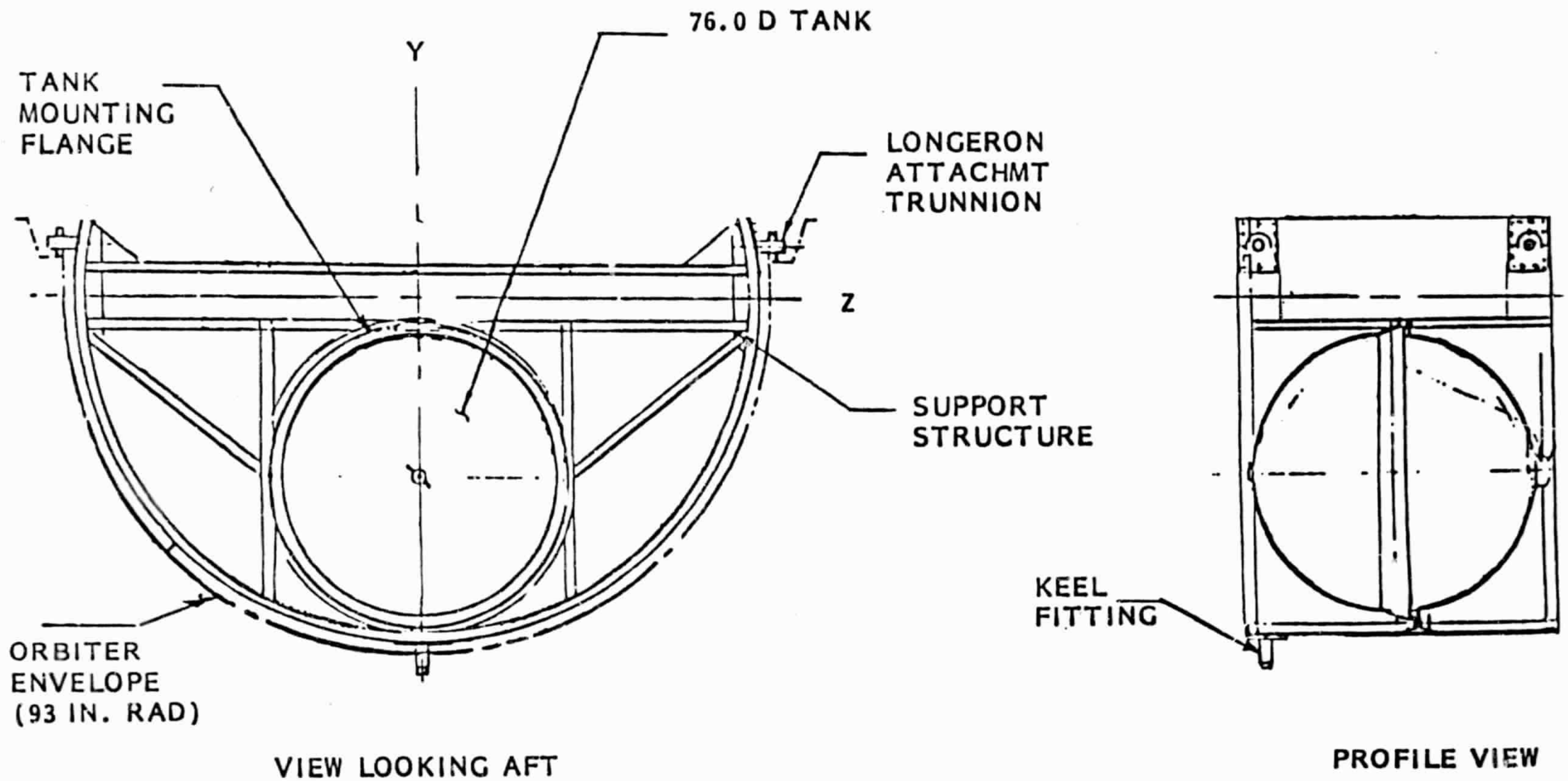

CANDIDATE SYSTEM TANKAGE ARRANGEMENT

GROWTH CONCEPT

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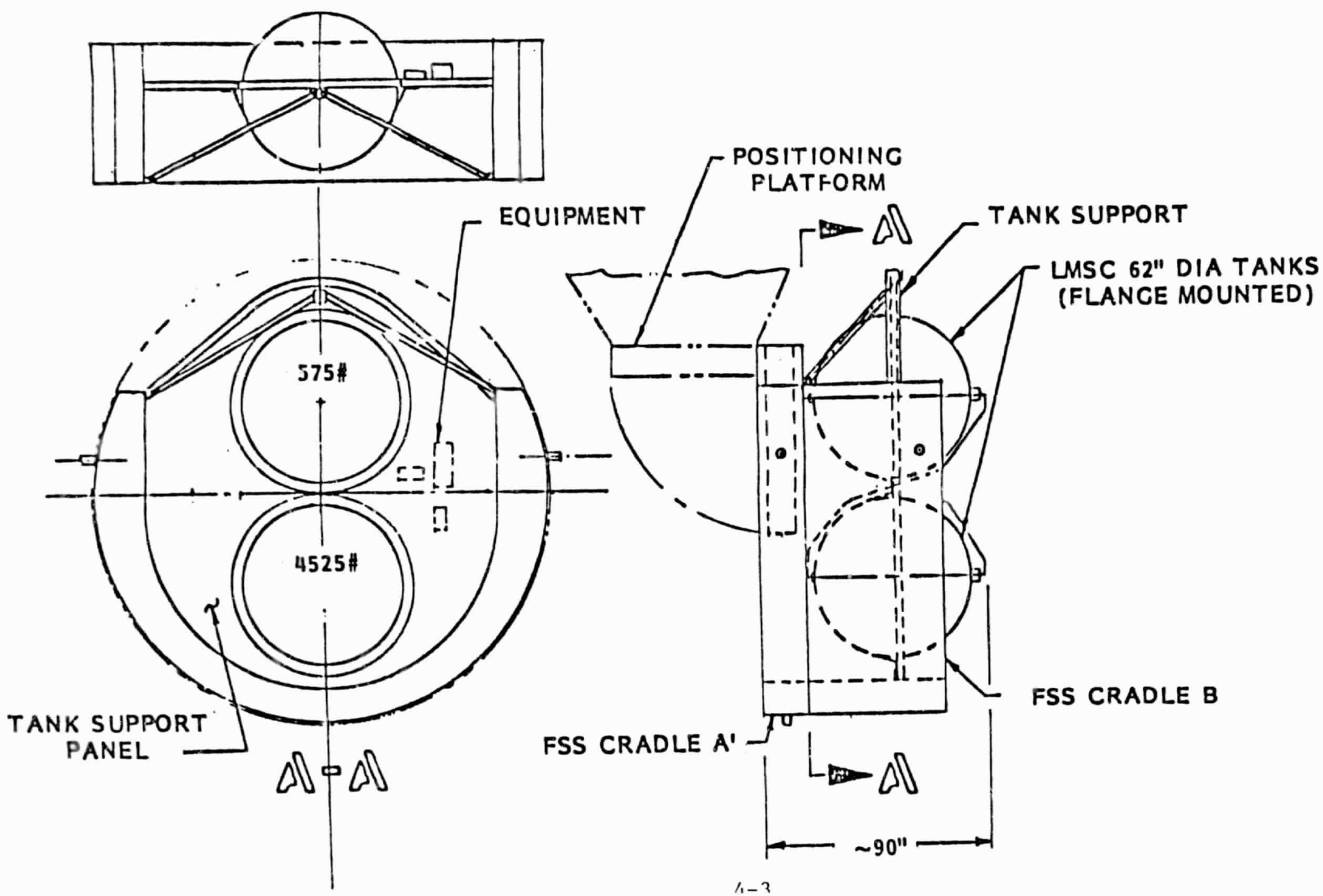
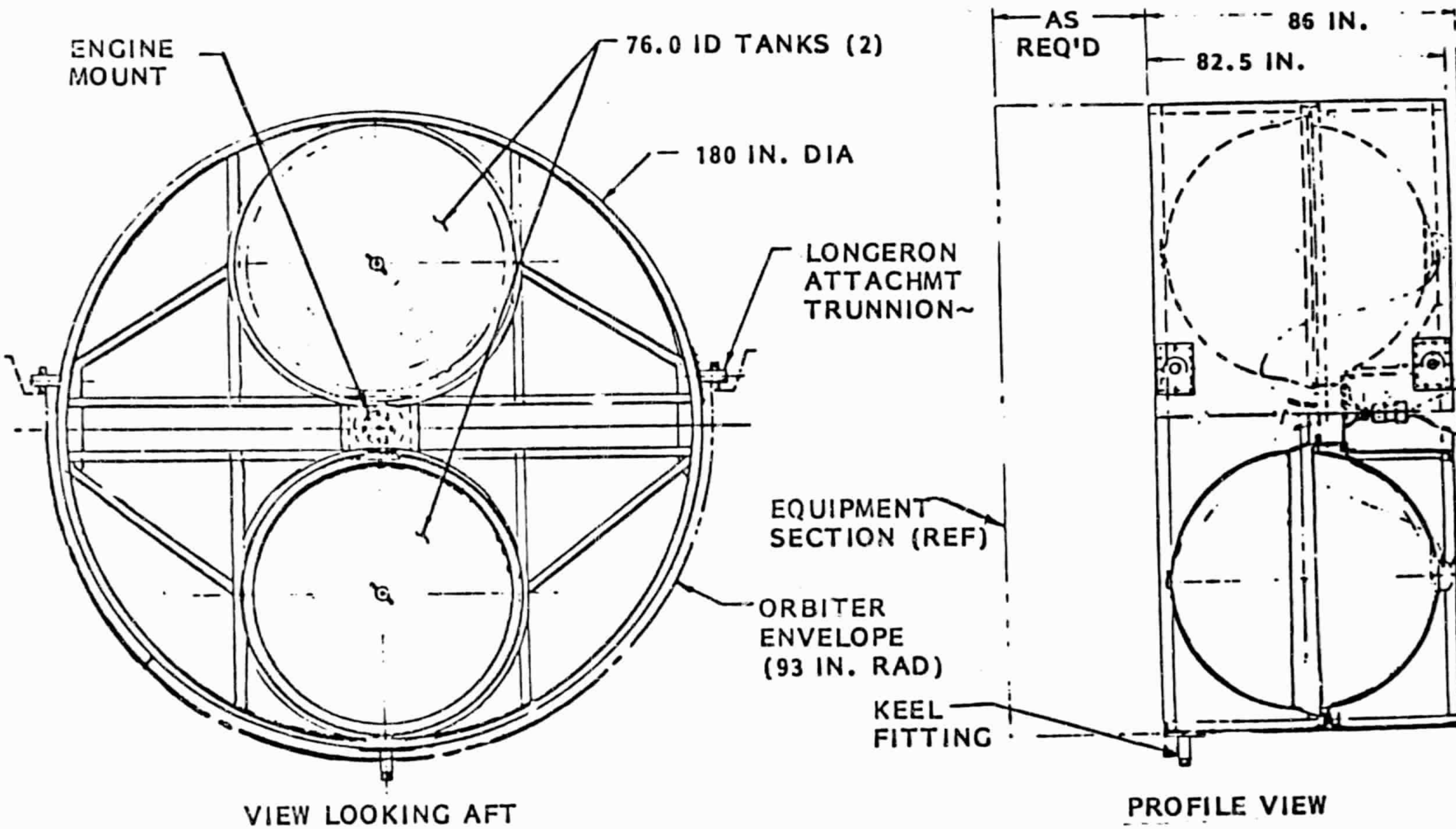


TWO TANK GROWTH SYSTEM CONCEPT



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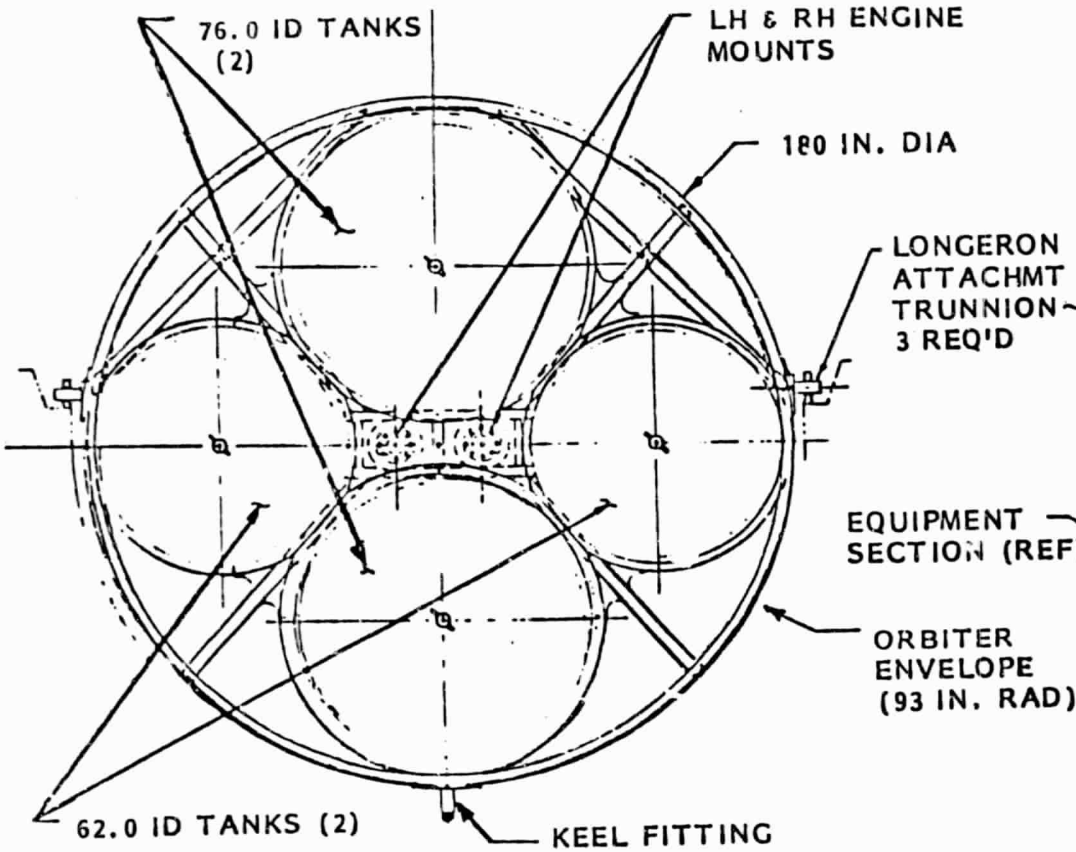
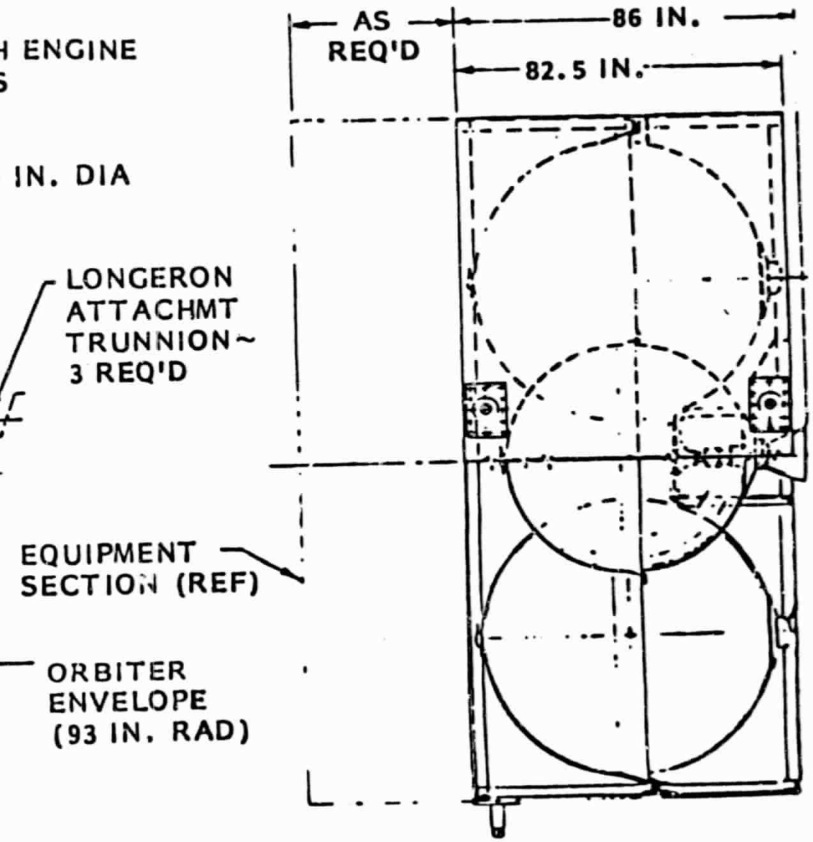
FOUR TANK GROWTH SYSTEM CONCEPT



VIEW LOOKING AFT



PROFILE VIEW

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INITIAL PTS CANDIDATE LAYOUTS
(MULTI-TANK CONCEPTS)

AFTER INITIAL CONCEPT LAYOUTS OF SINGLE (74" DIA) AND DUAL (62" DIA) TANK APPROACHES (30TH CRADLE MTD.), AN EVOLUTIONARY GROWTH SERIES OF PTS CANDIDATES WERE EXAMINED. THE FOLLOWING TWO WORD CHARTS PRESENT A DISCUSSION OF THE THREE (3) MULTI-TANK CONCEPTS. THE VERSATILITY OF THE BASIC DESIGN APPROACH IS READILY APPARENT IN THAT IT INCORPORATES MANY FEATURES OF WHICH 4 ARE WORTHY OF HIGHLIGHTING:

A. MINIMUM ORBITER X_o LENGTH AND MULTI-LOCATION POSITIONABLE

B. MONO OR BI-PROPELLANT ACCOMMODATION

C. POTENTIAL FOR ADDED TANK GROWTH SEGMENT

D. POTENTIAL FOR BERTHING PLATFORM INTEGRATION

PROPELLANT TRANSFER SYSTEM (PTS) CANDIDATE LAYOUT

A. BASIC PTS LAYOUT

1. INCORPORATES 10 FUEL TANKS
   - 584 LBS FUEL EACH TANK (5840 LBS FUEL)
   - ~95 LBS WT. FOR EACH TANK (950 LBS TANKS)
   - TANK DIMENSIONS = 28 IN. DEEP BY 36 IN. DIA.
2. INCORPORATES 2 PRESSURANT TANKS
   - 90 LBS PRESSURANT EACH TANK (TIMES 2) = 180 LBS N_2
   - 105 LBS WT FOR EACH TANK (210 LBS TANKS)
   - TANK DIMENSIONS = 26 IN. DIA SPHERE
3. CRADLE
   - SPACE FRAME (TRUSS WORK) CONSTRUCTION
   - 2 TO 3 TRUNIONS (DEPENDS ON ASSOCIATE STURCTURES) AND 1 KEEL TONGUE
   - DIMENSIONS

     √ X_o = 29 IN. WITHOUT TANKS AND 30 IN. WITH TANKS
     √ Y_o = ~180 IN.
     √ Z_o = ~144 IN.
   - MATERIAL IS
   - DESIGNED FOR ORBITER LAUNCH AND CRASH LANDING LOADS (LOADED-FUEL)
   - MODULAR FEATURES

     √ GROWTH
     √ PERMITS INCORPORATION OF 'POSITIONING PLATFORM' OF BERTHING DEVICE
   - GRAPPLE FIXTURE INCORPORATED
   - BRACKETRY FOR PWR/SIGNAL/COOLING (?) LINES

PROPELLANT TRANSFER SYSTEM (PTS) CANDIDATE LAYOUT

B. BASIC PTS GROWTH CONCEPT

1. INCORPORATES 15 FUEL TANKS
   - 584 LBS FUEL EACH TANK (8760 LBS PROPELLANT)
   - ~95 LBS WT FOR TANK (1425 LBS OF TANKS)
   - TANK DIMENSIONS = 28 IN. DEEP BY 36 IN. DIA
2. INCORPORATES 3 PRESSURANT TANKS
   - 90 LBS PRESSURANT EACH TANK (270 LBS N_2)
   - 105 LBS WT FOR EACH TANK (315 LBS OF TANKS)
   - TANK DIMENSIONS = 26 IN. DIA EACH SPHERE
3. CRADLE
   - SPACE FRAME (TRUSS-WORK) CONSTRUCTION
   - 3 TRUNIONS AND 1 KEEL TONGUE
   - DIMENSIONS

     $\surd X_o$ = 29 IN. WITHOUT TANKS AND 30 IN. WITH TANKS
     $\surd Y_o$ = ~180 IN.
     $\surd Z_o$ = ~180 IN.
   - MATERIAL IS
   - DESIGNED FOR ORBITER LAUNCH AND CRASH LANDING LOADS (LOADED-FUEL)
   - MODULAR FEATURES

     √ADDED 2500 LB FUEL SEGMENT
   - GRAPPLE FIXTURE INCORPORATED
   - BRACKETRY FOR PWR/SIGNAL/COOL[illegible]G (?) LINES

PTS LAYOUTS

THE FOLLOWING THREE PTS CONCEPT LAYOUTS PRESENT THE MINIMUM (30 IN.) LENGTH (X_o ORBITER REFERENCE) APPROACH. THE BASIC LAYOUT PROVIDES ADEQUATE TANKAGE (INCLUDING PRESSURANT TANKS) FOR THE REFERENCE MISSION & INHERENTLY PERMITS EITHER MONO OR BI-PROPELLANT MIXTURES. FULL CARGO BAY DIAMETER IS USED WITH NOMINAL TRUNNION & KEEL TONGUE I/F'S TO THE ORBITER. THE 2ND LAYOUT ILLUSTRATES THE VERSATILITY OF THIS APPROACH VIA INCORPORATION OF A BERTHING PLATFORM (BP). THE BP ALSO CAN INCORPORATE 'AUTOMATED' UMBILICAL INTERCONNECTS WITH A SPACECRAFT. THE GP IS A MODULAR UNIT AND COULD ACCOMMODATE THE MMS FSS OR ST DEPLOYMENT MAINTENANCE PLATFORM (DMP) PRELIMINARY DESIGN. THE 3RD LAYOUT PRESENTS THE CONCEPT FOR A TANKAGE 'GROWTH MODULE' THUS SUBSTANTIALLY INCREASING PROPELLANT SUPPLY.

