

# Assembly Operations Handbook (AOH): S6 Truss Delivery

## STS-119 (Mission 15A)

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Mission Operations Directorate  
Cargo Integration and Operations Branch

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National Aeronautics and  
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Lyndon B. Johnson Space Center  
Houston, Texas

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**Assembly Operation Handbook (AOH)  
STS-119 (Mission 15A)**

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Prepared by

*Original Approval Obtained*

---

Dustin Keiser, Book Manager  
USA/Cargo Operations and  
Integration Branch

Approved by

Approved by

*Original Approval Obtained*

---

Kent Hodson,  
Lead/Assembly and Checkout Officer  
USA/Cargo Operations and  
Integration Branch

*Original Approval Obtained*

---

Lisa Blok, Group Lead  
NASA/Cargo Operations and  
Integration Branch

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A-1 – A-10	Final
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## **PREFACE**

This document was prepared by the Cargo Integration and Operations Branch, Operations Division, Mission Operations Directorate (MOD), National Aeronautics and Space Administration (NASA), Lyndon B. Johnson Space Center (JSC), Houston, Texas, with editorial support from Integrated Documentation Services (IDS).

Comments concerning the technical content of this document should be directed to DO5, Dustin Keiser, 281-244-1688.

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## CONTENTS

Section	Page
<b>1.0 INTRODUCTION .....</b>	<b>1-1</b>
1.1 PURPOSE .....	1-1
1.2 SCOPE .....	1-1
1.3 DESCRIPTION .....	1-2
<b>2.0 STAGE ARCHITECTURE DATA .....</b>	<b>2-1</b>
2.1 STAGE ULF2 AND 15A CONFIGURATION .....	2-1
2.1.1 Structures and Mechanisms .....	2-4
2.1.2 Electrical Power System .....	2-7
2.1.3 Command and Data Handling System.....	2-12
2.1.4 Communication and Tracking System .....	2-17
2.1.5 Motion Control System.....	2-19
2.1.6 Environmental Control and Life Support System .....	2-19
2.1.7 Thermal Control System .....	2-23
2.1.8 Robotics Systems .....	2-31
2.1.9 EVA Systems.....	2-34
2.2 MISSION 15A ASSEMBLY HARDWARE .....	2-35
2.2.1 Integrated Truss Segment S6 .....	2-35
<b>3.0 OPERATIONS SUMMARY .....</b>	<b>3-1</b>
3.1 ASSEMBLY MISSION OVERVIEW FOR MISSION 15A .....	3-1
3.2 MISSION SUMMARY .....	3-1
3.2.1 Cargo Manifest .....	3-2
3.2.2 Priorities and Constraints.....	3-3
3.2.3 Rendezvous and Docking .....	3-4
3.2.4 Docked Operations .....	3-4
3.2.5 Departure.....	3-4
3.3 S6 PRIMARY POWER CHANNEL 1B AND 3B ACTIVATION.....	3-5
3.3.1 Power Channel Activation Prep .....	3-5
3.3.2 Part 1: PVCU MDM Startup .....	3-6
3.3.3 Part 2: Initial Channel Activation of Channel.....	3-6
3.3.4 Part 3: PVTCS Activation.....	3-7
3.3.5 PART 4: ECU Activation and BCDU Configuration and Checkout.....	3-9
3.3.6 Part 5: PVM Radiator Deployment.....	3-9
3.3.7 Part 6: Battery Warmup .....	3-10
3.3.8 Part 7: Battery Charging .....	3-10
3.3.9 Part 8: Configure for Nominal Operations.....	3-11
3.4 SOLAR ARRAY WING DEPLOY .....	3-11
3.4.1 Flight Day 5 SAW Deploy Activities .....	3-11
3.4.2 Flight Day 7 SAW Deploy Activities .....	3-12
3.4.3 Flight Day 8 SAW Deploy Activities .....	3-12

<b>Section</b>	<b>Page</b>	
3.5	EXTRAVEHICULAR ACTIVITY OPERATIONS.....	3-17
3.5.1	Scheduled Extravehicular Activity Tasks .....	3-18
3.5.2	Unscheduled and Contingency EVA Tasks .....	3-56
3.5.3	Stage EVA Tasks.....	3-60
3.6	SSRMS ACTIVITIES.....	3-60
3.6.1	S6 Double Hand Off Overview and S6 install .....	3-60
3.7	TRANSFER ACTIVITIES .....	3-60
3.7.1	Cargo Transfer Bags.....	3-61
3.8	TRANSFER PAYLOADS .....	3-64
3.8.1	Glacier .....	3-64
3.8.2	Dome Gene .....	3-76
3.8.3	PCDF-PU.....	3-79
3.8.4	PCDF-PU Front Panel .....	3-81
3.8.5	Data Connections .....	3-84
3.8.6	Safety.....	3-84
3.8.7	National Lab Pathfinder-Vaccine 3 (NLP-Vaccine 3) .....	3-88
3.9	PAYLOADS OF OPPORTUNITY.....	3-93
3.9.1	Maui Analysis of Upper-atmospheric Injections .....	3-93
3.9.2	Shuttle Exhaust Ion Turbulence Experiments .....	3-95
3.9.3	Shuttle Ionospheric Modification with Pulsed Localized Exhaust....	3-97
<b>4.0</b>	<b>FLIGHT SPECIFIC UNIQUE INTERFACES AND SYSTEMS.....</b>	<b>4-1</b>
4.1	ORBITER SYSTEMS.....	4-1
4.1.1	Station-Shuttle Power Transfer System .....	4-1
4.1.2	Payload Deployment and Retrieval System.....	4-7
4.2	CREW INTERFACES .....	4-8
4.2.1	Portable Computer System.....	4-8
4.2.2	ISS Homepage Display .....	4-9
4.2.3	PCS Software .....	4-9
4.2.4	RS PCS .....	4-9
4.2.5	Station Support Computer .....	4-9
4.2.6	Multifunctional CRT Display System.....	4-10
4.3	STANDARD SWITCH PANEL .....	4-13
4.4	PAYLOAD DATA INTERFACE PANEL .....	4-13

<b>Appendix</b>		<b>Page</b>
<b>A</b>	<b>ACRONYMS AND ABBREVIATIONS .....</b>	<b>A-1</b>
<b>B</b>	<b>SUPPLEMENTARY DATA.....</b>	<b>B-1</b>
<b>C</b>	<b>CHANGE CONTROL .....</b>	<b>C-1</b>

## **TABLES**

### **Table**

2-1	Structures and mechanisms .....	2-4
2-2	Power systems capability summary at Stages ULF2 and 15A.....	2-8
2-3	C&DH capability summary at Stages ULF2 to 15A.....	2-12
2-4	C&T system capability summary at Stages ULF2 to 15A .....	2-17
2-5	MCS capability summary at Stages ULF2 to 15A.....	2-19
2-6	ECLSS capability summary at Stages ULF2 to 15A .....	2-19
2-7	TCS capability summary at Stage 15A.....	2-23
2-8	Robotics capability summary at Stages ULF2 to 15A.....	2-31
2-9	EVA capability summary at Stages ULF2 - 15A .....	2-35
3-1	EVA 1 Task List .....	3-19
3-2	EVA 2 Timeline.....	3-36
3-3	EVA 3 Task List .....	3-42
3-4	EVA 4 Task List .....	3-53
3-5	Unscheduled/contingency EVAs for STS-119/15A.....	3-58
3-6	CTB dimensions .....	3-61
3-7	PCDF interfaces .....	3-84
3-8	PCDF-EDR interfaces .....	3-88
3-9	GAP levels of containment .....	3-92
3-10	SIMPLEX groundsites .....	3-98

## FIGURES

<b>Figure</b>	<b>Page</b>
2-1	ISS configuration – Stage ULF2 (pre-15A) ..... 2-2
2-2	ISS configuration – Stage 15A (after undock) ..... 2-3
2-3	EPS overview at stage 15A ..... 2-11
2-4	C&DH overview at Stage 15A..... 2-16
2-5	USOS ECLSS overview at Stage 15A..... 2-22
2-6	15A External active thermal control system..... 2-29
2-7	15A TCS module overview ..... 2-30
2-8	Robotics overview at Stage 15A..... 2-33
2-9	MSS WS locations..... 2-34
2-10	PV blanket (fully deployed)..... 2-39
2-11	Mast canister ORU (pivot fittings deployed) ..... 2-49
2-12	Mast canister, FAST mast, and tip fitting interface ..... 2-52
2-13	Top view of mast tip fitting ..... 2-52
2-14	Upper and lower pivot fittings ..... 2-53
2-15	Lower pivot fitting locking strut sleeve ..... 2-54
2-16	Solar array blanket box..... 2-55
2-17	SABB latch mechanism ..... 2-56
2-18	PV blanket tensioning mechanisms..... 2-57
2-19	S6 RTAS interface plane ..... 2-66
2-20	S5 fine alignment/bolt assembly ..... 2-67
2-21	Long spacer fine alignment/nut installation (end view) ..... 2-68
2-22	Long spacer fine alignment/nut installation (isometric view)..... 2-69
3-1	STS-119/ISS-15A PLB layout..... 3-3
3-2	PVTCS Startup Pressure vs. Temperature..... 3-8
3-3	Thermal Conditioning Sun angle requirement ..... 3-13
3-4	Solar array mast bay definitions ..... 3-15
3-5	BRS Pin, Guide-wire Mech, and Tension Mech Locations ..... 3-15
3-6	One mast deployed and SABBs in high tension mode ..... 3-16
3-7	SA Deploy Timeline Options..... 3-17
3-8	S6 Install task locations ..... 3-20
3-9	Active RTAS side on S5 ..... 3-21
3-10	Passive RTAS side on S6..... 3-22
3-11	Primary attachment bolt mechanism ..... 3-23
3-12	SABB launch restraints..... 3-25
3-13	BGA launch configuration ..... 3-26
3-14	EVA interface to the BGA launch restraints..... 3-27
3-15	BGDTS hinge locks ..... 3-28
3-16	Keel pin rotation..... 3-29
3-17	SABB swing arms and pip pins..... 3-30
3-18	SABB locking strut sleeve (SABB unstowed) ..... 3-31
3-19	SABB (unstowed configuration)..... 3-31

<b>Figure</b>	<b>Page</b>
3-20 Mast tip fitting bolts.....	3-32
3-21 PVR launch restraints.....	3-33
3-22 PVR cinch (left view – cinch receptacle; right view – secured in the on-orbit clip).....	3-33
3-23 Winch bar (released from PVR).....	3-34
3-24 ECU shroud removal .....	3-35
3-25 PAS – (UCCAS shown here for reference).....	3-39
3-26 FHRC P-clamp locations .....	3-40
3-27 CETA cart positions.....	3-43
3-28 CETA cart relocation .....	3-44
3-29 CETA cart.....	3-45
3-30 CETA cart wheel bogies .....	3-45
3-31 CETA cart couplers .....	3-46
3-32 SPDM cover locations .....	3-47
3-33 The 3 SPDM OTCM covers.....	3-48
3-34 EP1 covers .....	3-49
3-35 LEE B repair .....	3-50
3-36 LEE B repair work area .....	3-51
3-37 Video paths of each radiator.....	3-54
3-38 Z1 Patch Panel.....	3-55
3-39 Half bag .....	3-62
3-40 Single bag (with window).....	3-62
3-41 Double bag .....	3-63
3-42 Triple bag.....	3-63
3-43 Glacier front panel .....	3-65
3-44 Glacier with VPMP mounted.....	3-66
3-45 Glacier backplate.....	3-67
3-46 Crew command interface.....	3-69
3-47 Glacier internal doors .....	3-70
3-48 Glacier door latch .....	3-72
3-49 Door captive lock (qty 2).....	3-72
3-50 Glacier door captive lock positioned for on-orbit sample transfer .....	3-73
3-51 Glacier door captive lock positioned for ascent and descent.....	3-73
3-52 Locker captive fasteners (qty 4).....	3-74
3-53 Cryocooler launch/landing locks .....	3-75
3-54 Intravehicular activity handle assembly .....	3-76
3-55 Prefixation apparatus.....	3-78
3-56 Culture chambers and fixation cylinders .....	3-78
3-57 PCDF-PU installed in an ISS locker .....	3-80
3-58 Principle of PCDF-PU installation into MDL.....	3-81
3-59 PCDF-PU front view after installation into MDL.....	3-82
3-60 EDR, including PCDF in isometric view.....	3-86
3-61 PCDF front panel connections.....	3-87
3-62 GAPS and hand crank in foam stowage block.....	3-89

<b>Figure</b>		<b>Page</b>
3-63	GAP with hand crank attached .....	3-90
3-64	GAP with alignment marks .....	3-90
3-65	FPA's .....	3-91
3-66	Low resolution all-sky imagery from OMS burn .....	3-94
3-67	Satellite diagnostics of artificial plasma turbulence.....	3-96
3-68	Symmetrical dual-OMS burn during orbital daylight.....	3-97
4-1	SSPTS architecture (OV-103 and -105) .....	4-1
4-2	PTU installation locations .....	4-3
4-3	Integrated PTU with additional hardware.....	4-4
4-4	APCU configuration .....	4-4
4-5	Bus wiring for return power to orbiter.....	4-5
4-6	SSPTS PTU front panel connections.....	4-6
4-7	A15 Panel switches for PTUs .....	4-7
4-8	PRLA latch locations .....	4-8
4-9	ISS homepage.....	4-10
4-10	SPEC 205: USOS ARP/DPTR moding.....	4-11
4-11	SPEC 179 - Power Transfer .....	4-12
4-12	SPEC 212: OIU .....	4-13
4-13	SSP 1 .....	4-14
4-14	SSP 2 .....	4-15
4-15	Payload Data Interface Panel 1 .....	4-16
4-16	Payload Data Interface Panel 2.....	4-16

## DRAWINGS

<b>Drawing</b>	<b>Page</b>
2.1 CARGO BAY LAYOUT.....	2-71
2.2 ISS EPS SYSTEM STAGE 15A OVERVIEW (Sheet 1 of 2).....	2-73
2.2 ISS ELECTRICAL POWER SYSTEM TRUSS OVERVIEW (Sheet 2 of 2).....	2-75
2.3 ISS C&DH SYSTEM – MODULES STAGE 15A OVERVIEW (Sheet 1 of 2).....	2-78
2.3 15A STAGE COMMAND AND DATA HANDLING OVERVIEW (Sheet 2 of 2).....	2-79
2.4 S6 HARDWARE OVERVIEW .....	2-81
2.5 SARJ CONNECTIVITY .....	2-83
3.1 S0 TRUSS INTEGRATED ASSEMBLY – STAGE 15A – ASSY COMPLETE (Sheet 1 of 7) .....	3-101
3.1 S1 TRUSS INTEGRATED ASSEMBLY COMPLETE (Sheet 2 of 7) .....	3-103
3.1 P1 TRUSS INTEGRATED ASSEMBLY COMPLETE 15A ASSEMBLY COMPLETE (Sheet 3 of 7) .....	3-105
3.1 P3/P4/P5 TRUSS INTEGRATED ASSEMBLY (Sheet 4 of 7) .....	3-107
3.1 S3/S4/S5 TRUSS INTEGRATED ASSEMBLY (Sheet 5 of 7) .....	3-109
3.1 S5/S6 TRUSS INTEGRATED ASSEMBLY (Sheet 6 of 7).....	3-111
3.1 P5/P6 TRUSS INTEGRATED ASSEMBLY (Sheet 7 of 7).....	3-113
3.2 SOLAR ARRAY BLANKET BOX (SABB) .....	3-115



## 1.0 INTRODUCTION

### 1.1 PURPOSE

The Assembly Operations Handbook (AOH) is produced by the Cargo Integration and Operations Branch (CIOB) of NASA's Mission Operations Directorate (MOD). It serves as a mission/stage-specific technical handbook and reference guide for all International Space Station (ISS) assembly, activation, checkout, logistics transfer, and payload (ISS and shuttle) operations. The AOH does not fly onboard the shuttle as part of the official crew Flight Data File (FDF) or Station Operations Data File (SODF), and it is not referenced by any scheduled crew or ground activities. It is, however, reviewed during the Flight Operations Review (FOR) by all applicable NASA and contractor personnel assigned to the mission, and all technical content is verified by the CIOB prior to launch as part of the Certification of Flight Readiness (CoFR) process of the Flight Readiness Review (FRR).

### 1.2 SCOPE

This version of the AOH addresses the nominal and contingency operations for shuttle Mission STS-119/15A and Stage 15A, which is defined as the entire time between STS-119 (ISS-15A) launch and the launch of the next assembly mission (currently STS-127 (ISS-2J/A)). It contains text descriptions, schematic drawings, diagrams, figures, and photographs of flight hardware and its associated operations. Both ISS and shuttle systems are described; however, the emphasis is on the multisystem functions required to support ISS assembly, activation, checkout, and logistics transfer operations.

In this AOH, the following components are referred to by their common name:

<b>Component</b>	<b>Common Name</b>
Unity module	Node 1
Zarya module	Functional Cargo Block (FGB)
Zvezda module	Service Module
Destiny module	U.S. Laboratory Module (U.S. Lab)
Quest module	ISS Joint Airlock or ISS Airlock
Harmony module	Node 2
Columbus module	Columbus

<b>Component</b>	<b>Common Name</b>
Kibo module	Japanese Experiment Modules (JEMs) JEM Pressurized Module (JPM) JEM Logistics Module Pressurized Section (JLP) JEM Exposed Logistics Module (ELM-ES) JEM Exposed Facility (JEF)
Dextre Manipulator	Special Purpose Dexterous Manipulator (SPDM)
Leonardo/Donatello/Michelangelo module	Multipurpose Logistics Module (MPLM)

Details covered in this document address the assembly configuration specific to the STS-119/15A Mission.

### **1.3 DESCRIPTION**

This document provides technical data on the mission to deliver the S6 truss segment, as well as ISS and space shuttle elements that are used during the assembly process. The emphasis is on the multisystem functions required to support assembly tasks. Additional technical data on specific ISS systems are found in JSC-36027, International Space Station System Handbook (ISSSH). Additional technical data for shuttle systems are found in JSC-11174, Space Shuttle Systems Handbook (SSSH).

Section 2 contains details of the existing ISS system architecture and capabilities before Mission 15A and the resulting configuration following 15A docked operations (Stage 15A). It includes descriptions of all new ISS elements and systems hardware delivered and installed during the docked mission, as well as any hardware that is planned to be installed or checked out during the subsequent stage operations (no shuttle present).

Section 3 contains an assembly mission overview for the assembly mission/stage ISS-15A. Included in this section is an overview of the following: ISS assembly sequence, shuttle cargo manifest, rendezvous and docking, docked ops, departure, deferred assembly tasks, and any mandatory functions required for future assembly stages. It also contains detailed descriptions of all ISS assembly, activation, checkout, logistics transfer, and payload operations planned during Mission 15A and the following stage, including all Extravehicular Activities (EVAs). The focus is on the primary mission objectives and the hardware/systems that are directly involved with docked operations.

Section 4 contains reference information on shuttle systems and crew interfaces that are used to assist with ISS assembly, activation, checkout, logistics transfer, and payload operations. This includes the Orbiter Docking System (ODS), and the Payload Deployment and Retrieval System (PDRS) among others.

## **2.0 STAGE ARCHITECTURE DATA**

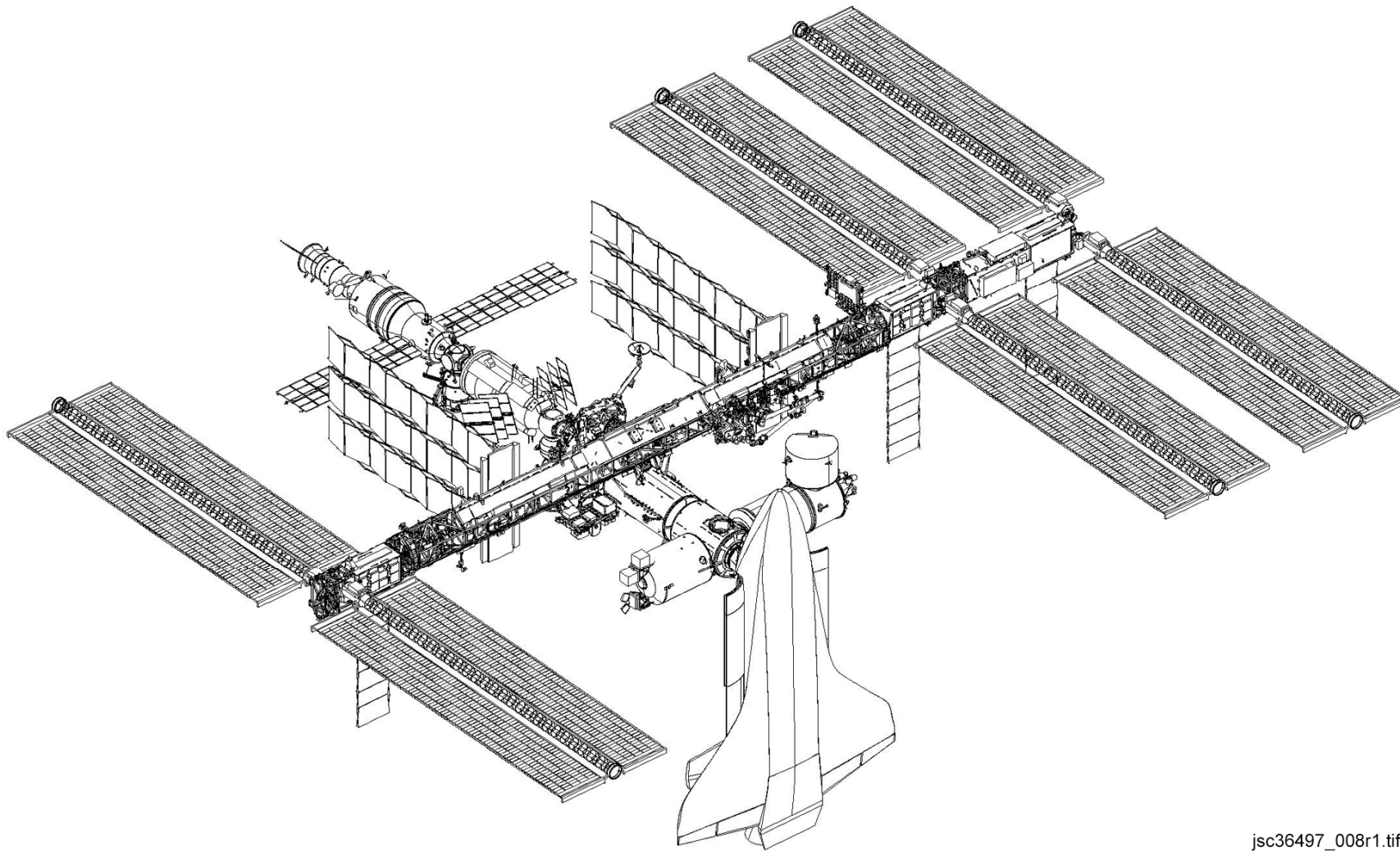
The focus of this section is on the changes made to the ISS systems due to the 15A Mission.

### **2.1 STAGE ULF2 AND 15A CONFIGURATION**

At Stage Utilization Logistics Flight 2 (ULF2), the United States On-Orbit Segment (USOS) consists of Node 1, Node 2, the U.S. LAB, European Space Agency (ESA) Columbus Module, Japanese Aerospace Exploration Agency (JAXA) Japanese Experiment Module (JEM) JEM Pressurized Module (JPM), Japanese Experiment Logistics Module - Pressurized Section (JLP), and Japanese Experiment Module Remote Manipulator System (JEMRMS), Pressurized Mating Adapter-1 (PMA-1), PMA-2, PMA-3, the Joint Airlock, the Zenith 1 (Z1) truss segment, all components of the primary truss (except for S6), and all major components of the Mobile Servicing System (MSS): Mobile Tracker (MT), Mobile Base System (MBS), Space Station Remote Manipulator System (SSRMS), and SPDM. Stage ULF2 does not add any new elements to ISS.

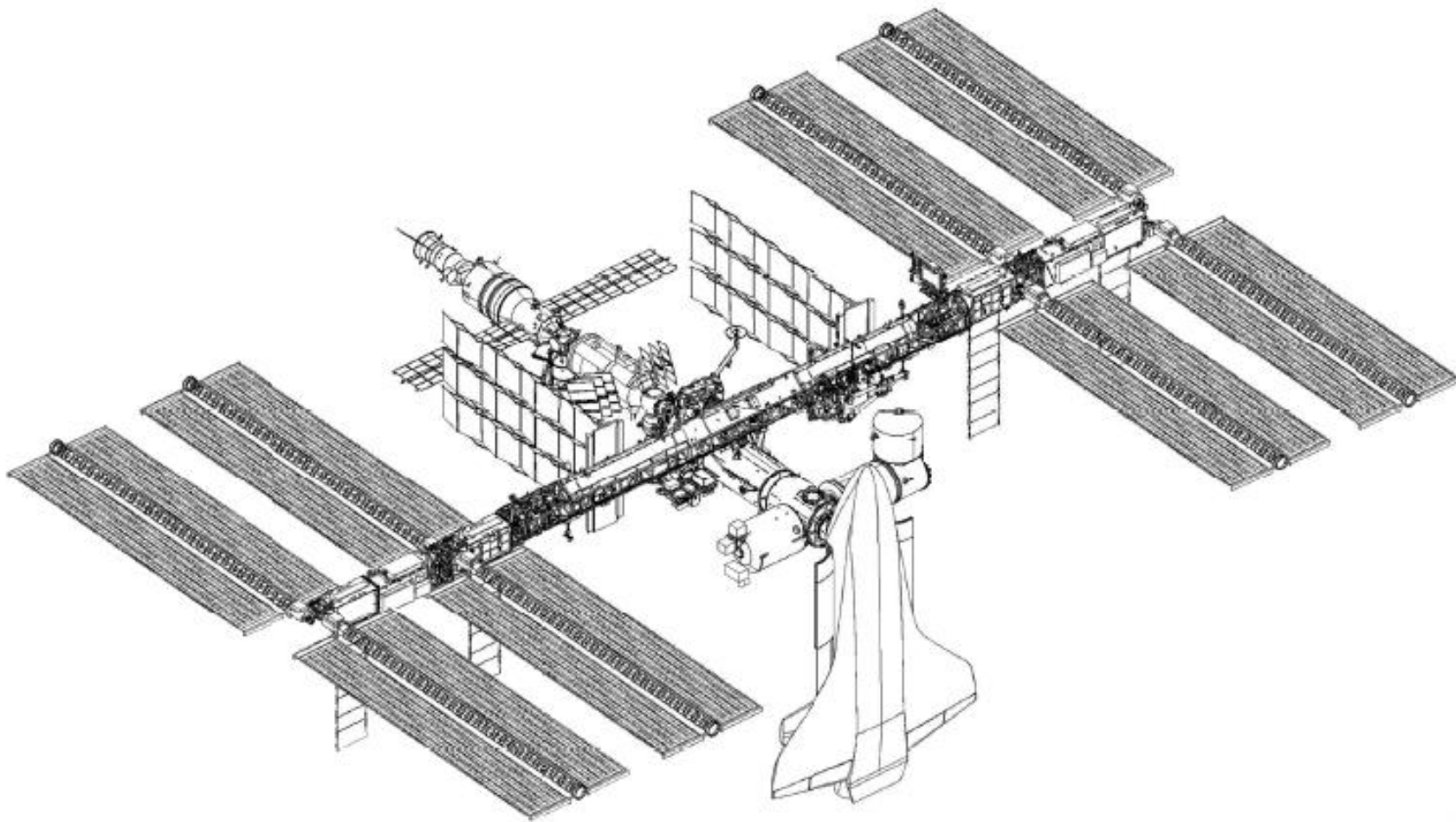
The Russian Segment (RS) consists of the FGB, the SM, Docking Compartment-1 (DC-1), a Soyuz-TMA vehicle, and two Progress-M1 vehicles.

The ISS on-orbit configuration at the completion of Stage ULF2 is shown in Figure 2-1. There are no changes to the ISS configuration during ULF2. Figure 2-2 shows the ISS configuration after STS-119 undock. The following sections provide an overview of the change in ISS capabilities from Stage ULF2 to Stage 15A.



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**Figure 2-1. ISS configuration – Stage ULF2 (pre-15A)**



**Figure 2-2. ISS configuration – Stage 15A (after undock)**

**2.1.1 Structures and Mechanisms**

**Table 2-1. Structures and mechanisms**

<b>Structure</b>	<b>Primary function</b>	<b>ULF2 Stage</b>	<b>15A Stage</b>
<b>Pressurized modules</b>			
SM	Primary living quarters for ISS crew	No comments	No change
FGB	Instrumentation and RS onboard stowage	No comments	No change
DC-1	Docking port cargo vehicles Airlock for Orlan EVAs	No comments	No change
PMA 1	Connects USOS and RS Onboard stowage	No comments	No change
Node 1	Connects USOS modules Onboard stowage	No comments	No change
Node 2	Connects USOS/IP modules Onboard stowage SSRMS operating base	MPLM temporarily attached to Node 2 Zenith ACBM	No change
PMA 3	Onboard, long-term stowage	No comments	No change
Airlock	Facilitates EVAs using Extravehicular Mobility Units (EMUs)	No comments	No change
U.S. LAB	On-orbit science facility Command and control of USOS systems	No comments	No change
Columbus Module	ESA on-orbit science facility	No comments	No change
PMA 2	Facilitates orbiter to dock to ISS	No comments	No change
Z1 dome	Onboard long-term stowage	No comments	No change
JPM	JEM science facility C&C of JEM systems	No comments	No change

**Table 2-1. Structures and mechanisms (continued)**

Structure	Primary function	ULF2 Stage	15A Stage
<b>Pressurized modules (continued)</b>			
Unpressurized structures			
JLP	JEM logistics/stowage facility	No comments	No change
Common Berthing Mechanism (CBM)	Mates USOS/IP modules together	Six active CBMs on Node 1 Five active CBMs and one passive on Node 2 One active CBM on U.S. LAB mated to Node 2 One active CBM on JPM zenith, occupied by JLP	No change
APAS	Used for the docking of arriving vehicles to the ISS	Four currently on orbit: one on each PMA and one at the forward end of the FGB. Only the APAS on the forward end of PMA 2 is currently available for docking	No change
S0 ITS	Supports main ISS truss structure	No comments	No change
S1 ITS	Supports EATCS loops and radiators	No comments	No change
P1 ITS	Supports EATCS loops and radiators	No comments	No change
P3/P4 ITS	Supports SARJ and P4 power channels	No comments	No change
S3/S4 ITS	Supports SARJ and S4 power channels	No comments	No change



**Table 2-1. Structures and mechanisms (continued)**

Structure	Primary function	ULF2 Stage	15A Stage
<b>Pressurized modules (continued)</b>			
P5 ITS spacer	Spacer truss between P4 and P6 provides clearance between the P4 solar array and P6 array Contains cables to pass data and power	No comments	No change
S5 ITS spacer	Spacer truss between S4 and S6 provides clearance between the S4 solar array and S6 array Contains cables to pass data and power	No comments	S6 will be installed on S5
P6 PVM	Provides power to the USOS	No comments	No change
S6 PVM	Provides power to the USOS	Not installed	Will be installed on Mission STS-119/15A
Z1 ITS	Supports four CMGs	No comments	No change
LAB Cradle Assembly (LCA)	Used during 8A to temporarily secure S0 ITS to U.S. LAB	No comments	No change
Segment-to-Segment Attach System (SSAS)	Used for connecting inboard truss elements	Four active SSAS (two on S0 and one each on S1 and P1) four passive SSAS (one each on S1, P1, S3/S4 and P3/P4)	No change

**Table 2-1. Structures and mechanisms (concluded)**

Structure	Primary function	ULF2 Stage	15A Stage
<b>Pressurized modules (concluded)</b>			
RTAS and Modified RTAS (M-RTAS)	Used for connecting outboard truss elements	Five active RTAS, three passive on orbit: One active RTAS on top of Z1 (used to connect P6 to Z1) One M-RTAS set connecting P4/P5 One set connecting P5/P6 One M-RTAS set connecting S4/S5 One active RTAS at outboard end of S5	Added one passive RTAS on S6 for connecting to S5
UCCAS/Payload Attach System (PAS)	Used for attaching unpressurized carriers to the S3/S4 and P3/P4 truss element	Two UCCASs delivered on P3/P4 on 12A. Four PAS on S3/S4	<i>EVA 2 deploys the P3 Nadir UCCAS and S3 Outboard/Zenith PAS</i> <i>EVA 4 deploys the S3 Inboard/Zenith PAS and the S3 Outboard/Nadir PAS</i>

### 2.1.2 Electrical Power System

Prior to 15A, the ISS had six fully functional power channels. 15A increases the power capability of the ISS to eight power channels with the addition of S6 Integrated Truss Segment (ITS). Table 2-2 provides an overview of the Electrical Power System (EPS) capability at the completion of Stages ULF2 and 15A, and Table 2-3 presents the EPS functional overview at Stage15A.

**Table 2-2. Power systems capability summary at Stages ULF2 and 15A**

System	ULF2 Stage	15A Stage
<b>Primary power system</b>		
Primary power generation USOS	All power channels fully functional, except S6 channels 1B and 3B (Power channels active are S4 channels 1A and 3A, P4 channels 2A and 4A, and P6 channels 2B and 4B)	S6 channels 1B and 3B are delivered, activated, and fully functional during 15A
Solar array tracking	Port SARJ is fully functional. Starboard SARJ is constrained to directed position (not autotracking) due to anomalous vibrations during rotation, and this condition is not expected to be resolved until ULF2 at the earliest  All BGAs (six) tracking on all gimbals/joints	The addition of S6 ITS adds two more BGAs: S6LWR-3B, S6UPR-1B (for a total of eight BGAs by mission end)
MBSUs	All four MBSUs on S0 active and cross-tied  MBSUs 2 and 4 receiving power from channels 2A, 2B, and 4A, 4B  MBSUs 1 and 3 receiving power from channels 1A and 3A	After S6 installation and activation, MBSUs 1 and 3 receive additional power from channels 1B and 3B, respectively
DCSUs	Six DCSUs onboard (one for each power channel)	Two more DCSUs are added with installation of S6, one for each S6 power channel
BCDUs	18 BCDUs onboard (three on each power channel)	Six more BCDUs become active with installation of S6  S6LWR-3B1 S6LWR-3B2 S6LWR-3B3 S6UPR-1B1 S6UPR-1B2 S6UPR-1B3

**Table 2-2. Power systems capability summary at Stages ULF2 and 15A  
(continued)**

System	ULF2 Stage	15A Stage
<b>USOS Secondary power system</b>		
DC-to-DC Converter Units (DDCUs)	LAB: Six DDCUs Node 2: Eight DDCUs Z1: Two DDCUs S0: Four DDCUs P1: One DDCU S1: One DDCU P4: Two DDCUs S4: Two DDCUs P6: Two DDCUs	S6 includes the addition of two DDCUs
Secondary Power Distribution Assembly/ Remote Power Distribution Assembly (SPDA/RPDA)	LAB: Four SPDAs N1: Four RPDAs N2: Two RPDAs, four SPDAs Z1: Two SPDAs A/L: Two RPDAs S0: Four SPDAs MT: Two RPDAs S1: Four SPDAs P1: Four SPDAs S3: Four SPDAs P3: Four SPDAs	No change
<b>USOS Electrical power subsystems</b>		
PVTCS	P4, P6, S4, PVTCS active and PVRs deployed	S6 PVTCS is activated and PVR deployed
PCU	Two PCUs are mounted on upper port side of Z1	No change

**Table 2-2. Power systems capability summary at Stages ULF2 and 15A  
(concluded)**

<b>System</b>	<b>ULF2 Stage</b>	<b>15A Stage</b>
<b>Russian segment power system</b>		
Primary power	SM solar arrays deployed and generating power (FGB arrays retracted)	No change
Secondary power	Four FGB ARCUs receiving USOS power from Z1 SPDAs  Two SM CHTs receiving USOS power from MBSU 2A  Two SM CHTs receiving USOS power from MBSU 4A	No change
<b>JEM segment power system</b>		
Primary power	None	No change
Secondary power	Two JPM PDU-Is Two JPM PDU-IIs	No change
Secondary power subsystem	JLP PDB fed from JPM Four JPM PDB-Is Seven JPM PDB-IIs Two JPM PDU-Is Two JPM PDU-IIs Four JPM PIBs	No change
<b>ESA segment power system</b>		
Primary power	None	No change
Secondary power	Node 2 DDCUs provide 120 V USOS secondary power to two redundant Power Distribution Units (PDUs) within the Columbus Electrical Power Distribution System (EPDS)	No change
Secondary power subsystem	Columbus PDUs distribute secondary power to all Columbus subsystems and payloads	No change

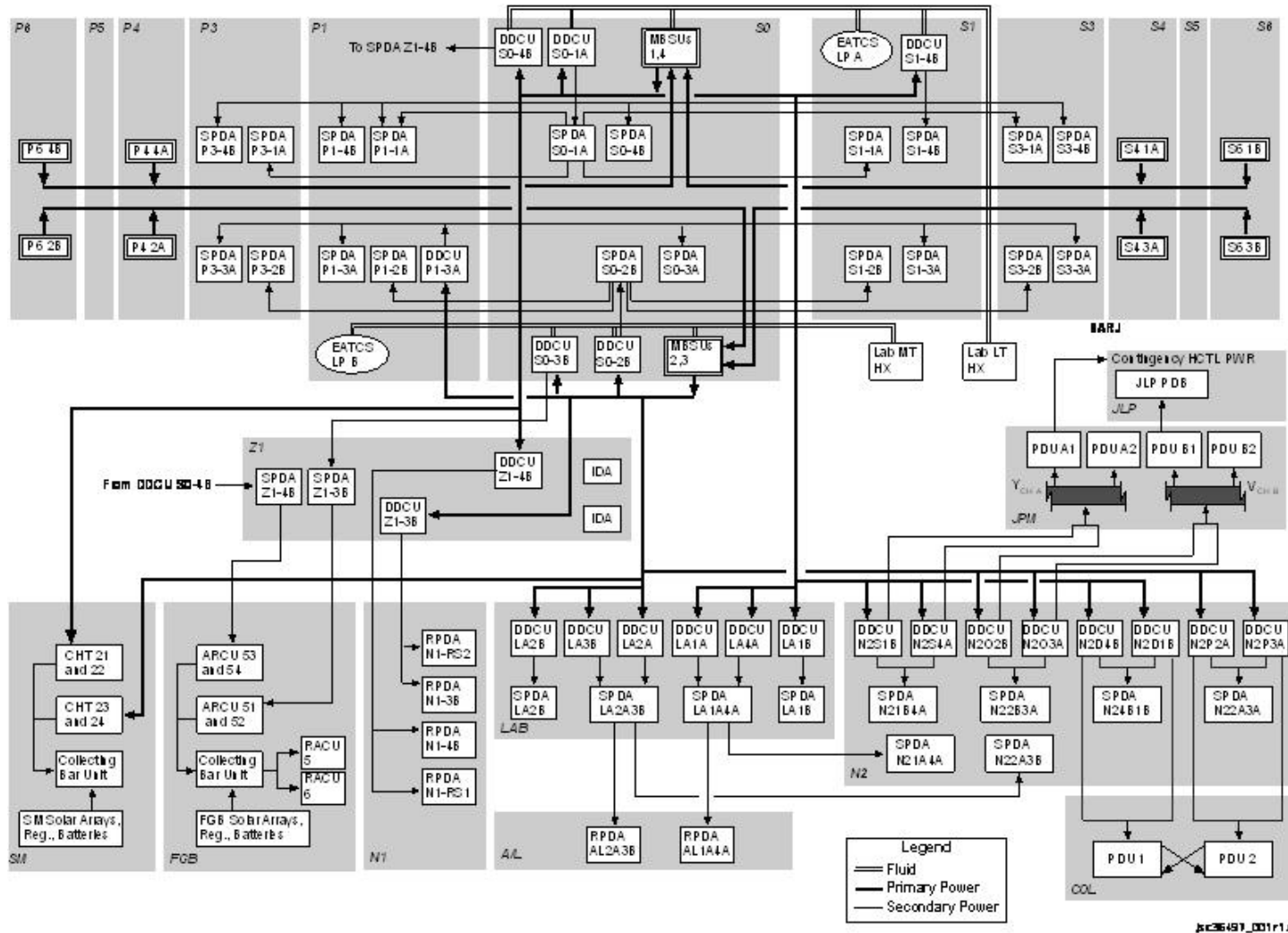


Figure 2-3. EPS overview at stage 15A

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### 2.1.3 Command and Data Handling System

ULF2 does not change the Command and Data Handling (C&DH) capability of the station. Table 2-3 provides an overview of the C&DH system capability at the completion of Stages ULF2 and 15A. Table 2-4 presents the C&DH functional overview for the USOS.

**Table 2-3. C&DH capability summary at Stages ULF2 to 15A**

System	ULF2 Stage	15A Stage
<b>Russian segment C&amp;DH system</b>		
SM computers	Control of SM DMS-R; control of RS MCS; control of IMCS (selectable)	No changes
FGB computers	Control of FGB systems	No changes
<b>USOS segment C&amp;DH system</b>		
C&C MDMs	Processing of ISS level software; coordinate C&W between ISS segments; crew interface with C&DH system (via PCS); connect to MCC via ISS communication subsystems Tier 1: Three MDMs – Primary, backup, and standby	No changes
GNC MDMs	Monitor and control of CMGs; perform calculations supporting USOS attitude control; coordinate overall ISS attitude control with RS Tier 2: Two MDMs – Primary and backup	No changes
Int MDMs	Monitor and control of internal ECLSS, EPS, and TCS systems of ISS Tier 2: Two MDMs – Primary and backup	No changes
Payload MDM	Control of USOS Payload C&DH network Tier 2: Two MDMs – Primary and backup	No changes

**Table 2-3. C&DH capability summary at Stages ULF2 to 15A (continued)**

System	ULF2 Stage	15A Stage
<b>USOS segment C&amp;DH system (continued)</b>		
PMCU MDMs	Control of EPS secondary power distribution Tier 2: Two MDMs – Primary and backup	No changes
EXT MDMs	Monitor and control inboard integrated truss segments (i.e., S0, S1, P1, P3, and S3) systems Tier 2: Two MDMs – Primary and backup	No changes
Node 1 MDMs	Control of Node 1, PMA, and Z1 heaters; control of PCU ops; control of CBM ops Tier 3: Two MDMs – N1-1 and N1-2 (considered Tier 2.5 with characteristics of both)	No changes
Node 2 MDMs	Control of Node 2 internal systems, command and control routing to IP elements; control of CBM Ops Tier 3: Two MDMs - N2-1 and N2-2	No change
PVCU MDMs	Control of S4, P4, and P6 solar arrays and power flow Tier 3: Six MDMs – PVCU-2A and PVCU-4A, PVCU-2B and PVCU-4B, PVCU-1A and PVCU-3A	Control of S6 solar arrays and power flow Tier 3: Two MDMs are added with the addition of S6: PVCU-1B and PVCU-3B
A/L MDM	Control of ISS joint airlock systems Tier 3: One MDM – A/L MDM	No changes
LAB MDMs	Monitor and control of U.S. LAB-related functions Tier 3: Three MDMs – LA-1, LA-2, and LA-3	No changes

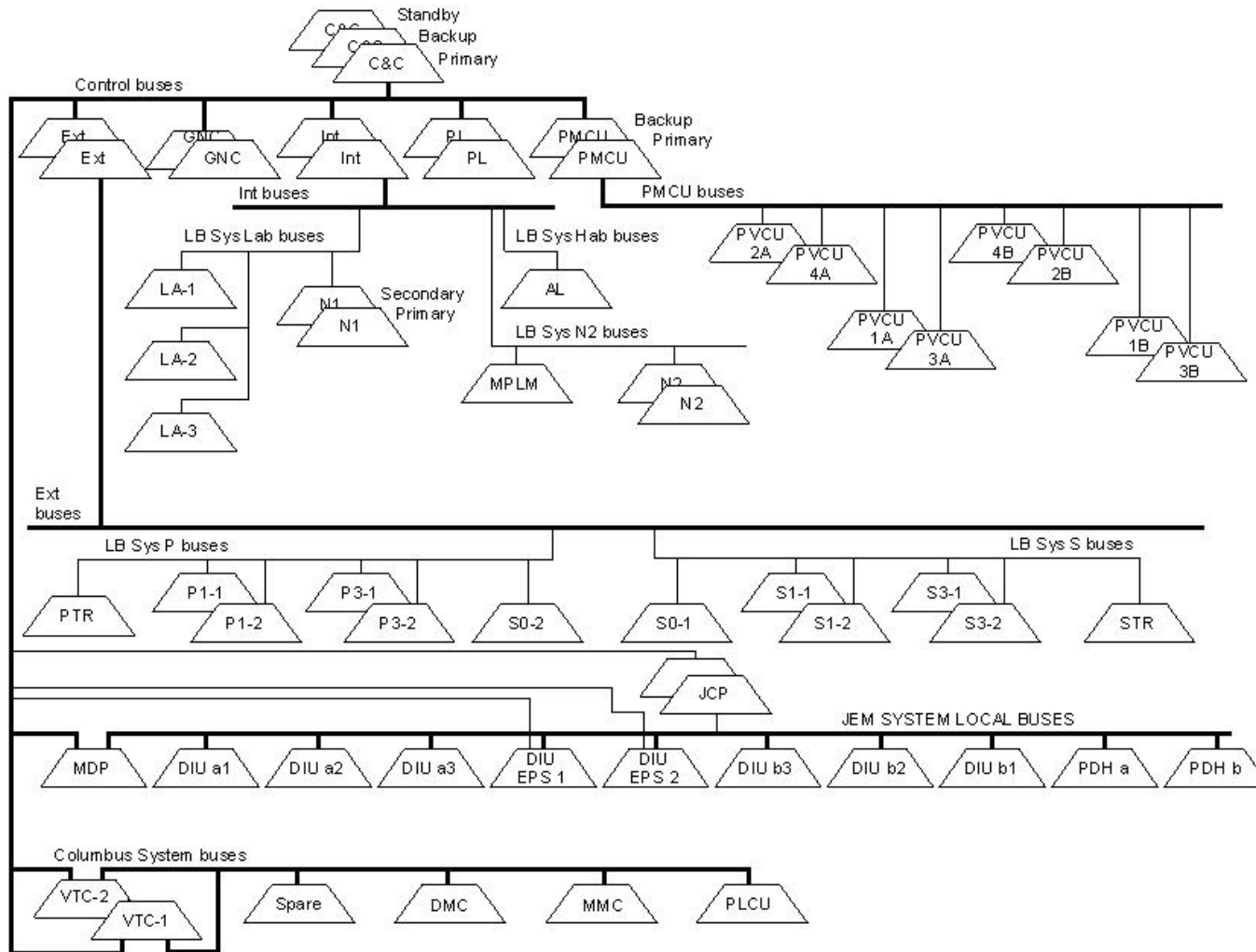


**Table 2-3. C&DH capability summary at Stages ULF2 to 15A (continued)**

<b>System</b>	<b>ULF2 Stage</b>	<b>15A Stage</b>
<b>USOS segment C&amp;DH system (concluded)</b>		
S0 MDMs	Monitor and control ITS S0 systems Tier 3: Two MDMs – S0-1 and S0-2	No changes
S1 MDMs	Monitor and control ITS S1 systems Tier 3: Two MDMs – S1-1 and S1-2	No changes
S3 MDMs	Monitor and control ITS S3 systems Tier 3: Two MDMs – S3-1 and S3-2	No changes
P1 MDMs	Monitor and control ITS P1 systems Tier 3: Two MDMs – P1-1 and P1-2	No changes
P3 MDMs	Monitor and control ITS P3 systems Tier 3: Two MDMs – P3-1 and P3-2	No changes
STR/PTR MDMs	Monitor and control systems on the starboard/port TRRJ that are primarily related to radiator and RBVM operations Tier 3: Two MDMs – STR and PTR	No changes
PCS	Crew interface with USOS C&DH system	No changes
<b>ESA segment C&amp;DH system</b>		
Columbus Data Management System (DMS)	Monitor and control Columbus-related functions. Interfaces with U.S. International buses Tier 3: Four Standard Portable Computers (SPCs) – Data Management Computer (DMC), Mission Management Computer (MMC), P/L Command Unit (PLCU), plus a spare SPC	No changes

**Table 2-3. C&DH capability summary at Stages ULF2 to 15A (concluded)**

System	ULF2 Stage	15A Stage
<b>JEM segment C&amp;DH system</b>		
JEM Control Processor (JCP)	The JPM contains two JCPs. There are two JCPs for redundancy (one in active mode and the other in secondary power off mode). The JCP interfaces with the C&C MDMs on the control buses	No changes
Data Interface Unit (DIU)	Eight non-redundant DIUs delivered with the JPM. DIUs translate commands and telemetry between JPM systems and the JCPs DIU-I (quantity six) DIU-III (quantity two)	No changes
Payload Data Handling Unit (PDH)	The JPM contains two PDHs. There are two PDHs for redundancy. PDHs handle payload data	No changes
Management Data Processor (MDP)	The computer that provides top-level management of the JEMRMS	No changes
Minimum Keep Alive and Monitor (MKAM)	Becomes SLT and available for minimum keep-alive monitoring, if required	No changes
Station Laptop Terminal (SLT)	Crew interface with JEM C&DH system	No changes



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**Figure 2-4. C&DH overview at Stage 15A**

**Verify that this is the correct version before use**

## 2.1.4 Communication and Tracking System

15A does not change the Communication and Tracking (C&T) capabilities of the station. Table 2-4 provides a summary description of the C&T system capability at the completion of Stages ULF2 and 15A.

**Table 2-4. C&T system capability summary at Stages ULF2 to 15A**

System	ULF2 Stage	15A Stage
<b>USOS C&amp;T system segment</b>		
S-band	Provides the primary source of commands, voice, and telemetry for the ISS and can be used in both high and low data rate modes String 1 S-band located on S1 String 2 S-band located on P1	No change
Ku-band	Provides ISS with two-way file transfer via the OCA, two-way video (including teleconferencing), and high-rate payload telemetry downlink (~150 Mbps); single string (both forward and return links)	No change
Internal audio	Distributes voice and C&W tones onboard the ISS; interfaces with other subsystems so that the audio signals can be distributed to the RS, the orbiter, EVA crews, and the ground	No change
Video	Generates, routes, displays, records, and plays back video images; also has interfaces for video transmissions to and from the ground (via the Ku-band system) or to the orbiter (while docked)	No change
UHF comm	Two-way RF voice between: ISS and an EVA crew; ISS and the orbiter; MCC-H and an EVA crew (uses both UHF and S-band subsystems) Orbiter commanding of critical ISS functions (e.g., moding to free drift) via RF link during arrival and departure (undocked) ops ISS transmission of critical telemetry (e.g., GNC mode) to the orbiter via RF link during arrival and departure (undocked) ops	No change

**Table 2-4. C&T system capability summary at Stages ULF2 to 15A (concluded)**

<b>System</b>	<b>ULF2 Stage</b>	<b>15A Stage</b>
<b>Russian C&amp;T system segment</b>		
Regul	Russian segment equivalent to S-band system	No change
Lira	Russian segment equivalent to Ku-band	No change
VHF	Russian segment equivalent to UHF; VHF-2 used primarily for space-to-space communications; VHF-1 and 2 can be used to talk with MCC-M when ISS is over ground sites	No change
ROS television subsystem	Russian segment video system	No change
<b>ESA segment C&amp;T system</b>		
Columbus Video Distribution System (VDS)	Collects video data and sends it for downlink via USOS or JEM assets	No change
Columbus internal audio	Two Audio Terminal Units (ATUs) One IAA	No change
<b>JEM segment C&amp;T system</b>		
Internal audio	Two ATUs (JEM ATU1, JEM ATU2) in the JEM module Two IAA – One in JLP, one in JPM. Each interfaces directly with the USOS SSSR system	No change
Video	Five TVCs on the JEM that interface with the USOS Video Distribution System (VDS) Three TVCs are internal Two TVCs are external, which is installed flight 1J by EVA	No change
Interorbit Communications System (ICS)	ICS-PM are transferred from JLP to JPM, but ICS full operation is not performed until ICS-EF is delivered on 2J/A. (The ICS allows direct communication between SSIPC and the JEM Segment for data, commanding voice and video – No USOS assets required.)	No change

### 2.1.5 Motion Control System

Mission 15A adds no new functionality to the ISS MCS or GNC system. Table 2-5 provides an overview of the MCS capability at the completion of Stages ULF2 and 15A.

**Table 2-5. MCS capability summary at Stages ULF2 to 15A**

System	ULF2 Stage	15A Stage
Guidance	RS thrusters used for reboost	No change
Navigation	RS systems: star mappers, horizon sensors, Sun sensors, magnetometers, GLONASS	No change
	Four Global Positioning System (GPS) units located in the U.S. Lab	No change
	Two GPS Antenna Assemblies (AA) located on S0	No change
	<i>ULF-2 installed the A-string GPS Antenna. JEM GPS is used for HTV and not a ISS system.</i>	<i>EVA 4 will install a GPS Antenna on the JLP for the GPS B string.</i>
	Two RGAs located on S0	No change
Control	Four CMGs on Z1 truss	No change
	RS thrusters	No change

### 2.1.6 Environmental Control and Life Support System

Mission 15A adds no new functionality to the ISS Environmental Control and Life Support System (ECLSS). Table 2-6 presents the ECLSS functional overview at the end of stage 15A. Figure 2-5 depicts the USOS ECLSS overview at the end of Stage 15A.

**Table 2-6. ECLSS capability summary at Stages ULF2 to 15A**

Subsystem	ULF2 Stage	15A Stage
<b>USOS ECLSS</b>		
<b>ACS</b>		
PCA	U.S. LAB, Joint Air Lock (A/L)	No change
High pressure gas tanks	Joint A/L, external	No change
ORCA	Located in the airlock; only functional when orbiter is docked	No change
Airlock depress pump	Crew Lock (C/L)	No change

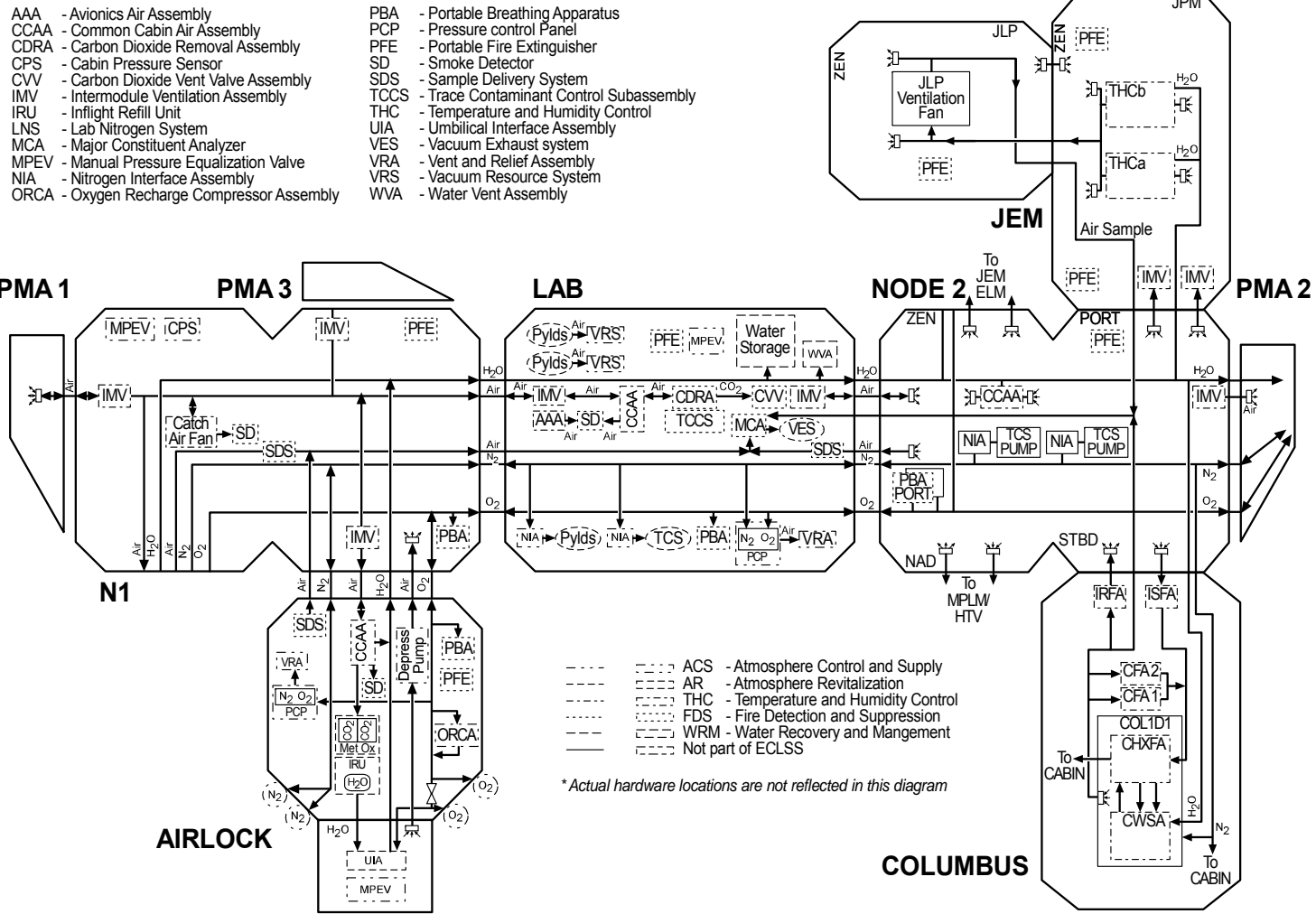
**Table 2-6. ECLSS capability summary at Stages ULF2 to 15A (continued)**

Subsystem	ULF2 Stage	15A Stage
<b>USOS ECLSS (continued)</b>		
ARS		
CDRA	Located in LAB1D6; interfaces with LTL of the thermal control loop Requires more power to regenerate, so is kept as backup for Vozdukh; used when more than three crewmembers are present on ISS	No change
TCCS	Located in LAB1D6	No change
MCA	Located in LAB1D6	No change
SDS	Located throughout USOS; provides samples for MCA	No change
TOCA	ULF2 brings up the TOCA and it is activated during the stage	No change
THC		
CCAA	Two located in the LAB, one in Node 2, and one in Airlock; includes ducts and the following: HEPA filters (six) WS CHX TCCV Airlock CCAA used for campout and provides cooling to ORCA	No change
IMV	Located throughout USOS and connected to RS through drag-through ducts; Russian IMV does not have isolation valves like US IMV does	No change
Condensate storage tank	75-kg tank located in LAB1D5	No change
WVA	Two-vent system for wastewater disposal in LAB	No change
Regen ECLSS	ULF2 brings up WRS 1 and 2. They are activated and connected to OGS during the stage	No change

**Table 2-6. ECLSS capability summary at Stages ULF2 to 15A (concluded)**

Subsystem	ULF2 Stage	15A Stage
<b>USOS ECLSS (concluded)</b>		
WHC	ULF2 brings up WHC and it is activated during the stage	Performs load testing
<b>Russian ECLSS [COX] systems</b>		
Atmosphere Control Subsystem [COГC]		
Elektron oxygen generator	Primary means of adding oxygen; located in SM; interfaces with SM internal thermal control loop	No change
Portable Repress Unit [БНП]	Two high-pressure air tanks in transfer compartment of SM and in DC; only for off-nominal ingress or during rapid depress; manually operated valve	No change
Progress vehicle	Primary means for adding air to station; carries tanks with crew-operated manual valves	No change
Solid Oxygen Generator [ТГК]	Two located in SM with numerous cartridges onboard	No change
Vozdukh	Primary means of CO <sub>2</sub> removal; located in SM; interfaces with internal thermal control loop; currently can support three crewmembers	No change





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Figure 2-5. USOS ECLSS overview at Stage 15A

## 2.1.7 Thermal Control System

ULF2 does not change the thermal capability of ISS. Table 2-7 provides an overview of the Thermal Control System (TCS) capability at the completion of Stages 1J and ULF2. Figure 2-6 and Figure 2-7 present the TCS external and internal overview at the end of Stage 15A.

**Table 2-7. TCS capability summary at Stage 15A**

System	ULF2 Stage	15A Stage
<b>External Thermal Control System</b>		
Active system	ETCS active	No change
Heat collection	Two Interface Heat Exchangers (IFHXs) (U.S. Lab) rejecting heat to External Thermal Control System (ETCS) Six IFHXs (Node 2) rejecting heat to ETCS Other truss components rejecting heat to ETCS	No change
Heat transportation	ETCS interfaces with IFHXs for both LAB and Node 2 ETCS stats: Working fluid: Ammonia Two independent loops Loop A interfaces with LAB LTL IFHX, COL MT IFHX, and N2 MT IFHX Loop B interfaces with LAB Moderate Temperature Loop (MTL) IFHX, COL LT IFHX, and N2 LT IFHX One PM in each loop One Ammonia Tank Assembly (ATA) and one Nitrogen Tank Assembly (NTA) in each loop	No change

**Table 2-7. TCS capability summary at Stage 15A (continued)**

<b>System</b>	<b>ULF2 Stage</b>	<b>15A Stage</b>
<b>External Thermal Control System (concluded)</b>		
Heat rejection	ETCS: All ETCS radiators deployed Each radiator capable of rejecting 11.67kW	No Change
Controlling MDMs	EXT, truss MDMs, Port Thermal Radiator (PTR), Starboard Thermal Radiator (STR): loop control, RBVM control	No Change
<b>Internal Thermal Control System</b>		
Heat collection	Cold plates USOS heat exchangers (CCAA, AAA, payload HXs, Regen HX) Columbus TCS JEM TCS	No change
Heat transportation	LAB: Two connectable Loops: Low Temperature Loop (LTL) and Moderate Temperature Loop (MTL) Normally operated in Single LT mode Working fluid: Water One Pump Package Assembly (PPA) for each loop Node 2: LTL and MTL loops Columbus MTL and LTL loops JEM MTL and LTL loops	No change
Heat rejection	Two Lab IFHXs (interface with the ETCS) Six Node 2 IFHXs (interface with the ETCS)	No change

**Table 2-7. TCS capability summary at Stage 15A (continued)**

System	ULF2 Stage	15A Stage
<b>Internal Thermal Control (concluded)</b>		
Controlling MDMs	INT MDMs: IATCS system control, generate Caution and Warning (C&W) messages, failure recovery, leak recovery, heater control, cmd/telemetry routing, PPA control LA-1: LTL hardware LA-2: MTL hardware N2-1: MTL Hardware N2-2: LTL Hardware COL MDMs control the Columbus TCS The MDMs control the JPM active TCS	No change
<b>Russian Segment Thermal Control System [COTP]</b>		
<b>SM Internal TCS</b>		
Heat collection	Some equipment air-cooled by Ventilation System [CB] Warm air is cooled by Air Conditioner [CKB-1 and 2] Some equipment cooled by one of 25 coldplates; both loops flow through each coldplate	No change
Heat transportation	Two Internal Thermal Loops [КОБ-1, КОБ-2] Working fluid: Triol One loop usually works as prime with the other as backup; however, the two loops can be connected Two replaceable pump panels per loop [СПН1-4], each with two pumps in series (total of eight pumps)	No change

**Table 2-7. TCS capability summary at Stage 15A (continued)**

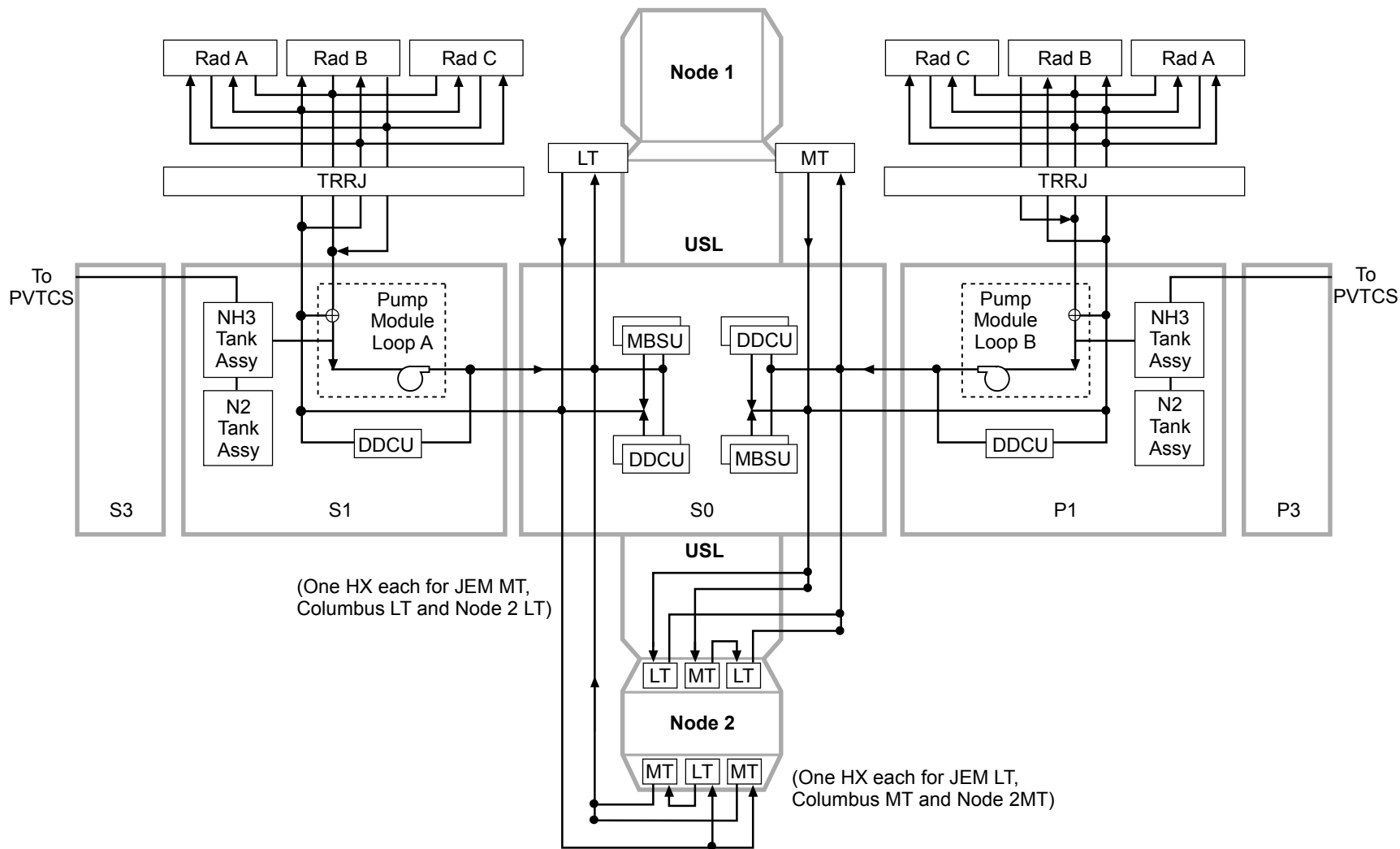
<b>System</b>	<b>ULF2 Stage</b>	<b>15A Stage</b>
<b>Russian Segment Thermal Control System [COTP] (continued)</b>		
Heat rejection	Interfaces with external loops [KOX-1 and 2] through Liquid-to-Liquid Heat Exchangers [ЖЖТ]	No change
<b>SM External TCS</b>		
Heat collection	Interfaces with Internal Loops [КОБ-1 and 2] through Liquid-to-Liquid Heat Exchangers [ЖЖТ]	No change
Heat transportation	Working fluid: Polymethyl siloxane (silicone organic fluid) Two External Cooling Loops [KOX-1, KOX-2] Each loop contains two external pump assemblies with two pumps each (eight pumps total)	No change
Heat rejection	Ten radiator panels [PTO] located on external portion of PO Radiators reject total of 5.5 kW	No change
<b>FGB Internal TCS</b>		
Heat collection	Four Gas-Liquid Heat Exchangers [ГЖТ] cool the crew cabin (three) and equipment (one) Nine coldplates collect heat from RACUs, ARCUs, MDMs, matching units [УС-31], and Voltage Converter [ПС]	No change
Heat transportation	Two redundant internal Thermal Control Loops [БГК] Working fluid: Triol Each internal loop contains two replaceable pump panels [СПН] with two pumps per panel (eight pumps total)	No change

**Table 2-7. TCS capability summary at Stage 15A (continued)**

System	ULF2 Stage	15A Stage
<b>Russian Segment Thermal Control System [COTP] (concluded)</b>		
Heat rejection	Interfaces with the external loops (HГK 1 and 2) through two Liquid-to-Liquid Heat Exchangers [ЖЖТ]	No change
<b>FGB External TCS</b>		
Heat collection	Interfaces with internal loops (BГK 1 and 2) through two Liquid-to-Liquid Heat Exchangers [ЖЖТ]	No change
Heat transportation	Working fluid: Polymethyl siloxane (silicone organic fluid) Two redundant External Hydraulic Loops [HГK 1 and 2] Each loop contains six pumps (four fixed, two replaceable); nominally, only 1 of the 12 pumps operates at a time	No change
Heat rejection	12 Radiators [PTO]	No change
<b>ESA segment TCS system</b>		
<b>Columbus Internal TCS</b>		
Heat collection	21 cold plates CHX removes humidity and extraneous heat from module air	No change
Heat transportation	Single water loop contains both LT and MT sections Two Water Pump Assemblies (WPA1 and 2); only one active at a time Ten Water On-Off Valves (WOOV1-10) allow for bypass of either of the CHX cores and either of the Node 2 HXs Four Water Modulating Valves (WMV1-4): Two per WPA (WMV1 and 3 associated with WPA1, and WMV2 and 4 with WPA2) control water temperature at CHX and P/L inlet branches	No change
Heat rejection	Water loop interfaces with Node 2 MTL and LTL HXs	No change

**Table 2-7. TCS capability summary at Stage 15A (concluded)**

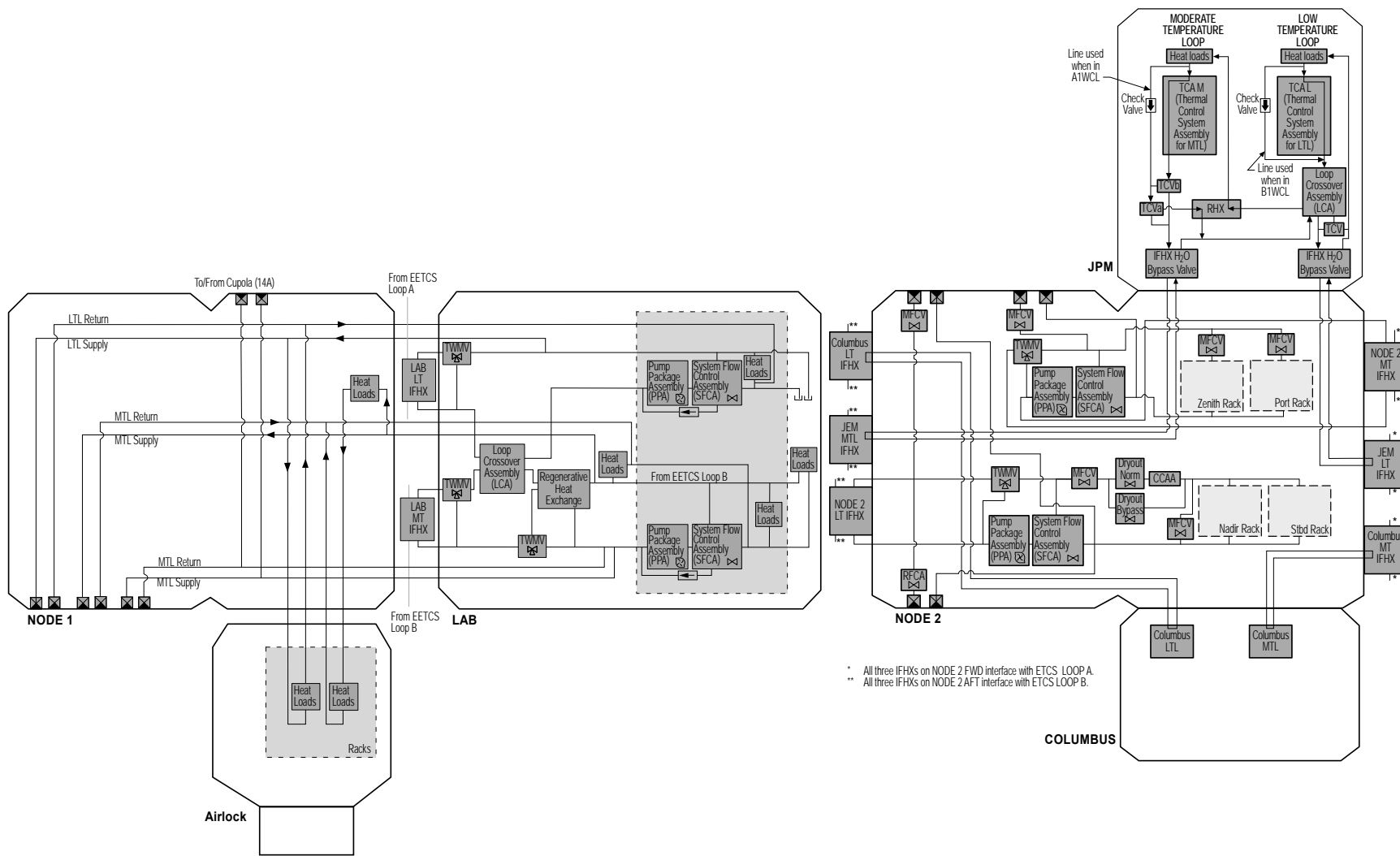
<b>System</b>	<b>ULF2 Stage</b>	<b>15A Stage</b>
<b>JEM TCS</b>		
<b>Columbus External TCS</b>		
Passive TCS (PTCS)	MLI covers all external surfaces of the Columbus Module	No change
<b>JEM Internal TCS</b>		
Heat collection	Cold plates collect heat CHX (Cabin Heat Exchanger) removes humidity and extraneous heat from module air	No change
Heat transportation	Two water loops (LT and MT) that can be run as a single loop Two H <sub>2</sub> O IFHX bypass valves for bypass of either of the Node 2 IFHXs	No change
Heat rejection	Water loop interfaces with Node 2 MTL and LTL IFHXs	No change
PTCS	One JLP and two JPM heater controllers control heaters on the module shells	No change
<b>JEM External TCS</b>		
PTCS	MLI covers all external surfaces of the JEM Modules	No change



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**Figure 2-6. 15A External active thermal control system**





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Figure 2-7. 15A TCS module overview

## 2.1.8 Robotics Systems

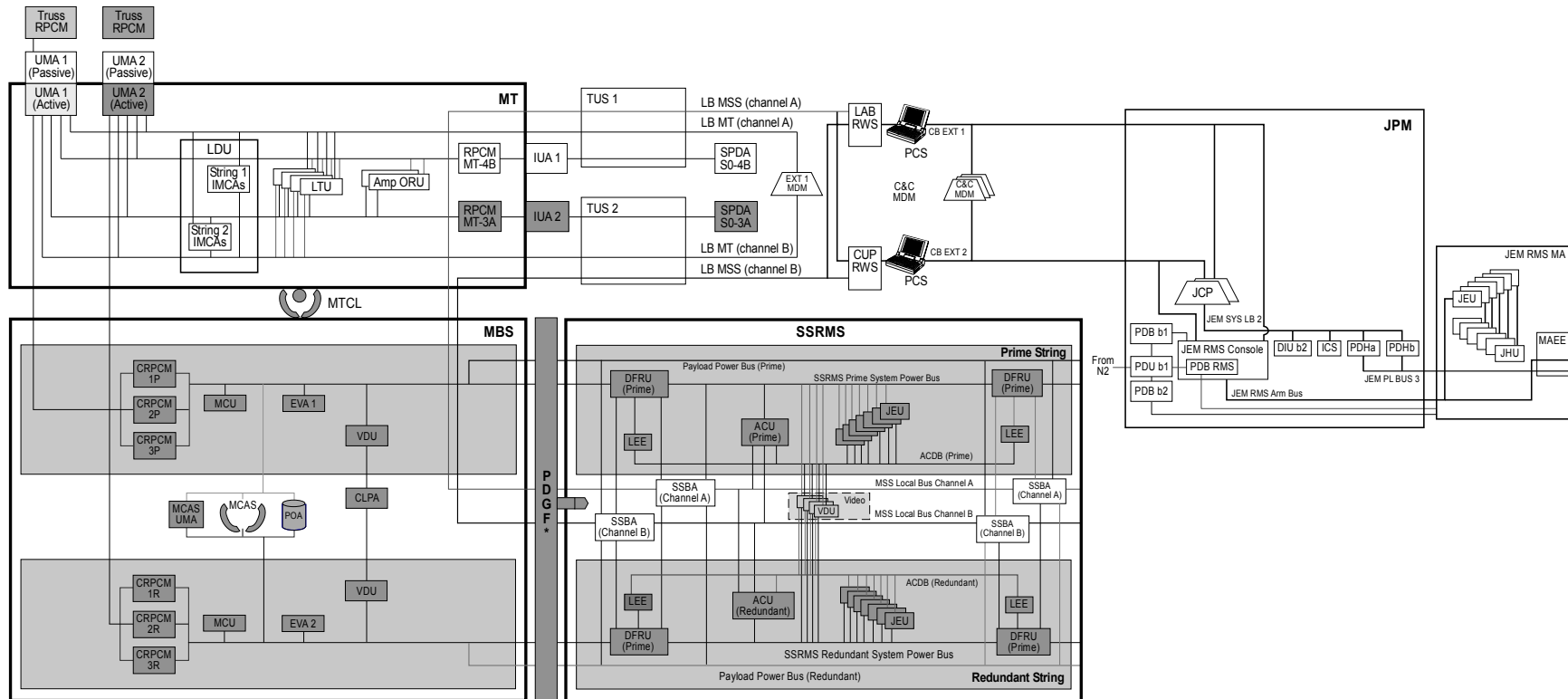
Mission ULF2 and 15A deliver no new robotic hardware to orbit. Table 2-8 provides an overview of the ISS robotics capability at the completion of Stages ULF2 and 15A. Figure 2-8 and Figure 2-9 show overviews of the robotics configuration and MSS worksites.