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4-12, 4-13, 4-14

PTS FLUIDS UMBILICAL SYSTEM

The assembly drawing opposite illustrates the elements of the concept evolved for linking the PTS to spacecraft tankage during propellant resupply operations. Consisting of male and female umbilical halves, it employs two connector sets for the transmission of both gas and liquid through one umbilical. The baseline system interconnects use a Fairchild Stratos Co. connector developed under a contract from JPL for the Mariner Program, but are scaled up for use with 3/4 inch diameter propellant lines (the original design used 1/2 inch lines). Because of the engagement requirements, both couplings must be identical, so the pair designated for gas use are adapted to 1/4 inch input/output lines.

Two approaches are incorporated in the umbilical system to insure that inadvertent connection of gas to propellant lines cannot occur. First, each umbilical half is provided with one male and one female connector in the proper gas/liquid relationship. Since no coupling or fluid transfer can occur in a male-to-male or female-to-female relationship, reversal of umbilical orientation will not constitute a hazard. Second, the male umbilical half is provided with a key pin which mates with a key slot in the cuff of the female umbilical <u>only</u> when the halves are properly oriented.

Once inserted, the connection is made by a jack screw assembly operated by a 7/16" socket drive. In actual operation, the astronaut would manually remove dust covers from both the PTS and satellite receptacles, pick up the PTS receptacle, insert it properly, and crank it into the connected position. The "A" and "B" systems would be keyed differently so that fuel and oxidizer lines could not be interchanged. Color coding of lines and receptacles is also suggested. The mated housings are sealed to render them leak tight. If there is any leakage within the receptacle a 1/2" diameter line is provided from the receptacle to allow leak detection and safe venting of the leak.

SATELLITE MATING RECEPTACLE

The drawing shows a typical satellite mating receptacle containing a propellant (liquid) connector and a pressurant gas connector. As launched, the receptacle will be closed with a plug assembly for dust and debris exclusion. Handles on the plug allow the astronaut to remove it prior to servicing. A tether keeps it in the vicinity of the connector for replacement after servicing. The receptacle is hard mounted to the satellite structure. Where the lines exit the receptacle they are sealed with elastomeric o-rings.

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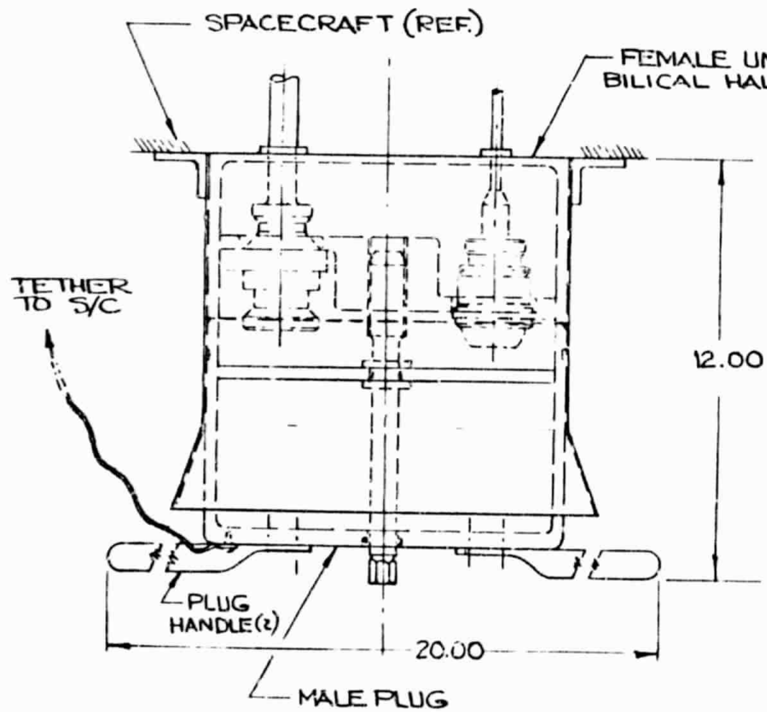
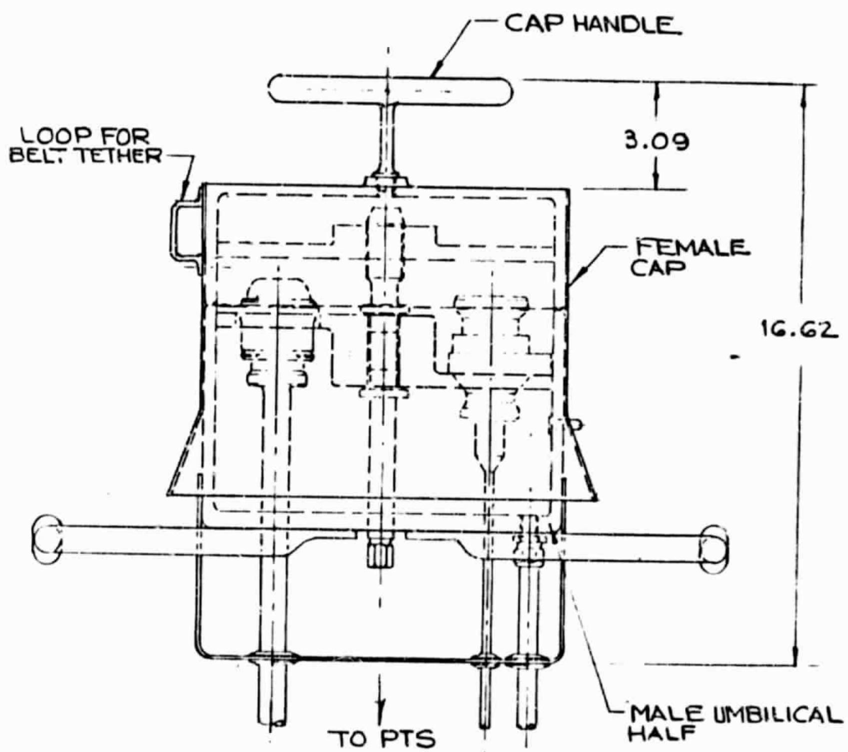
UMBILICAL STOWAGE SYSTEM



STOWAGE ~ SPACECRAFT
UMBILICAL HALF



STOWAGE ~ PTS/ORBITER
UMBILICAL HALF

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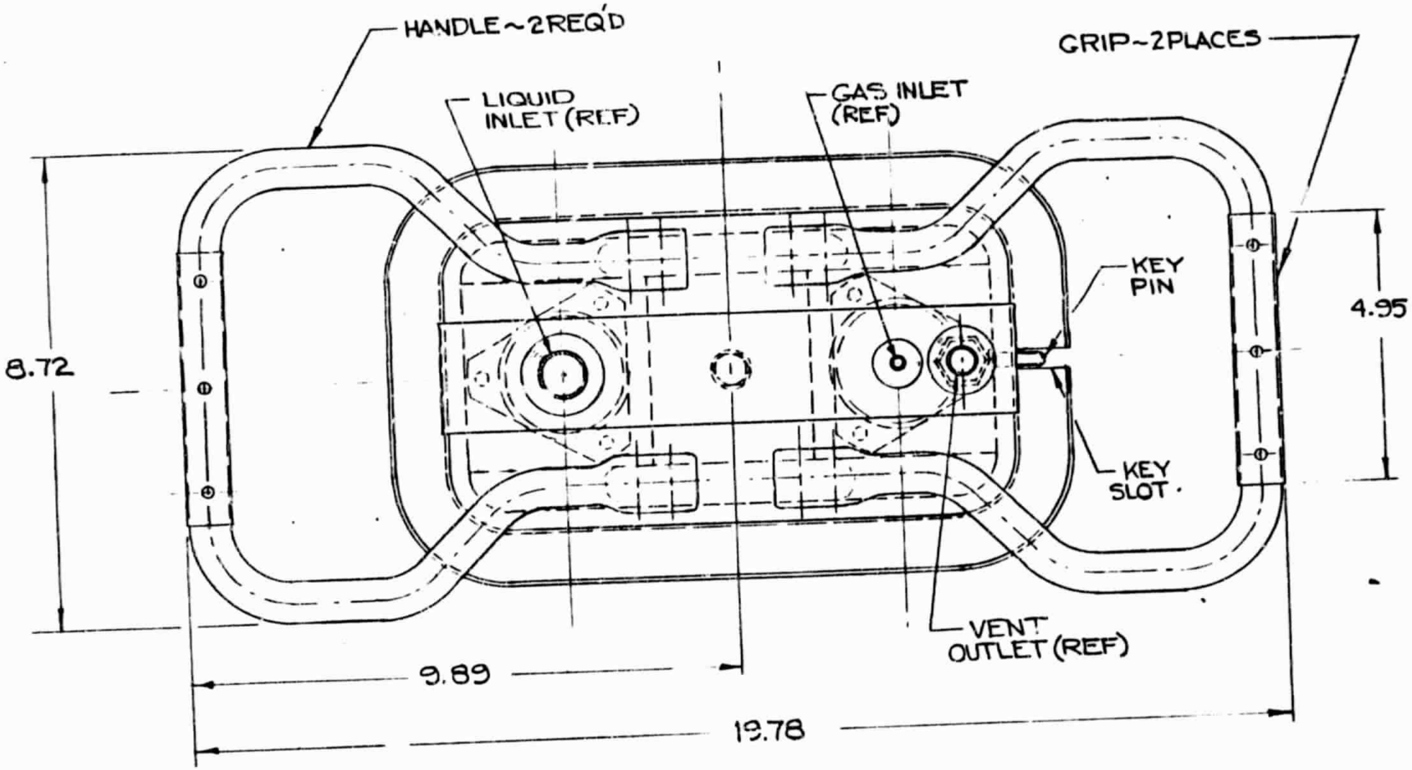
PTS FLUIDS UMBILICAL SYSTEM

END VIEW

The drawing opposite shows the handle arrangement for astronaut use in mating the PTS and satellite propellant interconnects.

PTS FLUIDS UMBILICAL SYSTEM (cont'd)



END VIEW OF UMBILICAL FROM ORBITER SIDE

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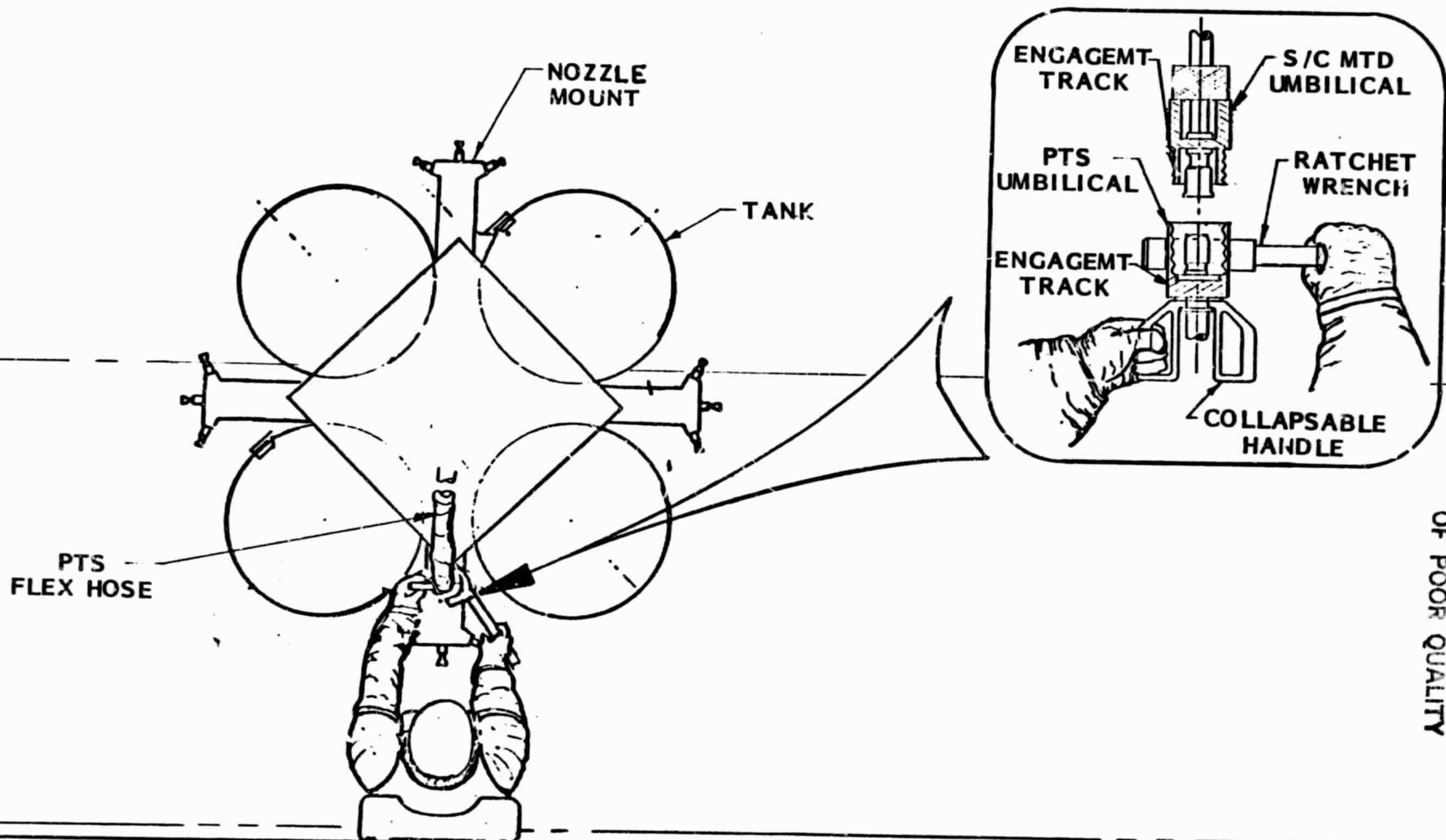
UMBILICAL ENGAGEMENT/ALIGNMENT & MATE/DEMATE I/F

THE TWO PTS UMBILICAL HALVES ARE LINKED BY AN EVA MANUALLY POSITIONED UMBILICAL ENGAGEMENT DEVICE. THE EVA TASK OF ENGAGING THEM IS SHOWN IN THE OPPOSITE FIGURE. THE STOWED PTS UMBILICAL IS UNSTOWED FROM THE ORBITER AND POSITIONED/MATED TO THE S/C MOUNTED UMBILICAL. THERE THE TWO UMBILICAL CONNECTORS ARE ENGAGED VIA A PRE-INSTALLED ALIGNMENT & ENGAGEMENT TRACK. A RATCHET WRENCH TOOL IS THEN USED TO DRIVE THE TWO CONNECTORS TOGETHER FOR SUBSEQUENT PROPELLANT TRANSFER.