**Table 2-8. Robotics capability summary at Stages ULF2 to 15A**

System	ULF2 Stage	15A Stage
<b>USOS Robotics system</b>		
SSRMS	<p>SSRMS contains two identical strings: prime and redundant; strings cannot be cross-strapped; a failure in one part of a string causes loss of the whole string</p> <p>SSRMS contains two Latching End Effectors (LEEs), each capable of acting as a base passing power and data through to the SSRMS</p> <p>Two PTUs: one on each boom of the SSRMS; each PTU contains one camera</p> <p>Two LEE cameras: (one on each LEE tip/base)</p> <p>When attached to MT, SSRMS is powered only when MT is docked at a worksite</p> <p>When attached to MT, SSRMS sends/receives video and data through TUS</p>	No change
RWS	<p>Two RWS units: LAB1P5 (LAB), LAB1S5 (Cupola)</p> <p>Only one RWS can be in active control of the SSRMS at a time</p>	No change
SPDM	<p>SPDM was installed on the U.S. LAB PDGF during mission STS-123/1JA. The SPDM is required for EVA 3 tasks (blanket box removals, CLPA install). After completion of the EVA the SPDM is reconfigured to the “arm stowed” config</p>	No change
MT	<p>Can dock at any of eight worksites</p> <p>MT stops located on bulkheads of S0, S1, P1, S3, and P3 trusses (five total)</p> <p>ETRS on P3 and S3 allows a CETA cart to fit outboard of the MT while at the P3 WS</p>	No change
MBS	<p>Contains four Power and Data Grapple Fixtures (PDGFs) for SSRMS connection and a POA for storage of payloads or ORUs</p> <p>Powered only when MT is docked at a worksite</p> <p>Sends/receives video and data through TUS</p>	No change

**Table 2-8. Robotics capability summary at Stages ULF2 to 15A (concluded)**


<b>System</b>	<b>ULF2 Stage</b>	<b>15A Stage</b>
<b>JEM segment Robotics system</b>		
JEMRMS	JEM MA activated and partially deployed	No change
JEM RWS	JEM RWS deployed in JPM and activated	No change



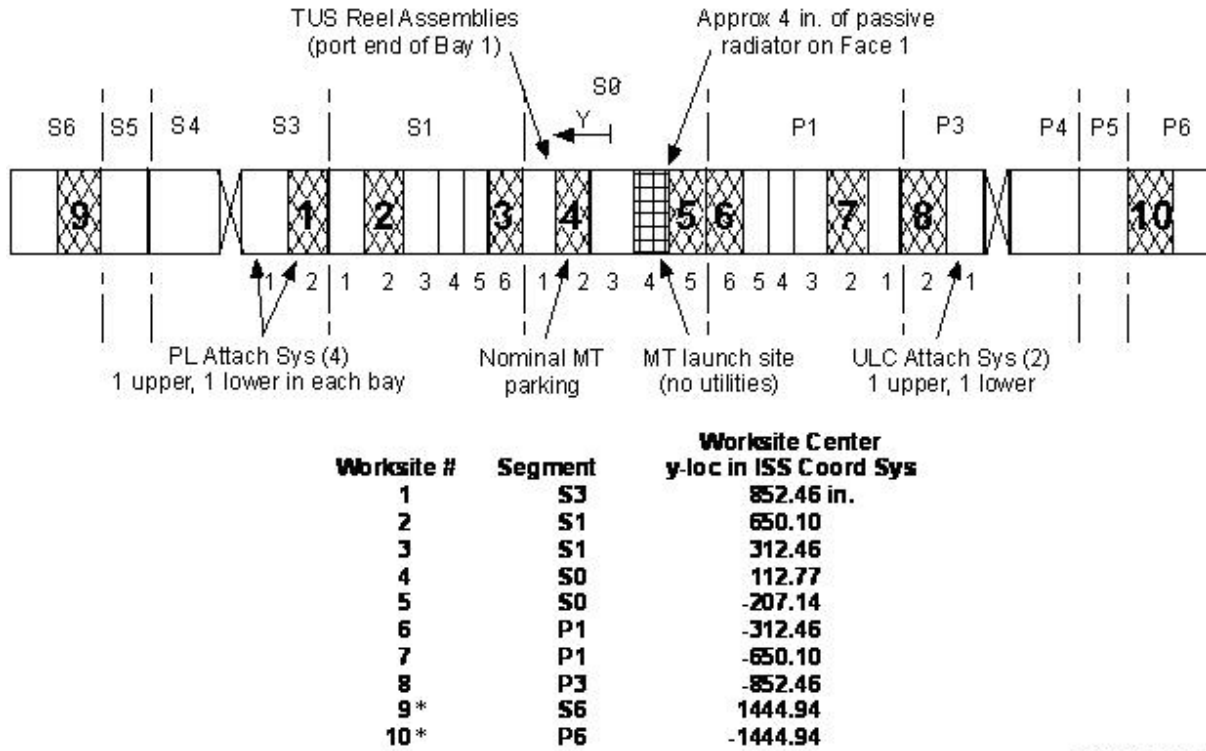
\* There are four identical PDGFs on the MBS

jsc36497\_006r1.cvx

**Figure 2-8. Robotics overview at Stage 15A**

 Represents an MSC worksite with four hardened MT latch fittings, two passive MT positions sensors (zenith rail) and utility port (prime and redundant passive UMAs).

Each box in each truss segment denotes a truss bay, with the corresponding truss bay number below it.



JSC36497\_00472.dwg

**Figure 2-9. MSS WS locations**

\* Note regarding MT Worksite (WS) 9 and WS 10: MT/CETA rails (including WS 9 and WS 10 UMAs) were deleted from S5, S6, P5, and P6 per ISS SSCN 009951A, approved on 8/29/06. As a result, WS 9 and WS 10 are no longer a part of the ISS baseline assembly complete configuration.

### 2.1.9 EVA Systems

Mission 15A adds no EVA system hardware. Table 2-9 provides an overview of the EVA capability at the completion of Stages ULF2 and 15A.

**Table 2-9. EVA capability summary at Stages ULF2 - 15A**

System	ULF2 Stage	15A Stage
E/L	Contains equipment and tools for EVA operations	No change
C/L	Depressurizes to facilitate transfer of crew and equipment to and from space during EVA ops	No change
CETA	Two CETA carts allow for translation of crew and equipment along ISS truss	No change
DC-1	RS docking port that doubles as EVA portal for Orlan EVAs	No change

## 2.2 MISSION 15A ASSEMBLY HARDWARE

### 2.2.1 Integrated Truss Segment S6

The primary payload on Mission 15A is the starboard outboard Photovoltaic (PV) module element and long spacer, designated as S6 ITS. *The static length of the truss segment is 541.19 inches (just over 45 feet).* Drawing 2.6 depicts the entire S6 Photovoltaic Module (PVM), including S6 isometric and overview views. The PVMs include all hardware outboard of the alpha gimbal outboard bulkhead. The PVM element houses the hardware and software required to collect, store, convert, and distribute electrical power to loads within the segment and to other ISS segments. The overall End-to-End (ETE) architecture for the assembly-complete configuration represents a configuration that has a rated capacity of 76.4 kW average and 100 kW peak. S6 also includes hardware that thermally conditions PVM Online Replacement Units (ORUs). PVM S6 is part of the ISS EPS that includes the solar arrays, beta gimbals, energy storage subassembly, Power Management and Distribution (PMAD) ORUs, and cabling. The S6 module provides power channels 1B and 3B.

Functionally and structurally, S6 is nearly identical to P6, even using similar ORUs. The primary difference is that the S6 long spacer does not incorporate any Early External Thermal Control System (EETCS) or communication equipment.

#### 2.2.1.1 Overview

Solar array output is fed through dedicated Sequential Shunt Units (SSUs). The SSUs regulate the array output. The regulated Direct Current (dc) voltage is transferred through the beta gimbals to the Direct Current Switching Units (DCSUs). DCSU output power goes to the Main Bus Switching Units (MBSUs) on ITS S0, via the Solar Alpha Rotary Joint (SARJ) to power ISS loads. The DCSU output also goes to the batteries, via the Battery Charge/Discharge Units (BCDUs) and powers DDCUs on the Integrated Equipment Assembly (IEA). During eclipse, power is fed from the batteries to the BCDUs and then to the DCSUs. The BCDUs regulate the power to and from the

batteries. The DDCUs in the IEA convert the DCSU output to 120 V dc secondary power and feed it back through the DCSU, which distributes it to the PV loads as secondary power for the Electronic Control Unit (ECU), Pump Flow Control Subassemblies (PFCS), and line heaters. The MBSUs place the S6 regulated DC distribution power onto the ISS feeder network. The primary feeders follow the ISS truss structure, providing the distribution power to the DDCUs, which convert primary distribution power to secondary distribution utility-grade power.

### **2.2.1.2 Command and Data Handling Hardware**

The Photovoltaic Controller Unit (PVCU) MDM contains the hardware and software necessary to control all the PVM internal functions. The MDM dimensions are 9.15 by 6 by 12.993 inches.

The EPS control system is based on a hierarchical set of communicating processors and embedded controllers that manage, coordinate, and control each part of the system. At the top of the EPS control hierarchy is the PVCU control application in the control software located in the Command and Control (C&C) MDM (Power Management Controller Application (PMCA)). This hierarchy is reflected in the block diagram of Figure 2-4.

The Photovoltaic Controller Application (PVCA) resides in the Space Station Multiplexer/Demultiplexer (SSMDM) platform. The platform has designated PVCUs on the PVMs on the P6 and S6 segments that control all the respective PVM ORUs. For each of the S6 and P6 PVMs, two PVCUs are on the PV IEA. One PVCU serves as the bus controller for the PV module, while the other PVCU serves as a warm backup unit. When one of the PVCUs fails, the PVCU control application that resides in the Power Management Control Unit (PMCU) in the C&C MDM performs the failure switchover. The warm backup PVCU then becomes the bus controller for the PV module.

The PVCU externally interfaces with the PMCU via the 1553 local bus. The PVCU externally interfaces to (the lower control tier) DCSUs, BCDUs, SSUs, ECUs, DDCUs, and the PFCS via the 1553 user bus. Internally, the PVCU contains the PVCA, which executes on the 80386SX processor. The processor interfaces with the Bus Interface Adapter (BIA) to communicate with the module MDM or the PMCU over the local bus. The processor interfaces with the Serial Parallel Digital (SPD) 1553 cards to control the interface over the user bus with the lower control ORUs. The processor interfaces with the Input/Output Card Controller (IOCC) to retrieve sensor data.

The SSMDM, a special-purpose computer, provides the data processing resources to support control and management of ISS C&DH onboard functions and provides data exchange with other devices over 1553 interfaces.

The PVCA implements the functionality of the following MDM utilities:

- a. IOCC utilities – The IOCC utilities provide routing of Input/Output (I/O) control and status information to the standard I/O cards on the IOCC input/output backplane and provide for retrieval of received sensor data from the IOCC.
- b. BIA utilities – The BIA utilities provide for the transfer of 1553 messages to and from specific subaddresses for transmission to or receipt from the bus controller of the BIA 1553 bus channel.
- c. SPD1553 support – The SX backplane support provides routing of I/O control and status information to the SPD1553 cards on the SX backplane. It also provides routing for data transfer to and retrieval of received data from the SPD 1553 cards.
- d. Time utilities – The time utilities provide for maintenance and control of MDM clocking and timing hardware.
- e. MDM health monitoring utilities – The MDM health monitoring capability provides for monitoring the status on the various MDM cards and provides background and cyclic Built-In Test (BIT) operations, which include reporting of failure occurrences to the BIT summary and BIT results tables.
- f. Memory load and dump functions – The extended MDM utilities provide for memory load and memory dump functions. These functions are able to memory load/dump the PVCU, including SPD 1553 cards and Electronically Erasable Programmable Read-Only Memory (EEPROM), and coordinate memory transfers to firmware controllers via the associated SPD 1553 cards.

When the MDM is powered on, execution begins in the MDM startup state (resident in firmware). After successful completion of MDM startup, the MDM elaboration state is entered. While in this state, the MDM elaborates the Ada program from the application software load image. Once elaboration is completed, the MDM enters the MDM standby state, where it attempts to synchronize with the C&DH bus network. Upon synchronization, the MDM transitions to the MDM operational state, where PVCA process states are defined.

Independent of the current MDM process state, if an MDM hard failure is detected or if an MDM diagnostic command is received, the MDM transitions to the MDM diagnostic state.

When the PVCA User Application Software (UAS) is integrated with the MDM utilities, Ada Run Time Environment (RTE), and the underlying MDM hardware implementation, it provides a software interface to the PV module equipment for the PMCA Computer Software Configuration Item (CSCI) and the control tier. The PVCA receives commands and associated data from the PMCA CSCI and provides status/data to the PMCA CSCI via the 1553 local bus.



### **2.2.1.3 EPS Hardware**

The electrical equipment subsystem conditions and controls PVM dc power and provides dc power to the PMAD system for distribution throughout the EPS.

The PV electrical equipment subsystem consists of dc hardware. The dc electrical equipment provides a command capability to isolate members of the energy storage subsystem and to isolate one or both Solar Array Wings (SAWs). It also provides dc power bus voltage control signals to the solar array SSUs. The dc electrical equipment has the automatic capability to isolate equipment in the event of a short-circuit fault. The dc electrical equipment provides power distribution to the PV power module, main dc power bus isolation, and redundant PVCU MDMs.

#### **2.2.1.3.1 Photovoltaic Blankets**

The principal function of energy collection is to provide a means for collecting solar energy. This function is accomplished by the PV blankets. The PV blankets are part of the SAW that is responsible for converting sunlight into electrical energy. To meet the power demands of the ISS, each SAW has two blankets of solar cells, labeled right and left, with a total of 32,400 solar cells that produce approximately 31 kW at Beginning of Life (BOL) and approximately 26 kW after 15 years at End of Life (EOL).

The PV blankets are stowed inside a containment box called the Solar Array Blanket Box (SABB) and are compressed by a tensioning mechanism internal to the SABB. The SABB protects the fan-folded blanket during ground handling, launch, orbital maintenance, and descent. The blanket boxes also provide a structural support (along with the mast) to hold the deployed blanket flat while on orbit. The blankets of solar panels are retracted/deployed by means of an articulating mast contained in the mast canister.

Although solar cells perform the energy conversion process, solar array output is proportional to the surface area of the array. Each PV blanket provides a flat surface (approximately 4.57 m wide and 32 m long when fully deployed) that contains 16,200 solar cells (8 cm<sup>2</sup> each). Each blanket comprises 82 active panels, two inactive panels, and two Flat Collector Circuits (FCCs). Figure 2-10 shows a fully deployed PV Blanket.



**Figure 2-10. PV blanket (fully deployed)**

- a. Active panels – Active panels contain 200 silicon PV cells connected in a series. Two active panels are wired in a series to provide 41 independent circuits, or strings, per blanket, 400 cells per string. The FCC provides electrical string connectivity between active panels and also conveys primary power from each individual string to the containment box wire harness forming the output from the blanket. Organized in this way, each array string is an independent power source capable of providing power for user loads.

The active panels contain five module assemblies supported by a coverlay assembly. Each module assembly consists of 40 solar cell assemblies, a flexible printed circuit, and bypass diodes. A solar cell assembly is an 8-cm-square PV cell (solar cell) protected on the Sun-facing surface with a thin coverglass. The solar cells are made of silicon and have a nominal 14.5 percent sunlight-to-electricity cell conversion efficiency. The flexible printed circuit is a Kapton/copper/Kapton laminate welded to the solar cells to provide an electrical series interconnection for module solar cell assemblies. The bypass diode is connected in parallel to every eight solar cell assemblies. Its functions are (1) to minimize the performance impact of fractured or open cell circuits, and (2) to eliminate potential cell damage because of reverse bias heatup during shadowing.

- b. Inactive panels – Inactive panels are integrated into the top and bottom of the blanket. These inactive panels prevent shadowing of the active panels by providing additional spacing from the blanket box base and cover and protect the end active panels when the blankets are in the retracted state. An FCC note is that if all the cells within a single string were simply wired in a series, one failed-open cell would render the entire string useless. The string design, however, incorporates bypass diodes that automatically bypass cells in groups of eight if cells fail open or are shadowed (shadowed cells have failed-open characteristics).

The power generation system is designed around protecting and then positioning solar cells to collect solar energy on orbit. During insolation, the solar cells receive sunlight and convert it into electricity. Thus, the operational characteristics of the solar cells and array strings form the basis for the voltage and current (i.e., power) characteristics of the ISS EPS. It is important to understand these operational characteristics before discussing the design and operation of the primary power voltage regulation component. Thus, the next paragraph provides an overview of the function and characteristics of solar cells and array strings.

Silicon PV cells are solid-state devices that use the PV effect of semiconductor materials to generate electricity directly from sunlight. Transparent backing of the individual cells results in a slight increase in power generated because of back illumination (from the light reflected from the Earth) and low operating temperature. The amount of photons entering a cell depends on the intensity of the solar flux. The solar flux in the vicinity of the Earth is about  $1400 \text{ W/m}^2$ . Current cell technology allows about 14.5 percent of the solar flux to be converted into usable power.

#### **2.2.1.3.2 Sequential Shunt Unit**

The SSU is used in the ISS EPS to match available PV array power output to primary distribution bus load demand, and also to regulate the level of the primary bus voltage during the insolation portion of the orbit. The SSU has three modes of operation: regulation, unshunted, and shunted. The SSU regulates available PV array power by dynamically summing individual array string outputs (available from a total of 82 strings per array wing) onto a single SSU output node. Array strings that are not summed onto this output node are shunted (shorted back onto themselves) on a per-string basis. Each string provides diode blocking of its input to prevent the backflow of power from the output. The SSU performs both coarse and fine voltage regulation of the final summed array output by shunting or unshunting the quantity of array strings required to satisfy an internal control loop. The setpoint of this control loop is programmed from an external source through a buyer-furnished interface unit.

The SSU is capable of controlling output voltage to  $\pm 3$  V dc when regulating to a setpoint between 133 V dc and 177 V dc. The SSU accommodates the Load Fault Detect/Protect (LFDP) feature that provides protection to the EPS for hard faults. The LFDP causes the SSU to shunt all of its outputs when the SSU output voltage falls below or equal to  $100 \pm 4$  V for 0.05 millisecond (ms).

The LFDP function can be disabled via the control system. This is necessary for startup, restart, and contingency operations. The SSU has an overvoltage protection feature that maintains the output voltage below 200 V dc maximum for all operating conditions. While supporting on-orbit replacement, the ORU enclosure houses all functional elements of the SSU (including the buyer-furnished interface unit) and supports mechanical and electrical interface to the ISS. The SSU is located on the platform subassembly that supports the solar array mast canister. Its envelope is 30 by 20 by 12 inches. Its maximum thermal generation value is 386 W. The maximum parasitic power loss of an SSU is 115 W.

### **2.2.1.3.3 Direct Current Switching Unit**

The DCSU provides the power switching and fault isolation functions for interconnecting array and battery source power to the MBSU through the alpha gimbal roll rings and DDCUs located on the PV IEAs. Its dimensions are 28 by 40 by 12 inches.

The DCSU consists of a primary power bus, secondary power bus, and associated switchgear for source selection, array wing isolation, battery isolation, MBSU isolation, and DDCU isolation. The two DCSUs on each IEA follow a channelized power architecture, maintaining output isolation prior to the MBSU. Primary power switches implement source selection and source distribution to functions.

During normal operation, both array and battery power are provided to the DDCU and MBSU. This configuration is changed in the event of faults or when maintenance and safety requirements cause specific equipment to be isolated.

The DCSU internal power supply receives three power inputs, two primary power inputs, and one dc control power input. The internal power supply normally operates from one of the two primary power inputs. In the event of loss of primary power, the power supply operates from its dc control power input, which is sourced from the batteries via the BCDU.

Power switching operations are normally commanded by the PVCU via the DCSU Switchgear Controller Assembly (SCA). Also, each switch contains an autonomous power interrupt feature to protect the system components in the event of a fault-induced overcurrent condition. Switch status and health are monitored by the PVCU via the SCA.

The DCSU receives a secondary power input from the external DDCU on the IEA, or from the other DCSU on the IEA. DCSU RPCMs supply secondary power to solar power module loads, such as the beta gimbal ECU and the photovoltaic TCS PFCS.

Monitored parameters in the DCSU include input currents, output currents, input voltages, output voltages, baseplate temperature, and switch status.

#### **2.2.1.3.4 DC to DC Converter Unit**

The two DDCUs on the IEAs convert the DCSU output to 120 V dc power. This conditioned power is fed through RPCMs contained in the DCSUs for distribution to the ISS loads. Additional DDCUs, which are located in the Lab, Node 3, Node 2 and on truss segments S0, S1, and P1 convert power supplied by the MBSUs into secondary power for use in the other parts of the ISS. The two types of DDCUs are internal (DDCUI) and external (DDCUE). In addition, there are two DDCUs on Z1 that feed loads inside the Node. These Z1 DDCU-HPs are different in that they are mounted to Heat Pipe Radiators (HPRs). Because the HPRs are limited in the amount of heat they can reject, the Z1 DDCUs are operationally constrained to stay under 3 kW power usage. The Z1 DDCUs have Multilayer Insulation (MLI) thermal shrouds on the HPRs that must be removed before DDCU activation. The dimensions for the DDCUI, DDCUE, and DDCU-HP are, respectively, 27 by 16 by 10; 27.25 by 23 by 12; and 68 by 25 by 14 inches.

#### **2.2.1.3.5 Remote Power Controller Module**

RPCMs are electronic switches used to control, protect, and isolate secondary distribution lines. The six types of RPCMs differ in rated output current, number of switches per module, and trip functions. Types I, II, and V provide current limiting. Type IV provides a single bidirectional switch that trips under/over-current conditions based on a present time delay. Types III and VI provide fast tripping in the event of overcurrent conditions. They have two overcurrent trip levels with separate time delays. The RPCMs receive commands and transmit data via a redundant 1553 data bus. The RPCMs are mounted within the DCSUs, Secondary Power Distribution Assembly (SPDAs), and Remote Power Distribution Assembly (RPDAs). Each DCSU on S6 contains one Type I and one Type IV RPCM.

#### **2.2.1.3.6 Energy Storage Subsystem**

The energy storage subsystem stores energy during the sunlit portion of the orbit for use during eclipse and system startup. The energy storage subsystem consists of six Ni-H<sub>2</sub> batteries, each with a dedicated BCDU. During eclipse, the energy storage subsystem discharges stored energy to the dc power bus. During sunlight, the energy storage subsystem receives and stores energy generated by the solar array.

Discharge is enabled automatically, based on the bus voltage. Charge is enabled automatically, based on the bus voltage, but the charge rate profile is controlled by the PVCU (MDM) command. The energy storage subsystem also provides power to the dc control bus and has the capability to detect and protect against short-circuit faults.

#### **2.2.1.3.7 Battery ORUs**

The batteries receive and store energy during sunlit orbit and discharge energy during eclipse orbit.

The batteries store energy for use during eclipse. The Ni-H<sub>2</sub> battery design was selected because of its high energy density (light weight) and proven heritage in space applications since the early 1970s. Each battery has a nameplate capacity of 81 A-h and an average discharge voltage of 95 V dc. For the purpose of achieving a 6.5-year design life, a maximum of 35 percent of the rated capacity may be discharged during a normal eclipse. This equates to 2.7 kWh/battery available for a reference orbit eclipse. During a contingency orbit, an additional 1.8 kWh may be discharged without exceeding 80 percent depth of discharge.

A PV power module battery consists of 76 Ni-H<sub>2</sub> cells (60 plates per cell) in a series to produce the 95 V dc average discharge voltage. The cells are divided into two assemblies of 38 for packaging in the ORU box. Therefore, each battery is composed of two battery subassembly ORUs wired in series. The exterior of the battery ORU box (Type II) has a thermal blanket attached to help maintain the intercell temperature difference.

The battery subassembly ORU includes the Battery Signal Conditioning and Control Module (BSCCM) that interfaces with the Local Data Interface (LDI) in the BCDU. The BSCCM provides battery ORU pressure, temperature, and voltage measurements and individual cell voltage measurements to the BCDU. The BSCCM receives battery heater on/off and deadfacing resistor commands from the PVCU via the BCDU.

The battery subassembly ORU (dimensions 41 by 37 by 19 inches) includes the battery heaters. Each ORU contains two (redundant) heater circuits that are controlled by the switches in the BSCCM. The battery heaters receive power through the BCDU.

Each cell within a battery assembly is mounted in a graphite epoxy sleeve that provides mechanical support and a heat conduction path to the cell baseplate, where heat is delivered to the TCS. For support and rigidity, the 38 cell and sleeve assemblies are fastened to the baseplate via mounting feet at the sleeve bases and are joined at the sleeve tops via a support plate.

The battery subassembly ORU includes fuses that provide fault isolation protection to the main power buses.

### **2.2.1.3.8 Battery Charge/Discharge Unit**

The BCDU is an ISS ORU that controls and conditions battery charging and discharging and provides monitoring and interface to the battery ORU. Its dimensions are 40 x 28 x 12 inches.

The BCDU is a bidirectional power converter that is capable of being paralleled with up to two other BCDUs. In the charge mode, it accepts power from the voltage-regulated primary power bus and outputs a regulated current to control the charge rate of the battery ORUs. In discharge mode, it accepts power from the battery and outputs a regulated voltage to the primary power bus. The BCDU provides protection for the primary power bus and dc control power bus. The BCDU is commanded and monitored via a 1553 data bus. The BCDU also includes provisions for controlling and monitoring external battery parameters. The BCDU is an ISS ORU. The LDI module serves as a data interface between the BCDU and the 1553 data bus. The functions of the LDI are communication with the BCDU, acquisition of monitoring data, and provision of discrete and analog signals for control purposes within the BCDU. The LDI also interfaces with the BSCCM located in the battery ORU. The LDI makes information from the BSCCM available on the 1553 data bus.

Descriptions of the four BCDU modes (standby, discharge, charge reduction, and charge) are given in the following:

- a. Standby mode – The BCDU is in the standby mode when the power converter is commanded off. When it is in the standby mode, it is capable of communication with the PVCU.
- b. Discharge mode – The BCDU enters the discharge mode when the voltage on the primary I/O falls below the BCDU voltage set point. When it is operating in the discharge mode, it accepts power at its battery I/O port and provides power at a regulated voltage at its primary input/output port based on PVCU set points.
- c. Charge reduction mode – The BCDU enters the charge reduction mode when the SSU cannot regulate the bus. The BCDU reduces the battery charge current to regulate the primary bus. When it is operating in the charge reduction mode, it performs as a shunt regulator at the input/output port. It regulates the voltage at its primary input/output port based on PVCU setpoints. The shunt power provides an output current at the battery input/output port that is less than the commanded charge current level.
- d. Charge mode – The BCDU enters the charge mode when the voltage on the primary I/O port rises above the BCDU mode/regulation voltage setpoint. When the BCDU is operating in the charge mode, it accepts power at its primary input/output port and provides a regulated output current at its battery I/O port that is based on PVCU setpoints.

The BCDU receives four operational setpoint commands from the PVCU.

1. Regulation – Sets the voltage level at which the BCDU regulates the primary bus and determines when the BCDU changes modes
2. Current – Sets the charge current level
3. Constant – Sets the ratio at which each BCDU in parallel delivers power to the primary bus
4. Charge voltage limit – Sets the voltage level of the battery input/output port at which the BCDU limits to prevent the battery ORUs from being overcharged

Monitored parameters in the BCDU are output currents and voltages, input currents and voltages, baseplate temperature, battery cell voltages, pressures, and temperatures.

#### **2.2.1.3.9 Ground Straps**

Ground straps are required to connect every element of the ISS. The mechanical interface is not designed for fault control or for Electromagnetic Interference (EMI) control. The ground straps provide the necessary continuity between structural elements. Each ground strap is capable of carrying 200 steady state amps. For Mission 15A, three of the four ground straps connecting S6 to S5 are required for S6 activation. The S6 to S5 ground straps are EVA connected on EVA 1 during S6 installation.

#### **2.2.1.4 Thermal Control System**

The TCS acquires and transports excess heat from the energy storage (batteries) and electrical equipment assemblies to dedicated EPS radiators for rejection to space. The coolant consists of 110 pounds of ammonia (NH<sub>3</sub>).

The TCS is a single-phase modular heat exchange system. The system includes a deployable PVR with dual cooling loops; two PFCSs; and fluid circuit(s) with single-tubed PV Radiant Fin Heat Exchanger (RFHX). For all PV modules, one-half of the actively cooled, heat dissipating electrical equipment is cooled by each of the two PFCSs. Each PFCS uses one of the dual cooling loops through the PVR. Fluid Quick Disconnect Couplings (FQDCs) are used to facilitate ORU removal and replacement (PFCS to IEA, and radiator to IEA). Accumulators located in the PVR and PFCS allow the fluid to expand over the operating temperature range and to accommodate allowable system leakage. FQDCs and accumulators are both used as aids to leak detection.

Once detected, a leak can be isolated to the PFCS, the radiator, or the tubing and FQDCs within the framework. Leaks within the framework are isolated by visual inspection or by the ammonia servicer. The ammonia servicer is used to detect leaks by loading NH<sub>3</sub> into different sections of the thermal loops and monitoring pressure.



A Flow Control Valve (FCV) within the PFCS regulates the flow rate through the radiator while maintaining constant flow through the RFHX. More flow through the radiator results in a higher heat rejection. The TCS maintains the IEA electrical components and energy storage equipment (batteries) within their acceptable temperature range. The TCS maintains a nominal temperature range from 32° to 50° F at the battery cell sleeve.

Each battery and electrical ORU baseplate is a structure that transfers heat from the heat generating components to the RFHX. Heat is removed first from the batteries, followed by heat removal from the electrical equipment ORUs. The generated heat is then transferred from the RFHX to the coolant tubes within the framework, where it is carried away to the PVR and then ejected to space. The PFCS and radiator are both ORUs. Each IEA contains two PFCSs and one radiator.

#### **2.2.1.4.1 Pump and Flow Control Subassembly**

The PFCS pumps the heat transfer fluid for distribution to the strongback heat exchangers and radiator, and regulates the temperature of the TCS ammonia coolant, based on PVCU input commands. Its dimensions are 40.41 by 28.81 by 18.88 inches.

The PFCS is composed of two pumps, an accumulator, an FCV, sensors and electrical cables, and motor controllers needed to provide controlled flow for transferring the heat from the IEA coldplates to the PVR. Each PFCS delivers 1300 lbm/hr minimum of ammonia coolant at 1° F.

The FCV regulates the temperature of the ammonia coolant flowing to the strongback by controlling the amount of ammonia flowing through the radiator and from the IEA. Maximum flow is maintained through the strongback to enhance heat transfer in the coldplate heat exchanger flow tubes. The flow from the strongback is connected to the radiator and to a bypass line that shunts around the radiator. The FCV regulates the amount of flow through the radiator and bypass line to control the temperature of the mixed fluid that flows through the strongback. A second pump is in the PFCS to meet reliability requirements. The setpoint temperatures, measured at the battery cell sleeve, are remotely adjustable in 1.0° F increments in the range from 32° to 50° F. The nominal battery sleeve setpoint is 38° F.

Motor controllers within the PFCS control the pumps and FCV. Temperature sensors, pressure and position indicators, and flowmeters are used to monitor the operating condition of the TCS. The PVCU provides commands and receives status data from the LDI located in the PFCS.

#### **2.2.1.4.2 PV Radiator**

The radiator subassembly radiates waste heat to space. Its dimensions are 44 by 12 by 7 feet. The radiator subassembly is composed of a direct flow deployable radiator. The ammonia coolant flows through tubes in the extrusions of the radiator panels and thus transfers heat to the radiator panel surface. A high emission,

low absorption coating on the surface then radiates the waste heat to space. The radiator design provides sufficient radiating area to reject the required waste heat at the worst-case design condition.

The design features seven radiator panels. Each panel has an approximate area of 10.3 by 5.3 feet and is constructed of an aluminum honeycomb matrix with Inconel flow passages. Hinges connect the panels, which are arranged in a folding array. Fluid connections are via manifolds and flexible hoses. The array is deployed on orbit using a scissors-type deployment mechanism similar to the one employed in the Skylab program to successively deploy solar panel arrays. The mechanism accomplishes deployment and retraction using an electric motor and a cable drive system. The cable drive was selected for simplicity and high reliability. Cinching into the stowed configuration is required for EVA and telerobotic ORU removal.

Dual fluid loops help ensure that there is a higher probability of not losing complete heat rejection capability in the event of penetration by micrometeorites or orbital debris. The deployment system provides the capability of manual deployment or retraction by EVA or Remote Manipulator System (RMS) in case of motor or drive train failure. A cinching mechanism capable of withstanding launch loads is included.

#### **2.2.1.4.3 Quick Disconnects**

Quick Disconnects (QDs) are provided to facilitate connecting ammonia transfer lines between the radiators and IEA, and between the IEA and PFCS. Components designated FQDC are at the ORU-to-IEA interfaces and are engaged or disengaged when the ORUs are installed and removed. Another type of manually operated QD is line-mounted and provides for system servicing, bypass, and isolation.

#### **2.2.1.5 Structures and Mechanisms**

Each PVM beta gimbal/solar array assembly consists of one SSU, one SAW, and one Beta Gimbal Assembly (BGA). These elements interact functionally to provide electric power through the IEA to the ISS loads. The dimensions of the BGA are 8 by 8 by 2 feet.

##### **2.2.1.5.1 Solar Array Wing**

The SAW includes the mast canister, a mast, and the left and right SABB ORUs. The mast canister ORU provides structural support to the SABB. Likewise, the beta gimbal platform subassembly provides structural support to the mast canister. Drawing 3.2 shows these interfaces.

For the launch configuration, each SABB is fastened to the IEA via two clamshell restraints. One restraint has six 5/8-inch bolts on the zenith side, and the other has two 5/8-inch launch restraint bolts on the nadir side. The BGA is secured to the IEA with two launch restraint bolts on the -X face of the BGA platform. In addition, three Thruster Assist (TA) clamps restrain the BGA cable to the IEA.

For the on-orbit operational configuration, the EVA crew first releases the eight SABB launch restraint bolts to free the SABBs from the IEA. Next, two antirotation pip pins are pulled from the drive mechanism of the launch restraint bolts, and the three TA clamps on the BGA cable are released. Two BGA launch restraint bolts are driven to release using a Pistol Grip Tool (PGT). With the release of the BGA launch restraints, the SAW/BGA is free to swing outward and is locked into the deployed position with four hinge locks. This motion positions the SAW/BGA approximately 8 feet away from the IEA structure.

Next, the SABBs are manually rotated (by EVA)  $\pm 90^\circ$  to the unstowed position and secured via pip pins to the mast tip fitting. Once all manual operations are complete, the BGAs transition to the commanded angle for SAW deployment. The SABBs are commanded to unlatch and the SAW is deployed by extending the mast tip fitting and top half of the SABB away from the IEA. Once the mast is fully extended, the PV blankets are tensioned by commanding the SABB latches back to the latched position. All of these functions have EVA interfaces and can be accomplished manually, if necessary.

The primary power produced by the right and left PV blankets is routed through the mast canister to the SSU via 82 array strings in wire harnesses on the blanket boxes and mast canister. Secondary power and control signals from the ECU SAW controller are routed to Motor Drive Assemblies (MDAs) in the blanket boxes and mast canister to perform deployment and retraction functions.

Note: There are two possible secondary power sources to support SAW functions; i.e., one DCSU RPCM input from each S6 power channel. The ECU input selector utilizes the first power source that becomes active but switches to other input if the initial source fails.

Material selection was based upon requirements for a 15-year operational lifetime in a natural environment of contamination and orbital debris. The majority of the metallic structure is made of aluminum. The blanket structure is a series of Silicon Oxide (SiO) coated and noncoated Kapton and limited panels. The panels, which are laminated in fiberglass scrimcloth, are connected with loops and a pin similar to a piano hinge. This hinge is reinforced with an aluminum foil doubler for additional atomic oxygen protection.

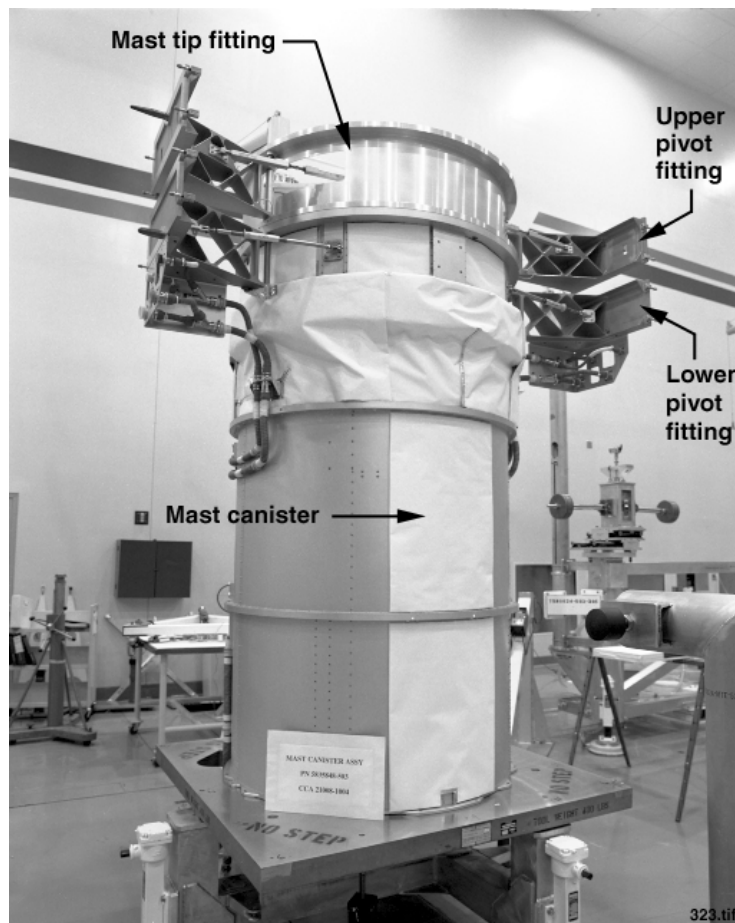
During operation, the wing must be in the extended position to collect sunlight and convert it into dc power. The wing is designed to allow for a total of 35 extension and retraction cycles. The wing is attached to the BGA and is oriented toward the Sun by the alpha and beta gimbals. The electrical interfaces of the wing are to the SSU and to the BGA ECU via the beta gimbal platform subassembly. All wing connectors are routed through the platform and are interfaced with the SSU or ECU. The power produced by the blanket is routed to the SSU. The wing has provisions for EVA; EVA handholds are on the mast canister and on the SABB ORUs.

For handling, the wing also has Flight Support Equipment (FSE) support pads that are located on the blanket box ORUs and on the mast canister. During ground operations, the wing is handled as an assembly, not as separate ORUs.

### 2.2.1.5.2 Mast Canister/Folding Articulated Square Truss Mast

The purpose of the mast ORU is to deploy, support, and retract (stow) the solar array blankets.

The following items make up the mast ORU: the canister, the Folding Articulated Square Truss (FAST) mast, upper and lower pivot fittings, tip fitting, MDA, wire harness, and beta gimbal platform subassembly. Figure 2-11 shows the mast ORU without the beta gimbal platform subassembly.



**Figure 2-11. Mast canister ORU (pivot fittings deployed)**

The mast canister houses the FAST mast while in the retracted position and also provides a means for extending the FAST mast. The top of the canister has a tip fitting that supports the upper pivot fitting and upper half of the SABB. The mast canister is supported at its base by the beta gimbal platform assembly.

The FAST mast is a storable, hinged truss structure used to support the solar array blanket during normal wing operation. The bays of the FAST mast are 30.4 in<sup>2</sup> and 40.5 in. long (along the axis of the mast). The FAST mast is composed of aluminum longerons, stainless steel wire rope diagonals, metal rigid battens, and flexible fiberglass battens. The flexible fiberglass battens provide the force to maintain the mast in the unfolded (fully extended) configuration. The FAST mast is attached to the deployment nut at its base and to the mast tip fitting at its tip. The FAST mast provides the structural load path for on-orbit loads from the tip fitting to the canister.

The FAST mast is extended and retracted by rotating the half-height deployment nut mechanism. The half-height deployment nut consists of a metal cylinder with four helical grooves located on the inner cylinder wall. The nut, located inside the top one-third portion of the stationary outer shell of the mast canister, is attached to the canister shell with four trundle roller bearing packages. The nut is referred to as a half-height deployment nut because the height of the nut is approximately half the height of a FAST mast bay. A ring gear at the base of the nut can be driven with an MDA to rotate the nut relative to the canister outer shell, or it can be driven manually with an EVA power tool. Each corner of a FAST mast truss section has a roller that is guided into helical grooves. Rotation of the deployment nut acts to deploy the folded truss section or to stow the extended truss sections of the FAST mast. No moving parts are exposed.

When the mast is fully retracted, it consists of one fully deployed bay, one partially deployed bay, and a stack of fully stowed bays. The nut engagement rollers on the corner fittings of the upper batten frame of the partially deployed bay are just engaged in a slot of the four stack advance mechanism disks. The rollers advance the disks through one step (90°) as the mast begins to deploy. Normally, this would advance the stack of undeployed bays by one stowed batten pitch; however, the stack advance lanyard has a design feature that prevents this from occurring on the initial bay deployment.

Each of the four lanyards has spring-loaded tensioners that take up slack in the lanyards. This slack allows the slotted disks to rotate 90°, equal to one stowed batten pitch. Therefore, for this step of the stack advance operation, the slotted disk rotates, but the stack cannot advance until the slack is taken up. After this first step, the slack has been taken up, and the lanyard can apply tension to advance the stack. A detent mechanism serves to keep the lower batten of the partially deployed bay from moving prematurely toward the nut. Stowed battens have a tendency to remain stowed due to the spring force of the flexible battens.

As the partially deployed bay moves toward full deployment, the longeron roller of this bay engages the S-track, and the nut engagement roller on its lower batten corner fitting is forced through the detent mechanism. At this point, the detent mechanism restrains the next batten below the one that just moved through the detent. This procedure prevents a potential for slack in the stack advance lanyard, because now there is a missing batten frame in the stack, and the stack has not yet been advanced. The procedure also prevents the stack advance cradle from disengaging the end batten by

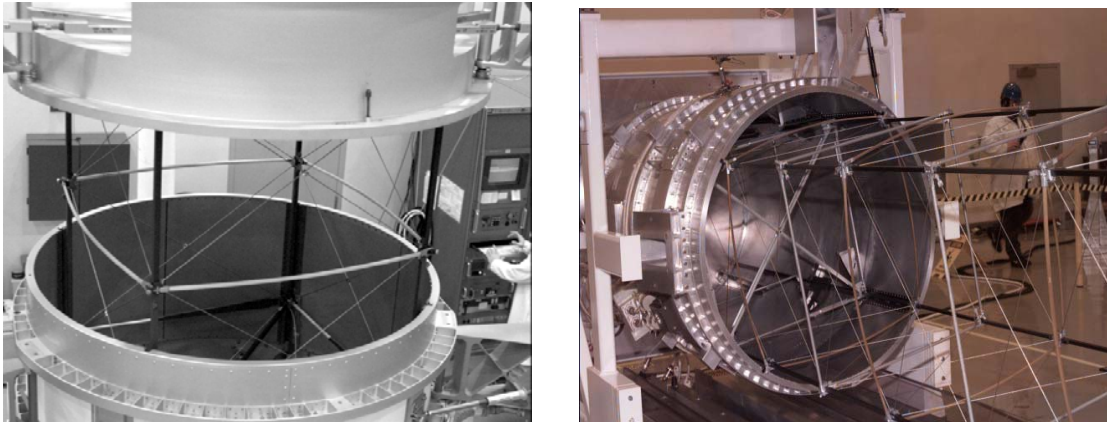
preventing the potential for slack. The detent and the tensioner also keep the stack tight during the time that the batten is pulled through the detent and before it engages the stack advance mechanism and advances the stack.

All the batten frames, including the last one (called the end batten), advance through the detents and the stack advance mechanism. As the end batten moves through the stack advance mechanism, it becomes disengaged from the stack advance cradle. The cradle continues to advance and engages locating pins that retain its position while it awaits the return of the end batten during retraction. The lugs on the end batten contact redundant limit switches at full extension, and a signal is sent to the wing controller. In turn, the mast canister MDA is controlled to the “off” mode, and the mast extension process is terminated.

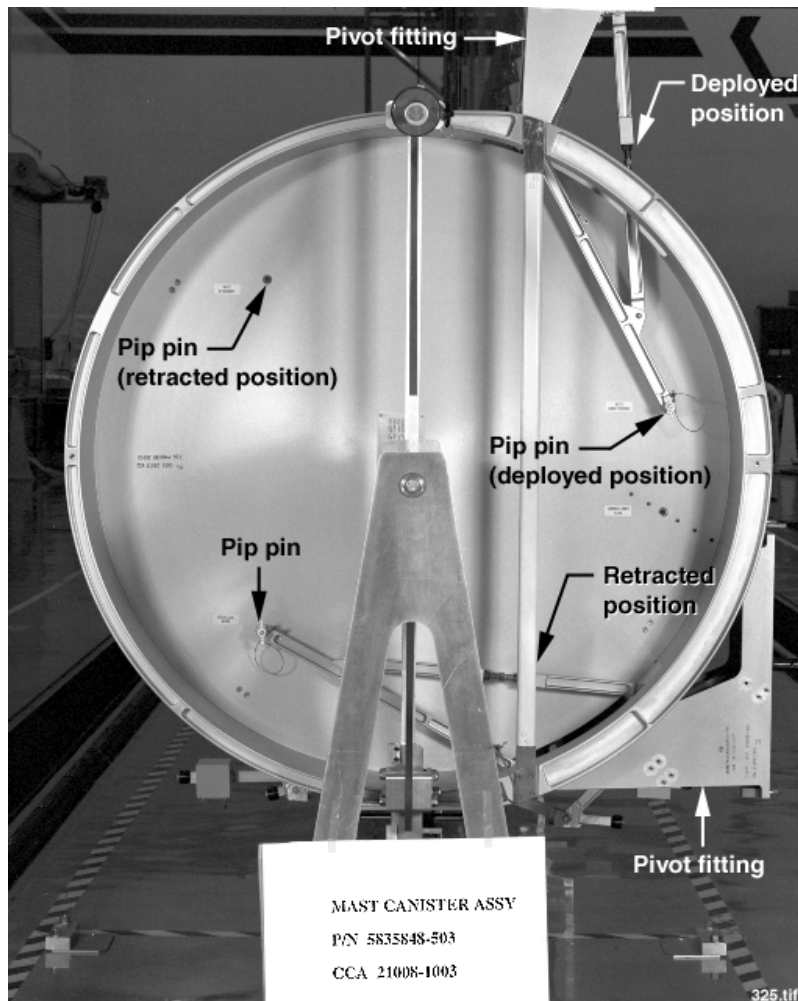
As the mast begins to retract, the end batten engages the stack advance mechanism and rotates the slotted disk 90° through the first step. The tensioner takes up the slack that is created in the lanyard until the end batten engages the cradle and puts a load on the lanyard. The slack is now removed, and the slotted disk is synchronized with the stack advance process. At this point, the end batten also passes through the detent mechanism. After the lanyard is pulled tight, the end batten is in position for retraction of the first full bay on the bottom end. As successive bays retract, the stack is forced progressively lower until the cradle reaches the canister bottom. The last batten to pass through the stack advance mechanism rotates the slotted disks and allows the lanyard to unwind. They would become slack except for the spring tensioners; therefore, the system is ready for deployment.

The detents are designed to provide little resistance to the rollers moving in the downward (retracting) direction. When fully retracted, redundant limit switches, located between the tip fitting and canister, send a signal to the PMAD computer that, in turn, interrupts the power to the mast canister MDA and discontinues the retraction process. Mast direction can be reversed during any part of the deployment or retraction process. Figure 2-12 shows the canister, FAST mast, and tip fitting interface.

The tip fitting supports the solar array blanket by providing a structural connection between the FAST mast and the upper pivot fitting. The tip fitting is connected to the top end of the FAST mast and moves with the mast during FAST mast deployment. Three 7/16-inch bolts support launch loads. The bolts are spaced 120° apart around the circumference of the canister, connecting the tip fitting with the mast canister, support launch loads. These bolts are released during EVA 1. The tip fitting reacts both launch and on-orbit loads and has pip pins to hold the SABB ORUs in either the retracted or deployed configuration. Figure 2-12 shows the mast tip fitting. In addition, the SABB upper pivot fitting restraint mechanism for the retracted (bottom) and deployed (top) positions are visible in Figure 2-13.



**Figure 2-12. Mast canister, FAST mast, and tip fitting interface**



**Figure 2-13. Top view of mast tip fitting**

The tip fitting also has EVA-compatible handhold areas for manual positioning of SABB ORUs from retracted to deployed configuration.

**Verify that this is the correct version before use**



The pivot fittings provide the interface between the mast canister and the SABB. The EVA crew manually swings the pivot fitting from its stowed position to its on-orbit unstowed position during EVA 1. The lower pivot fitting is hinged between the lower half of the SABB and the mast canister. The upper pivot fitting is hinged between the upper half of the SABB and the mast tip fitting. The fittings are shown in Figure 2-14.



**Figure 2-14. Upper and lower pivot fittings**

When deployed, the lower pivot fitting is constrained from rotation about the hinge by a locking strut sleeve. Figure 2-15 shows the deploy sequence of the locking strut sleeve.

The upper pivot fitting is constrained from rotation by inserting a pip pin into the top of the mast tip fitting, as shown in Figure 2-14. The upper pivot fitting has EVA handholds for manual positioning of the SABB ORUs. The SABB electrical interface connector is located on the lower pivot fitting.

The MDA provides the mechanical force to extend and retract the FAST mast. The MDA connects to a pinion gear, that, in turn, meshes with the ring gear of the half-height deployment nut in the canister. When the MDA is energized, the deployment nut is rotated, and the FAST mast is extended or retracted. The MDAs are common for the mast ORU and the two blanket and box ORUs. The MDA contains a brushless dc motor that is mounted to the canister outer shell. The motor receives power from the ECU.

The ECU provides power, control logic, and instrumentation signal processing for the SAW. Solid-state switches in the ECU furnish power to the FAST mast MDAs and to the blanket and box MDAs. To a minor extent, the switches in the ECU furnish power to the blanket box limit switches, MDA temperature sensors, and stall sensors. Control



logic is provided by the ECU for control of the deploy/retract and latch/unlatch operations of the MDAs. The limit switch status data provide open/close position information on the mast extend/retract and the blanket box latch/unlatch conditions. The mast maximum allowable weight is 885 lb. The FAST mast MDA torque is estimated at 110 in-lb at a speed of 180 rpm.

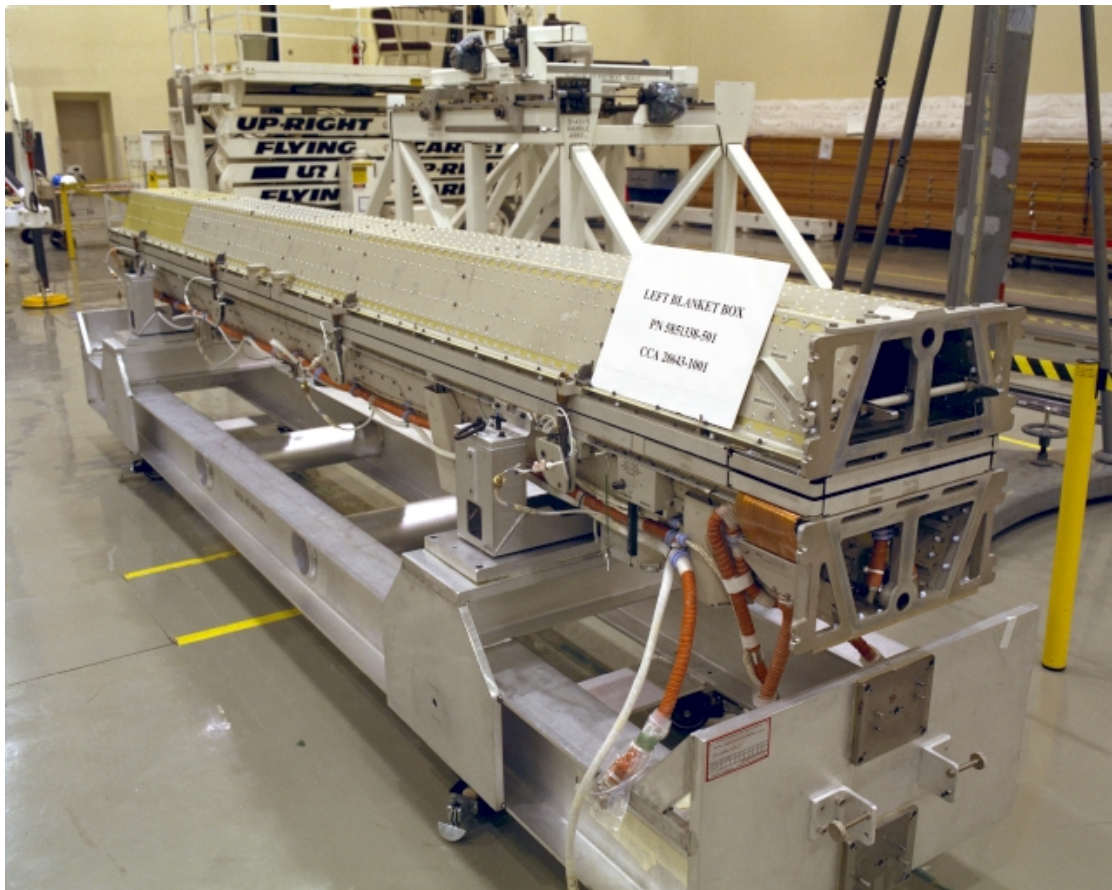


**Figure 2-15. Lower pivot fitting locking strut sleeve**

**Verify that this is the correct version before use**

### 2.2.1.5.3 Left and Right SABB

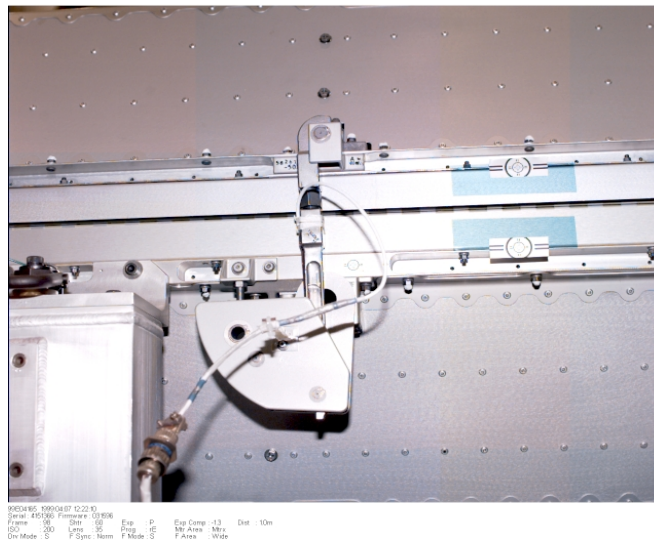
The SABB ORUs consist of a containment box cover assembly, containment box base assembly, and blanket assembly that are 20 inches high. The cover assembly does not contain any major subcomponents. The base assembly contains the latch mechanism, MDA, guide-wire mechanism, blanket restraint pins, and blanket tension mechanism. The containment box cover and base are latched together to protect the blankets during launch. The blankets are compressed between two foam pads (one in the cover and one in the base). The preload and launch support pins, or Blanket Restraint System (BRS), prevent the blankets from moving during launch accelerations and damaging the solar cells. Figure 2-16 shows the SABB.



**Figure 2-16. Solar array blanket box**

The SABB ORUs physically interface with the mast ORU pivot fittings and the IEA support brackets during launch. For on-orbit operation, the SABB ORUs are designed to guide solar array extension and retraction and to tension the blanket after full mast extension is achieved. The physical and electrical interfaces are at the mast ORU pivot fittings. The containment box cover is attached to the upper pivot fitting, and the base is attached to the lower pivot fitting. The electrical interface is located at the lower pivot fitting. The left SABB ORU has an additional EVA handhold.

A containment box latching mechanism is used before flight to establish the solar array blanket preload. The latch mechanism consists of an adjustable hook located on the containment box base; a roller located on the containment box cover; a latch mechanism drive that actuates all eight latches simultaneously; and a shaft connecting the blanket and box MDA to the latch mechanism. The latch mechanism is shown in Figure 2-17. There are four pairs of adjustable hooks and rollers for a total of eight. During latching, the containment box MDA drives the shaft, moving the adjustable hooks, which capture and engage the rollers. As the adjustable hooks translate, they capture the rollers and draw the cover toward the base. As the cover and base move closer together, the foam pads preload the folded blanket. A manual backup to latch and unlatch the blanket and box ORUs is provided as part of the latching mechanism.



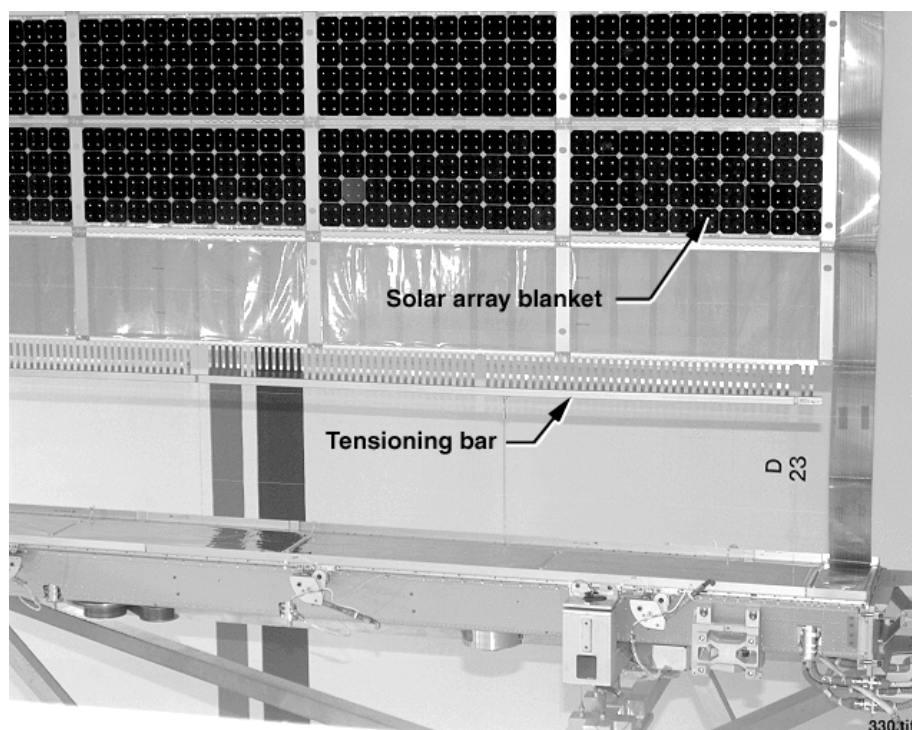
**Figure 2-17. SABB latch mechanism**

During deployment, the guide-wire mechanism maintains tension in three guide wires, which provide restraint to the unfolding blanket and maintain blanket planarity during extension. Each guide-wire tensioning mechanism nominally exerts 1 lb of force.

To maintain blanket flatness and achieve the minimum natural frequency requirement of the wing, tension loads are applied to the blanket. The tension mechanisms are actuated by latching and unlatching commands to the blanket box MDA. The tension mechanisms can be manually activated by an EVA crewmember. The tension mechanisms are tensioned when the blankets are retracted and the box is latched.

Upon initial unlatching of the blanket box, the tension mechanisms in the box reduce the spring tension from approximately 40 lb to 5 lb for each mechanism. The tension mechanisms maintain 5 lb of tension during the entire blanket extension cycle. The process of retracting the blankets is the same in reverse: box command unlatch (tension mechanism reduces tension), blanket retraction, and box latching (tension reapplied). When the blanket is fully extended, two tension mechanisms in each blanket box apply a nominal load of 75 lb to each blanket.

The tension force is transmitted from the mechanism pulley to a distribution bar and from the bar to the blanket via helical springs. The springs compensate for base deflection under the tension load. A 0.25-inch distribution rod and approximately 160 springs are used at the top and at the bottom of the blanket. The rod is held to the top blanket box cover by clamps in 17 locations. The clamps themselves are bolted to the box. The springs are wrapped around the rod and connect directly to the blanket. The bottom distribution bar and springs stow out of the way of the blanket upon release of tension force. During on-orbit operation, the blanket temperature varies with season and Sun/eclipse cycling. The tension mechanism has compensation pulleys and springs to maintain the tension loads over roughly 9 inches of expansion/contraction thermal movement. The tensioning bar, springs, and PV blanket interface can be seen in Figure 2-18.



**Figure 2-18. PV blanket tensioning mechanisms**

#### **2.2.1.5.4 Beta Gimbal Assembly**

The BGA (8 by 8 by 2 feet) is a structural link between the IEA and the PV SAWs. The two BGAs per SAW are located on each PVM. Functionally, the BGA allows rotational freedom about the ISS beta axis while maintaining structural strength and stiffness for the remaining five degrees of freedom. The BGA consists of the platform; ECU; Bearing, Motor, and Roll Ring Module (BMRRM); Beta Gimbal Housing Subassembly (BGHS); and Beta Gimbal Deployment/Transition Structure (BGDTS).



a. **BGA operating modes** – Specific operational scenarios provided are defined in the following list of operating modes:

1. Angle command mode – Alignment of the SAW is maintained to commanded angle information received over a dual 1553 data bus. Pointing of the SAW to the solar vector is brought about by local tier and user tier controllers.

Data from the MCS system is operated on by these controllers to provide the continuous stream of commanded angle information necessary for solar vector tracking. The commanded angle information may also come from sources other than the MCS system. The commanded angle information is compared to the relative angular position in the BGA ECU control loop. The ECU commands the BMRRM to rotate the BGA until the differential angle error is within the angular error tolerance.

2. Latch mode – The angle command mode is implemented to drive the system to one of 128 maintenance/plume load positions. One of the antirotation latches is then actuated within the BMRRM to prevent beta angle rotation. All nonessential functions are then disabled, allowing for EVA or telerobotic maintenance of ORUs on any side of the beta axis.
3. Rate mode – When the BGA is used for fairly constant alpha rotation (approximately 4 deg/min), a rate mode is available. In this mode, MCS downloads a rate to the ECU. The ECU then calculates a new step position every second to follow the downloaded rate. This new position feeds into the position servo-loop.

b. **Functional groups** – Major components of the BGA are contained in the following four functional groups: (1) control group, (2) structural group, (3) electrical transmission group, and (4) Beta Gimbal/Photovoltaic Array Assembly (BG/PVAA) deployment group.

1. Control group – Group 1 controls the beta axis pointing functions. The beta rotation axis is defined by two sets of angular contact bearings located between the IEA bulkhead and the wing. This rotation axis is normal to the alpha axis. Its angular rotation range is unlimited. Angular displacement from a predetermined zero reference is measured by a position resolver that is mounted coaxially with the two sets of bearings.

Beta axis position is controlled by a positional servo-loop that incorporates a structural dynamics filter and a proportional derivative integral feedback. The rotational rates are limited primarily by the control loop to approximately 1 deg/min. Angular accelerations at the beta axis are produced by torques from these parasitics and other disturbance torques that tend to disturb the pointing of the wing. The beta axis drive motor provides the torque between the wing and the IEA to compensate for these accelerations of the wing. It also provides the torque required when the wing is repositioned. Angular accelerations are

inertial. Maximum beta axis acceleration is limited by the torsional fragility of the wing and Preintegrated Truss (PIT) structures.

Beta axis pointing control is brought about by the user tier controller. Actual pointing of the SAW is controlled locally by the BGA. Components associated with this group are the ECU, the drive motor, and the relative angle position resolver.

2. Structural group – Group 2 provides the structural load path between the wing and the IEA. Bending moments, in the plane normal to the beta axis, and loads, applied radially or axially, at the base of the SAW are transferred to the attachments at the BGA bulkhead structure. Torsion about the beta axis is also transferred by this group and the drive motor of group 1 or the antirotation latches during maintenance and launch. Actual torsional loads are modified by the control loop and motor characteristics. This group contains the platform subassembly, the structural elements that support the axis bearings, and the axis bearings. The BGHS and the BGDTS complete the structural path to the IEA.
3. Electrical transmission group – Group 3 allows electrical power and signal transmission across the beta axis. Electrical power produced by the wing is transferred through the BGA over the entire beta axis rotational range. Control power and signals for modules located on the wing side of the BGA are also transferred across the axis. This transfer is provided by an electrical rotary coupling, the roll ring subassembly (mounted coaxially with the axis bearings and torque motor), and the BGA interconnect cable subassembly (contained in the platform subassembly). Source power is transferred from the SSU to the DCSU. Two redundant paths of secondary dc power are transferred from the DCSU RPCMs to the ECU. Dc control bus power is transferred to the SSU from the IEA. Dual 1553 data buses transmit user tier controller data to the ECU and SSU.
4. BG/PVAA group – Group 4 allows for stowage of the complete BG/PVAA on the PV cargo element during launch. The group deploys the BG/PVAA about 8 ft away from the IEA after removal from the Space Shuttle Program cargo bay, without further installation of components. Group 4 consists of the BGHS, BGDTS, and platform. The deployment is needed to allow a full operational rotation envelope of the BG/PVAA. The deployment action is initiated via EVA release of the IEA retention mechanism, which holds the platform to the IEA. A stored energy device then rotates BGDTS, causing a BG/PVAA deployment. The BGDTS-to-IEA interfaces are aligned to provide minimal error during solar tracking the solar arrays. Parallelism between beta joint axes across the IEA structure and orthogonal positioning with the alpha axis are important in providing maximum EPS power and reduction of plume load forces. No intended retraction function is associated with the BGA. SAW deployment and retraction control resides in the user tier controller, located on the IEA. User tier commands are translated by the BGA to appropriate MDA actions.

### **2.2.1.5.5 Bearing, Motor, and Roll Ring Module**

This module provides the beta axis rotational capability and structural support for the SAW, SSU, and ECU; each is attached to the platform subassembly. The module consists of two angular contact bearing sets, one module housing, one drive motor, one roll ring subassembly with position resolver, and two antirotation latches. Between the platform subassembly and the BGHS, it supplies the driving torque (peak stall torque, at peak voltage, 312 in-lb) that is required to establish and maintain the angular position as commanded by the ECU. The bidirectional transfer of electrical power, command signals, and data between the SAW, SSU, ECU, and the IEA-mounted EPS components is effected through the roll ring subassembly.

Mounted inside the BGHS, the BMRRM provides 360° continuous angular rotational freedom about the beta axis. All structural loads between the platform and the BGHS are transferred through this module. One angular contact bearing set consists of a pair of angular contact bearings, mounted back-to-back. The outboard angular contact bearing set (closest to the platform subassembly) transfers axial and radial loads from the platform to the BGHS. The inboard angular contact bearing set is allowed to float axially in the inner bearing housing structure. Radial loads in this set are reacted through the BGHS. Axial loads are not carried by this set. The two angular contact bearing sets are mounted approximately 20 in. apart. This arrangement allows moment loads, normal to the beta axis, to be reacted by the moment couple developed as radial loads at each end of the BGHS.

The drive motor is mounted coaxially with the angular contact bearing sets. This allows the beta axis to be driven directly, with no physical contact between driving elements. The drive motor used is a brushless dc wire-wound device using high energy product magnets. The angle position resolver serves the dual purpose of commutation of the brushless dc torque motor and measurement of the relative angle between the IEA and the SAW line of sight, with an angular accuracy of 11 arc min, peak error.

The roll ring subassembly is incorporated into this module. This is the rotational coupling device that allows transmission of electrical power and signals over the entire beta axis rotational range. It has three types of rotary coupling elements. The highest capacity elements carry maximum power generated by the SAW to the IEA. This element is the largest rotary coupling element in the subassembly. An intermediate capacity element carries dc control power to the SSU and secondary power to the ECU. The third type of rotary coupling carries signal level power. It is the same physical size as the dc control power rotary coupling; the only difference is the number of rolling conducting rings between inner and outer coupling conductors.

Two antirotation latches are in the BMRRM, each 92.81° apart. In the rotating flange, there are 64 holes (5.625° apart); therefore, by oscillating between the latches, 128 latching positions are available. The antirotation latches are latched in the “zero” position for launch.