UMBILICAL ENGAGEMENT/ALIGNMENT & MATE/DEMATE I/F



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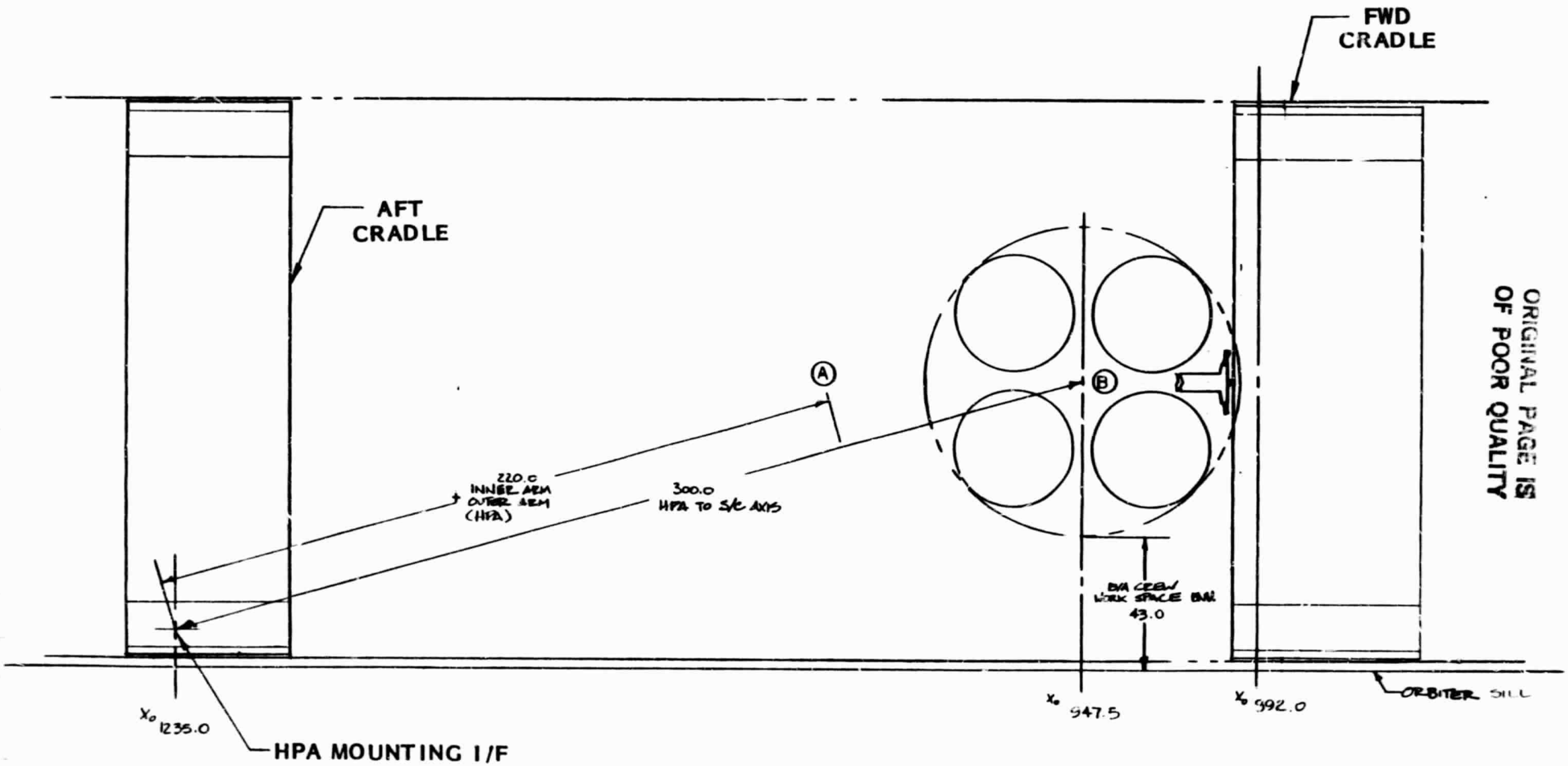
S/C POSITION CANDIDATES RELATIVE TO THE PTS/CRADLE

TWO POSITIONS FOR S/C LOCATION WERE IDENTIFIED RELATIVE TO HPA 'LENGTH.' THE 1st POSITION (STA. 1235 X_o ORBITER COORDINATE) ASSUMES AN HPA ARM LENGTH OF APPROXIMATELY 220 IN. (18.3 FT.). IN THIS POSITION, THE S/C IS A SIGNIFICANT DISTANCE FROM THE PTS/CRADLE, THUS REQUIRING LONGER UMBILICAL TO PTS TANK FLUID LINES. THE SECOND POSITION (STA. 947.5 X_o ORBITER COORDINATE), AND ORIGINALLY GIVEN AS BASELINE, LOCATES THE S/C ADJACENT TO THE PTS/CRADLE. HPA LENGTH IS NOW 300 IN. (25 FT.). THIS RESULTS IN HIGHLY DESIRABLE SHORT FLUID TRANSFER LINE LENGTH. HOWEVER, NEAR THE END OF THE STUDY, THE SHORTER HPA LENGTH (18.3 FT.) AND STATION X_o 1235 WAS STATED AS THE DESIRED LOCATION BASED ON HPA LENGTH LIMITATIONS.

HPA POSITIONING OF S/C RELATIVE TO FWD CRADLE



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PTS EVA APPROACHES

THERE WERE TWO BASIC EVA PTS SERVICING APPROACHES IDENTIFIED DURING THE STUDY AND ARE PRESENTED ON THE FACING PAGE. IN EITHER CASE, DIRECT "GLOVES ON" PARTICIPATION BY THE EVA CREWPERSON WAS ESTABLISHED FOR MATE AND DEMATE OF THE UMBILICAL AND POTENTIAL OVER-RIDE OF THE PTS CRITICAL VALVING. ADDITIONALLY, PROPELLENT LINE MANAGEMENT AND WORK STATION SET-UP AND TEAR-DOWN WERE TASKS ALSO ALLOCATED TO THE EVA CREWPERSON.

PTS EVA APPROACHES

A. EVA SUPPORT FROM AN ORBITER CARGO-BAY SILL MOUNTED BRIDGE FITTING

   1. CREWPERSON POSITIONED VERTICAL (+ Z AXIS) TO ORBITER X_o AXIS COORDINATE

   2. CREWPERS POSITIONED ALONG THE ORBITER X_o AXIS COORDINATE

B. EVA SUPPORT FROM THE FWD CRADLE (UPON WHICH PTS IS MOUNTED)

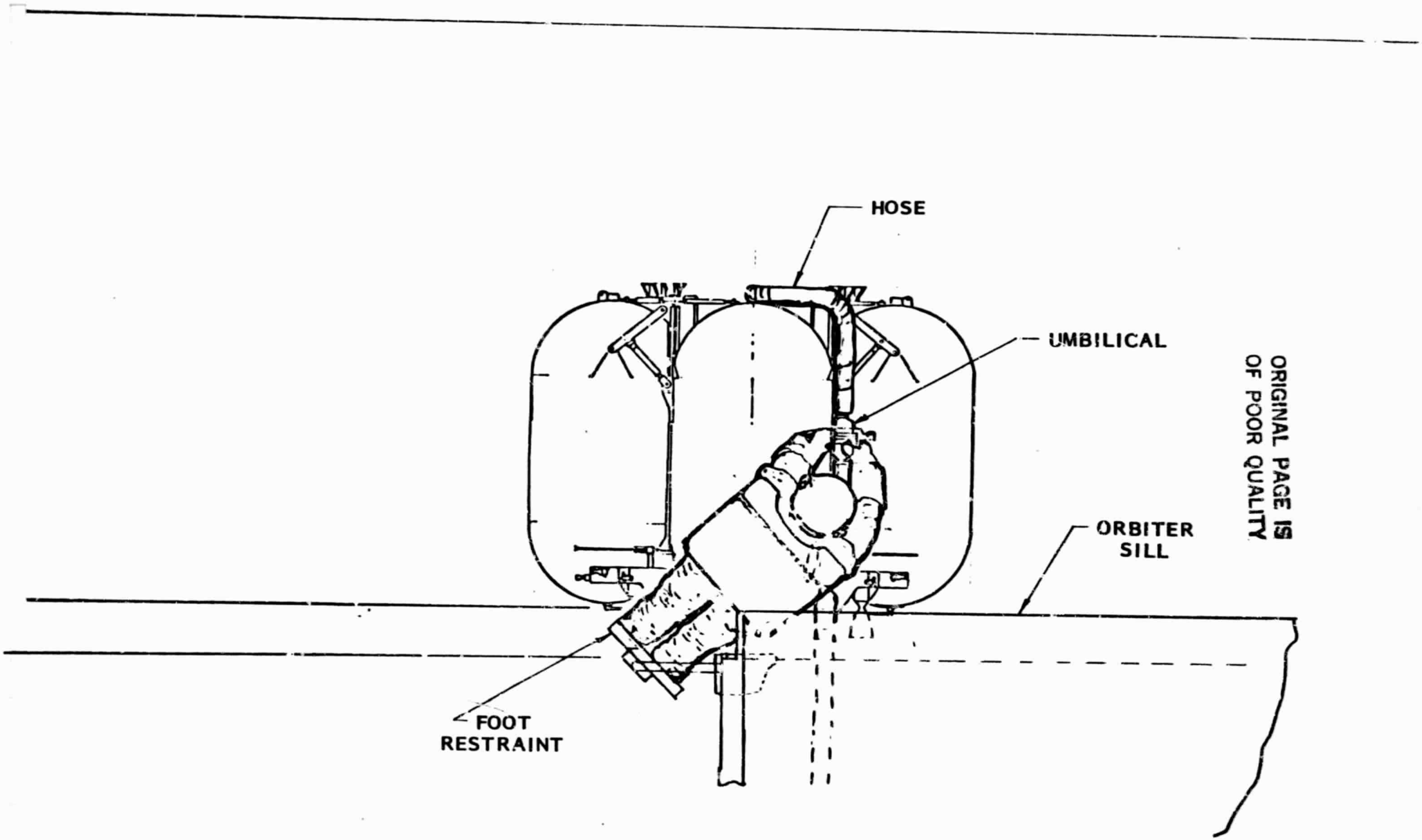
   1. CREWPERSON POSITIONED VERTICAL (+ Z AXIS) TO ORBITER X_o AXIS COORDINATE

HORIZONTAL UMBILICAL ACCESS POSITION

THE HORIZONTAL SERVICE POSITION IS SHOWN ON THE FACING PAGE. A HORIZONTAL POSITION RELATIVE TO THE ORBITER IS ASSUMED BY THE CREW MEMBER FOR ACCESS TO THE S/C PTS UMBILICAL.

IN THIS POSITION, THE MISSION PROPELLANT RESUPPLY SERVICE FUNCTIONS ARE CARRIED OUT FOR EVA MANUAL UMBILICAL MATE/DEMATE TASKS.

HORIZONTAL UMBILICAL ACCESS POSITION



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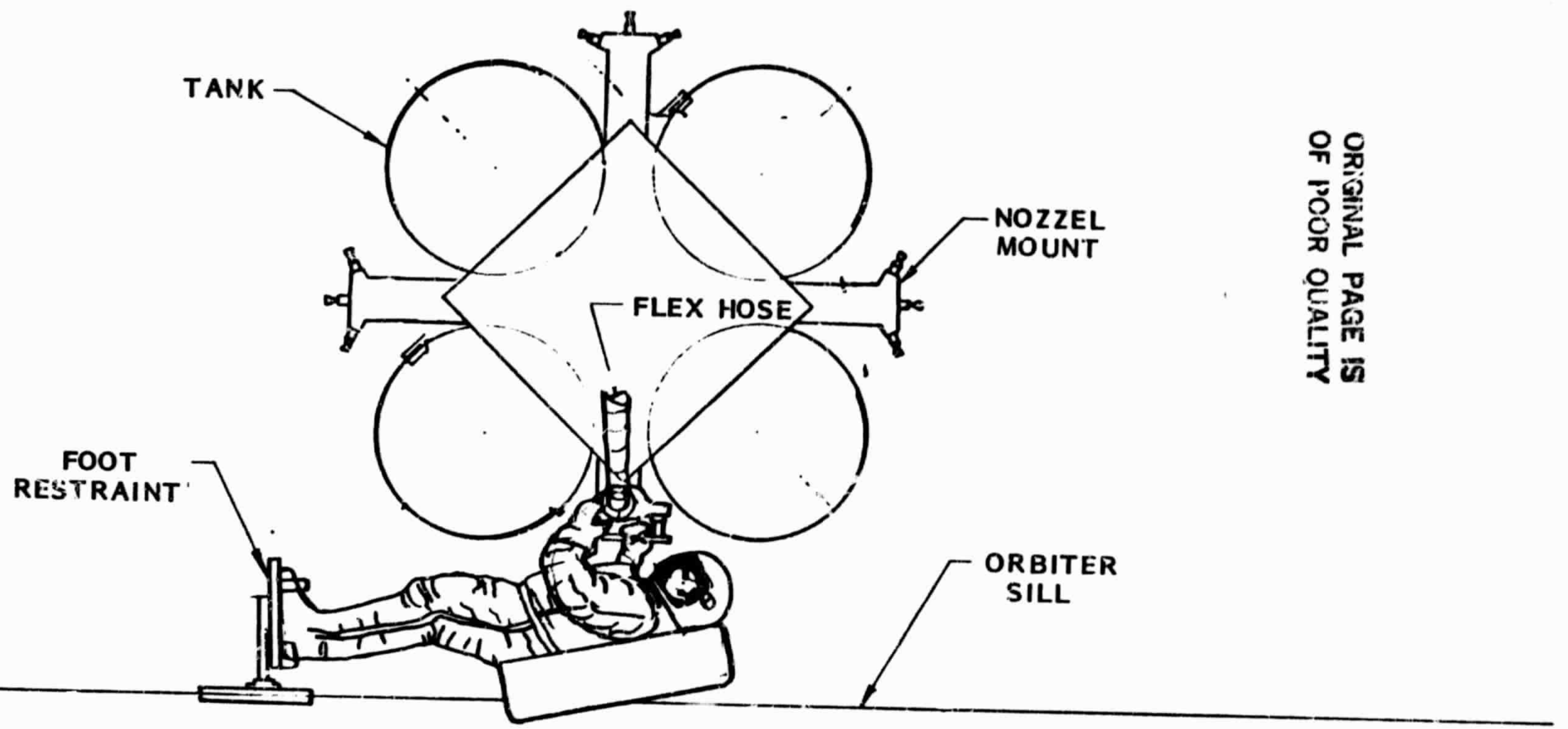
HORIZONTAL UMBILICAL ACCESS POSITION

THE OPPOSITE PAGE SHOWS THE PLAN VIEW OF THE ORBITER CARGO BAY WITH THE S/C POSITIONED FOR SERVICING. THE CREW PERSON IS RESTRAINED ADJACENT TO THE S/C AND HAS ASSUMED A HORIZONTAL POSITION RELATIVE TO THE ORBITER TO CONDUCT MISSION PROPELLANT RESUPPLY SERVICE TASKS WHICH ARE ASSOCIATED WITH UMBILICAL MATE/DEMATE. ALSO ILLUSTRATED IS THE FOOT RESTRAINT MOUNTED TO THE ORBITER SILL.

HORIZONTAL UMBILICAL ACCESS POSITION



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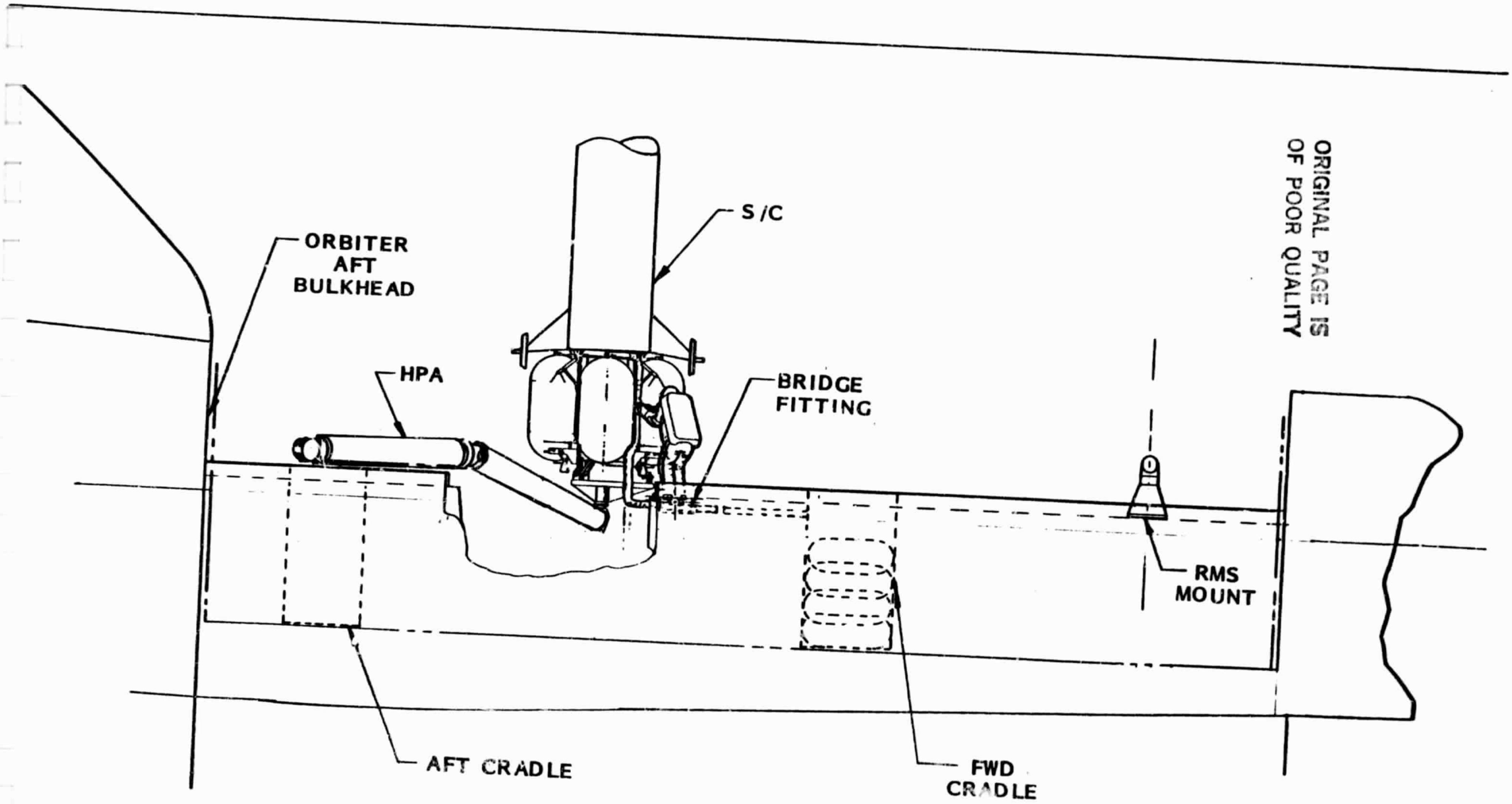
MID-BAY S/C SERVICING POSITION

THE ORBITER MID-BAY LAYOUT SHOWN IN THE OPPOSITE DRAWING PORTRAYS THE BASELINE SERVICING APPROACH TO ON-ORBIT S/C PROPELLANT REPLENISHMENT. THE TASK IS CONDUCTED VIA EVA BY THE CREWPERSON IN CONJUNCTION WITH THE RMS USED FOR S/C CAPTURE AND RETRIEVAL AND THE HPA USED FOR S/C BERTHING AND POSITIONING.

THE CREWPERSON WORKSTATION IS LOCATED MIDWAY BETWEEN THE FWD. AND AFT CRADLES ON THE STARBOARD SIDE OF THE ORBITER. THE ORBITER BRIDGE FITTING ADJACENT TO THE WORK STATION IS USED AS A RIGID MOUNTING SOURCE FOR PTS UMBILICAL STOWAGE, WORK STATION INTERFACE, UMBILICAL DISCONNECT, AND CREWPERSON RESTRAINING DEVICES.

MID - CRADLES SERVICING POSITION



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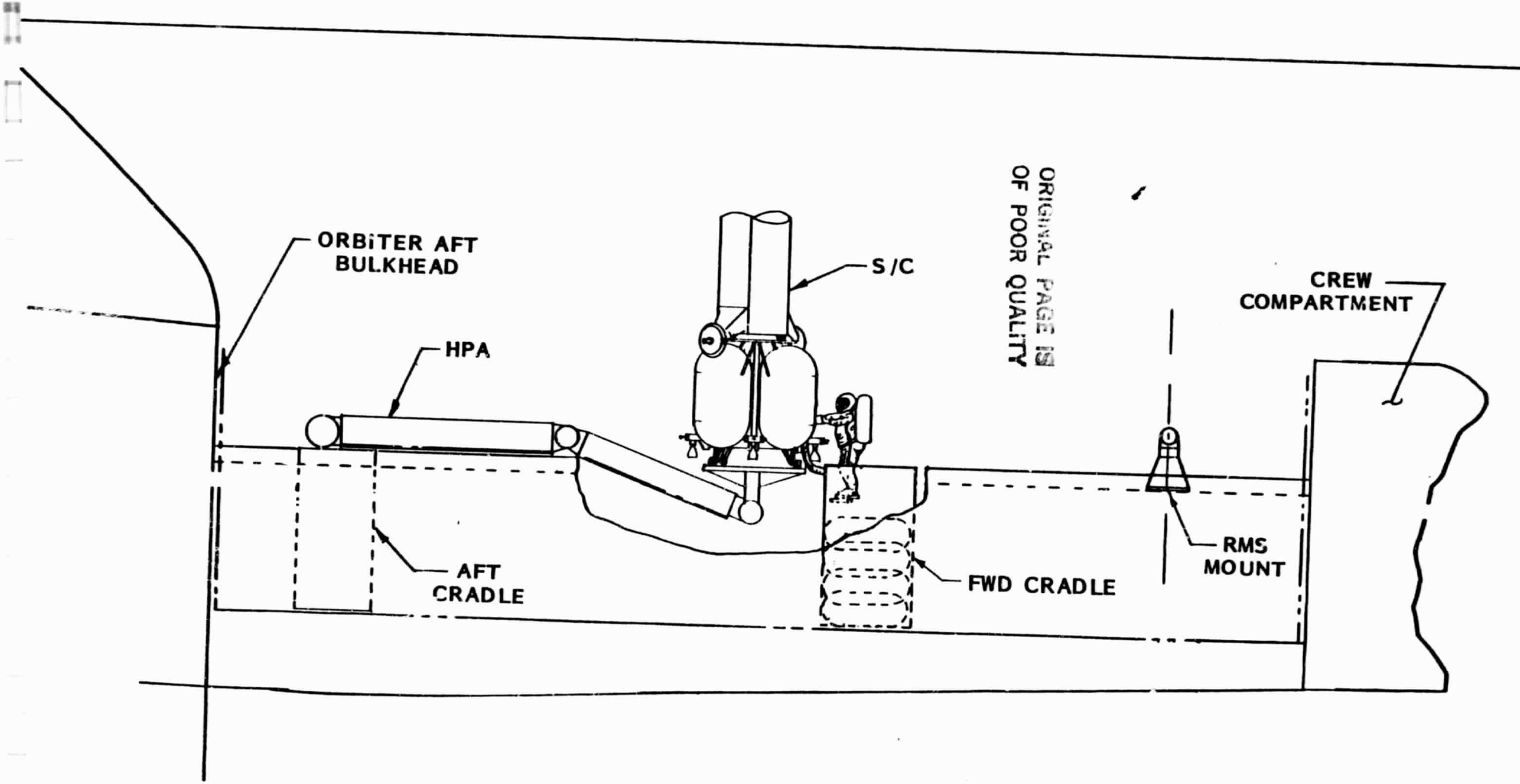
FWD S/C SERVICING POSITION

THE FWD POSITION SERVICING APPROACH SHOWN OPPOSITE ILLUSTRATES THE S/C TO BE BERTHED ON THE HPA/TILT-TABLE TO BE POSITIONED DIRECTLY BEHIND THE FWD CRADLE. THE EVA WORKSTATION SHOWN PORTRAYS THE CREWPERSON RESTRAINED FROM THE FWD CRADLE SERVICING THE S/C.

THE STOWAGE OF THE PTS UMBILICAL LINE AND THE MOUNTING OF CREWPERSON RESTRAINING DEVICES AND UMBILICAL DISCONNECT ARE MANAGED SIMILARLY AS IN THE MID-POSITION SERVICE CONCEPT.

AN APPARENT ADVANTAGE TO THIS FWD POSITION LOCATION IS THE SHORTENING OF THE DISTANCE BETWEEN THE PTS TANKS AND THE S/C; CONSEQUENTLY, THE MINIMIZING OF THE LENGTH OF THE PROPELLANT TRANSFER UMBILICAL LINE.

FWD - CRADLE SERVICING POSITION



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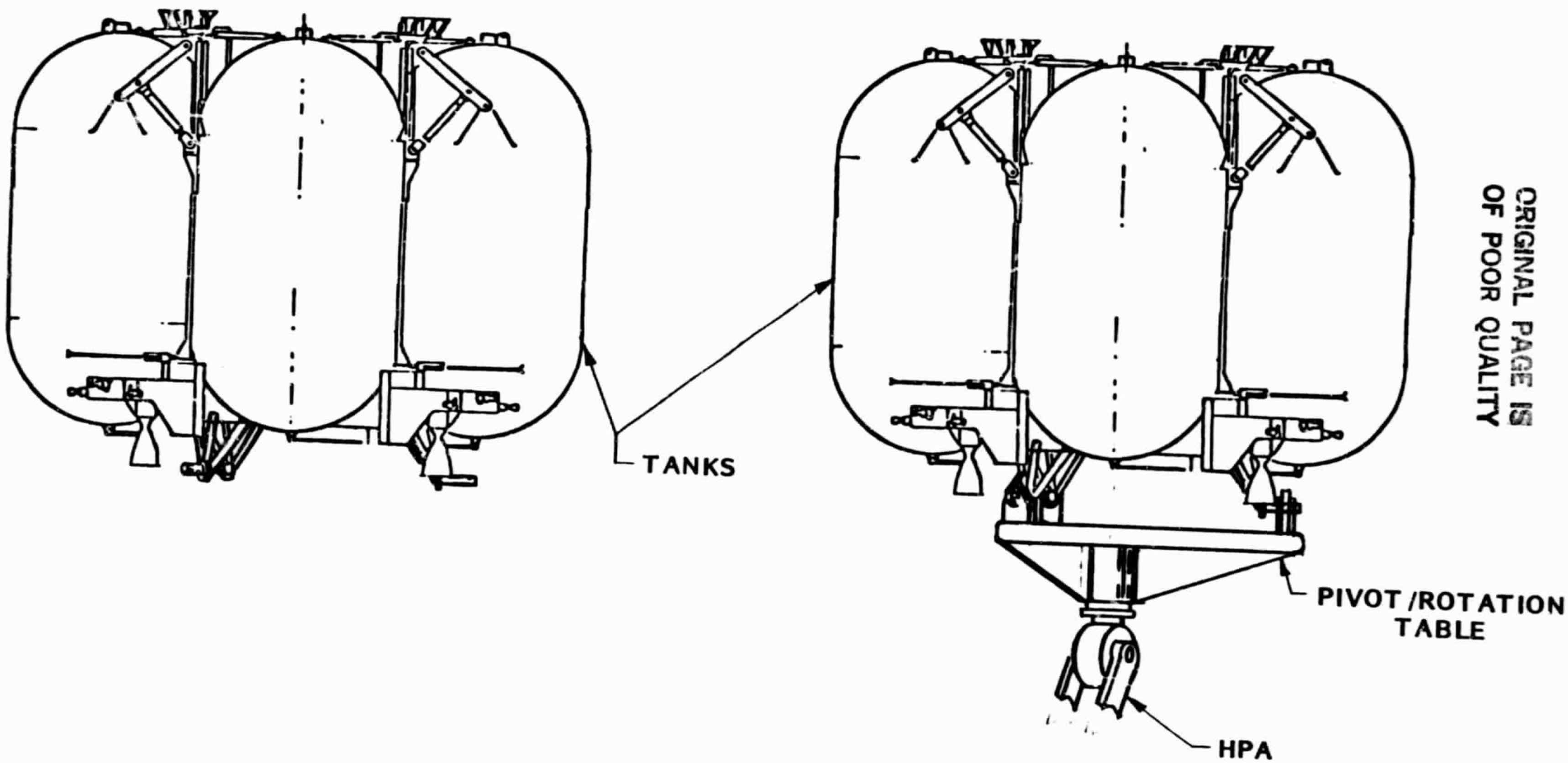
POSTULATED I/F TO HPA

THE S/C IS DEPICTED ON THE FACING PAGE CAPTURED AND BERTHED ON THE HPA TILT/ROTATION TABLE. ILLUSTRATED IS THE AFT-END BERTHING I/F JUST AFT OF THE NOZZLES & TANKAGE ASSEMBLY WHERE CAPTURE PINS ARE SHOWN ENGAGED TO THE BERTHING-TILT/ROTATION TABLE.

POSTULATED I/F TO HPA



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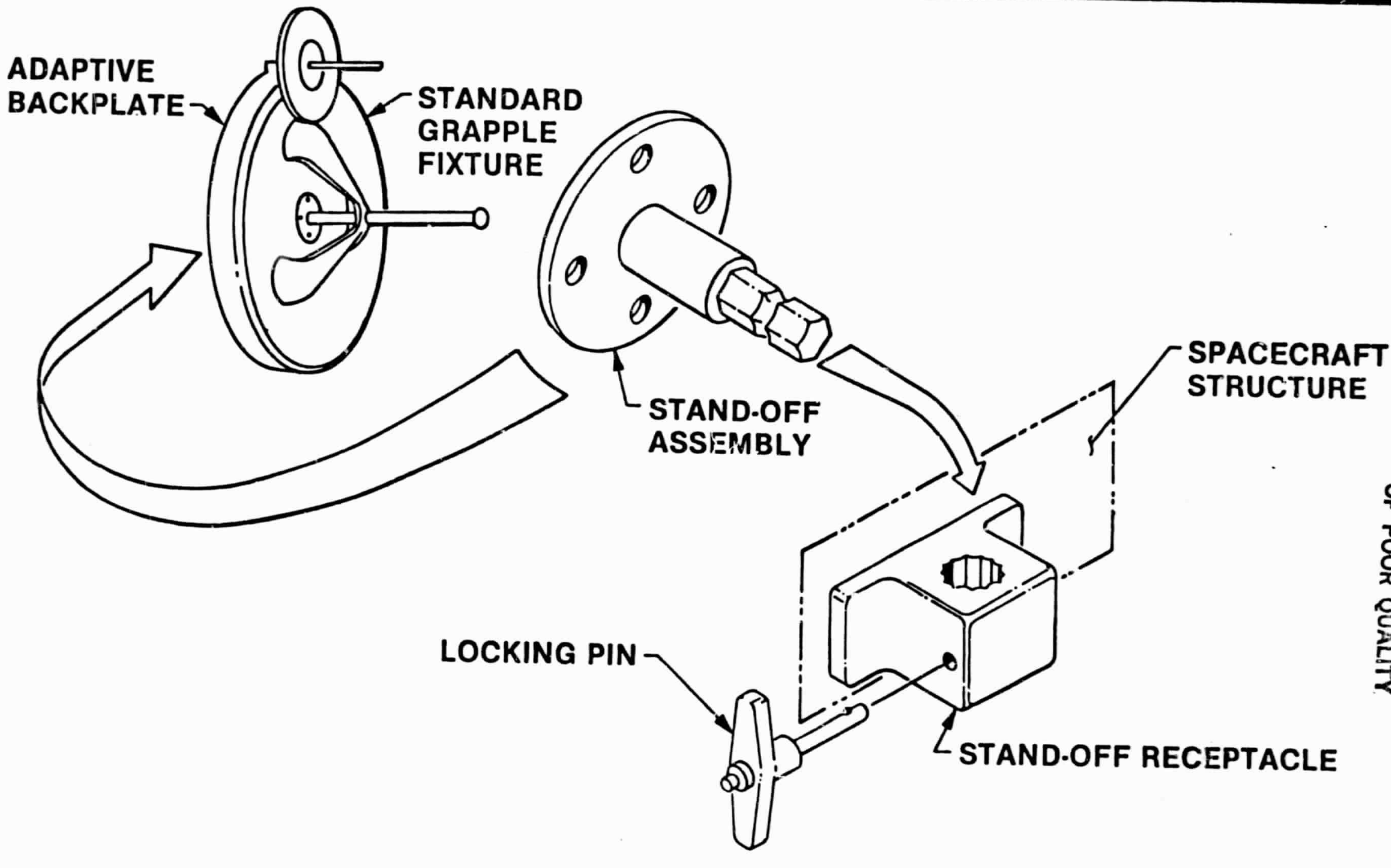
ATTACH/REMOVE GRAPPLE FIXTURE & STAND-OFF

THE PORTABLE GRAPPLE FIXTURE AND ASSOCIATED STAND-OFF ARE ILLUSTRATED ON THE FACING PAGE. THIS UNIT CAN BE USED FOR VARIOUS FUNCTIONS ASSUMING THAT THE INTERFACE STAND-OFF RECEPTACLE HAS BEEN LOCATED ON THE HARDWARE ITEM WHICH MAY BE GRASPED BY THE RMS FOR "REPOSITIONING," REMOVAL/REPLACEMENT, OR "JETTISON" TO SPACE. THE GRAPPLE FIXTURE IS A NASA STANDARD ITEM. THE UNIT IS PROVIDED WITH A STAND-OFF WHICH IS BOLTED ON THE REAR SURFACE AND PERMITS INSERTION INTO THE RECEPTACLE FOR MOUNTING TO THE DESIRED ITEM. SINCE THE UNIT IS PORTABLE, IT FALLS INTO THE CATEGORY OF ASE.

Attach/Remove Grapple Fixture and Stand-off



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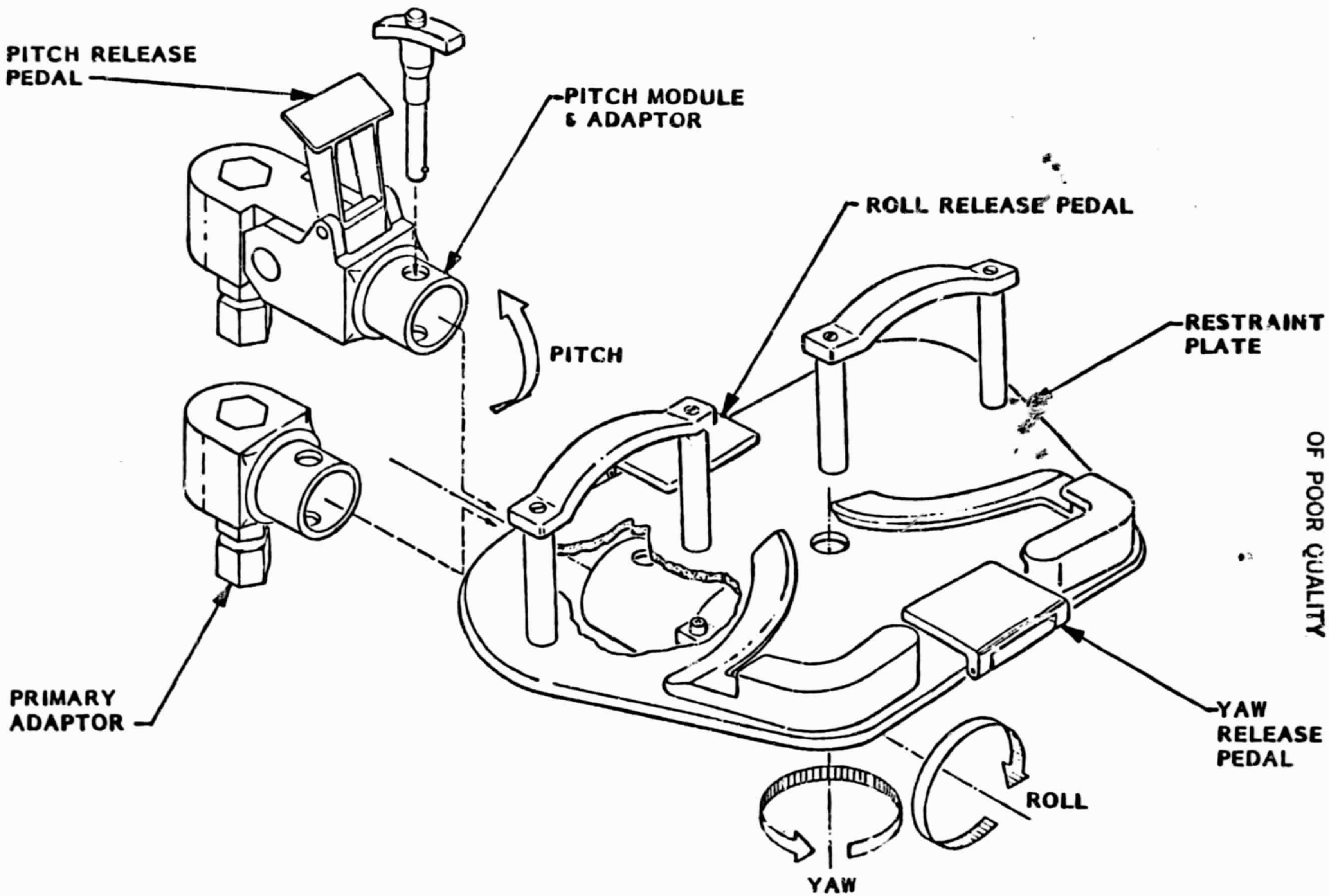
PORTABLE FOOT RESTRAINT ASSEMBLY

THE OPPOSITE PAGE PRESENTS THE PORTABLE FOOT RESTRAINT ASSEMBLY REQUIRED FOR EVA PROPELLANT TRANSFER FUNCTIONS AT THE PTS WORK STATION. THE UNIT IS PORTABLE AND REPOSITIONABLE TO ACCOMMODATE THE VARIOUS EVA CREW POSITIONS REQUIRED FOR ACCESS TO THE PTS FOR BOTH NOMINAL AND NON-NOMINAL OPERATIONS. CRITICAL TO THE FOOT RESTRAINT IS THE FACT THAT IT CAN BE OPERATED, E.G., ROLL, YAW, OR PITCH CONTROL, WITH THE CREW PERSON STILL RESTRAINED WITHIN THE UNIT. THE ROLL, YAW, AND PITCH CAPABILITY IS REQUIRED FOR DISCRETE "IN SITU" POSITIONING OF THE CREW PERSON DURING THE SET-UP/TEAR-DOWN OF THE WORK STATION, PROPELLENT LINE MANAGEMENT, UMBILICAL MATE/DEMATE, AND ANY PTS OVERRIDE FUNCTIONS REQUIRED.

FOOT RESTRAINT ASSEMBLY



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SECTION 5.0

EQUIPMENT LIST

PTS EQUIPMENT LIST

THE EQUIPMENT LIST DEVELOPED FOR THE BASELINE VENT, FILL & REPRESSURIZE SYSTEM IS SHOWN ON THE OPPOSITE PAGE. QUANTITIES ARE BASED ON DEVELOPMENT PROGRAM UNITS PLUS THREE OPERATIONAL SYSTEMS. THE SUPPLIERS LIST IS BASED ON THOSE COMPANIES WHO HAVE SUITABLE COMPONENTS IN THEIR CURRENT CATALOG, IT IS NOT TO BE CONSIDERED THE ONLY OR THE BEST SOURCE IN ALL CASES.