1. Steps to unlatch the antirotation latch

- (a) When commanded to unlatch, the ECU applies 15 V dc to the antirotation latch heating element within the latch, thereby heating the paraffin. The volumetric expansion of the paraffin occurs during the solid-to-liquid phase change and thus provides the motive force. This pressure is transformed by the actuator to mechanically work in a linear shaft motion, via a squeeze boot.
- (b) The motive force (350 lb) is used to pull the pin out of the latching hole. The toggle mechanism is then tripped, preventing the latch from reengaging after the actuator is turned off.
- (c) The actuation status limit switch is activated near the end of shaft travel and thus informs the ECU to cease power. The actuator paraffin then cools and solidifies.

2. Steps to latch the antirotation latch

- (a) To latch, the ECU applies 15 V dc and thus causes the actuator to expand; the expansion trips the toggle mechanism and limit switch again.
- (b) When the actuator cools, a spring is used to push the pin into a latching hole.
- (c) A second limit switch, known as the pin status switch, informs the ECU whether the latch pin is in the latching hole.

The antirotation latches are EVA-resetable by simply pushing in the latch pin and overcoming the spring force (~30 lb).

#### **2.2.1.5.6 Electronics Control Unit**

The ECU (23 by 12 by 38 inches) is the command and control link between the beta gimbal and SAW. The ECU brings about mast deployment or retraction, beta axis pointing, and health monitoring of functions associated with these tasks. It accepts secondary dc power and tier III control data from sources on the IEA. Internally, it conditions the secondary dc power and distributes regulated power to beta gimbal and SAW functions. The ECU is located on the platform subassembly. It is connected to the beta gimbal drive motor, located in the BMRRM, by a cable harness located in the platform subassembly.



The ECU receives two secondary dc power inputs and 1553 data bus information through the roll ring subassembly. All functions performed by the ECU are under direct control of the user tier controller on the IEA. To ensure plume load alleviation, the ECU is designed to perform the angle positioning function when one failure occurs. This failure tolerance is accomplished by providing the ECU with two secondary power sources from different DCSUs and two remote terminals from the 1553 data bus. One remote terminal accepts beta axis pointing commands and transmits BGA instrumentation data. The other remote terminal accepts mast deployment or retraction commands and transmits solar array instrumentation data.

The ECU implements two distinct functions that are controlled by the user tier controller. The first function is solar array mast deployment or retraction. The second function is positioning the SAW to the commanded beta axis angle. Solar array orientation consumes the majority of operating time for the ECU. The ECU is capable of implementing both the angle positioning function and the SAW deployment/retraction function when either, or both, of the two secondary power inputs are available.

Deployment, or retraction, of the solar array is implemented by feathering the solar array orientation function and implementing the proper sequence of commands to the MDAs. Sequence control is totally at the user tier controller level, with the exception that the ECU provides some health rejection functions. The ECU translates the user tier controller commands into the necessary RS422 control signals. Power for implementation of these commands also comes from the ECU power conditioning electronics.

Solar array orientation is to be performed only when the array deploy/retract function is not being implemented. The angle command mode accepts user tier controller information to perform the solar array orientation functions. This is the primary operating mode for the BGA. In this mode, the angle command data from the user tier controller are compared to the relative angle measurement provided by the beta axis resolver, located in the roll ring. The angle error signal produced by this comparison is used to apply a current to the BGA drive motor, causing the relative pointing error signal to go toward zero. The BGA motor commutation circuitry is stepped sine wave with current feedback. The magnitude of the relative pointing error is returned to the user tier controller. The solar array orientation function applies current to the platform latching mechanism upon command from the user tier controller. This latching is usually performed just before the solar array deploy/retract function or a maintenance action that requires specific positioning of the solar array.

Monitored and/or calculated parameters include BMRRM temperature, beta angle, beta error, latch limit switches, solar array limit switches, solar array MDA voltages, MDA temperatures, MDA stall status, discrete output voltage, and antirotation latch limit switches.

#### **2.2.1.5.7 Beta Gimbal Platform Subassembly**

The beta gimbal platform subassembly provides the structural interfaces for all PV power module components supported outboard of the beta axis. It also provides the electrical interconnections between these components. Permanently attached to the base of the solar array mast canister, it completes the extendable mast ORU.

On its +X and -Y sides, the platform subassembly provides an electrical and mechanical ORU interface with the SSU and ECU, respectively. On the -Z face, the platform subassembly provides an electrical and mechanical ORU interface with the BMRRM. Cabling between the SSU, ECU, and BMRRM is contained within the platform subassembly as well as the 1553 data bus stubbing transformers and transmission line terminations. On the +Z face, the platform subassembly is permanently attached to the base of the solar array mast canister. Cable harnesses from the SAW route to the SSU and ECU through connections in the platform side plate. During launch, the -X side of the platform subassembly attaches to the IEA to provide the load path between the IEA and solar array. During launch and BMRRM removal and replacement, a latching mechanism attaches the platform to the BGHS to provide a solar array to the IEA load path. During on-orbit operations, the main load path is from the array mast canister (+Z), through the platform, to the BMRRM (-Z). The platform subassembly outer dimensions are 42.12 by 30.5 by 13 inches.

#### **2.2.1.5.8 Beta Gimbal Housing Subassembly**

The BGHS provides the structural support of the BMRRM and shields the bearings, drive motor components, and roll ring subassembly from direct influences of the immediate environment. The beta gimbal housing also provides structural attachment points for the BGDTS. Included in the beta gimbal housing are the dual latching systems. One position of these latching systems secures the housing to the BMRRM, while the other secures the housing to the platform.

The BGHS is a cylindrical structure that transfers structural loads between the BMRRM and the BGDTS. During replacement of the BMRRM, the beta gimbal housing provides the structural support of the platform subassembly and the mast canister/PVAA. This major component is not an ORU, although a contingency release is available to separate the BGHS from the BGDTS.

The BGHS is not designed to be the primary load bearing path between the BG/PVAA and the IEA during launch. Its Outer Dimensions (OD) are 24.8 by 20 Inner Dimensions (ID) by 21 inches.

#### **2.2.1.5.9 Beta Gimbal Deployment/Transition Set**

The BGDTS guides and secures the BG/PVAA into the on-orbit location and orientation.

The BGDTS is composed of a four-bar linkage mechanism and is designed to provide and control the deployment motion of the BG/PVAA from the PV cargo element. Once fully deployed and secured, it transfers structural loads between the beta gimbal housing and the IEA. This major component is not an ORU.

The BGDTS is not designed to be the primary load bearing path between the BG/PV array assembly and the IEA during launch.

#### **2.2.1.5.10 Integrated Equipment Assembly**

The IEA (16 by 16 by 16 feet) conditions and stores the electric power collected by the PV arrays for use in ISS operations. The IEA serves as the PV power module launch structure and supports the PV power module outboard of the SARJ on orbit.

The IEA integrates the energy storage subsystem, the electrical equipment, the TCS, the structural framework, and the outboard SARJ bulkhead. The IEA is designed to support both launch and on-orbit operations with either a complete or a reduced (off-loaded) energy storage subsystem complement. A full complement consists of 12 battery ORU boxes and six BCDU ORU boxes.

The IEA is part of the outboard PV module and has a structural framework that attaches directly to the long spacer truss. The IEA structural framework is the hardware upon which the IEA ORUs are mounted. The framework provides the electrical cables and connectors to functionally integrate the IEA ORUs. It also provides the connectors to integrate the other PV power module and ISS components. The framework, which structurally consists of the strongback side rails, forward bulkhead, and aft bulkhead, also attaches the PV power module to the orbiter for launch.

The framework provides RFHX coldplates to extract the heat generated by the IEA ORU boxes. Heat generated in the ORUs is transferred through the radiant fin heat transfer area to the ammonia coolant flowing in tubes on the bottom of the coldplates. The fins add lateral structural stiffness to the coldplates in addition to increasing the thermal radiation heat transfer area. The ammonia coolant enters the strongback through fluid QDs and flows through serpentine tubes first to cool the batteries, then the BCDU ORUs, and then the electrical equipment ORUs.

The TCS tubing within the framework is repairable by removing and replacing only the section of failed tubing when it is accessible to EVA (there is no requirement to access tubing beneath the MM/OD cable box). The failed tubing is cut from the existing fluid circuit, and new tubing is installed. On-orbit tube cutting and swagging operations are done by the Boeing-Rocketdyne developed approach using fluid line repair Orbital Support Equipment (OSE).

The side rails allow EVA access to the TCS tubing for leak isolation and repair operations. The PVCU MDM adapter and PV array blanket box supports are EVA removable to facilitate the installation of the replacement coldplate platforms.

ORU equipment is contained in one of four types of ORU boxes or other enclosures. The ORU box provides mechanical support for the components and protects the components from the on-orbit environment. The electrical, mechanical, and thermal interfaces between the ORU equipment and the rest of ISS are contained in the ORU box.

The type I box is typical for the DCSU, MBSU, and BCDU. Batteries are in type II enclosures, PFCs in type III, and DDCU-Es in type IV.

#### **2.2.1.5.11 PV Spacers**

The S6 element includes a long spacer (28 by 16 by 16 feet) and several additional pieces of equipment, which are described below. When connected to the short spacer (type IV) truss element, the long spacer truss element establishes the proper inboard array to outboard array spacing. The long spacer also supports the cabling to interconnect inboard and outboard PV modules.

#### **2.2.1.5.12 Integration Hardware**

Integration hardware also includes miscellaneous Government Furnished Equipment (GFE) hardware used in the integration of each Solar Power Module (SPM). The PV integration hardware consists of lighting, utility ports, Trailing Umbilical System (TUS) guide roller assembly, and miscellaneous EVA hardware. The Space Shuttle Program integration hardware consists of active primary retention latch assemblies, active keel assemblies, and grapple fixtures.

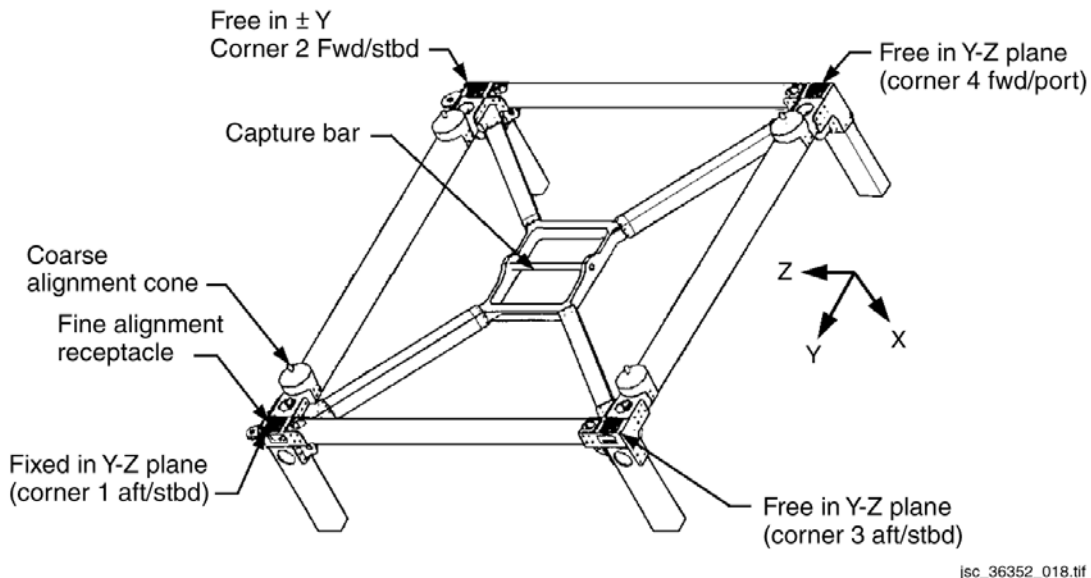
Lighting is provided on the SPM by portable lights. Fixed lights are not required. Lighting is as follows: EMU helmet light assembly, EVA flashlight, and SRMS lights.

EVA hardware consists of handholds, handrails, and Portable Foot Restraint (PFR) sockets, as required. EVA hardware is provided by Boeing-Canoga Park as GFE.

#### **2.2.1.5.13 Rocketdyne Truss Attachment System**

The Rocketdyne Truss Attachment System (RTAS) is the hardware used to align, mate, and attach the S6 long spacer to ITS S5. The mating is accomplished by use of the Shuttle Remote Manipulator System (SRMS)/SSRMS and by EVA astronauts. The RTAS consists of four sets of coarse-alignment cones/receptacles, four sets of fine alignment cones with integral bolt mechanisms and nuts, and a capture latch/capture bar mechanism to pull the interfaces together. The capture latch mechanism is provided by Boeing-Huntington Beach. All other components are designed and manufactured by Rocketdyne.

Figure 2-19 shows the S6 side of the RTAS interface plane. The S6 nadir (inboard, when being attached to ITS S5) face holds the capture bar, four coarse alignment cones, and four fine alignment nut assemblies.



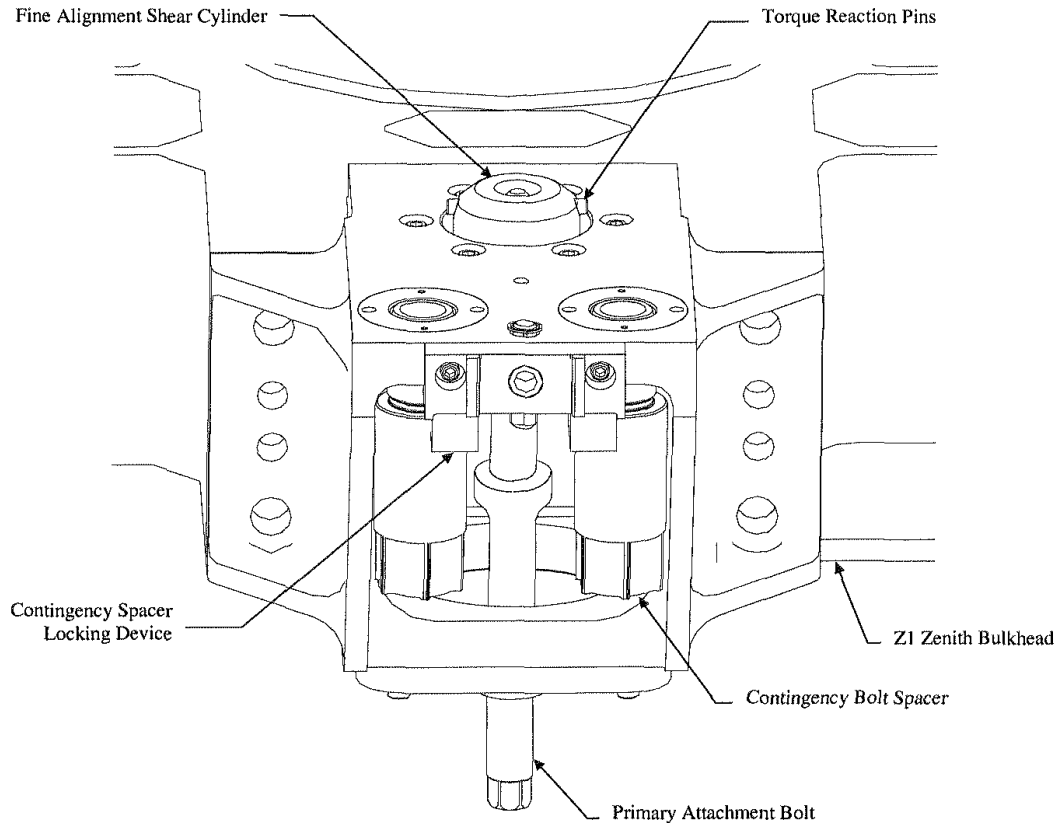
**Figure 2-19. S6 RTAS interface plane**

a. Operational overview

The mating of S6 is done by manipulating the S6 truss into position near the S5 RTAS connection face using the SSRMS. After putting the mated stack into free drift, the S6 is positioned so that all four S6 coarse alignment cones have their cylindrical tips at or below the plane of the S5 coarse alignment bushing faces. Meeting the Ready-to-Latch (RTL) criteria ensures that the capture bar of the S6 segment is placed within the capture envelope of the S5 capture latch. The EVA crew provides verbal alignment guidance to the SSRMS operator for the final SSRMS positioning of the S6 to the RTL position and calls to the SSRMS operator when the S6 is at the RTL position. The EVA crew then use the PGT to close the capture latch. As the latch jaws close upon the capture bar, the S5 and S6 segments are pulled together, and the fine alignment features engage. The S5 fine alignment/bolt mechanism is shown in Figure 2-20. When the fine alignment cones on the S5 side fully seat in their receptacles on the S6, the capture bar is approximately 1/4-inch from being fully seated in the capture latch. Continuing to close the capture latch deflects the capture bar by 1/4-inch and thus produces a 1850 lb preload between the S5 and S6 structures.

When the capture latch is fully closed upon the capture bar, the EVA crew tightens the primary structural attachment bolts to fasten the segments to each other. The bolt design incorporates a “self-feeding feature,” which provides a small axial force to initiate bolt thread engagement so that the EVA crewmember does not need to apply an axial force on the end of the bolt. The bolt preload is controlled by torque

alone. From the S5 shear cylinder, two pins engage matching slots in the S6 primary balls to react primary bolt installation torque. The EVA crew initially drives bolts 1 and 2. After completing the first three bolts, attitude control is allowed, provided the EVA crew does not continue any activity with the RTAS. After the bolts are fully tightened, the preload applied by the capture latch is released by EVA actuation, and the attachment process is complete.

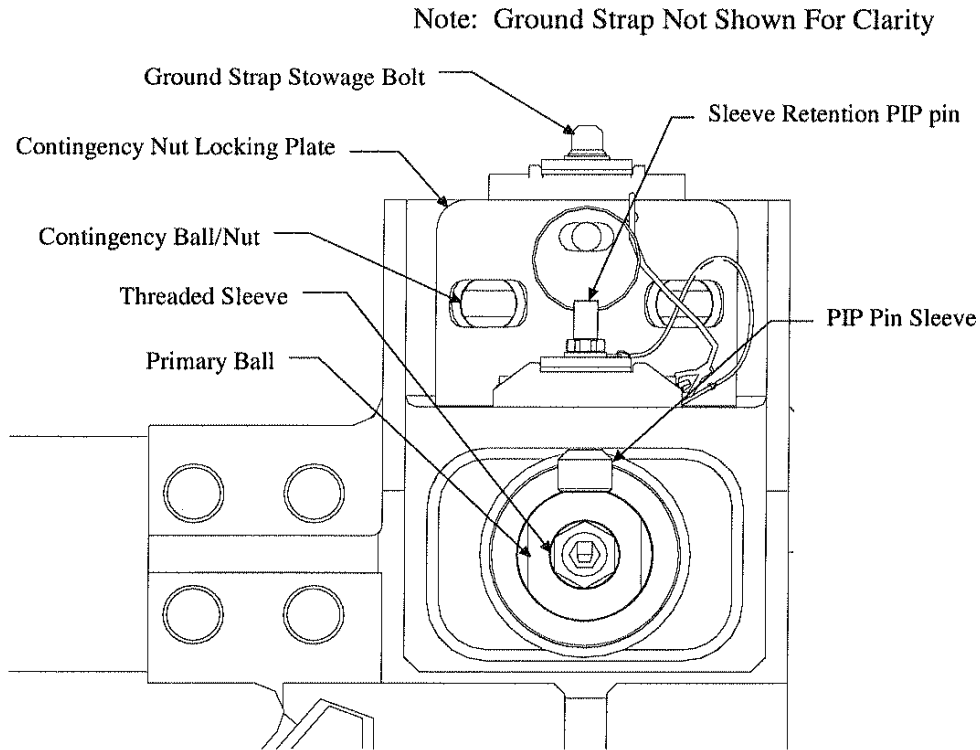


Note: Shown with launch restraint cap removed prior to berthing

**Figure 2-20. S5 fine alignment/bolt assembly**

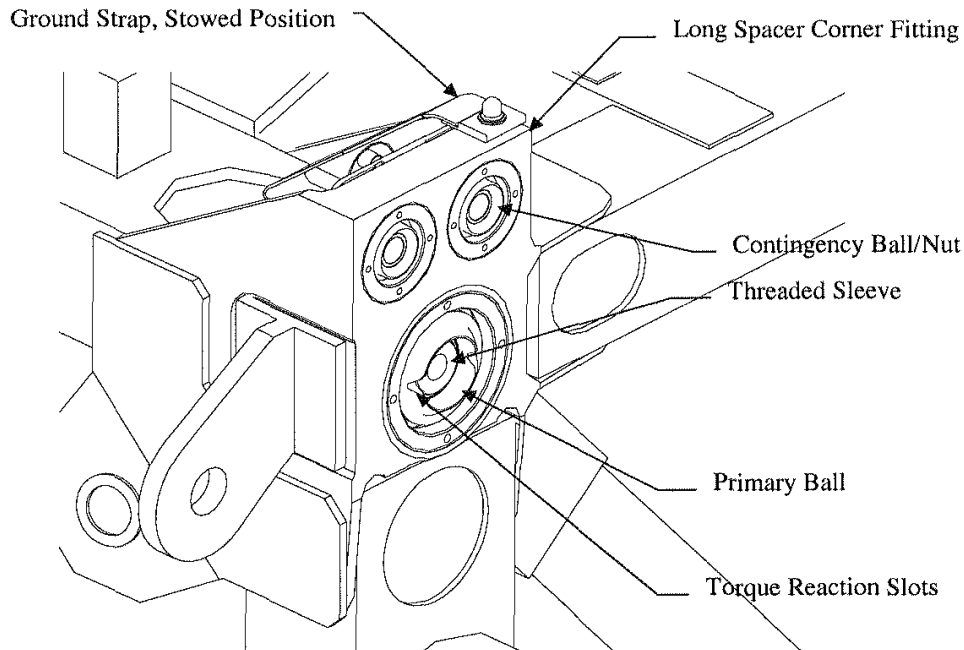
b. Contingency attach/detach features

Each fine alignment device incorporates two contingency attachment bolt/nut combinations to allow a structural connection to be made in the event the primary bolt cannot be engaged. The device also includes a release mechanism, an EVA-operated PIP pin, to allow disconnect of the S6 from the S5 should the primary EVA bolt become stuck in the S6 sleeved nut during engagement (see Figure 2-21). The RTAS design also includes the capability to replace the nut (threaded sleeve) in the S6 RTAS fine alignment assembly. The self-feeding nut in the S5 bolt assembly is made of plastic that shears off as the bolt/nut together are unscrewed, if the bolt has stuck to the nut at a significant depth. This feature is required because there is a small difference in thread pitch between the outer and inner diameters of the S6 sleeve/nut.



**Figure 2-21. Long spacer fine alignment/nut installation (end view)**

Contingency bolts and associated threaded spacers are launched within ITS S5 in the position shown in Figure 2-22 and the spacers are extended by EVA, if needed. The spacer serves to maintain the gap between the S5 fine alignment housing and the S6 corner fitting. Use of the spacer ensures that no bending moments are created due to the distance between the fine alignment shear cylinder's centerline and the contingency bolt's centerline; its use also ensures that there is less chance for interference between the bolt housing on the S5 and the corner fitting of the S6 long spacer. Contingency bolt installation torque is reacted at the S6 nut by a locking plate on the S6 RTAS assembly. After contingency bolt torquing, this plate is removed by EVA and stowed for future use. During bolt tightening/loosening, the threaded spacer is kept from turning using a special EVA wrench that is provided at two corners of the S5 attachment face.



**Figure 2-22. Long spacer fine alignment/nut installation (isometric view)**

**c. Attachment restraint**

Figure 2-22 indicates the degrees of freedom in the fine alignment assembly primary nuts located at each corner of the S6. Figure 2-22 shows a cross section of a fine alignment mechanism with the P5 primary EVA bolt engaged into the primary nut of the S6 long spacer. Spherical bearings are used around both the primary and contingency nuts to provide a limited rotational freedom about the Y- and Z-axes. This bearing arrangement provides relief for on-orbit differential thermal expansion and distortion that may occur between the S5 and S6 during on-orbit operations. The arrangement also allows relief for distortions due to manufacturing tolerances.

In addition to the rotational degree of freedom in the fine alignment primary nut assemblies, there are provisions for sliding in the Y-Z plane to allow for differential thermal expansion of the S6 and S5. One corner of the S6 incorporates a fine alignment nut assembly that is fixed from sliding in the Y-Z plane. A second corner incorporates a nut assembly that is allowed to slide in the Y-direction only. The two remaining corners incorporate nut assemblies that are allowed to slide in the Y-Z plane. This arrangement allows the RTAS bolts to react shear and torsion loads, while still allowing the structures to expand and contract thermally.

The sliding degrees of freedom in the S6 nut side of the fine alignment mechanism are accomplished by incorporating a gap between the bearing race and the corner fitting. The magnitude of these gaps is established based upon part tolerances and predicted thermal displacements. All of the contingency nuts in the S6 fine



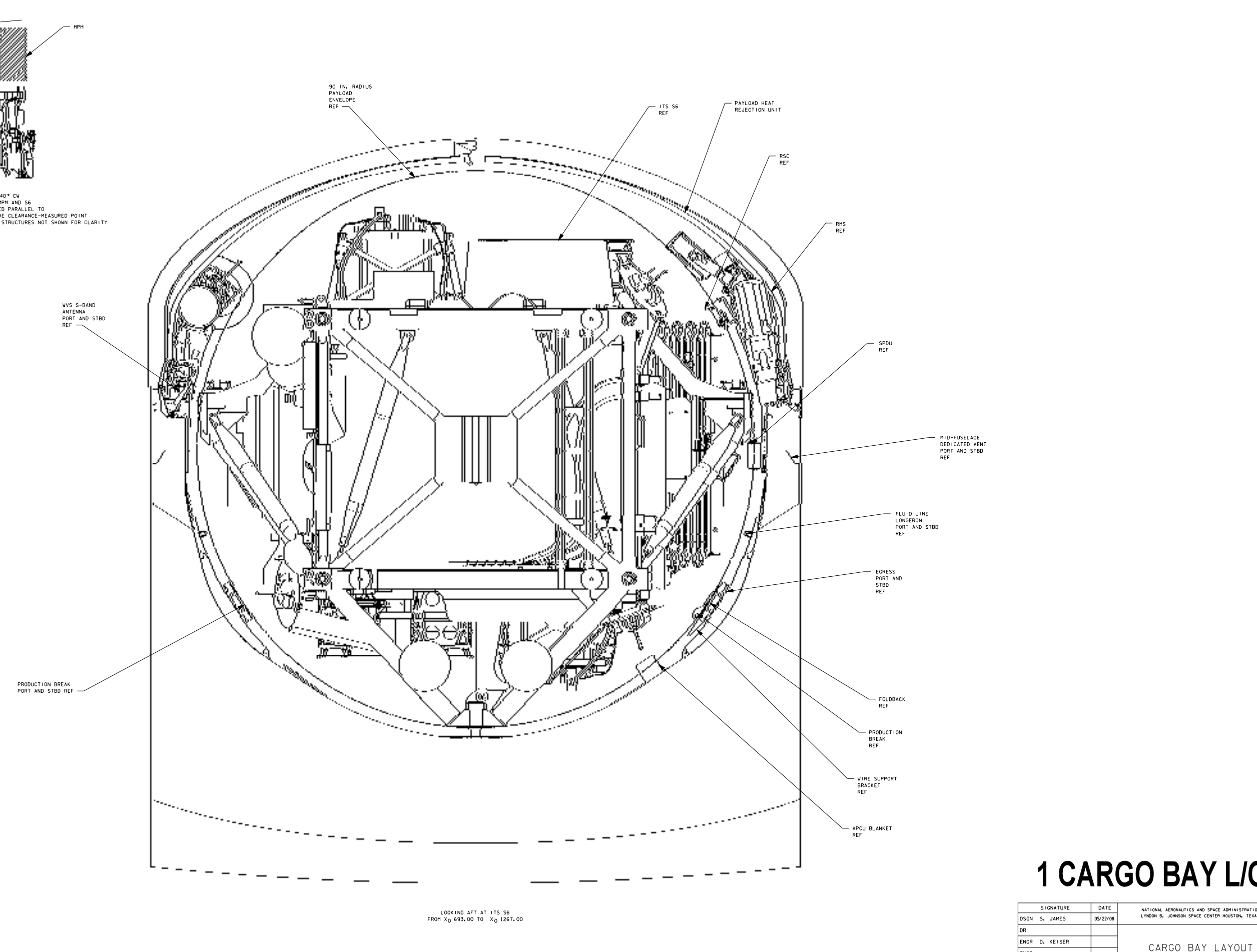
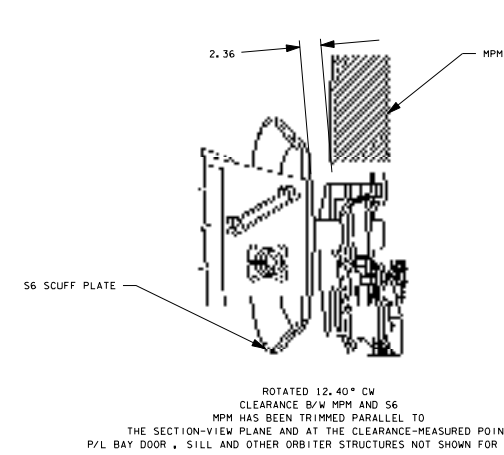
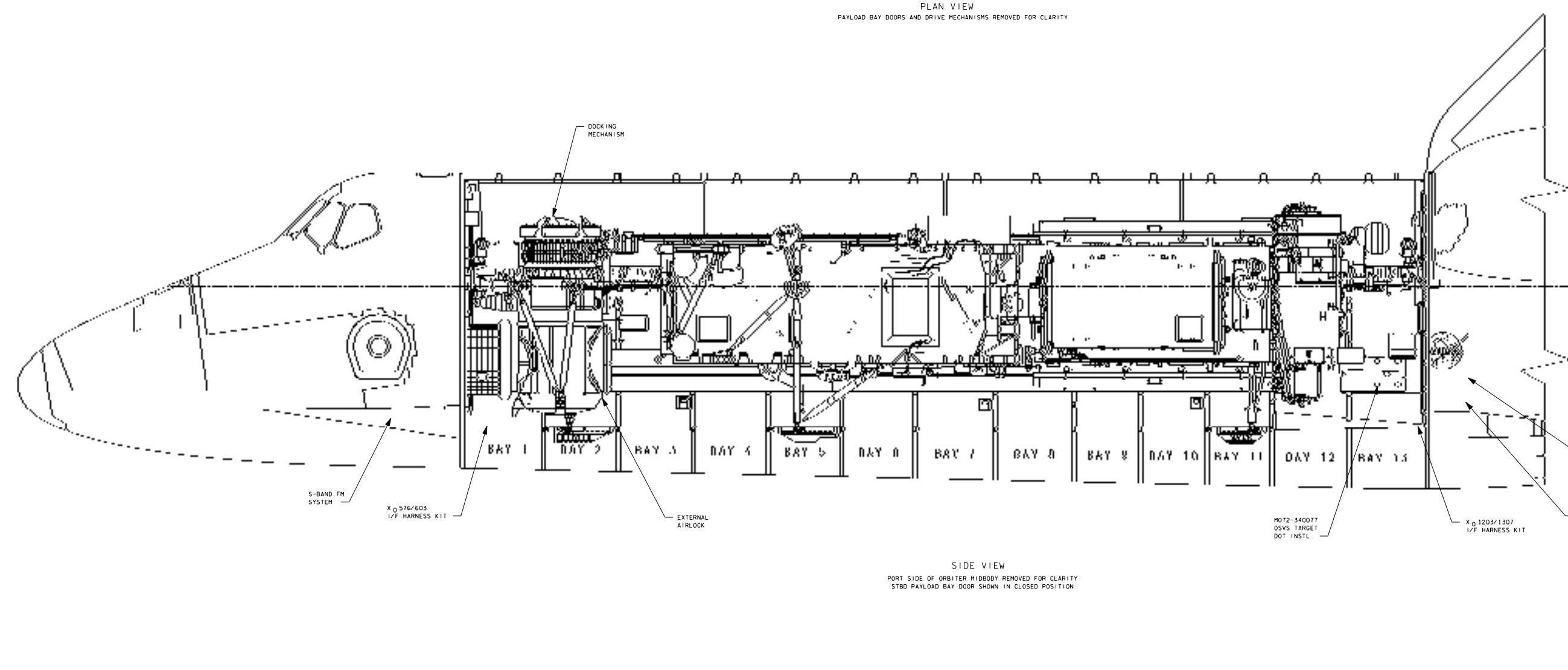
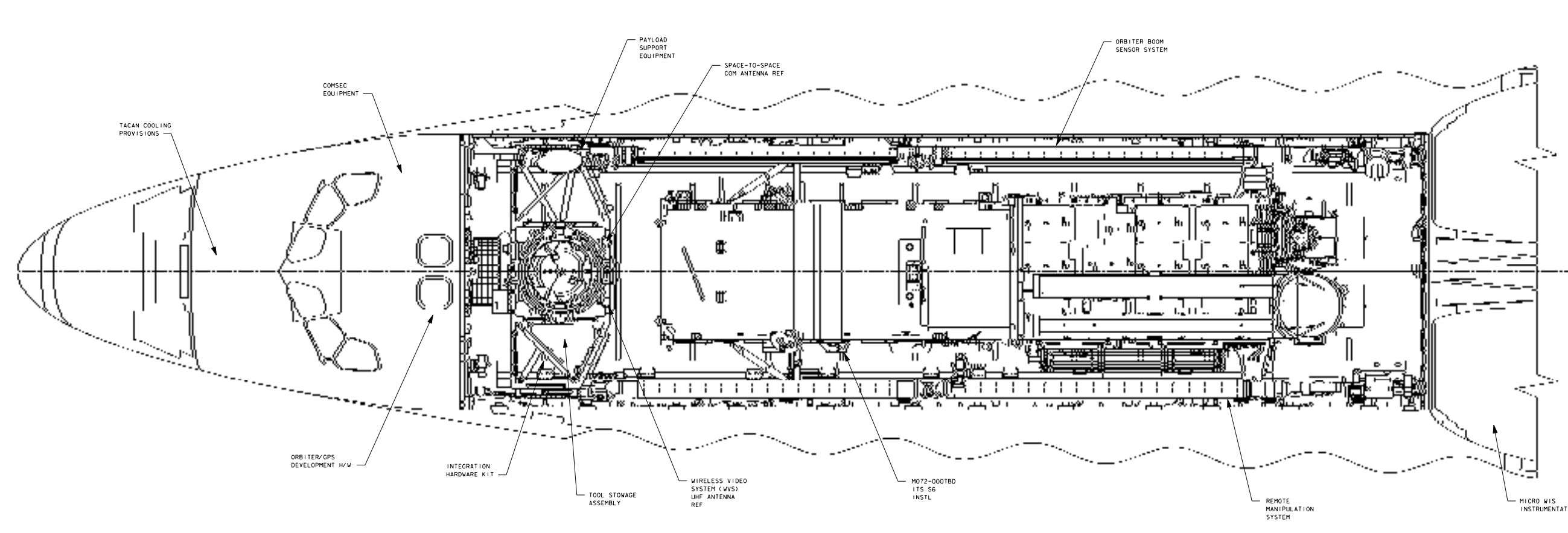
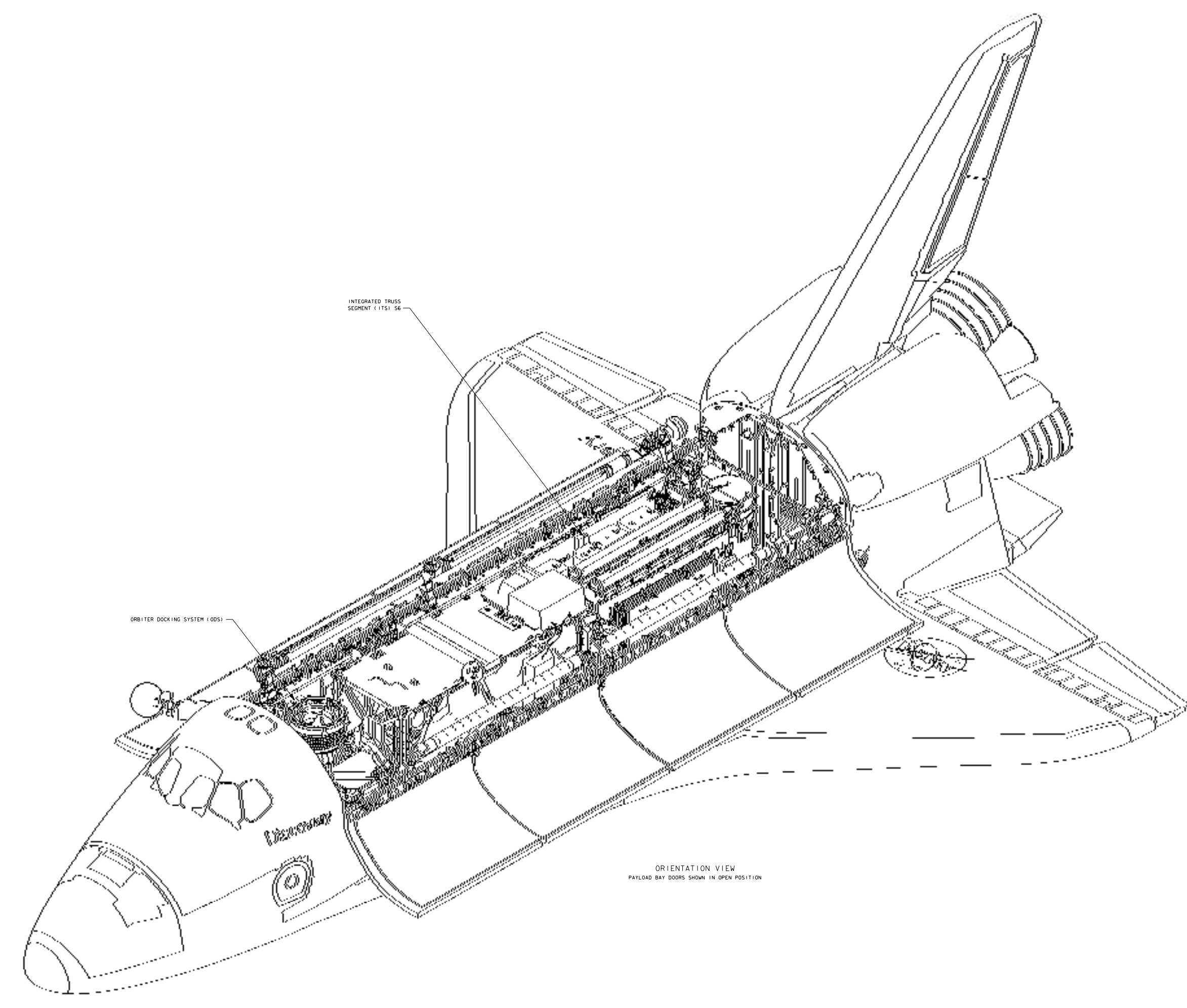
alignment device are allowed to slide in the Y-Z plane. The shear cylinders at the primary attach bolt locations still carry shear loads even when the contingency bolt is installed.

The primary and contingency races contain springs that keep the nut elements centered for fine alignment shear cylinder entry. The ball opening, shear cylinder tip, and the centering spring geometries ensure fine alignment feature engagement when lateral misalignments are present. Such misalignments may be due to thermal displacements and manufacturing tolerances.

d. S5-S6 load transfer

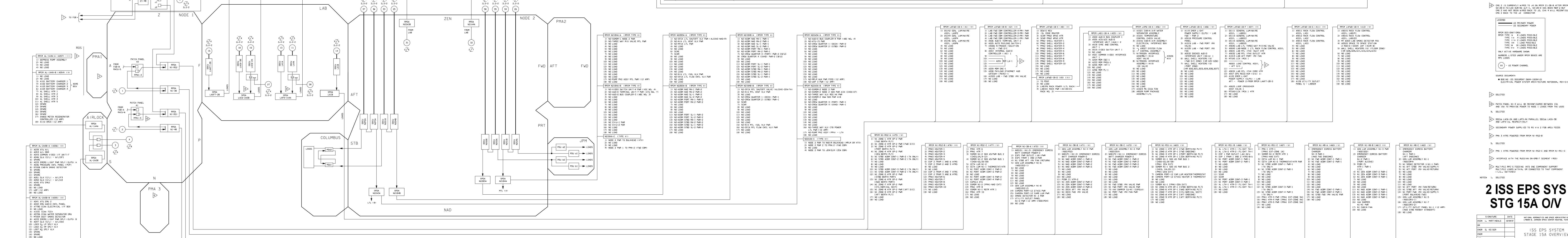
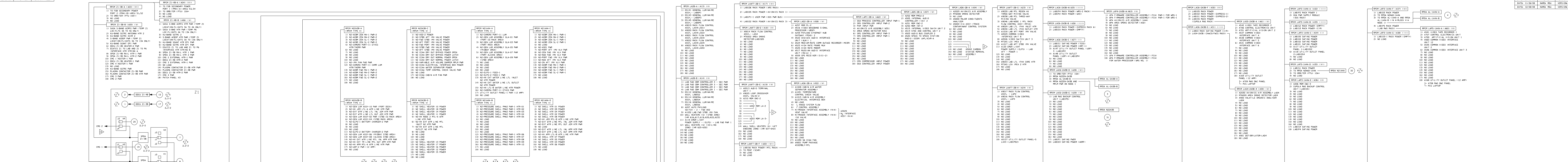
After the structural connection is made, loads are transmitted across the S5 to S6 interface in the following manner:

1.  $\pm Z$  in-plane shear load – Reacted by fixed truss joint and truss joint that is free to slide in the  $\pm Y$  direction
2.  $\pm Y$  in-plane shear load – Reacted by fixed truss joint only
3.  $\pm X$  axial load – Reacted by all four truss joint corners



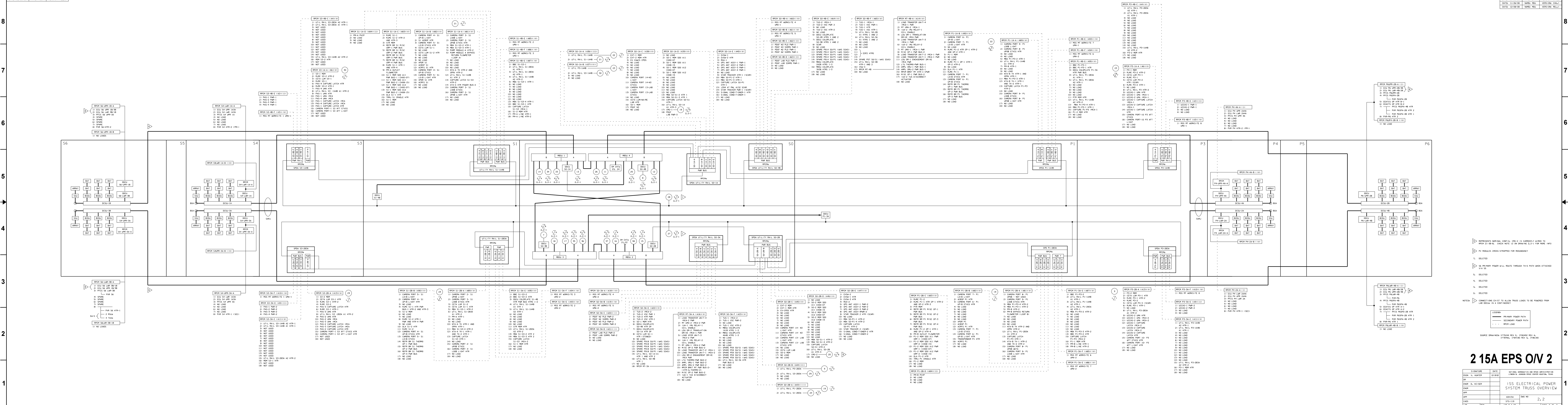
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SIGNATURE	DATE	NATIONAL AERONAUTICS AND SPACE ADMINISTRATION LORAIN W. JOHNSON SPACE CENTER, MISSION, TEXAS
ESON, S. JAMES	09/23/08	
DR		
ENGR. D. KEISER		
APP		
APP	ADMISA	DRG NO
CADS	515-119	2. 1
LTR	PCN	126L5 V 54



LEGEND: US PRIMARY POWER, US SECONDARY POWER, BROW DEFINITIONS, SOURCE DOCUMENTS, DELETED, PATCH PANEL NI-3 WILL BE RECONFIGURED BETWEEN 15A AND 15B TO PROVIDE POWER TO THE USDS, DELETED, PMA 3 INTS POWERED FROM BRON NI-952-B, DELETED, PMA 1 INTS POWERED FROM BRON NI-952-B AND BRON NI-951-C, INTERFACE WITH THE RUSSIAN ORN-DREBIT SECOND FROSS, MULTIPLE INTS FEEDING INTO ONE COMPONENT SUPPLY, MULTIPLE LOADS WITHIN, ONE CONNECTED TO THAT COMPONENT (I.E., SWITCHES), NOTESH 1. DELETED

Table with 2 columns: SIGNATURE and DATE. Includes fields for DSN, L, PART NAME, and DATE.



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SECONDARY POWER PATH  
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CONNECTING EXIST TO ALLOW TRUSS LOADS TO BE POWERED FROM LAB LOOUP IN A CONTINGENCY

2 15A EPS O/V 2

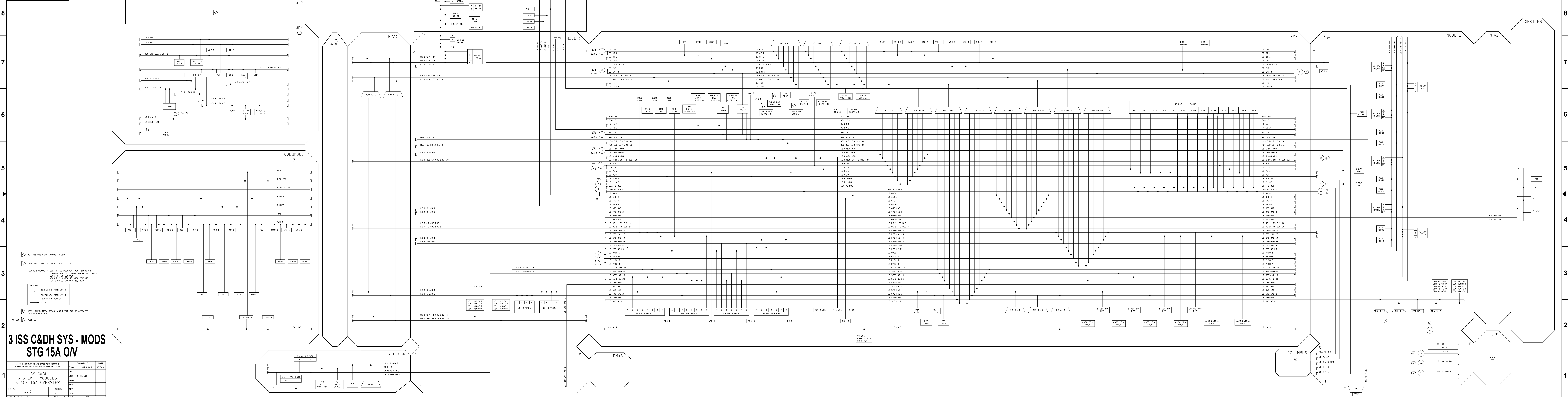
SIGNATURE	DATE	NATIONAL INVENTOR (S) AND/OR APPLICANT (S)
OSON V. WINTER	10/19/02	LYNN W. OSOBY AND/CHRISTOPHER W. WINTER
DR		
ENGR D. KEISER		
APP		
APP		
CADD		
TR		

ISS ELECTRICAL POWER SYSTEM TRUSS OVERVIEW

ADHISA	DWG NO
515-119	2, 2
126.5 X 54	

DATE: 06/15/08 NMCX: LAM VERSION: CNG.2  
DATE: 11/28/08 NMCX: RUC VERSION: CNG.1  
DATE: 12/08/08 NMCX: RUC VERSION: REL.1

SHEET 2 OF 2



NO 1553 BUS CONNECTIONS IN JLP  
 FROM N2-1 MOD D10 CARD. NOT 1553 BUS

SOURCE DOCUMENTS: BOEING ISS DOCUMENT D684-10000-02  
 COMPASS AND DATA HANDLING ARCHITECTURE DESCRIPTION DOCUMENT  
 VOLUME 24: HARDWARE ARCHITECTURE  
 REV 15/08 E, JANUARY 28, 2000

LEGEND:  
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 [ ] TEMPORARY TERMINATION  
 [ ] TEMPORARY JUMPER  
 [ ] STUB

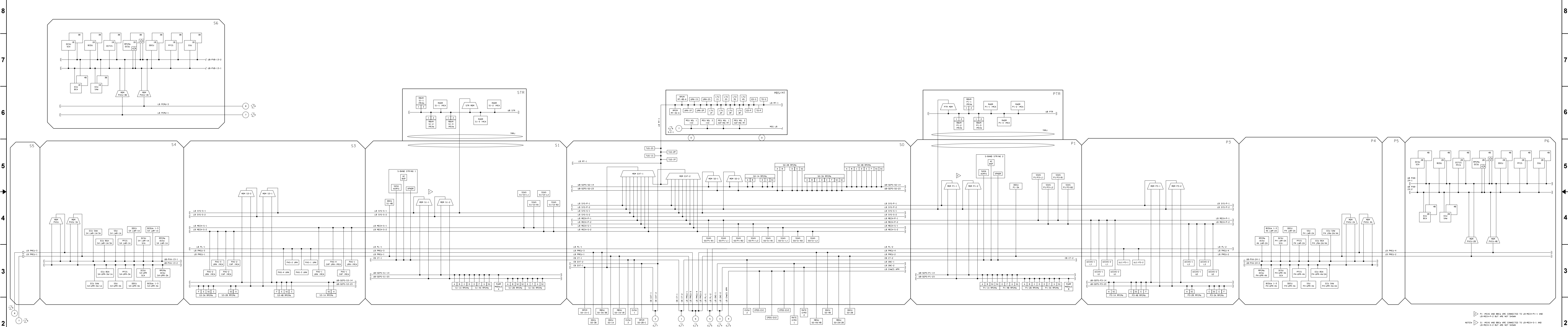
CPUS, TESTS, REEL, SPEC. AND DEFIB CAN BE OPERATED AT ANY CHMS PORT

NOTES: [ ] DELETED

**3 ISS C&DH SYS - MODS STG 15A O/V**

NO. 2, 3	DATE: 02/29/08	BY: SVJ	DATE: 02/29/08
ISS C&DH SYSTEM - MODULES STAGE 15A OVERVIEW	DESIGN: L. MARTINDALE	ENGR: D. KEISER	DATE: 10/09/07
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REV: 2	REV: 2	REV: 2	
REV: 3	REV: 3	REV: 3	
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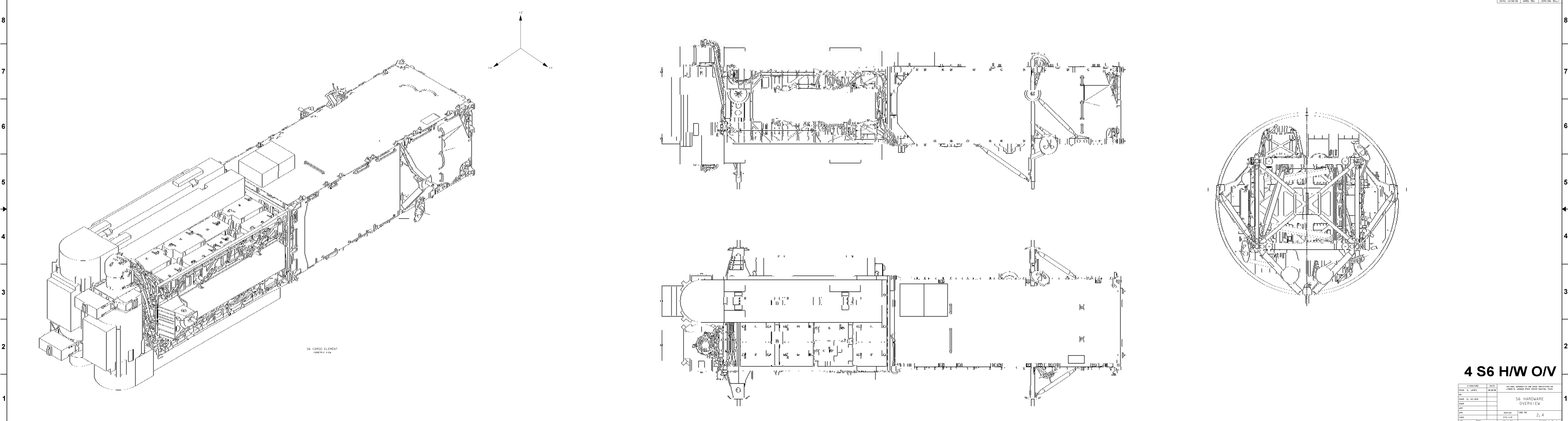




NOTES: P1 INCA AND BCCA ARE CONNECTED TO LB-MECH-P1-1 AND LB-MECH-P-2 BUT ARE NOT SHOWN  
S1 INCA AND BCCA ARE CONNECTED TO LB-MECH-S-1 AND LB-MECH-S-2 BUT ARE NOT SHOWN

# 3 15A STAGE C&DH O/V 2

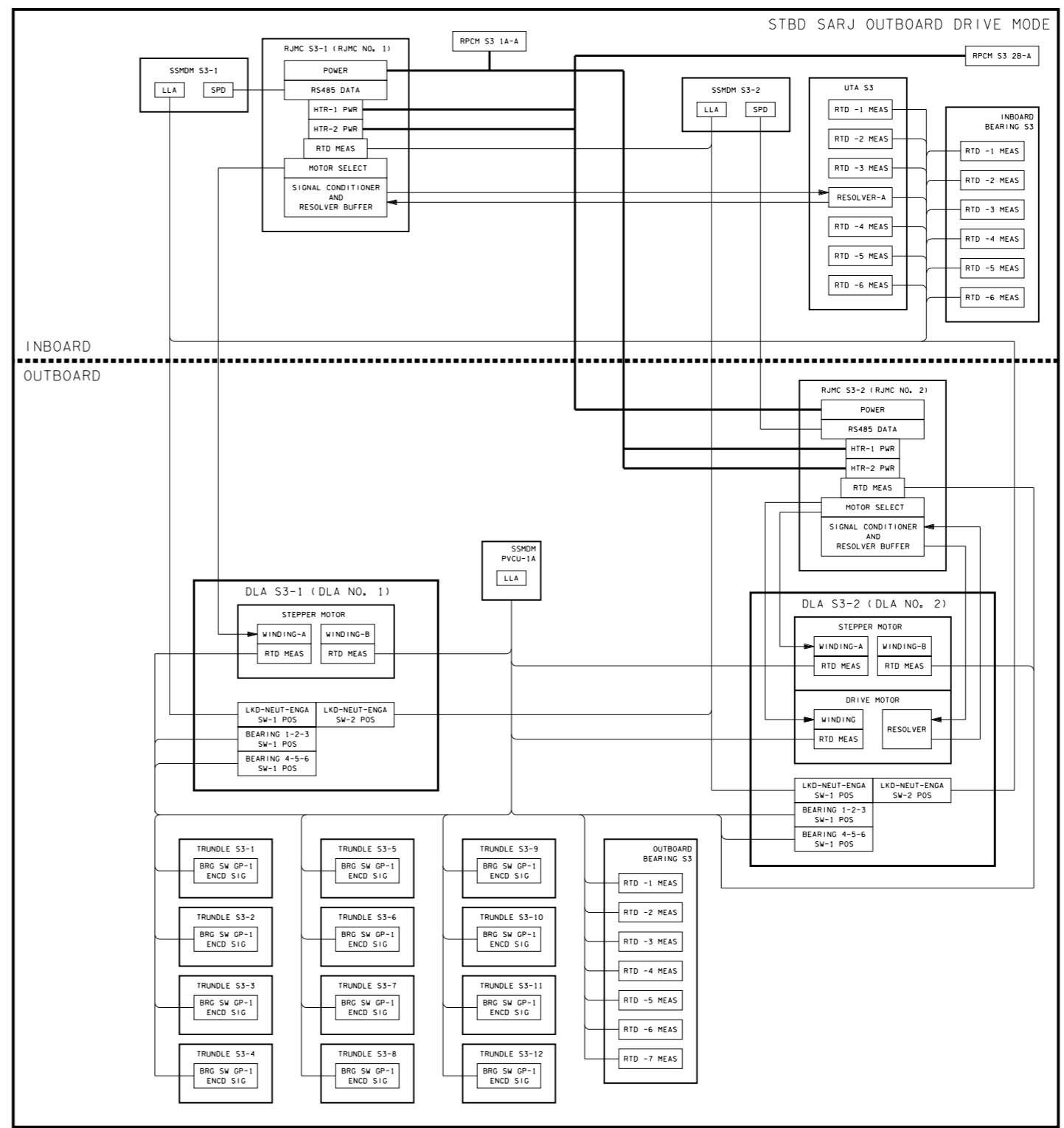
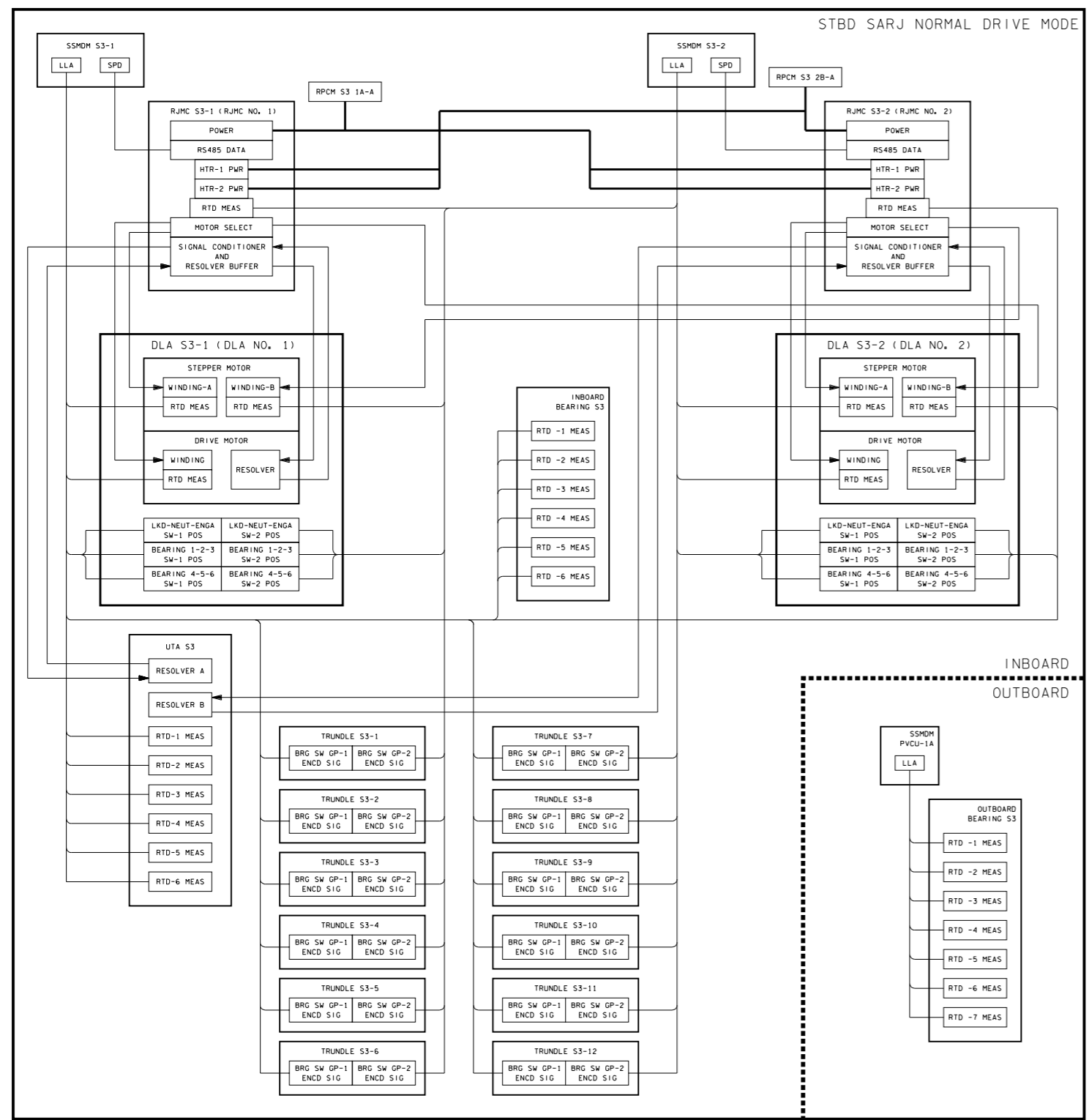
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DR	DESIGNED BY	1515/119
ENGR	DESIGNED BY	1515/119
APP	APPROVED BY	1515/119
CADD	DATE	12/08/08
TR	SCALE	1:1



S6 CARGO ELEMENT  
ISOMETRIC VIEW

# 4 S6 H/W O/V

SIGNATURE	DATE	NATIONAL AERONAUTICS AND SPACE ADMINISTRATION LYNN B. JOHNSON SPACE CENTER HOUSTON, TEXAS
DSGN S. JAMES	06/26/08	
ENGR D. KEISER		S6 HARDWARE OVERVIEW
APP		
APP	ADHISA	SWG NO 2.4
CADS	STS-119	
LTR	PCN	121 X 34



REFERENCE: MDC 94H070 REV E.2  
INTEGRATED ARCHITECTURE  
NOTEBOOK  
SOURCE DRAWINGS: 1F86181, 3R083742

# 5 SARJ CONN

SIGNATURE	DATE	NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
DR	6/29/05	LYNDON B. JOHNSON SPACE CENTER HOUSTON, TEXAS
ENGR D. KEISER		SARJ CONNECTIVITY
ENGR		
APP		
APP	ADH15A	DWG NO. 2.5
CADS	STS-119	
LTR	PCN	66 X 34



### **3.0 OPERATIONS SUMMARY**

#### **3.1 ASSEMBLY MISSION OVERVIEW FOR MISSION 15A**

Mission 15A (STS-119) is currently scheduled to launch No Earlier Than (NET) February 12, 2009 Eastern Daylight Time (EDT), aboard the Space Shuttle Discovery (OV-103). Mission 15A consists of a seven-person crew, which includes one ISS crewmember for rotation. STS-119 has a nominal mission duration of 14 days (4 undocked days + 10 docked days, +1 unscheduled docked day, +2 orbiter contingency or weather wave off days = 14+1+2). The flight provides 10 full docked days for ISS assembly, activation, and checkout activities. This extended docked timeframe is due to the capability of the Station/Shuttle Power Transfer System (SSPTS). The SSPTS is installed in the orbiter payload bay and converts 120 V dc power routed from the ISS into conditioned orbiter 28 V dc power, allowing the orbiter to conserve cryogenic fuel that is used to generate its electrical power. See Section 4.1.1 of this handbook for more details on the SSPTS.

The 15A mission serves to deliver and activate the S6 truss segment. This mission also performs four EVAs. These EVAs are conducted by the crew out of the ISS Joint Airlock. See Section 3.5.1 for more information concerning the EVAs. Reference the latest STS-119/15A Flight Requirements Document (FRD) (NSTS-17462-119) for more information.

<https://sspweb.jsc.nasa.gov/efrd/ViewFRD.cfm>

#### **3.2 MISSION SUMMARY**

The latest integrated flight planning manifest can be found at the following link:

<https://sspweb.jsc.nasa.gov/webdata/jis/FAWG/FAWG.pdf>

The preceding mission to STS-119/15A is STS-126/ULF2. Mission ULF2 delivers, activates, berths, and unberths the MPLM. ULF2 also manifests the Station Power Distribution Unit (SPDU) and Lightweight Multipurpose Experiment Support Structure Carrier (LMC). The mission following STS-119/15A is STS-127/2JA. STS-127/2JA installs the Japanese Exposed Facility (JEF) and the Japanese Experiment Logistics Module (ELM) to the port side of the JPM and manifests up to three experiments via the Japanese Experiment Logistics Module (JLE), which are transferred to the JEF (JLE is down-manifested empty in the shuttle PLB) to the port side of the JPM. The three experiments to be transferred via the JEM RMS to the JEF are the Interorbit Communication System (ICS) antenna and two JAXA payloads, Monitor of All-sky X-ray Image (MAXI) and Space Environment Data Acquisition equipment – Attached Payload (SEDA-AP).

### 3.2.1 Cargo Manifest

The primary cargo element delivered on ISS-15A is the ISS Integrated Truss Segment (ITS) Starboard Six (S6), which mates to ITS S5 and delivers the fourth and final PVM. The S6 PVM contains two SAWs, two beta gimbal/PV array assemblies, two Beta Gimbal Translation Structures (BGTs), one Integrated Equipment Assembly (IEA) – Type 1, one PV radiator and associated cabling. The S6 Long Spacer (LP) contains six battery sets and two spare BCDU ORUs. The LP utilizes both the SRMS and the ISS-provided SSRMS to accomplish the S6 install.

Reference the following PHALCON Systems Briefs for more detailed information on the PVM hardware:

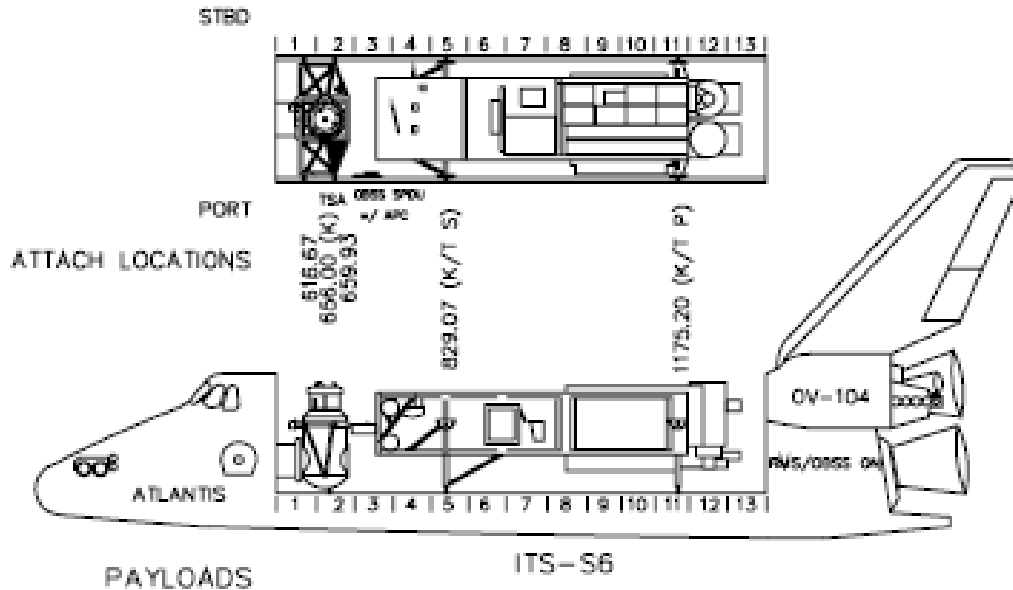
[http://mod.jsc.nasa.gov/di/di42/Training/Training\\_ORU\\_Specific/ORU\\_Spec\\_Lessons\\_list.html](http://mod.jsc.nasa.gov/di/di42/Training/Training_ORU_Specific/ORU_Spec_Lessons_list.html)

Structural dynamic characterization of the ISS using the External Wireless Instrumentation System (EWIS), which is located on the S6 truss segment, and the Structural Dynamic Measurement System (SDMS), which is located on the inboard truss elements of the ISS are performed to support the validation process of structural dynamic models.

Unique S6 Long Spacer equipment such as crew rotation equipment, special Extravehicular Activity (EVA) tools to support assembly operations, ISS Utilization payload samples/hardware and the ISS Portable Computer System (PCS) are stowed in the crew compartment.

Powered and passive ISS Middeck Utilization Payload hardware is transferred to the ISS.

Mated to the S6 PVM is a long spacer truss frame similar to the one on Portside Truss Structure, Segment 6 (P6). Unlike P6, the S6 long spacer contains no major ISS systems avionics. It also houses the capture bar, coarse alignment cones, fine alignment receptacles, and passive nuts of the EVA-driven RTAS, which is used to mate S6 to S5. Reference Figure 3-1 for the STS-119/15A Payload Bay (PLB) layout.



**Figure 3-1. STS-119/ISS-15A PLB layout**

The shuttle middeck on ISS-15A is filled with various ISS assembly and resupply hardware, logistics, and payloads. This includes EVA tools and equipment, PCS and Station Support Computer (SSC) accessories, Crew Health Care System (CHeCS) items, Photo/Television (P/TV) equipment, water transfer hardware, and a number of powered and unpowered ISS utilization payloads.

### 3.2.2 Priorities and Constraints

The S6 ITS is capable of safely sustaining the in-bay configuration until docking. The S6 ITS is removed from the PLB by the SSRMS which hands it off to the Shuttle SRMS while the SSRMS performs its walk off and the Mobile Base System (MBS) translates to WS1 on the MT. S6 is handed back to the SSRMS for installation on S5. The on-orbit tasks, sequence and duration that are required to be performed by the Shuttle for the International Space Station Program (ISSP), are provided by the ISSP to support timeline development. The ISSP mission activities that are provided by the ISSP, in a formal data submittal (which contains the ISS systems operations procedures provided by the ISSP), are used by the Space Shuttle Program (SSP) to develop an integrated orbiter/ISS FDF and Flight Plan to support the flight. The plan is developed using ISSP-supplied assembly/utilization crew activity requirements.

The STS-119/ISS-15A mission priorities are formally listed in the ISS Mission Integration Plan (MIP) NSTS-21510.

### **3.2.3 Rendezvous and Docking**

The orbiter has a rendezvous with the ISS at a planned altitude of 195 nautical miles (n. mi.). Nominal approach is along the +V bar to PMA2 on the Node 2 forward endcone with the ISS in the +XVV +Z nadir attitude. Prior to beginning the “final approach phase,” the orbiter performs the Roll and Pitch Maneuver (RPM) to allow the ISS crew to photograph the underside of the orbiter and inspect the orbiter tiles. Orbiter docking orientation is in the “tail-down” configuration (tail pointing toward Earth). For approach and docking, the ISS solar arrays are feathered to preclude thrust plume impingement on the array surfaces. ISS attitude moding is nominally performed automatically using the Androgynous Peripheral Attachment System (APAS) contact sensors, which signal the ISS to mode to free drift until a hard mate is established.

### **3.2.4 Docked Operations**

STS-119/15A is currently a 14+1+2 day mission with docking scheduled on FD03 and undocking scheduled on FD13. This gives the crew and ground ten full days of docked operations with some additional time available on FD3. After the shuttle docks with the ISS on FD03, the shuttle crew ingresses the ISS and begins performing middeck transfer operations. All hatches between the shuttle and ISS remain open throughout the docked mission since the four EVAs scheduled all occur from the ISS airlock. The ISS Control Moment Gyroscopes (CMGs) are nominally controlling the mated stack attitude. To conserve ISS propellant, attitude control is handed over to the shuttle (if propellant consumables are available) for performing attitude maneuvers and reboosts to a higher altitude. If time permits, additional transfer operations may be performed; however, the primary focus is on preparation for EVA 1 on FD05.

On the following day, the SRMS and SSRMS perform a double handoff to move ITS S6 out of the shuttle payload bay and into the install position. The crew also performs four EVAs. For detailed information on docked operations, refer to Sections 3.3 to 3.6 of this AOH.

Scattered throughout the docked timeframe, the crew is transferring items between shuttle to ISS, including transfers supporting the Flight Engineer (FE) crew exchange. For more information regarding transfer operations, refer to Section 3.7 of this handbook.

### **3.2.5 Departure**

The orbiter undocks from ISS on FD13. The ISS solar arrays are feathered and locked for undocking. ISS attitude hold is maintained until the orbiter has reached a clearance distance of no less than 600 ft. The orbiter performs a flyaround before departing.

### **3.3 S6 PRIMARY POWER CHANNEL 1B AND 3B ACTIVATION**

S6 activation is scheduled to begin and run in parallel with EVA 1 after the Extravehicular (EV) crew completes attachment of the S6 umbilicals. The S6 Primary Power Channel Activation is broken up into the following eight parts in order:

1. PVCU MDM Startup
2. Initial Channel Activation
3. PVTCS Activation
4. ECU Activation and Battery Config and Checkout
5. PVM Radiator Deployment
6. Battery Warmup
7. Battery Charging
8. Configure for Nominal Operations

These eight steps apply to each power channel 1B and 3B. Prior to starting power channel activation, there are preparation steps that need to be completed.

#### **3.3.1 Power Channel Activation Prep**

The following activities need to be complete before 1B and 3B power channel activation:

1. Seamless Power Channel Handover
2. Primary Power System (PPS) Powerdowns
3. Starboard SARJ Lock (needed for EVA1 to attach S5S6)
4. Starboard BGA Lock (needed for EVA1 to attach S5S6)

The Seamless Power Channel Handover cross ties Power Channel Buses 1A to 4A and Power Channel Buses 3A to 2A. These cross ties are completed by closing RBI 7 on all the MBSUs, which essentially shunt the master and slave power channels allowing the Port Power Channels to feed the Starboard Power Channels reducing ISS powerdowns needed prior to S6 attachment and activation. The difference between the Master and Slave channels is that the Master Channel always has the higher voltage regulation setpoint throughout the Seamless Power Channel Handover. For the Maximum Load Limit, the secondary loads of both channels Master and Slave should not exceed 9.0 kW immediately following the hot bus tie. If 12.2 kW (3 BCDUs) or 9.5 kW (2 BCDUs) is exceeded, then further ISS load shedding occurs until the total Output Power of less than the 12.2 kW or 9.5 kW bench marks are achieved.