PROPELLANT TRANSFER SYSTEM

EQUIPMENT LIST

Item	Drawing No. or Similar-to No.	Supplier
Filter, 1/4"	P/N 8155070	Wintec
Filter, 3/4"	P/N 8151050	Wintec
Vent & Press. Valve, 1/4"	P/N 1831-57	Pyronetics
Temperature Transducer	LTN - 3	Fenwal Electronics
Fill/Drain Valve, 3/4"	P/N 1846-2	Pyronetics
Propellant Tanks		PSI
Pressurant Tanks	P/N 4425011	Fansteel Precision
Flex Hose, 1/4"		Coast Metal Craft
Flex Hose, 3/4"		Coast Metal Craft
Flowmeter, 3/4"	P/N FT12A20-LB	Flow Technology
Burst Diaphram		Starline Engineering
Shutoff & Isolation Valves, 1/4"	P/N 6687	Consolidated Controls
Shutoff & Isolation Valves, 3/4"	P/N 3795	Consolidated Controls
Relief Valve	P/N 5760009-111	Parker Hannifin
3/4" Disconnect	P/N 74367000 P/N 74366000	Fairchild Stratos Fairchild Stratos
1/4" Disconnect	P/N 74367000 P/N 74366000	Fairchild Stratos
Pressure Regulator	P/N 73P620002-1001	Fairchild Stratos
1/4" Manifold Valve		
Pressure Transducer	P/N PA822	Gould

CREW UTILIZED EQUIPMENT

THE FOLLOWING THREE PAGES IDENTIFY THOSE EQUIPMENT AND/OR SUPPORT ITEMS SPECIFIED AS NECESSARY TO FACILITATE PTS PROPELLENT TRANSFER OPERATIONS. THE FIRST CHART INDICATES THOSE ITEMS ASSOCIATED WITH FLIGHT CREW SUPPORT WHICH ARE PROVIDED BY THE PTS DEVELOPMENT EFFORT. THE SECOND CHART PRESENTS THOSE ITEMS WHICH ARE MOUNTED OR INTEGRATED INTO/ONTO THE SPACECRAFT TO FACILITATE PROPELLENT TRANSFER. THE THIRD CHART IDENTIFIES THOSE ITEMS AND/OR SUPPORT CAPABILITIES NEEDED OF THE ORBITER AT VARIOUS TIMES DURING THE PROPELLENT TRANSFER OPERATIONS. IT SHOULD BE NOTED THAT NONE OF THE ITEMS ON THE THIRD CHART ARE PAYLOAD WEIGHT CHARGEABLE, AND THENCE, ARE STANDARD GENERIC ORBITER PROVIDED PROVISIONS.

PTS SUPPORT HDWR/PROVISIONS
EVA FLIGHT CREW SUPPORT

A. PTS AND/OR ORBITER *CARGO-BAY MTD CREW AIDS

1. STANDARD ITEMS
   - PORTABLE FOOT RESTRAINTS (PFR)
   - PFR RECEPTACLES
   - TETHER RINGS
   - HANDHOLD/RAIL
   - XLATION RAIL (IF REQD)
   - TETHERS (PERS/EQUIP)
   - CONNECTOR-WING TAB
2. MODIFIED ITEMS
   - RATCHET WRENCH WITH TORQUE LIMITER
   - RATCHET WRENCH SPECIAL END EFFECTOR (FOR VALVE OVERRIDE)
   - GRAPPLE FIXTURE-PORTABLE

B. UNIQUE ITMES

1. LEAK DETECTOR
2. SPILL KIT
3. PROPELLANT/PRESSURANT FLEX HOSE LINE MGMT & RESTRAINT DEVICES
4. UMBILICAL PROTECTIVE END CAPS (CAPTIVE)
5. BRIDGE FITTING 'BOLT-ON' MTG BRACKET

C. INTERNAL CABIN MTD/LOCATED EQUIPMENT

1. COMMAND & MONITOR PANEL
2. FLIGHT DATA FILE
3. ALTERNATE STOWAGE AREA FOR CREW AIDS

D. ORBITER KIT ITEMS

1. HELMET MTD LIGHTS FOR EMU

* CARGO-BAY MOUNTING IS OPTION

S/C MOUNTED CREW AIDS
EVA SUPPORT OF PTS OPS

A. UMBILICAL ENGAGEMENT & GUIDE FIXTURE

B. FORCE APPLICATION DEVICE (FOR UMBILICAL MATE/DEMATE)

POSSIBLY ONE INTEGRATED ASSY FOR EACH OF 4 UNITS

C. PROPELLANT/PRESSURANT FLEX HOSE MGMT I/F (D-RINGS) ~4

D. TOOL TETHER D-RINGS ~2

E. CODED UMBILICAL INTERFACES (PROPELLANT VS PRESSURANT)

F. PROTECTION FROM SHARP CORNERS, EDGES AND PROTRUSIONS

G. CAUTION FLAGS, MARKERS, PLATES, ETC.

ORBITER SUPPORT PROVISIONS FOR PTS ASSOCIATED FUNCTIONS

BASIC PROVISIONS

A. BAY XLATION HANDHOLDS/RAILS

B. BAY SILL-MTD SLIDE WIRE

C. BAY MOUNTED LIGHTS

D. BAY MOUNTED CCTV CAMERAS

E. AIRLOCK

F. SUITS & SUIT SUPPORT EQUIP

G. TETHERS - PERSONNEL & EQUIPMENT

H. PRE-BREATH APPARATUS (IF REQD)

I. PORTABLE LIGHT (OPTION)

J. TV MONITOR(S)

K. PSS PANEL(S) SPACE/VOL

L. PSS-PTS 'PWR/SGNL' CABLE (SMTCH)

M. CARGO-BAY LINER (OPTION-TBD)

N. BRIDGE FITTINGS

O. TRUNNION RETENTION DEVICES

P. KEEL RETENTION FITTING

Q. PWR/SIGNAL BREAKOUT PANELS

R. RMS

SECTION 6.0

OPERATIONS

EVA SUPPORT OF PROPELLENT TRANSFER

THE FACING PAGE PRESENTS IN SUMMARY FORM THE BASIC EVA FUNCTIONS ASSOCIATED WITH PROPELLENT TRANSFER ACTIVITIES. THESE FUNCTIONS HAVE BEEN ILLUSTRATED AND ARE PRESENTED IN THE FOLLOWING PAGES. TIMELINES FOR THESE FUNCTIONS HAVE BEEN PREPARED AND ARE INCLUDED IN THE CLASSIFIED APPENDIX TO THIS REPORT. THESE FUNCTION TIMELINES HAVE BEEN INCORPORATED INTO THE OVERALL SERVICING SCENARIO FOR THE SPACECRAFT AND THEREFORE, REPRESENT AN "INTEGRATED" TIMELINE FORMING THE BASIC CAP INPUT.

EVA SUPPORT OF PROPELLANT TRANSFER

PRIMARY EVA FUNCTIONS

1. WORK STATION SET-UP
2. PTS & S/C INSPECTION – BASIC INTEGRITY
3. INSPECTION (DETAILED) FOR PROPELLANT LEAKAGE
4. HANDLING & MANAGEMENT OF 'FLEX' PROPELLANT HOSE LINES
5. ENGAGEMENT & DISENGAGEMENT OF PTS SIDE UMBILICAL HALF WITH S/C SIDE UMBILICAL HALF FIXTURES
6. MATE & DEMATE OF UMBILICALS
7. MANUAL OVERRIDE OF PTS LOCATED CONTROLS (e.g., VALVES) IF REQD
8. MONITOR (IF REQD) OF CRITICAL PTS LOCATED DISPLAYS
9. LEAK ASSESSMENT IF APPROPRIATE
10. UTILIZATION OF LEAK KIT IF REQD
11. OTHER OVERRIDE OR UNSCHEDULED SUPPORT TASKS AS NECESSARY

PTS SERVICING SEQUENCE

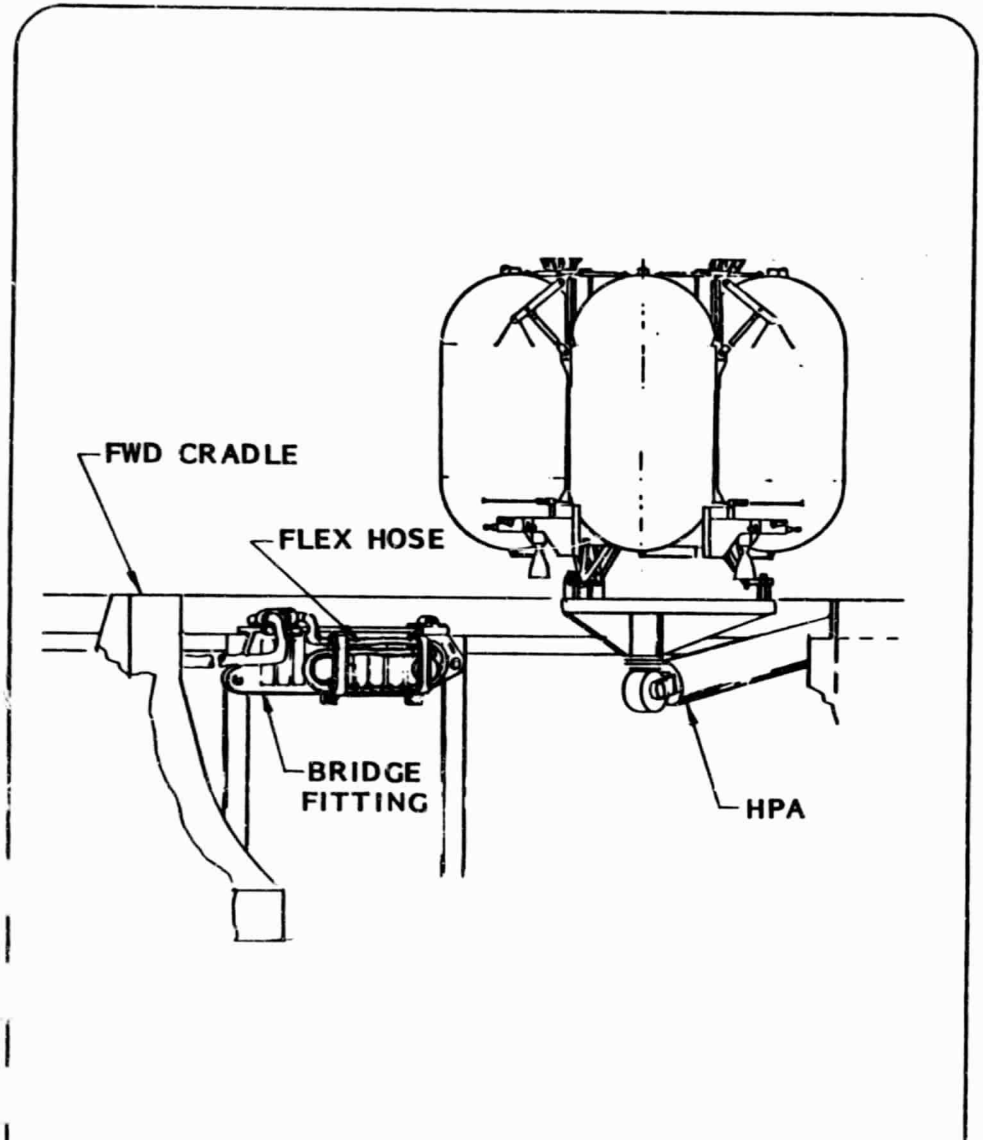
THE CREWPERSON EVA TASKS PORTRAYED IN THE OPPOSITE DRAWING REPRESENTS APPROACHES TO MANAGE THE PTS UMBILICAL FOR SUBSEQUENT MATING WITH THE S/C.

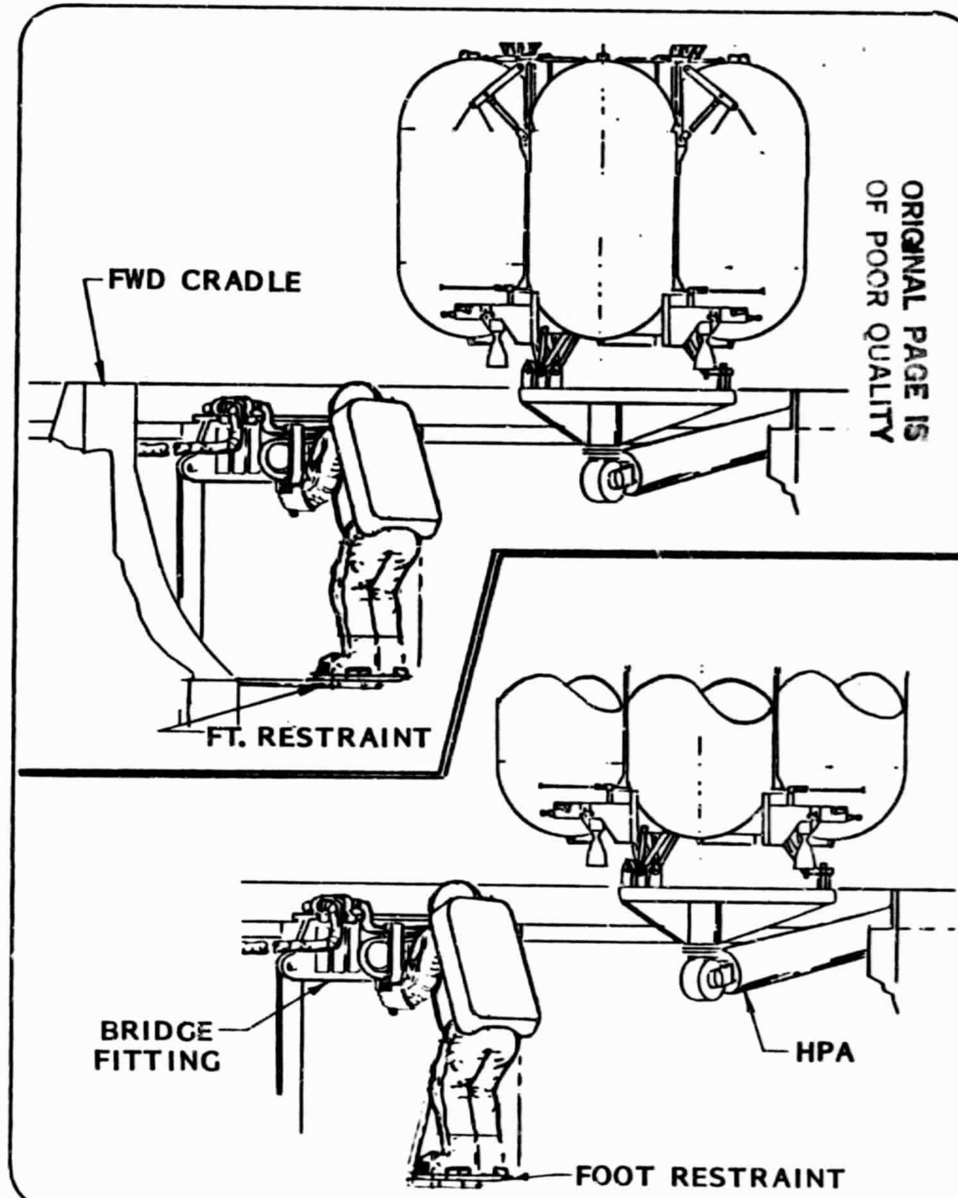
SHOWN OPPOSITE (CLOCKWISE) IS THE S/C LOCATED AT THE SERVICE POSITION BERTHED ON THE HPA AND TILT/TABLE. THE PTS UMBILICAL IS STOWED ON A SIMPLE STANDOFF PLATE MOUNTED TO THE ORBITER BRIDGE FITTING.

A SECOND SERVICE CONCEPT IS DEPICTED NEXT, AND IN THIS DRAWING THE CREW PERSON SERVICES THE S/C RESTRAINED FROM THE FWD CRADLE. THE CREWPERSON ASSUMES A HORIZONTAL POSITION RELATIVE TO THE ORBITER TO ACCOMPLISH HIS MISSION TASKS.

THE THIRD DRAWING (OPPOSITE PAGE) PRESENTS THE BASELINE EV SERVICING CONCEPT, AND POSITIONS THE CREWPERSON TO SERVICE THE S/C WHILE RESTRAINED ON A FOOT RESTRAINT MOUNTED TO THE STANDOFF PLATE AFFIXED TO THE BRIDGE FITTING OF THE ORBITER.

PTS SERVICING SEQUENCE





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PTS SERVICING SEQUENCE

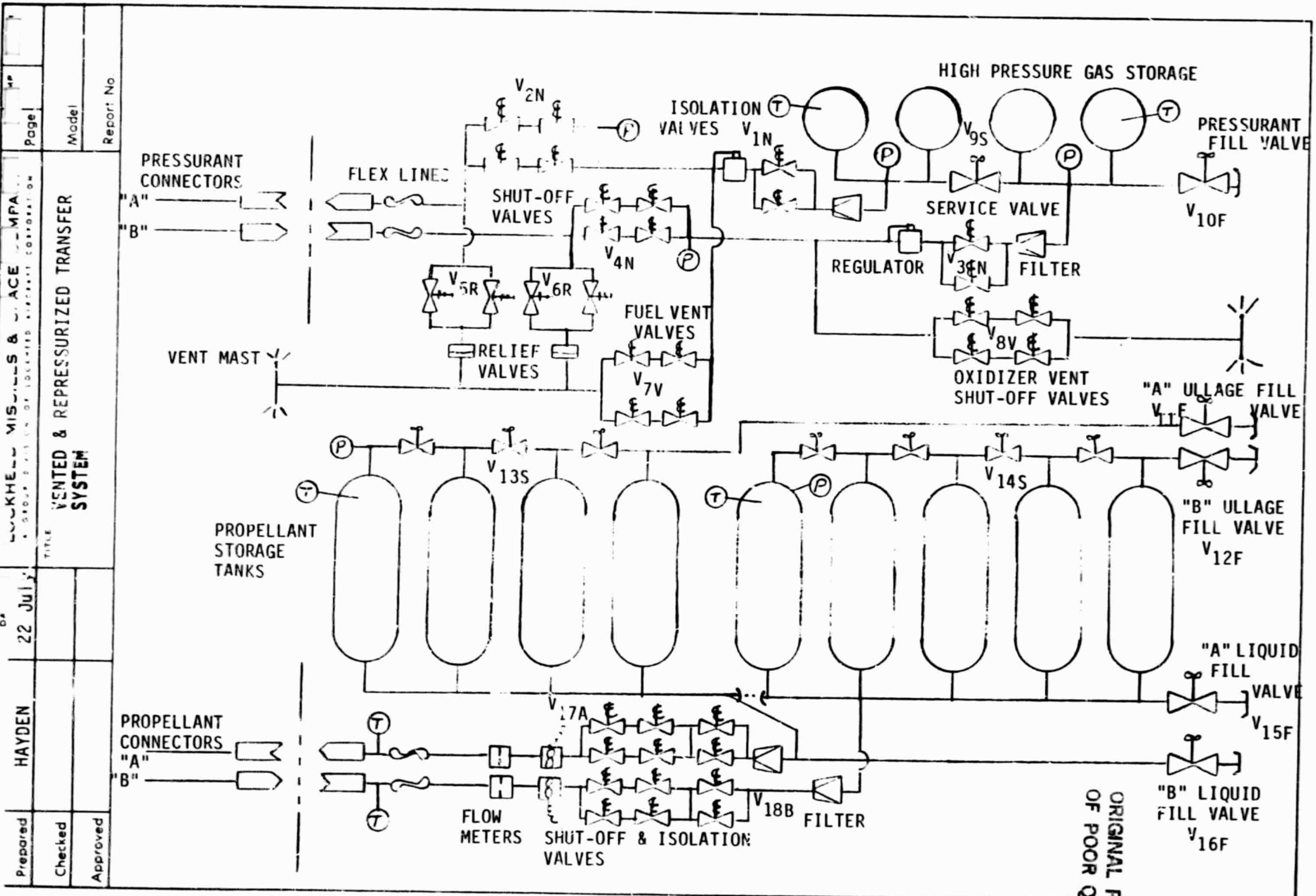
THE EVA TASKS REQUIRED TO MATE OR DEMATE THE PTS UMBILICAL TO THE S/C FOR PROPELLANT TRANSFER IS SHOWN IN THE OPPOSITE FIGURE. THE CREWPERSON IS RESTRAINED IN A FOOT RESTRAINT ADJACENT TO THE S/C. HE UTILIZES THE FLEX HOSE MANAGEMENT DEVICE TO POSITION THE PTS UMBILICAL HALF WITHIN CLOSE PROXIMITY OF THE S/C UMBILICAL HALF. AFTER THE PTS UMBILICAL CONNECTORS ARE IN POSITION & ALIGNED, THE CREWPERSON MATES THE TWO UMBILICALS USING A SIMPLE SCREW-DRIVE DRIVEN BY A STANDARD RATCHET WRENCH.