Once the power downs are complete, the Starboard SARJ is locked, and the BGA locks by engaging the antirotation latch. Primary Power Channel Activation does not begin until the EVA crew completes attaching S5/S6 truss segment and the power and data umbilicals.

### **3.3.2 Part 1: PVCU MDM Startup**

After the S6 umbilicals are connected and MBSU 1 Remote Bus Isolator (RBI) 8 and MBSU 3 RBI 8 are closed, the 1B and 3B DCSUs are supplied power, which in turn supply power to the 1B and 3B PVCUs. The first procedure of the PVCU MDM startup is used for the activation of PVCU-3B. PVCU-1B is scheduled to be activated as a backup once PVCU-3B activation has completed. If necessary, PVCU-1B activation can wait until battery thermal conditioning and charging. The S6 PVR only receives power and control from the 3B channel. Although limited radiator telemetry is sent to both the 1B and 3B MDMs, only the PVCU-3B MDM can be used for control of the PVR motor.

The next three items to follow PVCU MDM startup are BCDU Disable Loss of Control (LOC) Safing, BCDU Thermal Inhibit, and BCDU Polarity Safing. These procedures are implemented to inhibit all six of the S6 BCDUs safing functions during power channel activation.

The last item before commanding the PVCUs into the operational state is inhibiting the Power Channels Remote Terminals Fire, Detection, Isolation, and Recovery (FDIR). This disables the S6 RPCMs, BCDUs, DDCUs, PFCSSs, ECUs, and SSUs Remote Terminal FDIRs on the S6 truss segment. Disabling the data bus failure logic associated with a single primary power channel is required because failure logic may take undesired action on data buses associated with inactive power channels. An example of an undesired action is the PVCU declaring bus failures causing many downstream remote terminals to go unpowered.

The next step is to verify the Pre-Positioned Loads (PPLs). The activation procedure has a table listing all of the S6 PPLs.

### **3.3.3 Part 2: Initial Channel Activation of Channel**

Part 2 of the S6 Activation of Power Channels 3B and 1B occur in the following order:

1. DCSU Activation
2. DDCU Input Activation and Checkout
3. BCDU Activation
4. SSU Checkout
5. Shunt SSU

DCSU Activation consists of some DCSU status checks and closing RBI 6. From that point, the DCSU is able to draw power from the ISS Primary Power (PWR) Bus Channels 1B and 3B.

PVM DDCU Input Activation and Checkout provides power to the DDCU and verifies that the DDCU firmware activates nominally. This is done by closing RBI 5. Once closed, MCC verifies the DDCU input telemetry and temperatures. This is done because enabling and verifying the DDCU on RBI 5 prior to the other ORUs address inrush current concerns. DDCU input activation is completed once the RT FDIR is enabled.

Before BCDU Initial Activation, MCC needs to verify that the Master Channel SSU is regulating the bus and the total shunt current is greater than 5A. If those conditions are met, then we proceed to finish the Initial Channel Activation with BCDU Initial Activation, SSU Checkout, and Shunting SSU. If the current is less than 5A, then the Activation skips to PVM DDCU Output Activation of Part 3: The Photovoltaic Thermal Control System (PVTCS) Activation.

BCDU Initial Activation is performed to apply power to a primary power channel battery during channel activation. At the end of this task, RBIs 2, 3, and 4 on DCSUs 1B and 3B are closed.

SSU Checkout establishes power input to the SSU and verifies nominal performance of the SSU prior to use in regulating solar array power. This is done by closing RBI 1 on both the 1B and 3B DCSUs. DCSU RBI 1 should be closed only during isolation while the Master Channel SSU is regulating the primary power bus. After RBI 1 is closed, the PDCU MDM remote terminal FDIR are enabled for the SSU.

Finally, MCC completes the Initial Channel Activation by shunting the SSUs. If the SSU/ECU covers are not removed by the EVA crew prior to shunting the SSUs, MCC has to monitor the SSU left and right sidewall temperatures. If either side reaches 72.8° C, then the SSU must be powered off for a minimum of two eclipse periods prior to reactivation.

### **3.3.4 Part 3: PVTCS Activation**

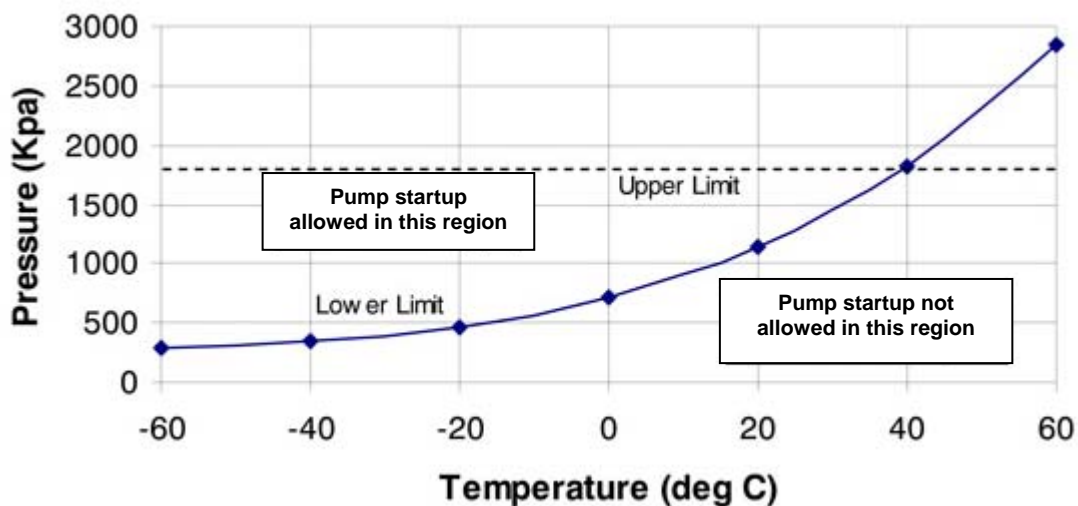
The PVTCS Activation is broken up into the following tasks:

1. PVM DDCU Output Activation
2. PVM RPCM Configuration
3. PVTCS Activation
4. Radiator Heater Activation

PVM DDCU Output Activation followed by PVM RPCM Configuration establishes PV Module DDCU power output to support downstream loads including the PVTCS, ECU,

SAW Deploy, and the BGA. Once the DDCUs are activated, MCC monitors a thermal clock until the PVTCS pumps are powered on. The length of the thermal clock is dependent on the beta angle. For the following expected conditions of a beta between -60° and 60°, an initial temperature less than 37.8° C, and an output power less than 1500 W, the S6 DDCUs can run for 1 hour without the PVTCS pump on.

PVTCS activation initializes and starts coolant flow for the primary power channel. Each of the two S6 power channels has a PVTCS system with Channel 1B being the upper channel and 3B being the lower channel. Channel 3B Pump/Flow Control Subsystem (PFCS) is activated first by closing Remote Power Controller (RPC) 3 on Remote Power Controller Module (RPCM) S6LWR-3B-A. Once the PFCS is powered on, the operator records the average Out Temp 1, Out Temp 2, Bypass Temperature, and Inlet Temperature. The PFCS can remain powered without a pump running for less than 2 hours if the temperature is greater than 37° C. The pump must be turned on to prevent damage to the PFCS electronics. If the temperature is less than 37° C, the PFCS can remain powered on for an unlimited amount of time. A reason to delay turning the pump on would be if PFCS inlet pressure is less than the allowable startup pressure. There is a potential for cavitations' below this pressure. The minimum startup pressure is plotted and the upper limit startup pressure is the dashed line at 1724 kPa in Figure 3-2 below.



**Figure 3-2. PVTCS Startup Pressure vs. Temperature**

Pump B spins up within 10 seconds after power up. If Pump B is successfully powered up, Pump A is not turned on. Pumps A and B are redundant of one another and do not operate simultaneously. During activation, Pump A is only used if Pump B has failed or is unavailable. After successful pump activation, the pump controls that were inhibited prior to activating the pump are turned on (i.e., PVTCS Closed Loop Control Algorithms, Pump Auto Switchover, Applying RPC Open Command Inhibit, PVTCS Minimum Inlet



Temperature Safing Algorithm, and Enabling PVTCS Max Outlet Temperature Safing Algorithms).

Radiator Heater Activation activates the heaters for PVTCS. Both the upper channel (1B) and the lower channel (3B) heaters are activated.

### **3.3.5 PART 4: ECU Activation and BCDU Configuration and Checkout**

ECU Activation is required for BGA and SAW control and necessary for SAW deploy on FD08. Both ECUs can run on a single supporting channel or in the nominal configuration where each ECU is supported by its respective power channel feed.

ECU Activation is run on the 3B ECU first, then the procedure runs again on the 1B ECU. The biggest constraint relative to ECU Activation is the shroud removal. If the shroud has not been removed as timelined in EVA1, the ECU can not be powered for more than 3 hours or until the BGA Power Supply (P/S) or SAW P/S temperatures exceed 51°C. Once the ECU is off, it must remain off for several hours. On the other hand, the ECU must be powered within 1 hour of shroud removal. BCDU Configuration and Checkout cannot begin until both Channels have been activated. For a description of the ECU, go to Section 2.2.1.5.6, Electronics Control Unit.

BCDU Configuration and Checkout requires that part 2 the Initial Channel Activation is complete and the total shunt current on the Master Channel is greater than 5A. The completion of the BCDU Configuration configures the BCDUs for Startup LOC safing. This puts the set points below the startup power source voltage to prevent battery discharge during checkout, warmup, and initial charging.

BCDU Pre-Warmup Checkout involves verifying the expected BCDU initial conditions prior to warm up and charging the batteries during primary power channel activation. BCDU 2 is charged before BCDU sets 1 then 3. The 2, 1, 3 priority allows Cold Plate (CP)-RBI power to BCDU 2 and the DCSU P/S on the other S6 channel first, then continues with CP to the SSU P/S and other BCDUs.

### **3.3.6 Part 5: PVM Radiator Deployment**

The PVM Radiator deployment cannot take place during an EVA because the crew is in the keep out zone for deployment. Before initializing the radiator deploy, all PVR Cinches and Winches must be removed by EV Crew and pressure in both thermal loops must be less than 1724 kPa. Higher pressures could damage the radiator during deployment.

When the initial PVR status checks are completed, the ISS/SSP stack must either be in CMG control with thrusters inhibited or in free drift, if the orbiter has attitude control. Thruster or Shuttle Reaction Control System (RCS) firings would risk possible structural damage to the PVR hardware when its motors are in motion. Once the PVR is deployed and the motors are turned off, the ISS/Shuttle stack resumes nominal attitude control followed by PVTCS and PVR status checks.

After PVM Radiator deployment is complete, the S4 BGAs are unlatched and returned to Autotrack. Also the 1A to 4A and 2A to 3A Power Channel bus ties performed in the Seamless Power Channel Handover are untied returning the power channels to their nominal configuration allowing powerup to all the loads that were shed prior to S6 attach.

### **3.3.7 Part 6: Battery Warmup**

Battery Warmup begins with the 1B2 and 3B2 BCDUs. Once warm up is complete, those batteries begin Part 7 Battery Charging, and the BCDU 1 sets begin Part 6 Battery Warmup, followed by the BCDU 1 sets charging and BCDU 3 sets beginning warm up on both power channels.

During BCDU 2 battery warm ups, the S6 BGAs are repositioned to the SAW Deploy position. This activity is only possible if the EV crew completes BGA launch lock release scheduled in EVA 1. BGA Launch Lock Release is discussed in Section 3.5.1.1.4. If the BGAs are not in the deploy position, battery warmup can press on. Battery warmup must be terminated for array deploy.

Also run in parallel with the Battery Warm up is positioning the S6 BGAs into the SAW deploy position. Go to Section 3.4.1 for more information on SAW Deploy.

### **3.3.8 Part 7: Battery Charging**

Each power channel has three BCDUs and six batteries with two batteries assigned to each BCDU. Batteries on BCDU strings 1B2 and 3B2 are charged at the same time. This is followed by batteries on BCDU strings 1B1 and 3B1, then lastly the batteries on the BCDUs 1B3 and 3B3 strings.

The first constraint is to battery charging whether or not the ISS is in eclipse mode. Based on Master Channel power availability, batteries on slave channel are either not charged or charged at a reduced rate in eclipse. The former requires time tagged commands to turn off the BCDU converter and open the FI before eclipse. The latter requires inhibiting of the SOC calculation and the new SOC set point uplinked. Nominal plan is to turn converters off and open the Focused Inspection (FI). Time to charge batteries can take up to 12 orbits depending on charge rate and charge method. Currently, each battery set is timed for 4 hours of charging. Battery set 2 is scheduled to start charging in the pre-sleep period of FD05. Battery sets 1 and 3 are scheduled to be completed with charging about halfway through FD06.

The BCDUs cannot be charged from their own array until the SAW is deployed and at least one BCDU is charged with its opposite channel control power feed. Otherwise, master channel charging should be continued.

### **3.3.9 Part 8: Configure for Nominal Operations**

Part 8 of the activation are all the clean up steps performed before the solar arrays are deployed on FD08. The solar arrays are not in their self-sustaining state until the SAWs are deployed. Part 8 begins with isolating the slave channel from the master channel. This is done by first opening the slave channels DCSU RBI 6, followed by unshunting the slave channel, then configuring Electronic Data Filter Method (EDFM), and lastly, LOC safing the BCDU. Once the slave channel is ready for nominal operations, the ground checks the statuses that the primary and backup PVCUs are in the nominal configuration and that the radiator is deployed. The power channel can be in self-sustaining mode without the radiator deployed. However, to support external loads, radiator deployment is necessary. Once those checks are complete, the channels' bus ties are made as necessary to reconfigure power to the downstream loads.

## **3.4 SOLAR ARRAY WING DEPLOY**

If FI is required, S6 SAW deploy activity happens over the span of flight days 5, 7, and 8. If FI is waved, then all of the FD07 and FD08 S6 SAW deploy activities are moved up to FD06. The SAW deploy activities scheduled for FD08 are replaced with a half off duty day for the crew. Since the nominal timeline plans for a required FI, the AOH documents the SAW deploy activities per that nominal timeline.

### **3.4.1 Flight Day 5 SAW Deploy Activities**

After the EVA crew has completed all of the S6 install activities on FD05, MCC commands the S6 BGAs to the Solar Array (SA) deploy position. SA thermal conditioning and visual verification requirements define the SAW deploy position and are discussed later in the section. During the battery warm up period, MCC feathers the starboard SARJ at 340° and run the 3B SABB Initial Unlatch followed by the 1B SABB Initial Unlatch. The purpose of these activities is to unlatch the blanket boxes and release the Blanket Restraint System (BRS) pins. Once complete, the BGAs are feathered and relatched into their deploy positions. The 1B BGA is locked at 60° and the 3B BGA is locked at 301°.

The BRS pin release requires the completion of the following EVA activities: deployment of the 4-bar linkage, the release of three bolts on the Mast tip fitting, and the rotation of the SABBs 90° from the launch configuration. There are a total of seven BRS pins on each SABB. Four BRS pins on the active side and three on the inactive side of each SABB. All BRS pins have to be visually confirmed released for each SABB. Once released, the BRS pins are never used again. Figure 3-5 shows all the BRS pin locations relative to the Tension Mechanism and Guide Wire Mechanism for each SABB.

The SABB unlatching, BRS pin release, and relatching are performed on FD05 as a test to verify that there are no SAW mechanism failures before heading into FD08. If a failure occurs, the Flight Control Team has extra days to replan FD08.

### 3.4.2 Flight Day 7 SAW Deploy Activities

The FD07 SAW Deploy activities are essentially prep activities that get the SAW primed for deploy on FD08. All FD07 activities take place during crew sleep periods. If powerdowns are needed for SAW feathering, they are performed first. If not the first step is to feather the S4 BGAs and lock the Starboard SARJ at 340°. This is followed by unlatching the S6 SABBs and deploying one bay from each mast. The day wraps up with relatching the SABBs in high tension. Figure 3-4 shows the solar array mast bay definitions. Figure 3-6 pictures 1 mast deploy in high tension mode.

### 3.4.3 Flight Day 8 SAW Deploy Activities

Just after crew wakeup on Flight Day 8, the ground maneuvers to SAW deploy attitude that places the 1B solar array within a 30° cone with respect to the normal of the array backside. This attitude is designed to maximize the thermal conditioning of the SA blanket and avoid shadowing of the Mast Longeron. Different attitudes are required for the 1B and 3B arrays. The 1B and 3B SA deploy attitudes are limited to a combined total of three insolation passes due to the external ISS hardware thermal limits. If the P6 array deployment takes longer than three insolation passes, the ISS must return to a pre-approved attitude to thermally recover from the SA deploy attitude. The exact attitude is beta angle dependent.

Below is an overview of the S6 Channel 1B/3B Solar Array deploy operations.

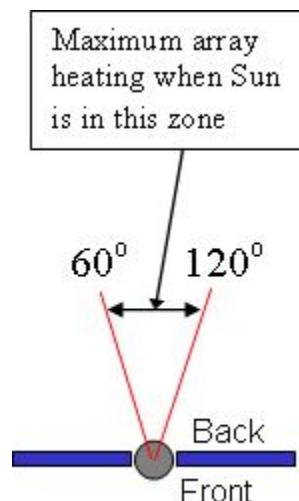
1. Handover to orbiter attitude control.
2. Maneuver to 1B deploy attitude.
3. Configure stack to free drift prior to mast motion.
4. At start of insolation, deploy 1B array to 49 percent.
5. Resume attitude control and thermally condition for 30 minutes.
6. Configure stack to free drift prior to mast motion.
7. Deploy 1B array to 100 percent (during insolation).
8. Feather 1B array prior to transitioning to ISS attitude control.
9. Handover to ISS attitude control.
10. Maneuver to 3B deploy attitude.
11. Configure stack to free drift prior to mast motion.
12. At start to insolation, deploy 3B array to 49 percent.
13. Resume attitude control and thermally condition for 30 minutes.

14. Configure stack to free drift prior to mast motion.
15. Deploy 3B array to 100 percent (during insolation).
16. Maneuver to mated Torque Equilibrium Attitude (TEA) attitude.

Note that the S6 channel 1B array is deployed under orbiter attitude control to avoid plume loads from ISS jets on the 1B array (facing aft towards ISS jets). ISS jets are not allowed while the SARJ is in the deploy position and channel 1B BGA not feathered. Similarly, the S6 channel 3B array is deployed under ISS attitude control to avoid plume loads from orbiter jets (facing forward towards docked orbiter).

The stack is required to be in free drift while the mast deploy motors are in motion. A mast bay is defined as one rigid batten to another rigid batten. During deploy, the crew monitors the tension reel and tension bar for motion. If during deploy the tension reel moves, then deployment is immediately aborted since the SA is experiencing stiction problems.

Thermally conditioning the SA blanket is to reduce the stiction forces on SA blankets Atomic Oxygen (AO) Coating. The AO coating on stowed SA panels over time fuses together. Stiction risk is why the 1B SA is deployed before the 3B SA. The 3B SA has been stored for 8 years versus 5.5 years (*relative to February 12, 2009 launch date*) for the 1B SA. To minimize stiction forces the array temperature must be maximized during deployment by maintaining a solar incidence angle between  $60^\circ$  and  $120^\circ$  on the back surface of the solar array. The 3B array is deployed after the 1B array to buy more thermal conditioning on that array. Figure 3-3 shows the thermal conditioning sun angle requirement for SA deploy.

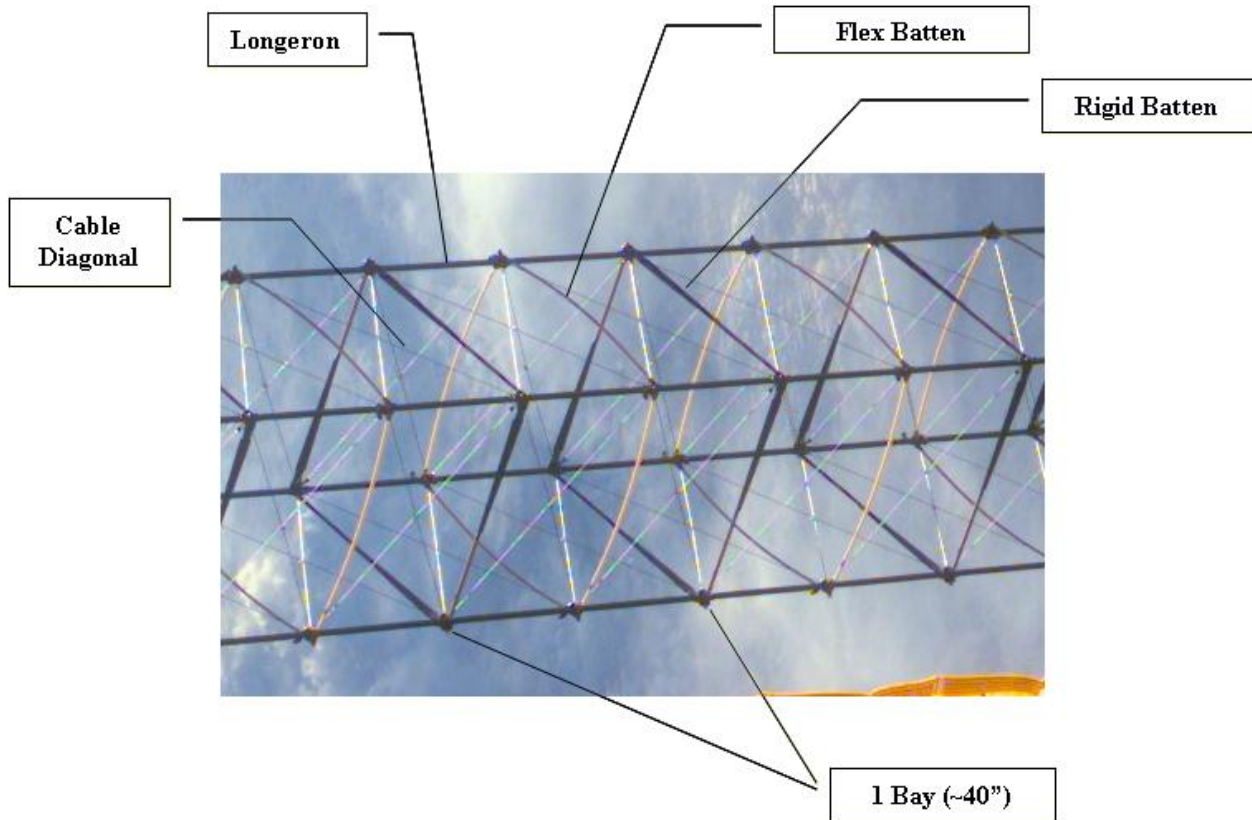


**Figure 3-3. Thermal Conditioning  
Sun angle requirement**

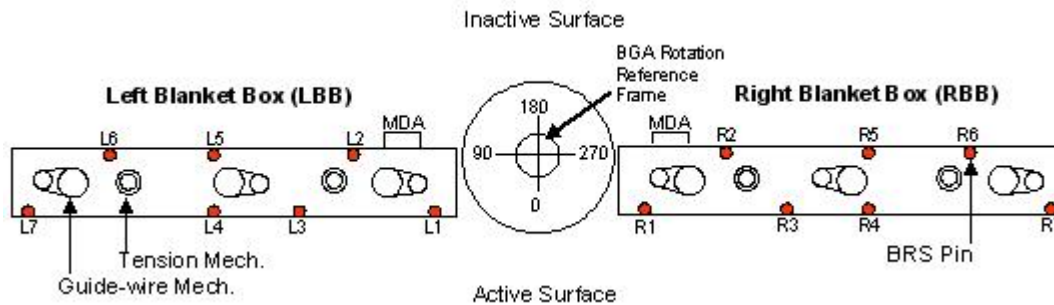
After the SA blanket has been thermally conditioned for 30 minutes, the vehicle stack is commanded to free drift and the remainder of the SA is deployed (100 percent or 31.5 mast bays). Deployment to 49 percent is completed during insolation to reduce any stiction forces and allow the crew to visually monitor SAW deployment. Deploying from 49 percent to 100 percent is the most likely time to experience stiction problems. So, if the crew sees the inboard tension reel rotate 1/8 turn between 49 percent and 75 percent, or a 1/4 turn from 75 percent to 98 percent, deploy is aborted immediately. Also during deploy from 75 percent to 98 percent, if either of the tension bars rise up greater than 3 inches from the blanket box sill, the deploy is aborted. Between 98 percent to 100 percent deployed (the last 1/2 bay), the tension bars of both blanket boxes rise about 20 inches off the blanket box sill, and the tension mechanisms rotate approximately 1.5 turns. The mast deploy limit switches indicate when the arrays are 100 percent deployed.

If during the SA deploy unacceptable motion is observed in the tension reel or tension bar, then deployment is aborted and the crew enters into the SA deploy malfunction procedure. The malfunction procedure applies a small amount of tension on the SA blanket to help mechanism motions. After the small SA blanket tension is applied, the SA blanket is thermally conditioned to reduce the blanket stiction forces. Once an SA panel or several panels release, the crew again incrementally moves the SA mast. If the crew does not observe unacceptable movement of the tension reel, then the SA continues to be deployed. If again additional stiction problems are encountered, the small tension is maintained until more SA panels are released, and a small tension is applied. This process is repeated until the SA blanket is fully deployed.

If deploy to 100 percent is not completed in one insolation period, the crew stops the SA deploy and returns to the appropriate deploy attitude. Once the sun rises on the next orbit, the SA blanket is thermally conditioned for 30 minutes, and the deploy sequence continues. Reference Figure 3-7 for the SA deploys timeline options.



**Figure 3-4. Solar array mast bay definitions**



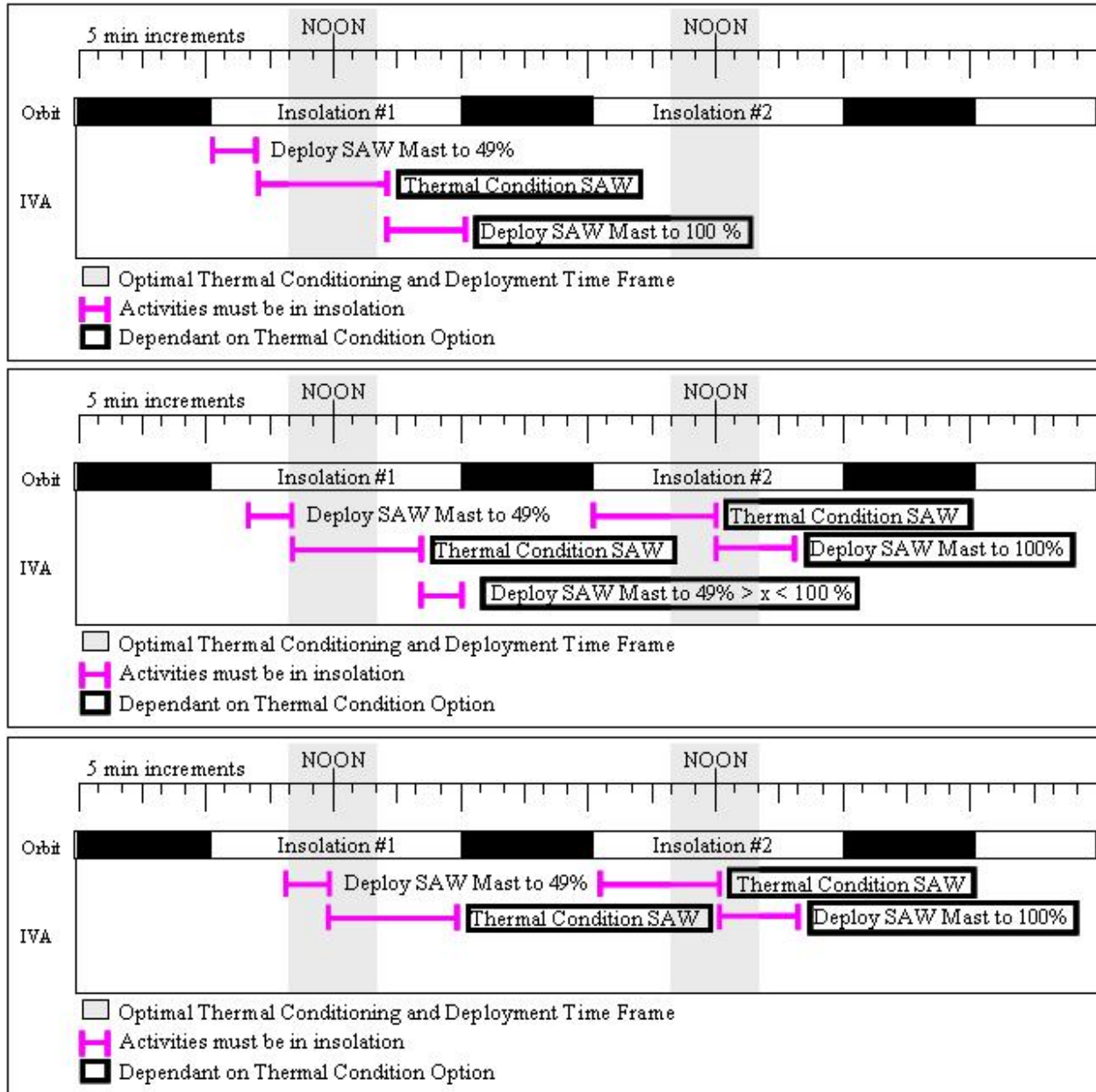
**Figure 3-5. BRS Pin, Guide-wire Mech, and Tension Mech Locations**



S116E06885

*Figure 3-6. One mast deployed and SABs in high tension mode*





**Figure 3-7. SA Deploy Timeline Options**

### 3.5 EXTRAVEHICULAR ACTIVITY OPERATIONS

Mission STS-119/15A has a total of four EVAs. The following sections describe the EVA tasks performed on this flight. The tasks for EVA 1 are set. Since EVAs 2 - 4 are mostly unique Get-ahead tasks, they are subject to change as the mission gets closer to launch. The sections below outline EVAs 1 through 4. It is recommended to double check the latest timeline overview and summary at the link below for the latest updates to EVAs 1, 2, 3, and 4 tasks.

[http://mod.jsc.nasa.gov/dx/DX32\\_b/15A/STS-119timelines.html](http://mod.jsc.nasa.gov/dx/DX32_b/15A/STS-119timelines.html)

### **3.5.1 Scheduled Extravehicular Activity Tasks**

#### **3.5.1.1 EVA 1**

The purpose of EVA 1 is to attach the S6 ITS to S5 of the ISS and get S6 into a good configuration for activation. All tasks scheduled on EVA 1 are required for S6 activation. EVA 1 takes place on FD05. Prior to the start of EVA 1, the starboard SARJ is commanded to the S6 install position and locked, and the S6 segment is moved to the preinstall position. BGAs 1A and 3A are positioned and locked. The port SARJ is also locked due to load constraints prohibiting EVA operation onboard of the SARJ while either SARJ is unlocked. Prior to EV crew helmet donning, the crew performing EVA prep and the Robotics crew must pass a sync point. If the array positioning occurs too early before the EV crew's egress, then there is the risk of getting out of power balance due to the arrays being feathered. If the EV crew dons helmets too early relative to the S6 ITS arrival to the preinstall position, then there is the risk of prematurely using EMU CO<sub>2</sub> removal assets when they are needed to maximize EVA time. It is necessary to give the EV crew a GO for helmet donning when the truss begins motion (via Joint Operator Commanded Automatic Sequence (OCAS)) to the preinstall position. Both EVA crews are in Free Flight (FF) for the duration of the EVA. The scheduled tasks for EVA 1 are as follows:

1. Attach S6 to S5.
2. Connect S5 to S6 Umbilicals.
3. Release SABB Restraints.
4. PVR Cinches and Winches Release.
5. Keel Pin Rotation.
6. BGA Release.
7. SSU and ECU Blanket Removal.
8. Unstow Nadir (1B) and Zenith (3B) SABBs.

Figure 3-8 displays all of the S6 install task locations. Table 3-1 shows the EVA 1 task list.