THE DEMATE AND UMBILICAL STOWAGE, AND CREW AIDS, STOWAGE, WORK STATION CLOSEOUT, ETC., IS ACCOMPLISHED IN A REVERSE-TASK SEQUENCE.

SYSTEM OPERATIONS SUMMARY

Operation of the system is conveniently divided into three (3) phases: Ground Operations, In-Orbit Service, and System Securing. The In-Orbit Service is further divided into vent, fill, and repressurize operations.

Valves are called out by name and an identifier. These are identical to the identifier on the system schematic. A table of valve identifiers follows the operating procedures. The names of satellite system valves is subject to correction when correct nomenclature is available.



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SYSTEM OPERATIONS SUMMARY

- SYSTEM GROUND FILL AND PRESSURIZE
- SATELLITE PROPELLANT TANK VENTING
- SATELLITE PROPELLANT TANK FILLING
- SATELLITE PROPELLANT TANK PRESSURIZATION
- SYSTEM SECURING

OPERATING PROCEDURES

VENTED & REPRESSURIZED SERVICE SYSTEMS

SYSTEM FILL

A. PROPELLANT GROUND SERVICE

1. INITIAL CONDITIONS

- BIPROPELLANT OR MONOPROPELLANT CONFIGURATION
- ALL TANKS FILLED WITH DRY NITROGEN (MONOPROPELLANT) OR HELIUM (BIPROPELLANT) AT 15 PSI
- ALL VALVES CLOSED
- SERVICE MODULE POSITIONED SO THAT ULLAGE END OF PROPELLANT TANKS IS UP
- CONTROL POWER CONNECTED TO TRANSDUCER CIRCUITS
- ULLAGE VALVE PORTS AT $V_{11}F$ AND $V_{12}F$ CONNECTED TO LOADING SYSTEM VENT LINES AND PRESSURANT LINES
- "B" CIRCUIT LINE CONNECTED TO "B" FILL VALVE (V_{15F})
- "A" CIRCUIT LINE CONNECTED TO "A" FILL VALVE (V_{16F}) (FOR BIPROPELLANT SYSTEM, FUEL = "A", OXIDIZER = "B")

2. FUEL SERVICE VALVES (V_{13S}) - OPEN

3. FUEL ("A" CIRCUIT) FILL VALVE (V_{16F}) - open

4. FUEL ULLAGE FILL VALVE (V_{11F}) AND EXTERNAL VENT LINE - OPEN

5. FUEL TRANSFER MONITORED ON FLOWMETER

6. FUEL FILL VALVE (V_{16F}) - CLOSED, SEALED (AT END OF FUEL SERVICE)

7. ULLAGE VENT LINE (EXTERNAL) - CLOSED

8. LOADING PRESSURANT VALVE (EXTERNAL) - OPEN

9. ULLAGE PRESSURE MONITORED

OPERATING PROCEDURES (cont'd)

10. LOADING PRESSURANT VALVE (EXTERNAL) - CLOSED (AT ULLAGE PRESSURE OF 300 PSI)
11. FUEL ULLAGE FILL VALVE (V_{11F}) - CLOSED, SEALED
12. FUEL SERVICE VALVES (V_{13S} AND V_{11F}) - CLOSED, SEALED
13. OXIDIZER SERVICE VALVES (V_{14S}) - OPEN
14. OXIDIZER ("B" CIRCUIT) FILL VALVE (V_{15F}) - OPEN
15. OXIDIZER ULLAGE FILL VALVE (V_{12F}) AND EXTERNAL VENT LINE - OPEN
16. OXIDIZER TRANSFER MONITORED ON FLOWMETER
17. OXIDIZER ("B" CIRCUIT) FILL VALVE (V_{15F}) - CLOSED, SEALED (AT END OF OXIDIZER SERVICE)
18. ULLAGE VENT LINE (EXTERNAL) - CLOSED
19. LOADING PRESSURANT VALVE (EXTERNAL) - OPEN
20. ULLAGE PRESSURE MONITORED
21. LOADING PRESSURANT VALVE (EXTERNAL) - CLOSED (AT ULLAGE PRESSURE OF 300 PSI)
22. OXIDIZER ULLAGE FILL VALVE (V_{12F}) - CLOSED, SEALED
23. OXIDIZER SERVICE VALVES (V_{14S}) - CLOSED, SEALED

NOTE: AT THIS POINT THE SPACE FROM THE ENTRANCE TO THE PROPELLANT FILTERS OUT TO THE PTS-SIDE DISCONNECTS CONTAINS A 15 PSI GAS BUBBLE. THIS SPACE SHOULD BE EVACUATED TO PRECLUDE THE ADIABATIC COMPR. DETONATION HAZARD.

B. PRESSURANT GROUND SERVICE

1. INITIAL CONDITIONS

   - ALL TANKS FILLED WITH DRY NITROGEN (MONOPROPELLANT) OR HELIUM (BIPROPELLANT) AT 15 PSI
   - ALL VALVES CLOSED
   - CONTROL POWER CONNECTED TO TRANSDUCER CIRCUITS
   - HIGH PRESSURE SUPPLY LINE CONNECTED TO FILL VALVE (V_{10F})

2. PRESSURANT FILL VALVE (V_{10F}) - OPEN

3. PRESSURANT SERVICE VALVE (V_{9S}) - OPEN

4. PRESSURANT PRESSURE, TEMPERATURE MONITORED

5. PRESSURANT FILL VALVE (EXTERNAL) - CLOSED AT 5000 PSI, 70°F OR (EQUIVALENT VALUES)

6. PRESSURANT FILL VALVE (V_{10F}) - CLOSED, SEALED

7. PRESSURANT SYSTEM SERVICE VALVE (V_{9S}) - CLOSED, SEALED (FOR BIPROPELLANT) - OPEN, SEALED (FOR MONOPROPELLANT)

C. <u>IN-ORBITER GROUND CHECK OUT</u>

1. CONTROL PANEL - CONNECTED, CONTINUITY LIGHT - ON

2. VALVE CONTROL SWITCHES, ALL - CLOSED

3. CIRCUIT BREAKERS - ALL SET

4. CONTROL POWER - APPLIED (CIRCUIT BREAKER SET)

5. STATUS LIGHT - ILLUMINATED, ALL SHOW CLOSED

6. FLOWMETER READINGS - RESET TO ZERO

7. CONTROL POWER - REMOVED (CIRCUIT BREAKER - PULLED)

8. PRESSURANT SERVICE VALVE (V_{9S}) - CLOSED (BIPROPELLANT), SEALED
   - OPEN (MONOPROPELLANT), SEALED

9. ULLAGE SERVICE VALVES (V_{13S}, V_{14S}) - CLOSED, SEALED
10. FLEX LINES (FOUR) - CONNECTED

SATELLITE SERVICE

A. INITIAL CHECK OUT - AFT CONTROL PANEL

1. CONTINUITY LIGHT - ON
2. VALVE CONTROL SWITCHES, ALL - CLOSED
3. CONTROL POWER - APPLIED (CIRCUIT BREAKER RESET)
4. STATUS LIGHTS - ILLUMINATED (ALL SHOW CLOSED)
5. FLOWMETER READINGS - ZERO OR RESET TO ZERO
6. SERVICE SYSTEM TEMPERATURE, PRESSURE READINGS - RECORDED
7. SATELLITE TEMPERATURE, PRESSURE READINGS - RECORDED

B. INITIAL CHECK OUT - SERVICE MODULE

1. SATELLITE - SERVICE MODULE CONNECTIONS - CONNECTED ("A" AND "B" SYSTEMS AND ELECTRICA), STATUS LIGHT(S) ILLUMINATED)
2. PRESSURANT SYSTEM SERVICE VALVE (V_{9S}) - CLOSED (BIPROPELLANT), SEALED
   - OPEN (MONOPROPELLANT), SEALED
3. SERVICE VALVES (V_{13S}, V_{14S}) - CLOSED, SEALED
4. FLEX LINES - CONNECTED
5. LEAK CHECK - NO LEAKS (METHOD IS TBD)
6. VENT MASTS - DEPLOYED AND CLEAR
7. CIRCUIT BREAKERS - SET
8. PRESSURE AND TEMPERATURE READINGS - RECORDED

C. SATELLITE ULLAGE GAS VENT

1. SATELLITE "A" CIRCUIT ULLAGE VALVES - OPEN
2. "A" CIRCUIT PRESSURANT SHUT-OFF VALVE (V_{2N}) - OPEN
3. "A" CIRCUIT VENT VALVE (V_{7V}) - OPEN
4. MONITOR PRESSURE IN SATELLITE PROPELLANT TANK
5. SATELLITE "A" CIRCUIT ULLAGE VALVE - CLOSED (AT PROPELLANT VAPOR PRESSURE)
6. "A" CIRCUIT PRESSURE SHUT-OFF VALVE (V_{2N}) - CLOSED
7. "A" CIRCUIT VENT VALVE (V_{7V}) - CLOSED
8. SATELLITE "B" CIRCUIT ULLAGE VALVES - OPEN
9. "B" CIRCUIT SHUT-OFF VALVE (V_{4N}) - OPEN
10. "B" CIRCUIT VENT VALVE (V_{8V}) - OPEN
11. MONITOR PRESSURE IN SATELLITE TANK
12. SATELLITE "B" CIRCUIT ULLAGE VALVE - CLOSED (AT PROPELLANT VAPOR PRESSURE)
13. "B" CIRCUIT SHUT-OFF VALVE (V_{4N}) - CLOSED
14. "B" CIRCUIT VENT VALVE (V_{8V}) - CLOSED

D. PROPELLANT TRANSFER

1. SATELLITE "A" CIRCUIT PROPELLANT VALVES - OPEN
2. "A" CIRCUIT ISOLATION VALVES AND SHUT-OFF VALVES (V_{17A}) - OPEN
3. MONITOR FLOWMETER(S) FOR PROPELLANT TRANSFER
4. "A" CIRCUIT ISOLATION VALVES AND SHUT-OFF VALVES (V_{17A}) - CLOSED AT END OF TRANSFER FLOWMETER READING
5. SATELLITE "A" CIRCUIT PROPELLANT VALVES - CLOSED
6. SATELLITE "B" CIRCUIT PROPELLANT VALVES - OPEN

7. "B" CIRCUIT ISOLATION VALVES AND SHUT-OFF VALVES (V_{18B}) - OPEN
8. MONITOR FLOWMETER(S) FOR PROPELLANT TRANSFER
9. "B" CIRCUIT ISOLATION VALVES AND SHUT-OFF VALVES (V_{18B}) - CLOSED AT END OF TRANSFER FLOWMETER READINGS
10. SATELLITE "B" CIRCUIT PROPELLANT VALVES - CLOSED
11. RECORD FLOWMETER READINGS AND TEMPERATURES, PRESSURES

E. SATELLITE REPRESSURIZATION

1. SATELLITE "A" CIRCUIT ULLAGE VALVES - OPEN
2. "A" CIRCUIT PRESSURANT ISOLATION VALVES (V_{1N}) - OPEN
3. MONITOR PRESSURE RISE ON "A" CIRCUIT PRESSURANT REGULATOR PRESSURE
4. "A" CIRCUIT PRESSURANT SHUT-OFF VALVES (V_{2N}) - OPEN
5. "A" CIRCUIT PRESSURANT ISOLATION VALVES (V_{1N}) - CLOSED (AT CALCULATED PRESSURE IN HIGH PRESSURE GAS STORAGE TANKS AND SATELLITE TANKS)
6. MONITOR TEMPERATURE, PRESSURE RISE ON SATELLITE "A" CIRCUIT
7. SATELLITE "B" CIRCUIT ULLAGE VALVES - OPEN
8. "B" CIRCUIT PRESSURANT ISOLATION VALVES (V_{3N}) - OPEN
9. MONITOR PRESSURE RISE ON "B" CIRCUIT PRESSURANT REGULATOR
10. "B" CIRCUIT PRESSURANT SHUT-OFF VALVES (V_{4N}) - OPEN
11. "B" CIRCUIT PRESSURANT ISOLATION VALVES (V_{3N}) - CLOSED (AT CALCULATED PRESSURE IN HIGH PRESSURE GAS STORAGE TANKS AND SATELLITE TANKS)
12. MONITOR TEMPERATURE, PRESSURE RISE ON SATELLITE "B" CIRCUIT
13. REPEAT STEPS 3, 4, AND 5 FOR "A" CIRCUIT AS REQUIRED TO ACHIEVE REPRESSURIZATION TO DESIRED VALUE IN SATELLITE TANK
14. REPEAT STEPS 9, 10, AND 11 FOR "B" CIRCUIT AS REQUIRED TO ACHIEVE REPRESSURIZATION TO DESIRED VALUE IN SATELLITE TANK

OPERATING PROCEDURES (cont'd)

15. AS DESIRED REPRESSURIZATION IS REACHED CLOSE ISOLATION VALVES V_{1N} AND V_{3N} AND PROCEED
16. SATELLITE "A" AND "B" CIRCUIT ULLAGE VALVES - CLOSED
17. "A" AND "B" CIRCUIT VENT VALVES - OPEN (RELIEVE LINE PRESSURE PRIOR TO SATELLITE DISCONNECT)
18. "A" AND "B" CIRCUIT PRESSURANT SHUT-OFF VALVES (V_{2N} AND V_{4N}) - CLOSED
19. "A" AND "B" CIRCUIT VENT VALVES - CLOSED
20. RECORD ALL PRESSURE AND TEMPERATURE READINGS
21. DISCONNECT "A" AND "B" CONNECTORS AND ELECTRICAL CONNECTORS

F. SECURING SYSTEM FOR LANDING

1. ALL VALVES - CLOSED
2. CONTROL POWER - OFF
3. PROPELLANT AND PRESSURANT CONNECTORS - DISCONNECTED
4. CONNECTOR COVERS - REPLACED
5. FLEX LINES - SECURE

VALVE IDENTIFIERS

IDENTIFIER	VALVE NAME
V_{1N}	PRESSURANT ISOLATION VALVES, FUEL OR "A"
V_{2N}	PRESSURANT SHUT-OFF VALVES, FUEL OR "A"
V_{3N}	PRESSURANT ISOLATION VALVES, OXIDIZER OR "B"
V_{4N}	PRESSURANT SHUT-OFF VALVES, OXIDIZER OR "B"
V_{5R}	RELIEF VALVES, FUEL OR "A"
V_{6R}	RELIEF VALVES, OXIDIZER OR "B"
V_{7V}	"A" CIRCUIT VENT VALVES
V_{8V}	"B" CIRCUIT VENT VALVES
V_{9S}	PRESSURANT SERVICE VALVE
V_{10F}	PRESSURANT FILL AND VENT VALVE
V_{11F}	"A" CIRCUIT ULLAGE FILL VALVE
V_{12F}	"B" CIRCUIT ULLAGE FILL VALVE
V_{13S}	"A" CIRCUIT SERVICE VALVES
V_{14S}	"B" CIRCUIT SERVICE VALVES
V_{15F}	"B" CIRCUIT LIQUID FILL VALVE
V_{16F}	"A" CIRCUIT LIQUID FILL VALVE
V_{17A}	"A" CIRCUIT SHUT-OFF AND ISOLATION VALVES
V_{18B}	"B" CIRCUIT SHUT-OFF AND ISOLATION VALVES

SECTION 7.0

RECOMMENDATIONS FOR PRELIMINARY DESIGN AND PROOF OF CONCEPT DEMONSTRATION - PROPELLANT TRANSFER SYSTEM

SECTION 8.0

COST & WBS

COSTS FOR THE LMSC SSS PROPELLENT TRANSFER SYSTEM

LMSC HAS COMPLETED THE FIRST ROUND OF COSTS FOR THE SSS PROPELLENT TRANSFER SYSTEM. THE FOLLOWING OVERVIEW IS PROVIDED TO AID THE CUSTOMER IN HIS EVALUATION OF THE COSTS AS DEVELOPED IN THIS PHASE OF THE STUDY.

GROUND RULES AND ASSUMPTIONS TO THE STUDY. THE FOLLOWING GROUND RULES AND ASSUMPTIONS APPLY TO THE SSS STUDY:

- W.B.S. PROVIDED AT THE 27 MAY 1982 T.I.M. WAS USED.
- THE GROUND RULE PROGRAM PLAN WAS ADHERED TO FOR ALL SCHEDULES.
- NO EXTRAORDINARY COST, SCHEDULE OR TECHNICAL RISK ITEMS WERE FOUND.
- LMSC WILL NOT USE ANY MAJOR SUBCONTRACTOR, ALTHOUGH A LARGE PART OF WORK IS IDENTIFIED TO WELL-ESTABLISHED PROVEN EQUIPMENT SOURCE CONTRACTORS.
- UNRECURRING VERSUS RECURRING COST BREAKOUT WAS GENERATED BY THE RCA PRICE MODEL AND REFLECTS THE PARTS FLIGHT APPROACH RECOMMENDED BY LMSC FOR THIS SYSTEM.
- RECURRING LOADS OF EFFORT FOR OPERATIONS SUBSEQUENT TO THE INITIAL LAUNCH ON ORBIT OPERATION AND RECOVERY PERIOD SUPPORT HAVE NOT BEEN INCLUDED.
- ALL COSTS ARE CONSTANT 1982 DOLLARS.
- COSTS AS PRESENTED EXCLUDE LMSC FEE.
- STATE OF THE ART MATERIALS ARE USED FOR COMPONENTS AND MINIMAL COSTS FOR QUALIFYING STRUCTURAL AND SYSTEM OPERATING HARDWARE ARE ASSUMED.
- EXISTING HARDWARE, KNOWN ENGINEERING APPROACHES, FLIGHT QUALIFIED HARDWARE OR MINIMAL MODIFICATION TO PROCESS DESIGN WAS USED FOR THE BULK OF THE SYSTEM.

COSTS FOR THE LMSC SSS PROPELLENT TRANSFER SYSTEM (con'd)

EMPHASIS HAS BEEN ON MODELING THE COST FOR THE SELECTED CONFIGURATION OF THE PROPELLENT TRANSFER AND SUPPORTING CREW SYSTEMS. THE RCA PRICE MODEL AND THE ASTEC MODEL HAVE BEEN USED SINCE THESE MODELS ALLOW INCORPORATION OF GREATER DETAIL AS THE DESIGN EVOLVES. THE LOCKHEED (CALIBRATED) PARAMETRIC VALUES DERIVED FROM OUR SPACECRAFT ACTUAL COST EXPERIENCE ARE USED IN THE RCA PRICE MODELING EFFORT. MODELING WAS DONE TO DEVELOP COST POSITIONS TO AID IN MAKE/BUY DECISIONS, AND FORECAST COST OF COMPONENT ITEMS. AS THE TECHNICAL BASELINE WAS DEVELOPED, THE MODELING OF COSTS FOR COMPONENTS, SUBSYSTEMS AND SYSTEMS INTEGRATION COSTS WAS COMPLETED. COSTS FOR GROUND SYSTEM EQUIPMENT, AGE,FACTORY TEST EQUIPMENT, AND MANUFACTURING TEST EQUIPMENT WILL BE ESTABLISHED LATER. COSTS BY FUNCTIONAL CATEGORY, LABOR, MATERIALS, SUBCONTRACT AND OTHER, WERE BROKEN OUT AND THE SPECIFIC COSTS BY LABOR CATEGORY IDENTIFIED (E.G., ENGINEERING, TEST, MANUFACTURING, QUALITY ASSURANCE, PROGRAM MANAGEMENT, TOOLING, ETC.). PROGRAMMATICS IMPACTS WILL BE MODELED AS THE ENGINEERING, QA, MANUFACTURING, PROGRAM MANAGEMENT, TEST AND OTHER PLANS ARE MADE DEFINITE. MODELING CAN ALSO ENCOMPASS LIFE CYCLE COSTS AND SUPPORT TO RISK ANALYSIS AND ASSESSMENT EFFORTS IN FUTURE STUDY EFFORTS.

LOCKHEED HAS SUPPORTED THE SSS STUDY TO THIS POINT IN TIME, BY COST ANALYSIS BASED ON PARAMETRIC COST MODELS. PARAMETRIC COST MODELS ARE BASED ON THE PREMISE THAT COST TO NONCOST RELATIONSHIPS EXIST, CAN BE IDENTIFIED, CAN BE SPECIFIED, AND THE COST EFFECTS RELATIONSHIPS (CERs) MATH-EMATICALLY REPRESENTED IN ALGORITHMS WITHIN THE MODEL. AS AN EXAMPLE, WEIGHT ON ORBIT, POWER REQUIRED, ALTITUDE OF ORBIT, SCHEDULE IMPERATIVES, MANUFACTURING COMPLEXITY OF STRUCTURES AND ELECTRONICS, ENGINEERING COMPLEXITIES, DISTRIBUTION OF WEIGHT BETWEEN ELECTRONICS AND STRUCTURAL COMPONENTS, ETC., ALL DRIVE COSTS OF THE SYSTEM. THE MODELS WHICH LOCKHEED USES ARE THE SAMSO/SUBSYNCHRONOS ORBITER, RCA PRICE, AND LMSC ASTEC MODELS. IN ADDITION TO THE CERs, THE MODELS ACCOUNT FOR THE QUANTITIES OF UNITS BUILT, PROTOTYPING REQUIRED, TOOLING REQUIREMENTS, SUBCONTRACTED COMPONENTS, GFE COMPONENTS, ETC. THE RCA PRICE MODEL HAS BEEN CALIBRATED BY LOCKHEED, USING THE RESULTS OF A FOUR-YEAR STUDY OF ACTUAL COSTS OF SPACECRAFT SYSTEM BUILT UNDER 8 MULTI-HUNDRED MILLION DOLLAR CONTRACTS FROM 1967 TO PRESENT. GLOBAL FACTORS (E.G., PROGRAM MANAGEMENT, PROCUREMENT BURDENS ET AL) HAVE BEEN CALIBRATED TO LOCKHEED'S AND AEROSPACE INDUSTRIES "STYLE" OF BUSINESS.

COSTS FOR THE LMSC SSS PROPELLENT TRANSFER SYSTEM (cont'd)

RCA PRICE MODELING HAS BEEN USED FOR THE STUDY; HOWEVER, PERIODIC "SANITY" CHECKS WERE MADE, USING ASTEC AND SAMSO I AS APPROPRIATE. THE COST MODELING EFFORT ENCOMPASS ALL FLIGHT SYSTEMS ELEMENTS, THRU ALL PHASES OF DESIGN, MANUFACTURING, TEST, LAUNCH AND FIRST ORBIT OPERATIONS.

PRELIMINARY LIFE CYCLE COST MODELING SHOULD BE INCLUDED IN THE PHASES OF THE FOLLOW-ON STUDY.

AS THE PROGRAM MANAGEMENT PLAN, THE WORK BREAKDOWN STRUCTURE, MASTER SCHEDULES, DETAILED SCHEDULES AND SCHEDULE NETWORKS ARE DEVELOPED, THE PARAMETRIC INPUTS TO THE MODEL WILL BE MODIFIED TO REFLECT THIS EVOLUTION WHICH INCLUDES:

1) <u>OTHER PLANS</u>: ENGINEERING, MANUFACTURING AND ASSEMBLY, TEST AND VERIFICATION, LAUNCH INTEGRATION, OPERATIONS SUPPORT, SUBCONTRACTING, PRODUCT ASSURANCE AND QUALITY CONTROL, RELIABILITY, SUPPORT ENGINEERING AND SOFTWARE PLANS WHICH WILL IMPACT THE COSTS AND WILL BE TAKEN INTO ACCOUNT BY ADJUSTING THE APPROPRIATE INPUT PARAMETERS OF THE MODEL.

2) <u>THE TECHNICAL BASELINE</u>: DEVELOPMENT OF THE INTERFACE DEFINITION, ISSUANCE OF THE REVISED PROGRAM REQUIREMENTS LISTS, SPECIFICATION OF REDUNDANCY, CROSS STRAPPING, AND SPECIFIC UNIT RELIABILITY AND SYSTEM RELIABILITY REQUIREMENTS SHOULD ALSO BE USED TO FINE TUNE THE COST MODEL IN FOLLOW-ON STUDY PERIODS.

3) <u>HARDWARE ELEMENTS</u>: HARDWARE SPECIFIED IN TERMS OF NEW, TO BE MODIFIED OR USED AS IS, "OFF-THE-SHELF," AND THE PARAMETERS REFLECTING ITS ENGINEERING COMPLEXITY, INTEGRATION REQUIREMENTS, PROTOTYPE DESIGN SUPPORT, REQUIREMENTS TOOLING FOR PROTOTYPES AND FLIGHT UNITS, ELECTRONIC VERSUS STRUCTURES WEIGHTS, SELECTED MANUFACTURING PROCESSES, ETC., SHOULD ALSO BE USED TO ENHANCE THE MODEL ACCURACY.

COSTS FOR THE LMSC SSS PROPELLENT TRANSFER SYSTEM (cont'd)

TO DATE, LMSC'S APPROACH HAS NOT INVOLVED SOFTWARE. IN THE EVENT THAT A COMPUTER ASSISTED MODE OF REFUELING IS ELECTED, THE RCA PRICES WILL BE USED IN PARALLEL WITH THE HARDWARE EXISTING EFFORTS. THE RCA SOFTWARE MODEL WILL BE USED, AS THE DEFINITION OF THE SOFTWARE SYSTEM, SUBSYSTEMS, SEGMENTS, CPCs AND CPCIs IS MADE, TO COST THIS EFFORT. SOFTWARE FOR TEST PURPOSES, AS WELL AS OPERATIONAL SOFTWARE ELEMENTS, WILL BE INCLUDED IN THE COST MODELING. MODELING WILL ENCOMPASS THE DEFINITION OF DATA PROCESSING REQUIREMENTS INCLUDING DATA TYPE, DATA CHARACTERIZATION, TIMING, QUEUEING, FORMATTING, SCOPE AND DETAIL. THE DATA CHARACTERIZATION WILL CONSIDER PRIMARY, BACKUP, EMERGENCY, DEGRADED MODES, RECOVERY ENABLING FEATURES AND DIAGNOSTIC ASPECTS. REQUIREMENTS FOR PRE- AND POST- PROCESSORS FOR ENGINEERING AND OPERATIONAL DATA WILL EFFECT THE COST OF THE SOFTWARE SYSTEM AND WILL BE REFLECTED IN THE MODELED COSTS. AS THE OVERALL MISSION REQUIREMENTS BECOME BETTER KNOWN, THE SOFTWARE CAPABILITIES FOR REAL TIME, OFF-LINE, INTERACTION AND ARCHIVING CAN BE ESTABLISHED AND WILL BE REFLECTED IN THE COST MODELING EFFORT.

IN LATER PHASES OF THE DESIGN, THE MODELING EFFORTS AND COST ANALYSIS COULD BE TUNED TO REFLECT MORE PRAGMATIC ISSUES INCLUDING THE FOLLOWING:

- o USE OF COMMON SET OF AGE FOR TEST AND HANDLING AT SUNNYVALE AND THE LAUNCH BASE, AND OTHER WAYS TO REDUCE COSTS OF ACE, FTE, MTE, MANUFACTURING HANDLING.

- o LOCKHEED USES A MATRIX MANAGEMENT APPROACH TO DEVELOP MULTI-PROGRAM SUPPORT GROUPS WITHIN THE ENGINEERING, MANUFACTURING, TOOLING PRODUCT ASSURANCE, MAINTAINABILITY, SAFETY, RELIABILITY, SOFTWARE DEVELOPMENT, MATERIALS PROCUREMENT, TEST AND HUMAN ENGINEERING DISCIPLINES. THIS LARGE BODY OF EXPERTISE IS AVAILABLE TO SUPPORT PEAK EFFORTS, WITHOUT THE ATTENDANT COSTS OF DEAD HEADING IN THE VALLEYS OF EFFORT. THE GLOBAL PARAMETERS CALIBRATED FOR THE PRICE MODEL REFLECT THE CALIBRATION OF THE MODEL TO LOCKHEED'S "STYLE" OF BUSINESS.

MODELING WILL BE USED TO FLAG UNREALISTICALLY SPANNED OR POSITIONED SCHEDULE ELEMENTS AS THE DETAILING OF SCHEDULES FOR ELEMENTS OF HARDWARE/SOFTWARE IS ACCOMPLISHED. COST IMPACTS OF SUCH SCHEDULE PROBLEMS CAN BE ASSESSED AND ADJUSTMENTS MADE TO REDUCE THE SYSTEM COST IMPACT.

THE FOLLOWING FOUR SHEETS PRESENT THE HARDWARE ITEMS AND ASSOCIATED STATUS FOR "ALL-UP" PROPELLENT TRANSFER SYSTEM.

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HARDWARE SUMMARY SHEET

SUBSYSTEM : CRADLE   WBS NO. : 10.02.01.02.08.02

WBS NO.	DESCRIPTION	M B	UNIT WEIGHT			NO. UNITS PRODUCED						PERCENT NEW DESIGN		DESIGN REPETITION		ENGRG/DEVEL DIFFICULTY	EXP	MFG/TEST DIFFICULTY
			WT	WS	MARGIN	E	Q	L	F	S	R	MECH	ELEC	MECH	ELEC			
.02	CRADLE STRUCTURE	M	899	899	0	½	-	-	1	-	-	100	-	60%	-	4	1	3
.01	SUBSYSTEM INT&TEST	-	-	-	-	-	-	-	-	-	-	100	-	-	-	4	1	3

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HARDWARE SUMMARY SHEET

SUBSYSTEM : TANKAGE & LINES　　　WBS NO. : 10 02.01.02.08.03

WBS NO.	DESCRIPTION	M B	UNIT WEIGHT			NO. UNITS PRODUCED						PERCENT NEW DESIGN		DESIGN REPETITION		ENGRG/DEVEL DIFFICULTY	EXP	MFG/TEST DIFFICULTY
			WT	WS	MARGIN	E	Q	L	F	S	R	MECH	ELEC	MECH	ELEC			
.02	VENT & PRESS VALVE 1/4"	B	.7	.7	0	2	1	1	1	5	-	0	0	-	-	2	1	2
.03	VENT & PRESS VALVE 3/4"	B	1.2	1.2	0	2	1	1	1	5	-	0	0	-	-	2	1	2
.04	ISOLATION & SHUT OFF VALVES 1.4"	B	.7	.7	0	2	1	1	40	4[illegible]	-	0	0	-	-	2	1	2
.05	ISOLATION & SHUT OFF VALVES 3/4"	B	1.2	1.2	0	2	1	1	28	32	-	0	0	-	-	2	1	2
.05	PRESSURE REGULATOR	B	2.5	2.5	0	2	1	1	4	3	-	0	0	-	-	2	1	2
.07	RELIEF VALVE 1/4"	B	1.2	1.2	0	2	1	1	10	1[illegible]	-	0	0	-	-	2	1	2
.03	BURST DIAPH.&HOLDER	B	.5	.5	0	2	1	1	10	14	-	0	0	-	-	2	1	2
.09	FLOW METER 3/4"	B	.5	15	0	2	1	1	4	8	-	0	0	-	-	2	2	2
.10	QUICK DISCONNECT	B	2.0	2.0	0	2	1	1	8	12	-	0	0	-	-	2	1	2
.11	PROP. TANK. LONG	M	34.8	34.8	0	2	1	-	8	1	-	60	-	80	-	2	1	2
.12	PROP. TANK SHORT	M	13.6	13.6	0	2	1	-	2	1	-	50	-	80	-	2	1	2
.13	PRESSURE TANKS	B	27.7	27.7		1	1		4	2	-	0	0	-	-	2	1	2
.01	SUBSYSTEM INT&TEST	M	-	-	-	-	-	-	-	-	-	50	-	-	-	3	1	2

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HARDWARE SUMMARY SHEET

SUBSYSTEM : CREW SYSTEM   WBS NO. : 10.02.01.02.0804

WBS NO.	DESCRIPTION	M B	UNIT WEIGHT			NO. UNITS PRODUCED						PERCENT NEW DESIGN		DESIGN REPETITION		ENGRG/DEVEL DIFFICULTY	EXP	MFG/TEST DIFFICULTY
			WT	WS	MARGIN	E	Q	L	F	S	R	MECH	ELEC	MECH	ELEC			
.02	LEAK DETECTOR	M	12	11.7	0	1	-	-	1	-	1	100	100	50	80	3	3	2
.03	COMMAND & MON.PANEL	M	46	44	0	1	-	-	1	-	1	100	100	50	80	3	3	2
.04	BRIDGE FTG-MTG.BKT	M	28	28	0	2	2	-	4	-	2	100	-	30	-	2	1	2
.05	HAND RAILS	M	12.8	12.8	0	2	-	-	2	-	2	100	-	50	-	2	1	2
.06	SPKL KIT PROP	M	4.0	4.0	0	1	1	-	4	2	1	100	-	30	-	4	3	3
.07	BRIDGE FITTING	GFE	160	160	-	-	-	-	1	-	-	-	-	-	-	-	-	-
.08	HAND HOLDS	M	2.0	2.0	0	2	2	-	8	4	-	20	-	50	-	1	1	2
.09	TETHER FTGS PERS	M	.25	.25	0	4	4	-	12	4	-	20	-	50	-	1	1	2
.10	TETHER FTGS EQUPT	M	.20	.20	0	4	4	-	12	4	-	20	-	50	-	1	1	2
.11	FOOT RESTRAINT.PORT	M	19.0	19.0	0	1	1	-	2	-	2	30	-	50	-	1	1	2
.12	FOOT RESTRNT RECEPT.	M	.75	.75	0	2	2	-	7	3	-	30	-	50	-	1	1	2
.13	PERSONNEL TETHER	GFE	.25	.25	-	-	-	-	-	-	-	-	-	-	-	-	-	-
.14	EQUIP TETHER	GFE	.25	.25	-	-	-	-	-	-	-	-	-	-	-	-	-	-
.01	SUBSYSTEM INT&TEST	-	-	-	-	-	-	-	-	-	-	100	100	-	-	3	3	3

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HARDWARE SUMMARY SHEET

SUBSYSTEM : GRAPPLE ASSEM WBS NO. : 10.02.01.02.03

WBS NO.	DESCRIPTION	M B	UNIT WEIGHT			NO. UNITS PRODUCED						PERCENT NEW DESIGN		DESIGN REPETITION		ENGRG/DEVEL DIFFICULTY	EXP	MFG/TEST DIFFICULT
			WT	WS	MARGIN	E	Q	L	F	S	R	MECH	ELEC	MECH	ELEC			
.02	GRAPPLE FIXTURE	M	22.5	22.5	0	1	0	0	1	0	0	100	-	0	-	4	3	3
.03	GRAPPLE FXT.MTG. ASSEM.	M	2.75	2.75	0	1	0	0	1	0	0	100	-	0	-	2	1	2
.01	INT & TEST	M	-	-	-	-	-	-	-	-	-	50	-	-	-	4	1	3

WORK BREAKDOWN STRUCTURE

THE WBS, FOR THE PTS, THROUGH LEVEL 7, IS SHOWN ON THE FACING PAGE. THIS WBS WAS USED FOR THE COST ESTIMATES WHICH HAVE BEEN SUBMITTED UNDER SEPARATE COVER.

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WBS LEVEL
3 — 4 — 5,6&7

WORK BREAKDOWN STRUCTURE

- 10.02.01 SERVICING HARDWARE
  - 10.02.01.02 AEROSPACE SERVICE EQUIPMENT
    - 10.02.01.02.01 INTEGRATION & ASSEMBLY
    - 10.02.01.02.02 MODIFIED GRAPPLE FIXTURE
      - 10.02.01.02.02.01 INTEGRATION & ASSEMBLY
      - 10.02.01.02.02.02 GRAPPLE ASSEMBLY
    - 10.02.01.02.03 GRAPPLE FIXTURE ATTACH OPTIONS
      - 10.02.01.02.03.01 INTEGRATION & ASSEMBLY
      - 10.02.01.02.03.02 GRAPPLE FIXTURE MATING ASSEMBLY
    - 10.02.01.02.04 PORTABLE FOOT RESTRAINTS
    - 10.02.01.02.05 MATE/DEMATE UMBILICAL
    - 10.02.01.02.06 BERTHING PLATFORM
    - 10.02.01.02.07 CARGO BAY RACK/SPARES PLATFORM
  - 10.02.01.02 CONTINUED
    - 10.02.01.02.08 FLUID TRANSFER MODULE
      - 10.02.01.02.08.01 INTEGRATION & ASSEMBLY
      - 10.02.01.02.08.02 CRADLE
        - 10.02.01.02.08.02.01 INTEGRATION & ASSEMBLY
        - 10.02.01.02.08.02.02 CRADLE STRUCTURE
    - 10.02.01.02.08 CONTINUED
      - 10.02.01.02.08.03 TANKS & LINES
        - 10.02.01.02.08.03.01 INTEGRATION & ASSEMBLY
        - 10.02.01.02.08.03.02 VENT & PRESSURIZATION VALVE 1/4"
        - 10.02.01.02.08.03.03 VENT & PRESSURIZATION VALVE 3/4"
        - 10.02.01.02.08.03.04 ISOLATION & SHUT OFF VALVES 1/4"
        - 10.02.01.02.08.03.05 ISOLATION & SHUT OFF VALVES 3/4"
        - 10.02.01.02.08.03.06 PRESSURE REGULATORS
        - 10.02.01.02.08.03.07 RELIEF VALVE 1/4"
        - 10.02.01.02.08.03.08 BURST DIAPHRAGM & HOLDER 1/4"
        - 10.02.01.02.08.03.09 FLOW METER 3/4"
        - 10.02.01.02.08.03.10 QUICK DISCONNECT
        - 10.02.01.02.08.03.11 PROPELLANT TANK (LONG)
        - 10.02.01.02.08.03.12 PROPELLANT TANK (SHORT)
        - 10.02.01.02.08.03.13 PRESSURIZATION TANKS
    - 10.02.01.02.08 CONTINUED
      - 10.02.01.02.08.04 CREW SYSTEMS
        - 10.02.01.02.08.04.01 INTEGRATION & ASSEMBLY
        - 10.02.01.02.08.04.02 LEAK DETECTOR
        - 10.02.01.02.08.04.03 COMMAND & MONITOR PANEL
        - 10.02.01.02.08.04.04 BRIDGE FOOTING MATING BRACKET
        - 10.02.01.02.08.04.05 HAND RAILS
        - 10.02.01.02.08.04.06 SPILL KIT PROPELLANT
        - 10.02.01.02.08.04.07 BRIDGE FITTING (GFE)
        - 10.02.01.02.08.04.08 HAND HOLDS
        - 10.02.01.02.08.04.09 TETHER FOOTINGS - PERSONNEL
        - 10.02.01.02.08.04.10 TETHER FOOTINGS - EQUIPMENT
        - 10.02.01.02.08.04.11 FOOT RESTRAINT - PORTABLE
        - 10.02.01.02.08.04.12 FOOT RESTRAINT RECEPTACLE
        - 10.02.01.02.08.04.13 PERSONNEL TETHER (GFE)
        - 10.02.01.02.08.04.14 EQUIPMENT TETHER (GFE)

11 AUG 1982

SERVICING SYSTEM

WORK BREAKDOWN STRUCTURE

THE TOP-LEVEL WORK-BREAKDOWN STRUCTURE (WBS) THROUGH LEVEL 4 IS SHOWN ON THE FACING PAGE. THE DICTIONARY FOR THIS WBS IS TOO VOLUMINOUS FOR THIS REPORT. IT IS AVAILABLE ON REQUEST FROM THE PROGRAM OFFICE.

SEE

WBS. INSERT

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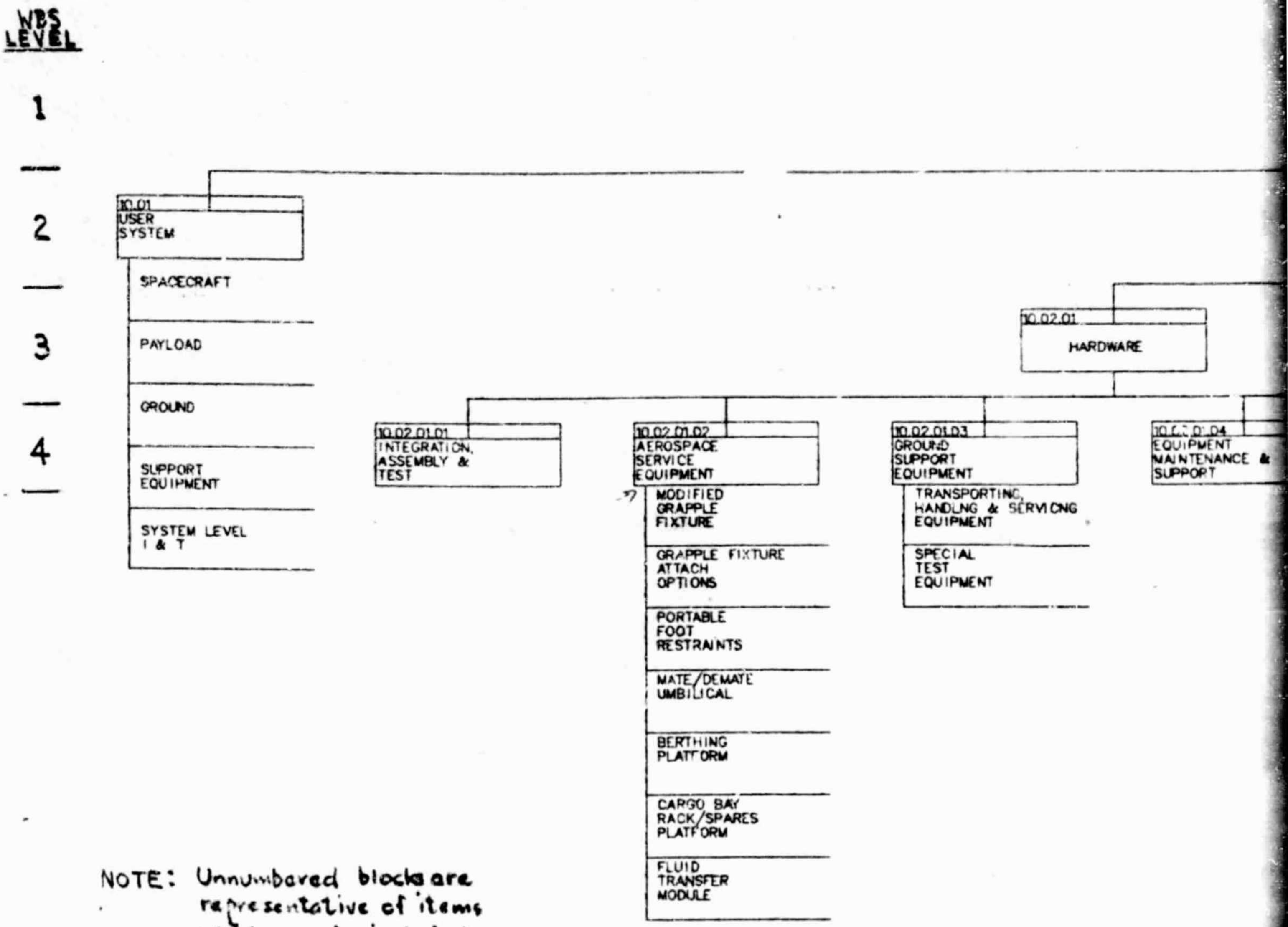

NOTE: Unnumbered blocks are representative of items which may be included under each respective WBS element, are not intended as WBS expansion at this time, and are subject to change.

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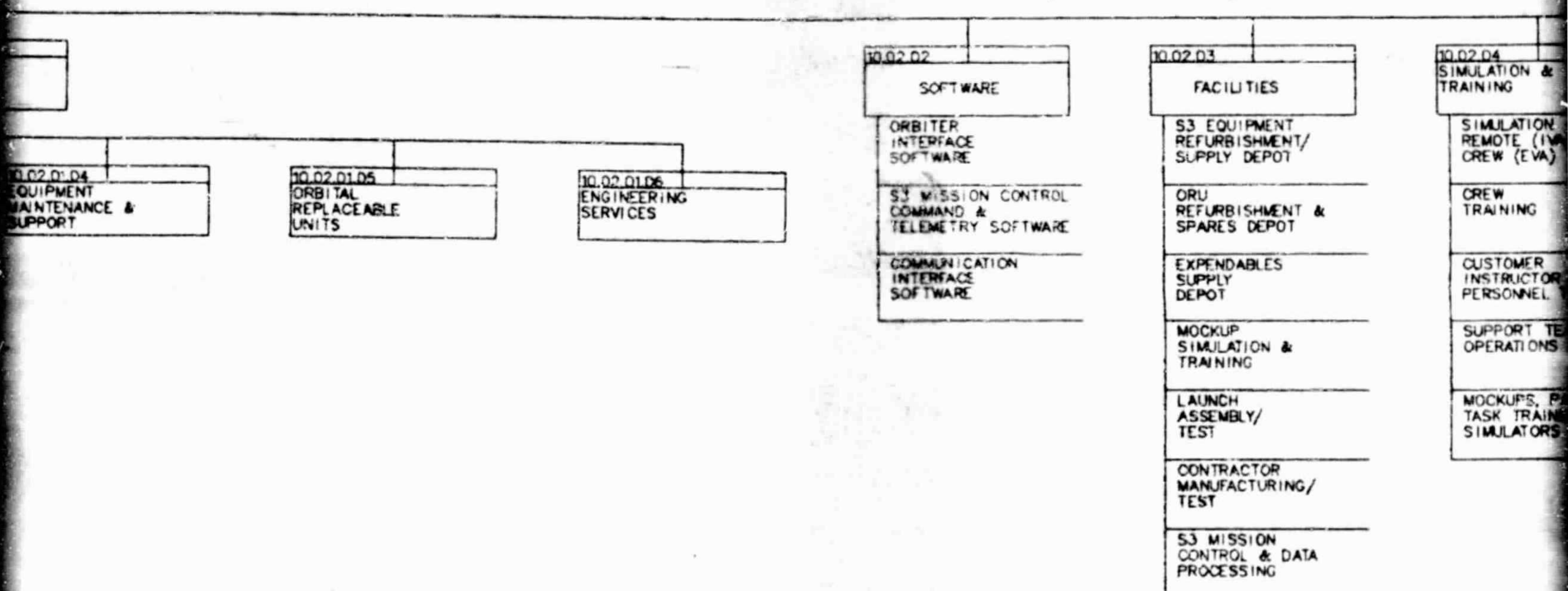

2

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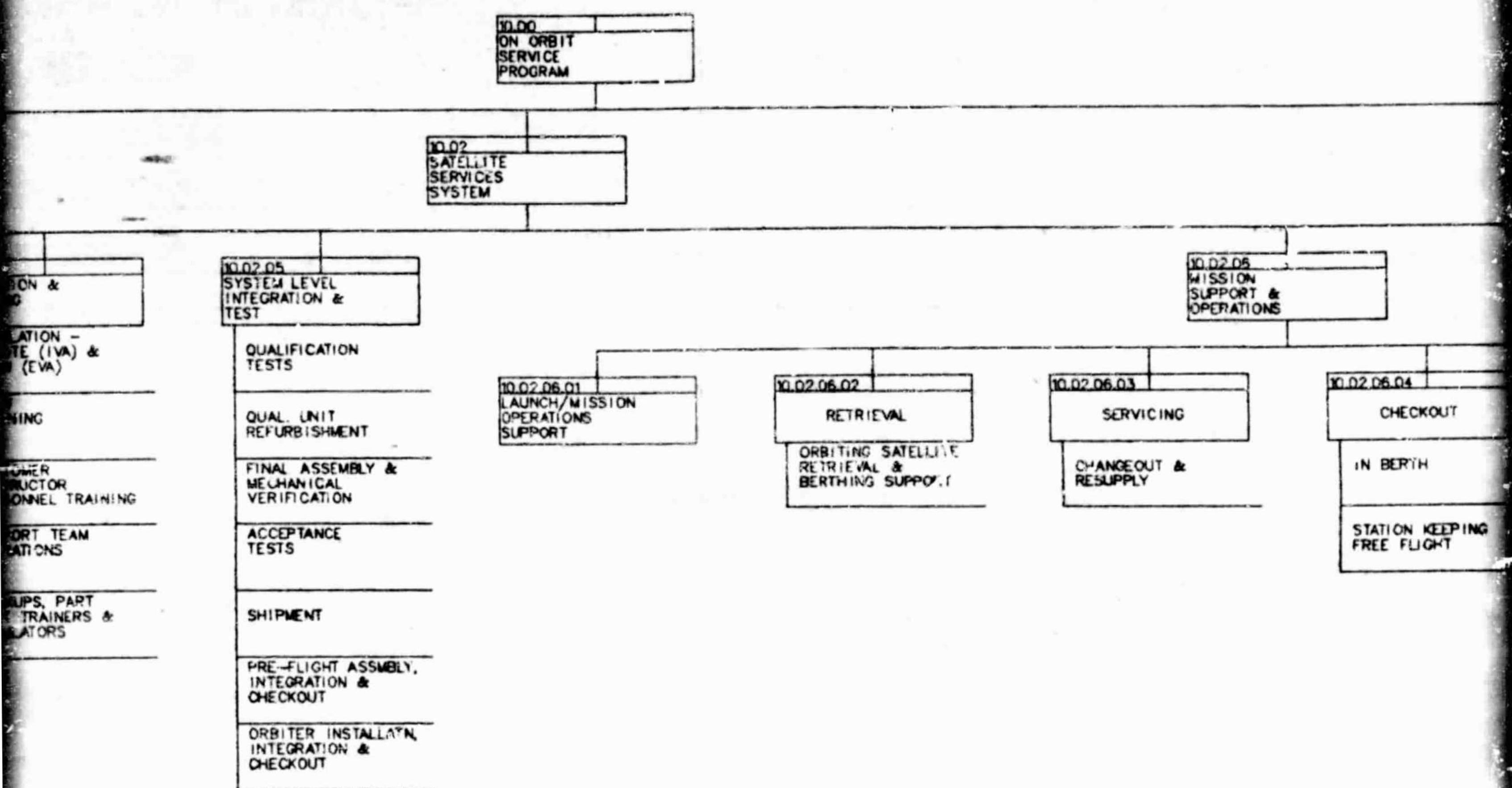
WORK BREAKDOWN STRUCTURE



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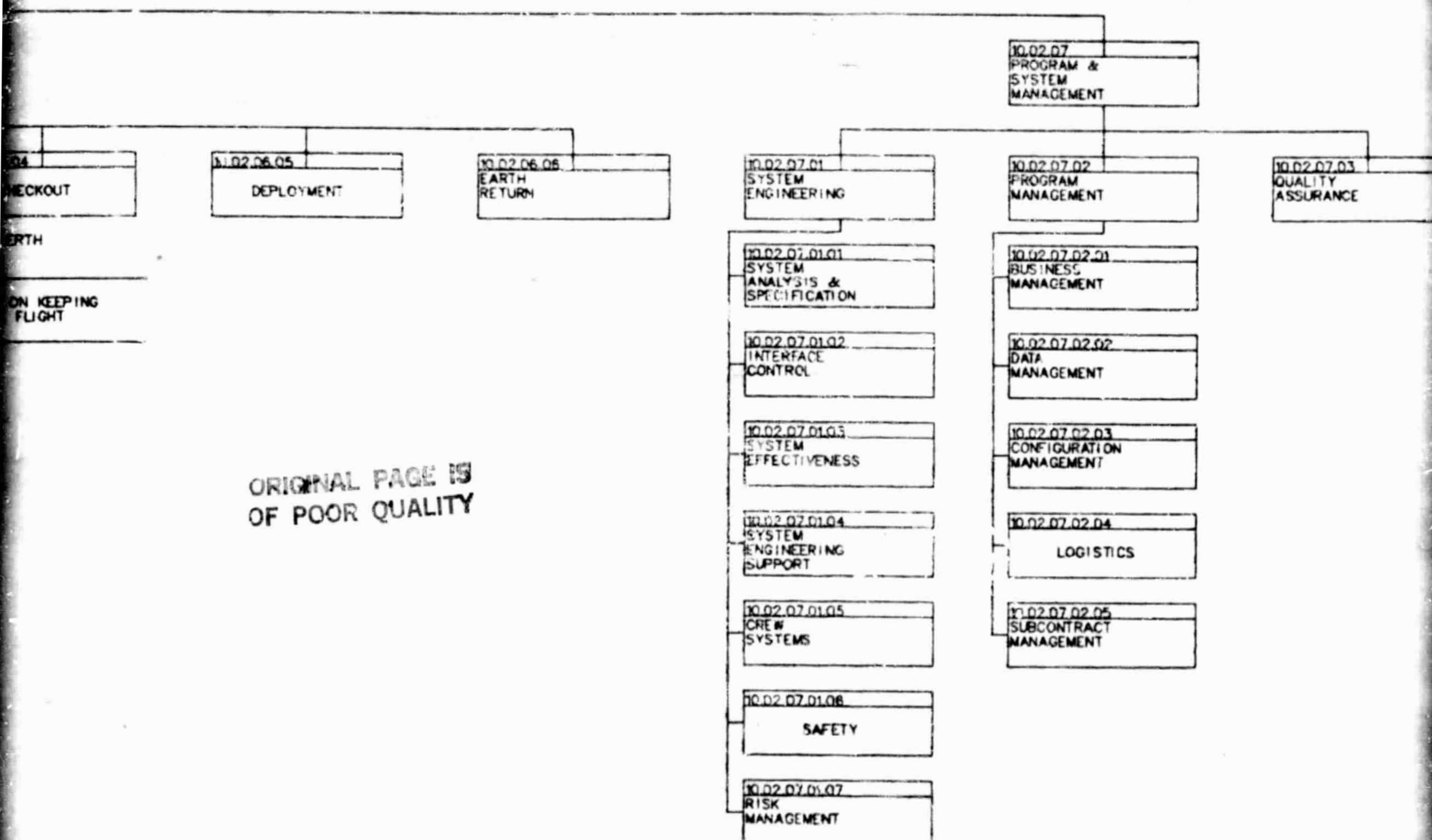

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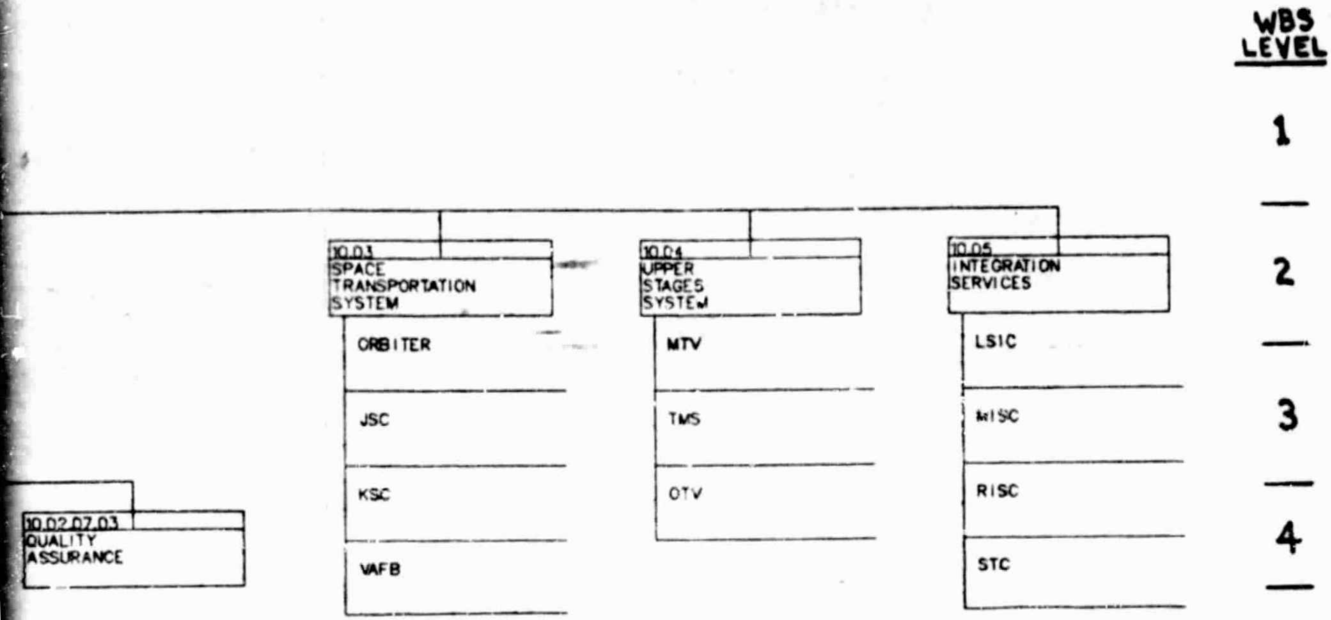

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SECTION 9.0

APPENDIX SUMMARY

CLASSIFIED APPENDIX CONTENTS

THE CLASSIFIED APPENDIX LMSC .058768A, IS TRANSMITTED UNDER SEPARATE COVER. THE CONTENTS ARE:

- SELECTED BASELINE PTS - (U)
- PTS TOP-TIER SPECIFICATION - (U)
- PTS WEIGHT STATEMENT - (U)
- GENERAL SERVICING MISSION SCENARIO (TIME LINE) - (U)

SECTION 10.0

CONCLUSIONS

CONCLUSIONS

THE BASELINE PROPELLANT TRANSFER SYSTEM CAN BE BUILT WITH LOW COST AND RISK USING EXISTING OR MODIFIED COMPONENTS.

THE SYSTEM WILL BE ADAPTABLE TO REFUELING EITHER MONO-PROPELLANT OR BI-PROPELLANT SPACECRAFT AND MAY BE USED AS AN OMS KIT.

A PROOF OF CONCEPT FLIGHT DEMONSTRATION CAN BE DESIGNED AND FABRICATED WITHIN 12 TO 18 MONTHS USING SURPLUS OR AVAILABLE COMPONENTS.

THE PROOF OF CONCEPT DEMONSTRATION AND THE PRELIMINARY DESIGN PHASE SHOULD BE STARTED AS SOON AS POSSIBLE.