**Table 3-1. EVA 1 Task List**

PET HR : MIN	IV/SSRMS	EV1 – Swanson	EV2 – Arnold	PET HR : MIN
00:00	SSRMS: S6 Pre-Install setup	<b>EVA 1 POST DEPRESS, EGRESS &amp; SETUP (00:50)</b> <ul style="list-style-type: none"> <li>• Post Depress/Egress (00:20)</li> <li>• Setup (00:30)</li> <li>• Translate to S5 (retrieve APFR from CETA cart)</li> <li>• Install APFR in S5 WIF 11</li> </ul>	<b>EVA 1 POST DEPRESS, EGRESS &amp; SETUP (00:50)</b> <ul style="list-style-type: none"> <li>• Post Depress/Egress (00:20)</li> <li>• Setup (00:30)</li> <li>• Translate to S5</li> <li>• Temp stow crewlock bag on S5</li> </ul>	00:00
01:00	SSRMS: S6 Pre-install Position	<b>ATTACH S6 to S5 (01:05)</b> <ul style="list-style-type: none"> <li>• RTAS Bolt 1 &amp; 2 Check at 150 cm</li> <li>• GCA at 30 cm</li> <li>• GCA at 15 cm</li> <li>• GCA to first contact</li> <li>• Verify Impending CLA contact</li> <li>• Bolt initial torque</li> <li>• Bolt 1 and 3 final torque</li> </ul>	<b>ATTACH S6 to S5 (01:05)</b> <ul style="list-style-type: none"> <li>• RTAS Bolt 3 &amp; 4 Check at 150 cm</li> <li>• GCA at 30 cm</li> <li>• GCA at 15 cm</li> <li>• GCA to first contact</li> <li>• Drive CLA</li> <li>• Ground strap install</li> <li>• Bolt 2 and 4 final torque</li> <li>• Release CLA</li> </ul>	01:00
	SSRMS: GCA to first contact			
	SSRMS: Limp after initial CLA contact			
02:00		<b>CONNECT S5 to S6 UMBILICALS (00:55)</b> <ul style="list-style-type: none"> <li>• Connect umbilicals (4)</li> <li>• Move APFR to S6</li> </ul>	<b>CONNECT S5 to S6 UMBILICALS (00:55)</b> <ul style="list-style-type: none"> <li>• Connect umbilicals (assist EV1)</li> </ul>	02:00
	√MCC-H GO for S5 to S6 umbilicals			
	√MCC-H in CMG Control			
03:00	SSRMS: S6 ungrapple	<b>PVR CINCHES AND WINCH RELEASE (00:45)</b> <ul style="list-style-type: none"> <li>• Release cinches (6)</li> <li>• Release winch PIP pin (2)</li> </ul>	<b>RELEASE SABB RESTRAINTS (01:35)</b> <ul style="list-style-type: none"> <li>• Release Nadir/Inboard SABB</li> <li>• Release Nadir/Outboard SABB</li> <li>• Release Zenith/Inboard SABB</li> <li>• Release Zenith/Outboard SABB</li> </ul>	03:00
		<b>KEEL PIN ROTATION (00:15)</b>		
04:00		<b>BGA RELEASE (00:30)</b> <ul style="list-style-type: none"> <li>• Release TA Clamps, Zenith BGA Bolts (00:15)</li> <li>• Release TA Clamps, Nadir BGA Bolts (00:20)</li> </ul>		04:00
		<b>UNSTOW NADIR (1B) SABB (01:00)</b> <ul style="list-style-type: none"> <li>• Deploy Nadir SABB Wing</li> <li>• Release Mast Tip Fasteners</li> </ul>	<b>UNSTOW ZENITH (3B) SABB (01:00)</b> <ul style="list-style-type: none"> <li>• Deploy Zenith SABB Wing</li> <li>• Release Mast Tip Fasteners</li> </ul>	
05:00				05:00
		<b>SSU AND ECU COVER REMOVAL (00:10)</b> <b>CLEANUP AND A/L INGRESS (00:55)</b>	<b>SSU AND ECU COVER REMOVAL (00:10)</b> <b>CLEANUP AND A/L INGRESS (00:55)</b>	
06:00		<b>PRE-REPRESS (00:05)</b>	<b>PRE-REPRESS (00:05)</b>	06:00
	EVA 1 PET = 06:30 hr			

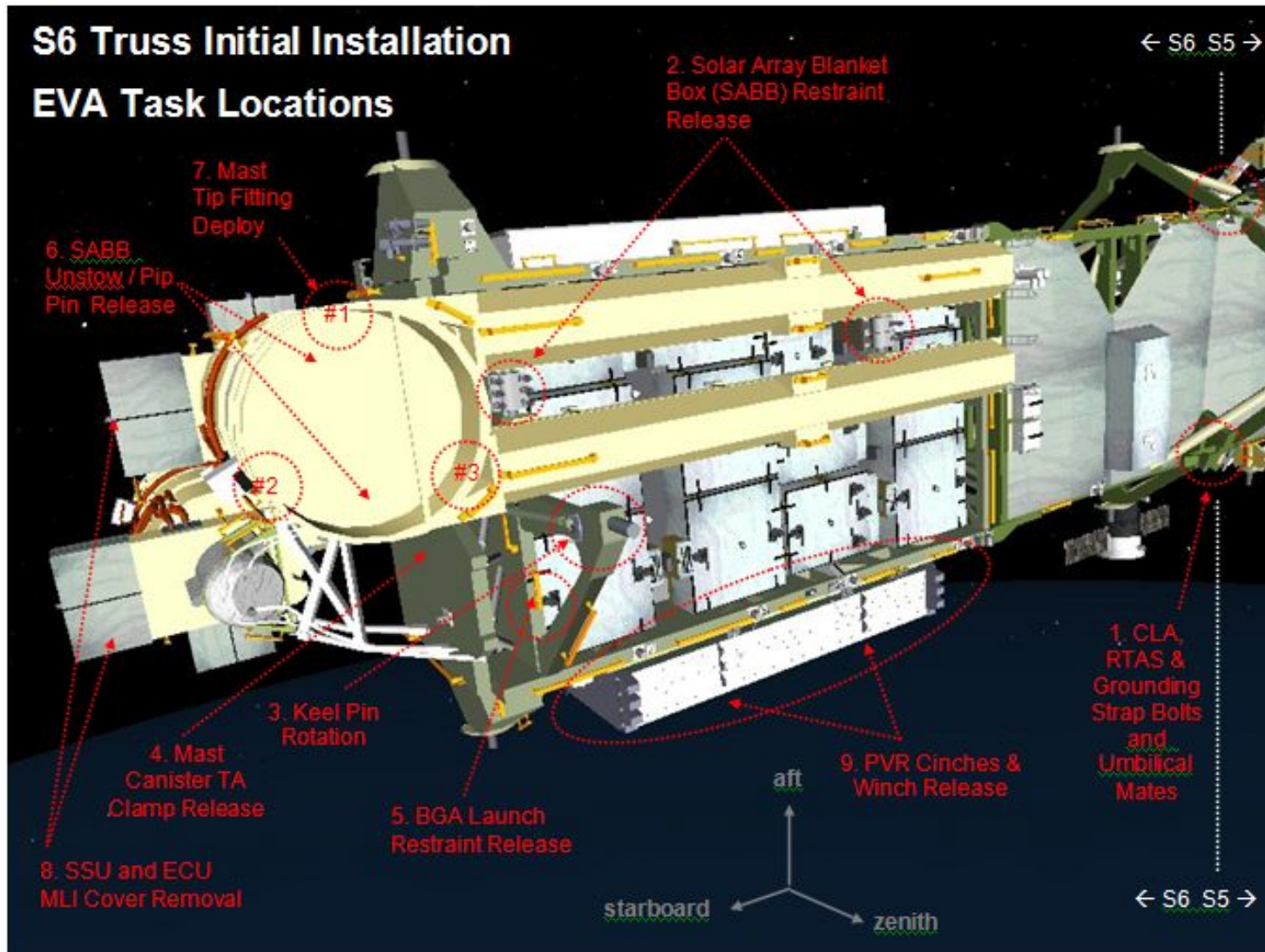
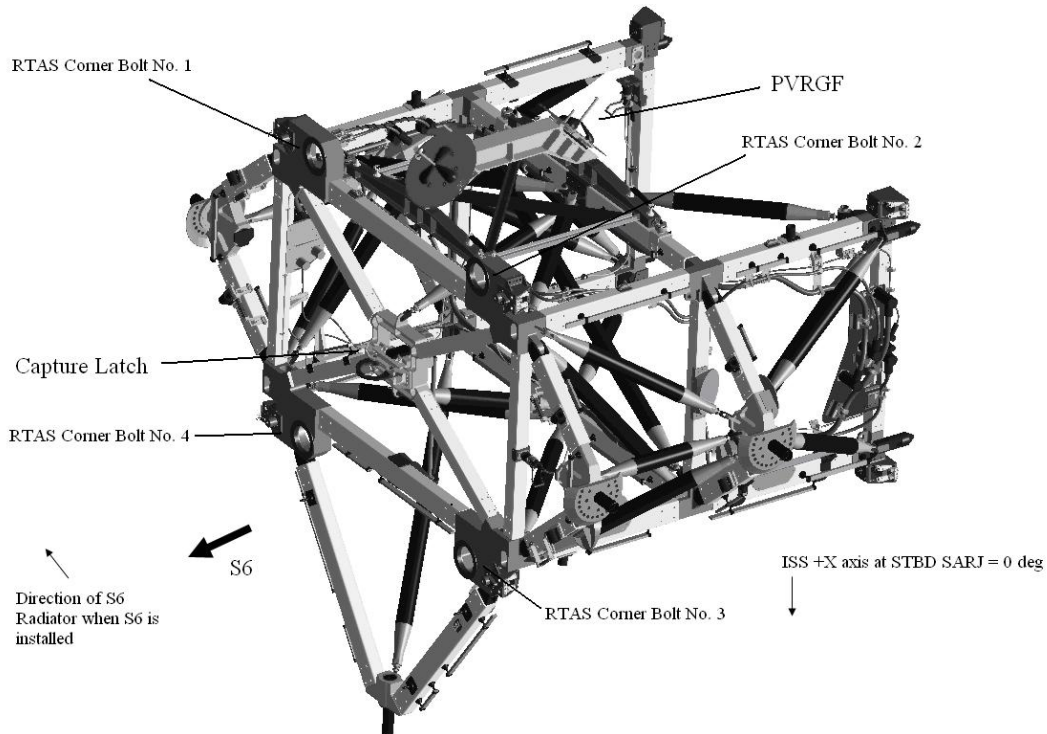


Figure 3-8. S6 Install task locations

### 3.5.1.1.1 Attach S6 to S5

The first operation is to attach the S6 element to the S5 truss section using the RTAS. The active half of the RTAS, located on S5, contains four primary attachment bolt mechanisms and one capture latch assembly that attaches to the passive side on S6. The active side of the RTAS is shown in Figure 3-9. The S6 side of the interface is a passive device that contains four primary attachment bolt receptacles, one capture latch bar, and four coarse alignment cones. Figure 3-10 shows the S6 interface.

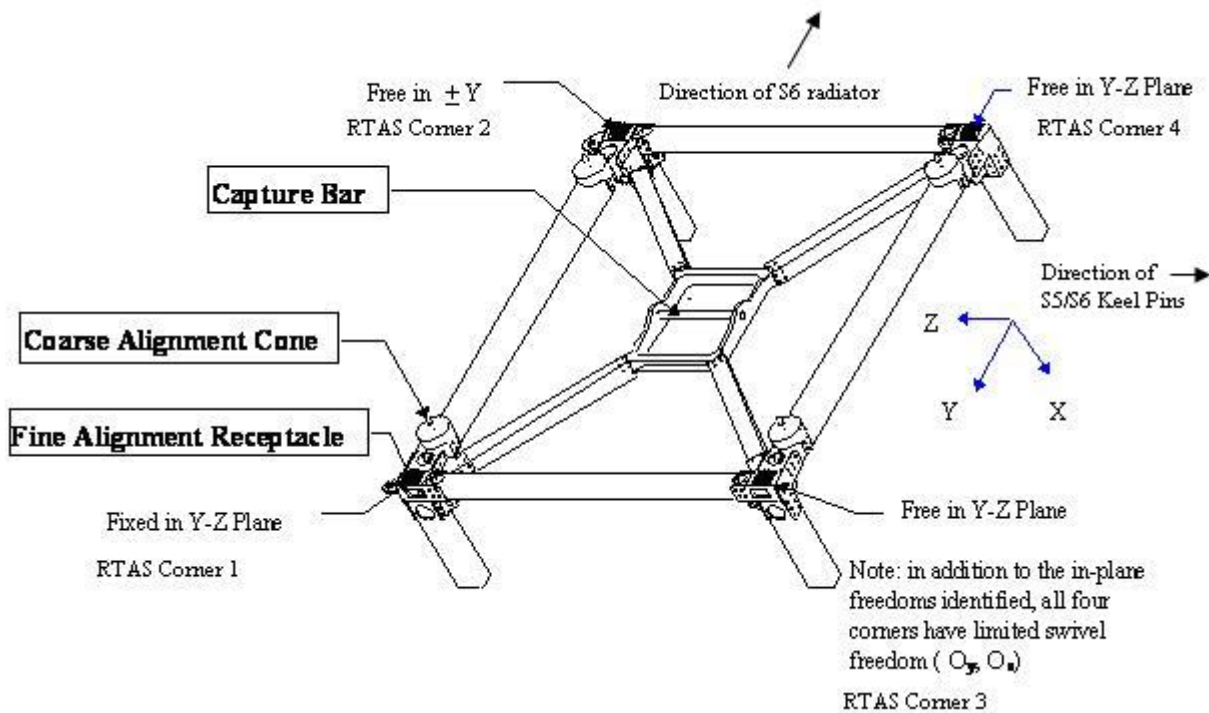


**Figure 3-9. Active RTAS side on S5**

The first step in the S6 to S5 installation process is to maneuver the S6 element into the Ready-to-Latch (RTL) position using the SSRMS. EVA crewmembers Ground Control Assist (GCA) S6 to the RTL position, and verify the element is in the RTL position by confirming that all four S6 coarse alignment cones protrude into the S5 bushings. In this position, the capture bar is within the capture envelope of the capture latch assembly, and the coarse alignment guides are within their respective envelopes.

Once the S6 is in the RTL position, an EVA crewmember drives the capture latch assembly, using a PGT, which causes the fingers of the capture latch to close on the capture bar. This closing action results in a preload applied to the primary bolt mechanism. After the capture latch is driven to a hard stop, the EVA crewmembers measure the distance at the RTAS corners using a small equipment tether hook. The gap between all four S6 to S5 housing surfaces must be less than 0.6 inches prior to primary bolt driving.





**Figure 3-10. Passive RTAS side on S6**

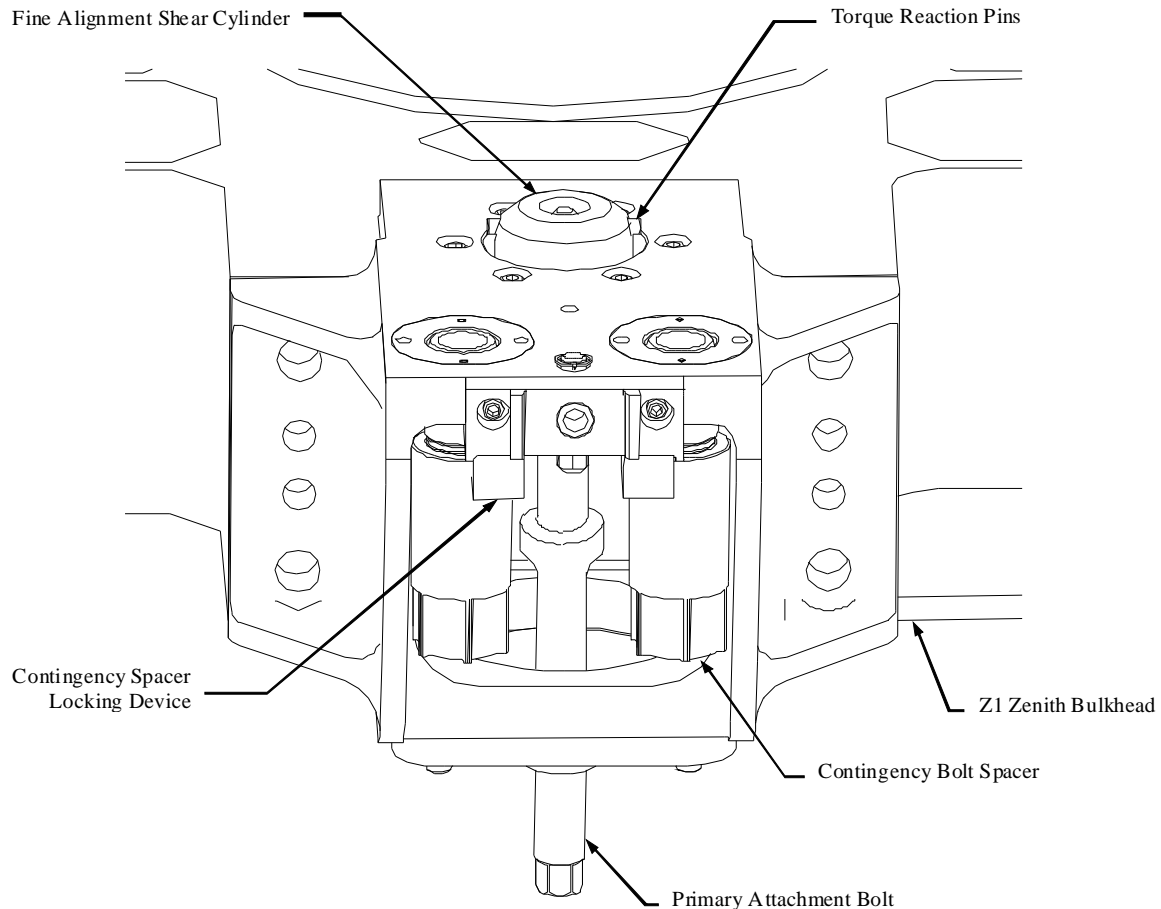
Using a PGT, the next step is for the EVA crewmember to drive the primary attachment bolts (four, one at each corner) to their final torque values of 57 ft-lb for bolts 1 and 3; 52 ft-lb for bolts 2 and 4. Bolt 1 is required to be fastened first, directly followed by bolt 2. Bolt 3 and bolt 4 can be completed in either order. After bolt torque, the EV crewmember measures the distance between the S6 to S5 housings with a small equipment tether hook. The distance must be a minimum of 0.33 inches and a maximum of 0.576 inches after primary bolt driving. During the bolt driving, there are Communications checks every ten seconds to protect against the SSRMS safing. If communication is not confirmed after 12 seconds, the EV crew stops bolt driving until communication is regained. After this check is completed, one side of a grounding strap located near each bolt is released from S6 and attached to S5 to ensure proper grounding. After all bolts are secured, the capture latch is released and driven back to its RTL position. The primary bolt mechanism is shown in Figure 3-11.

### 3.5.1.1.2 Connect S5 to S6 Umbilicals

After verifying that the power inhibits are in place, the EVA crewmember connects the four S5 to S6 power and data utilities.

There are two power connectors, P259/J259 and P260/J260. These connections are used to start up the S6 power channels and to supply S6 power to ISS. P259/J259 connects S6 power channel 1B DCSU to the MBSU 1 input. Harness W01-P259 on S5 is disconnected from dummy receptacle S5 J159 and connected to S6 J159.

P260/J260 connects S6 power channel 3B DCSU to the MBSU 3 input. Harness W01-P260 on S5 is disconnected from dummy receptacle S5 J160 and connected to S6 J160. Since the power inhibit for these connections is to open one RBI on the respective MBSU input, no powerdowns of station loads are required.



Note: Shown with launch restraint cap removed prior to berthing

**Figure 3-11. Primary attachment bolt mechanism**

The two data connectors, P253/J153 and P254/J154, connect the 1553 buses that communicate between the PMCU Multiplexer/Demultiplexers (MDMs) in the U.S. Lab and the S6 channel PVCU MDMs. P253/J153 connects the A side of the Local Bus (LB) PMCU-1 and LB PMCU-3 1553 buses. Harness W02-P253 on S5 is disconnected from dummy receptacle S5 J153 and connected to S6 J153. P254/J154 connects the B side of the LB PMCU-1 and LB PMCU-3 1553 buses. Harness W02-P254 on S5 is disconnected from dummy receptacle S5 J154 and connected to S6 J154. The A and B channels of the 1553 buses are redundant, so a minimum of one of these connectors must be mated to activate the S6 power channels.

### **3.5.1.1.3 Release of Solar Array Blanket Box Launch Restraints**

The next EVA operation is to release the SABB launch restraints. The SABBs are secured to the IEA for launch by two brackets that restrain trunnion fittings on the blanket boxes themselves. On the outboard end of the IEA, a clamshell bracket restrains movement of the SABB during launch. This clamshell is composed of two separate pieces, with the lower bracket attached to the IEA and the upper bracket plate secured to the lower bracket via six 5/8-inch bolts. When the six clamshell bolts are tightened, an SABB trunnion extending perpendicular to the SABB is clamped between the upper and lower brackets and secured to the IEA. The EVA crew unfastens the six captive bolts on the upper plate, thus releasing the SABB trunnion. The upper bracket is then stowed in an Orbital Replacement Unit (ORU) transfer bag.

The inboard bracket is also a clamshell design; however, it is held in place with only two 5/8-inch bolts. The EVA crew unfastens the two captive 5/8-in. bolts to release the SABB trunnion and rotates the upper plate backward until a soft detent is engaged. Figure 3-12 shows the location of the two brackets on the IEA and the bracket detail.

### **3.5.1.1.4 Release of Solar Array Wing Beta Gimbal Launch Restraints**

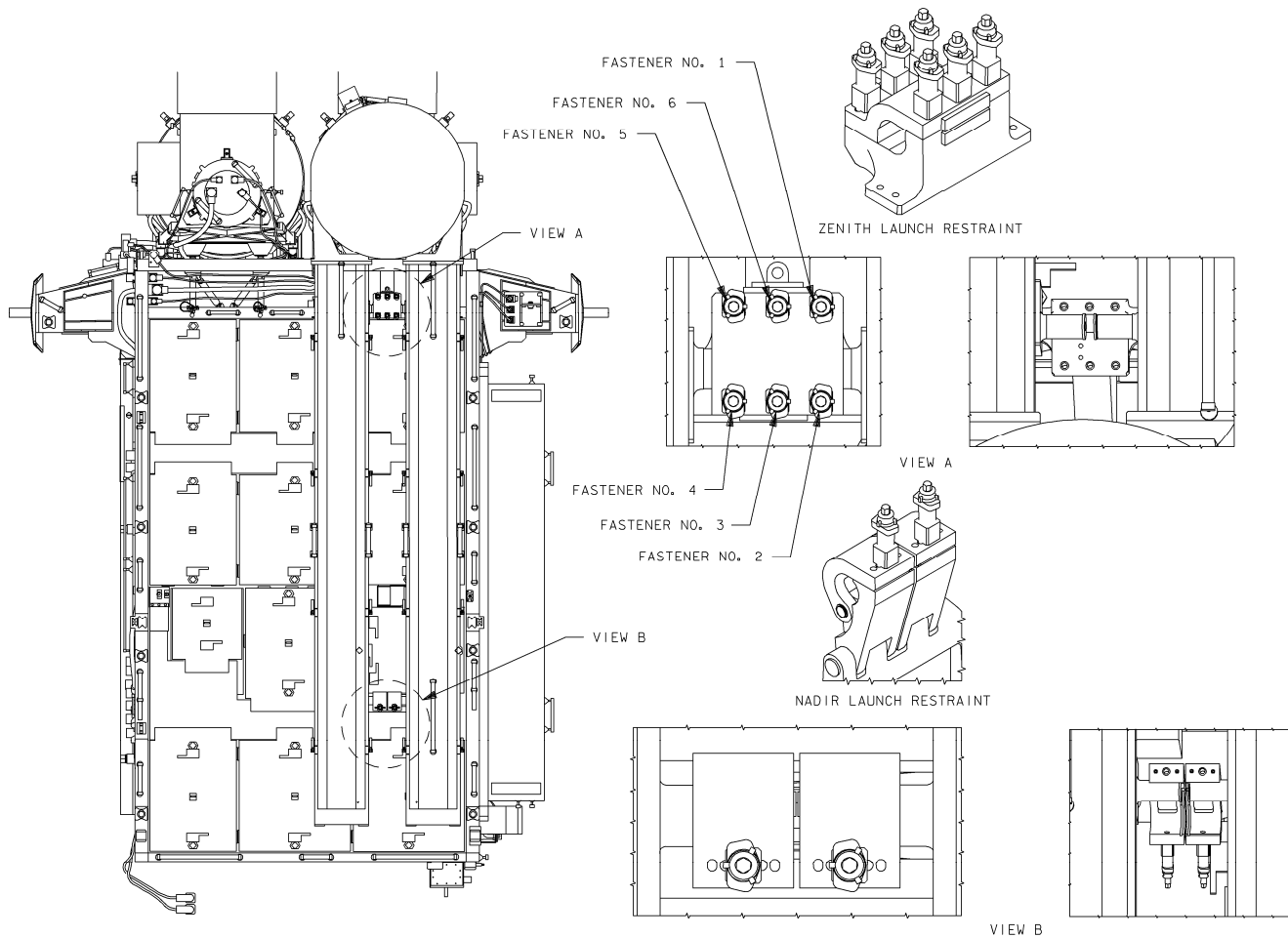
The BGA serves as the structural interface between the IEA and the SAW. The BGA has three TA clamps that secure the BGA power/data cable to the IEA bulkhead during launch. In addition, the BGA has two bolt assemblies that prevent BGA deployment because of launch loads. The SABB launch restraints must be removed prior to BGA deployment.

As shown in Figure 3-13, when the BGDTS (the four-bar deployable linkage system that structurally attaches the BGA to the IEA) is in the folded configuration, the BGA platform is flush against the IEA outer bulkhead.

For deployment, the EVA crew first unfastens the TA clamps to provide sufficient slack in the cable to support BGA deployment. While in the vicinity, the EVA crew next removes the ECU and SSU thermal covers to preclude overheating during SAW activation. The next step is to release the bolt retention system. The BGA platform contains a nut assembly that extends toward the IEA bulkhead. A bolt extending through the IEA bulkhead to the nut assembly serves as the retention mechanism. This retention bolt assembly has an EVA interface on the side opposite the nut assembly. The retention bolt assembly has an antirotation pip pin to prevent inadvertent rotation of the bolt during launch. The EVA crew pulls the pip pin and uses a PGT to disengage the retention bolts 50 turns. See Figure 3-14 for launch restraint detail.

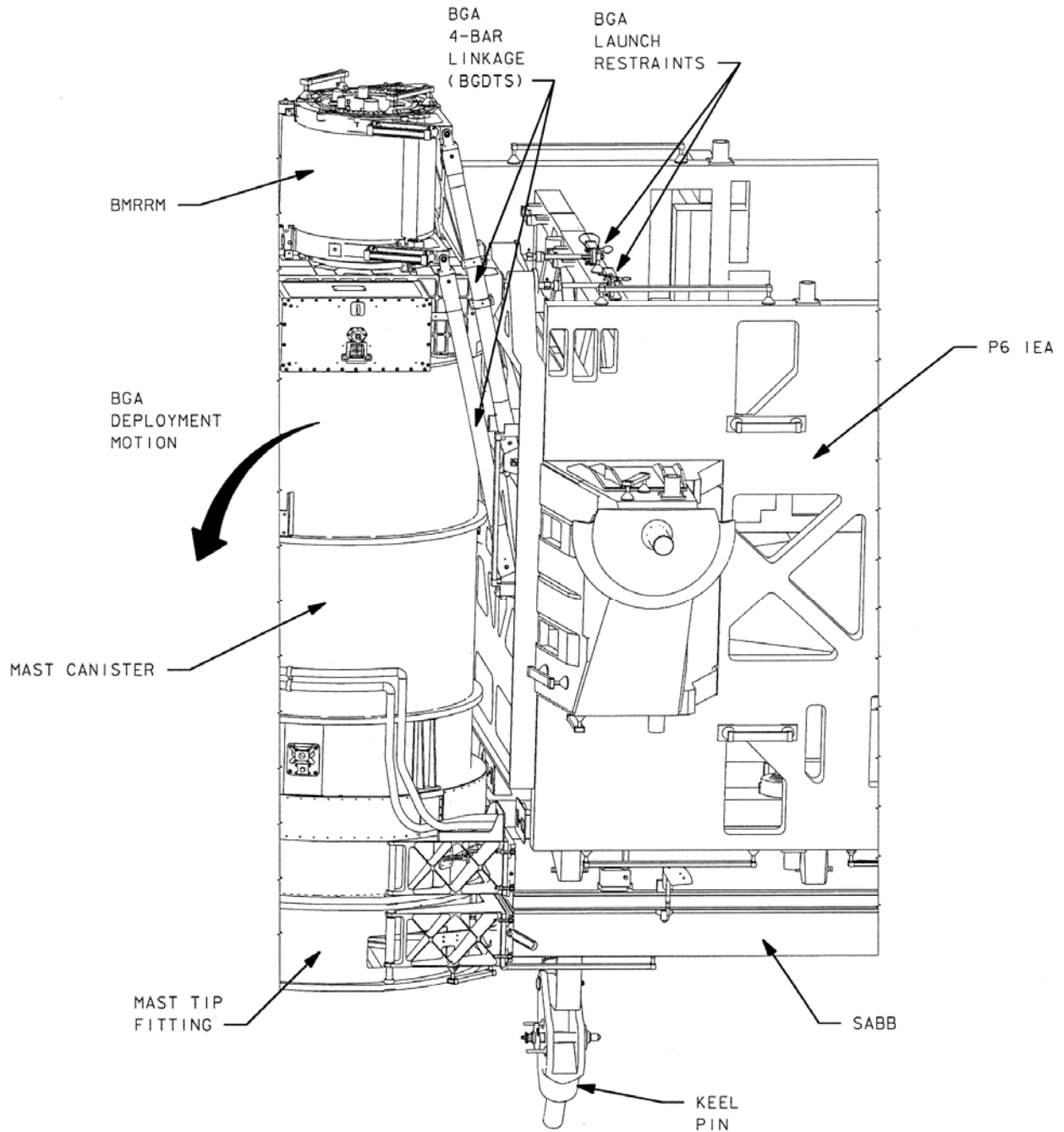
At the release of the second bolt, the BGA is free to swing outward and upward/downward into its deployed position via a spring force. The BGDTS has eight hinge locks (two per hinge) that lock the BGA into the deployed position (see Figure 3-15). If the spring force is not sufficient for full deployment, the EVA crew can exert a small force on the BGA to achieve full deployment. After deployment, the antirotation pip pins are reinserted into their original locations.





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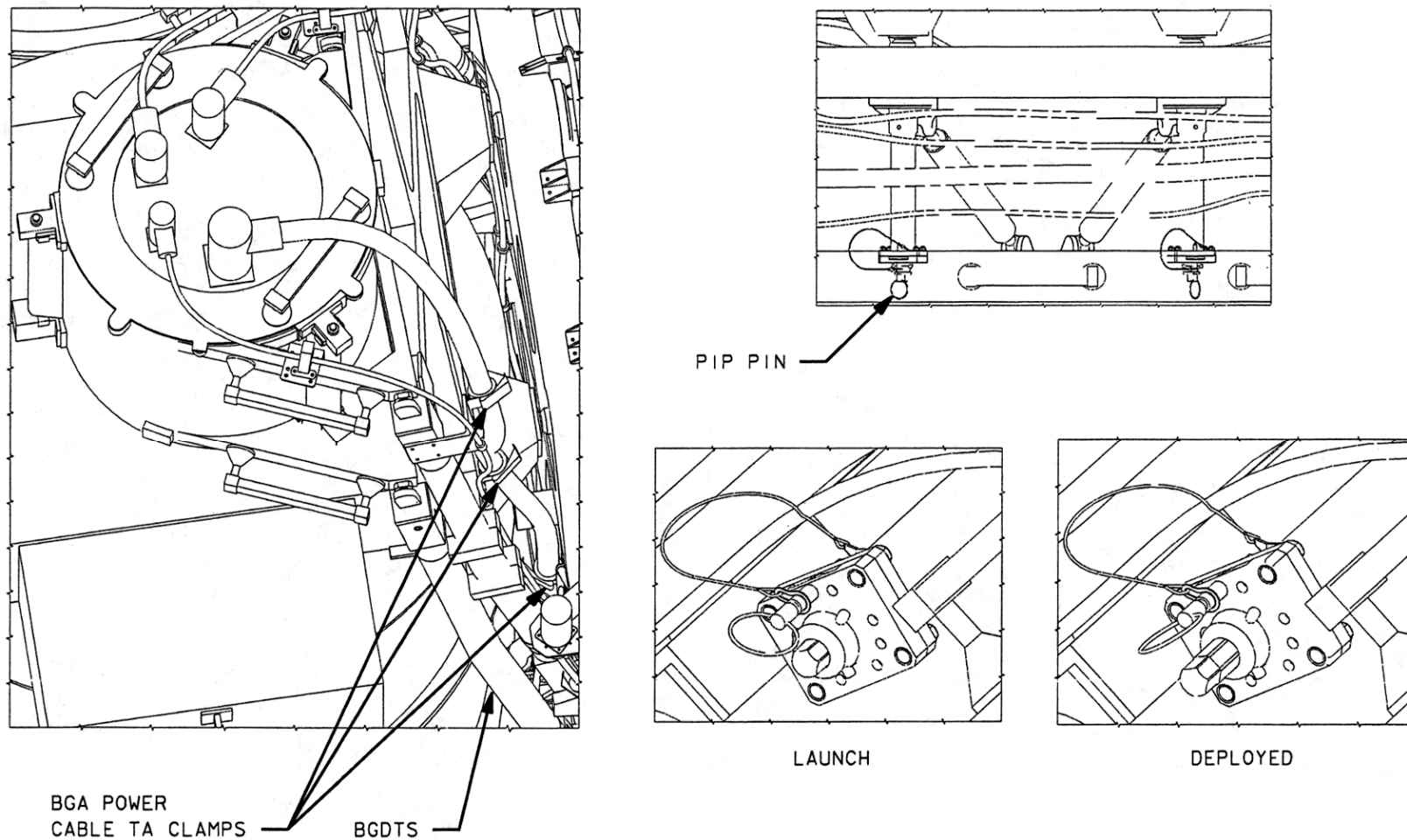
**Figure 3-12. SABB launch restraints**



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**Figure 3-13. BGA launch configuration**

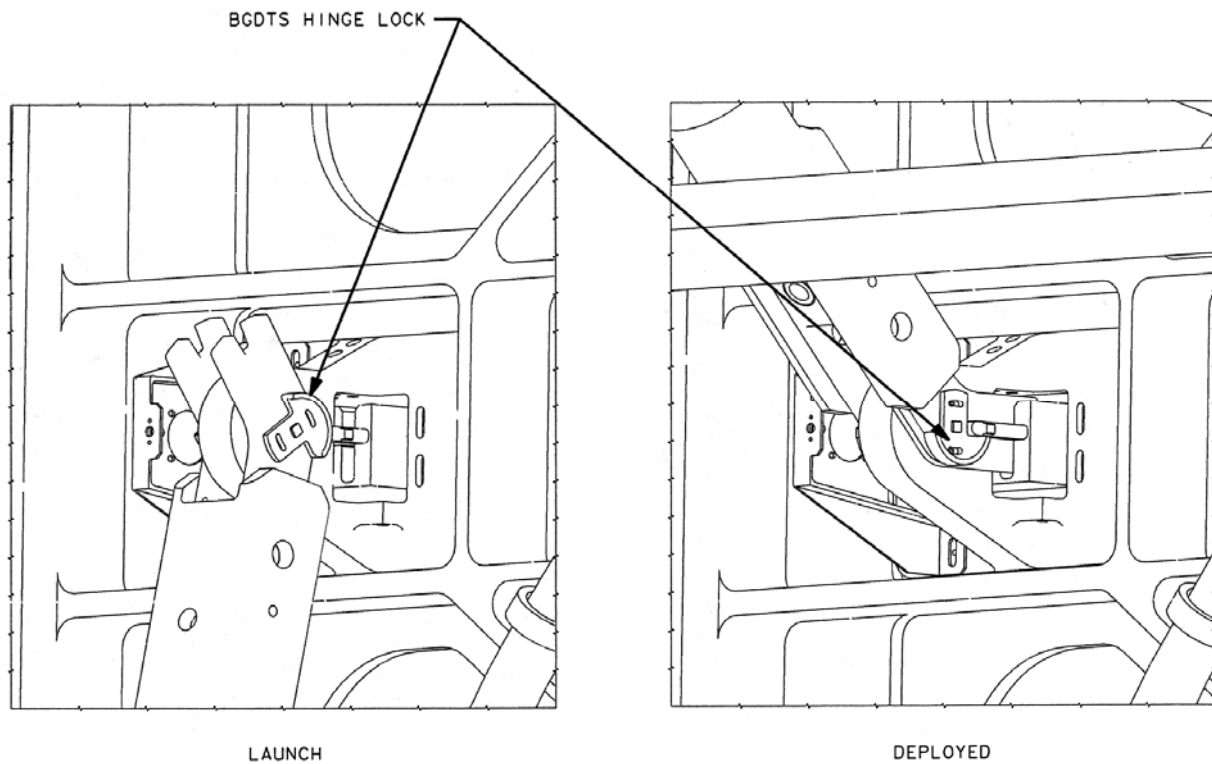
**Verify that this is the correct version before use**



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**Figure 3-14. EVA interface to the BGA launch restraints**

**Verify that this is the correct version before use**

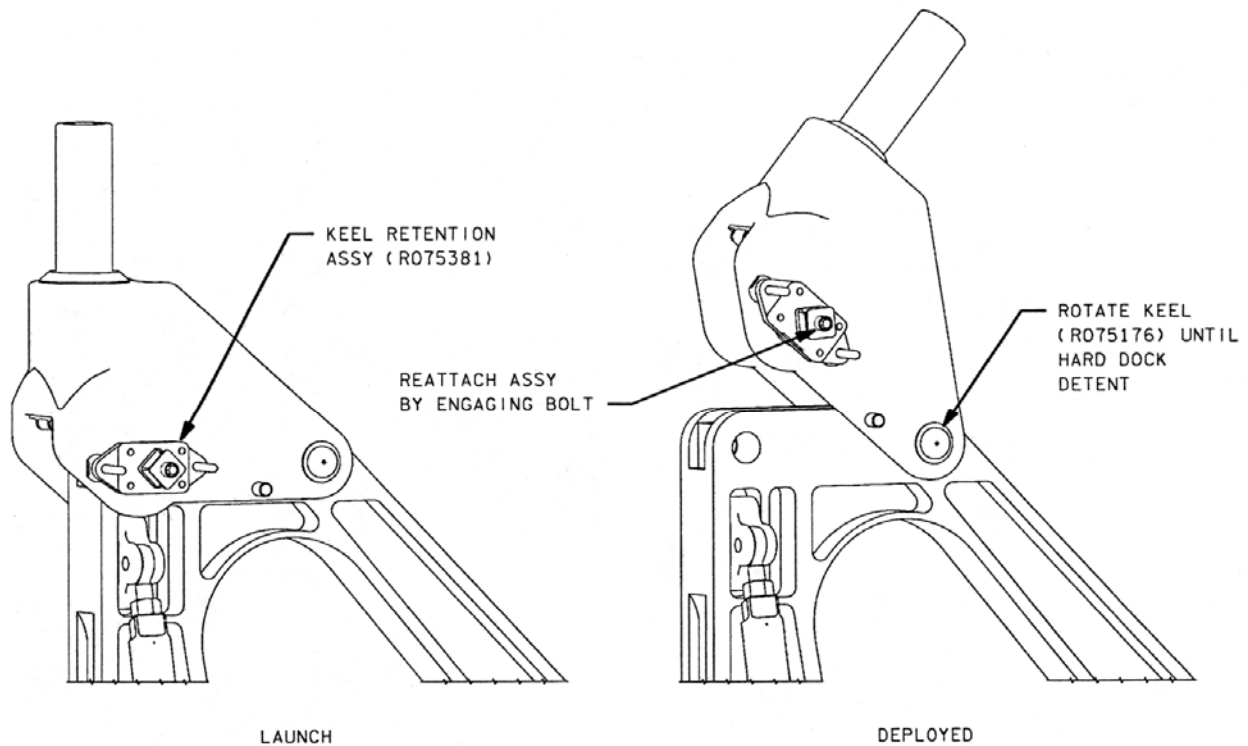


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**Figure 3-15. BGDTS hinge locks**

#### **3.5.1.1.5 Integrated Equipment Assembly Keel Pin Rotated**

Figure 3-16 shows the keel retention assembly and keel pin rotation. The EVA crew uses a PGT to disengage the bolt on the keel retention assembly, freeing it to pivot clear of the SABB for deployment. To release the keel pin, the bolt is completely removed from the retention assembly, and the keel trunnion is rotated and secured into a hard detent. Finally, the EVA crew engages the bolt back into the retention assembly for permanent stowage.

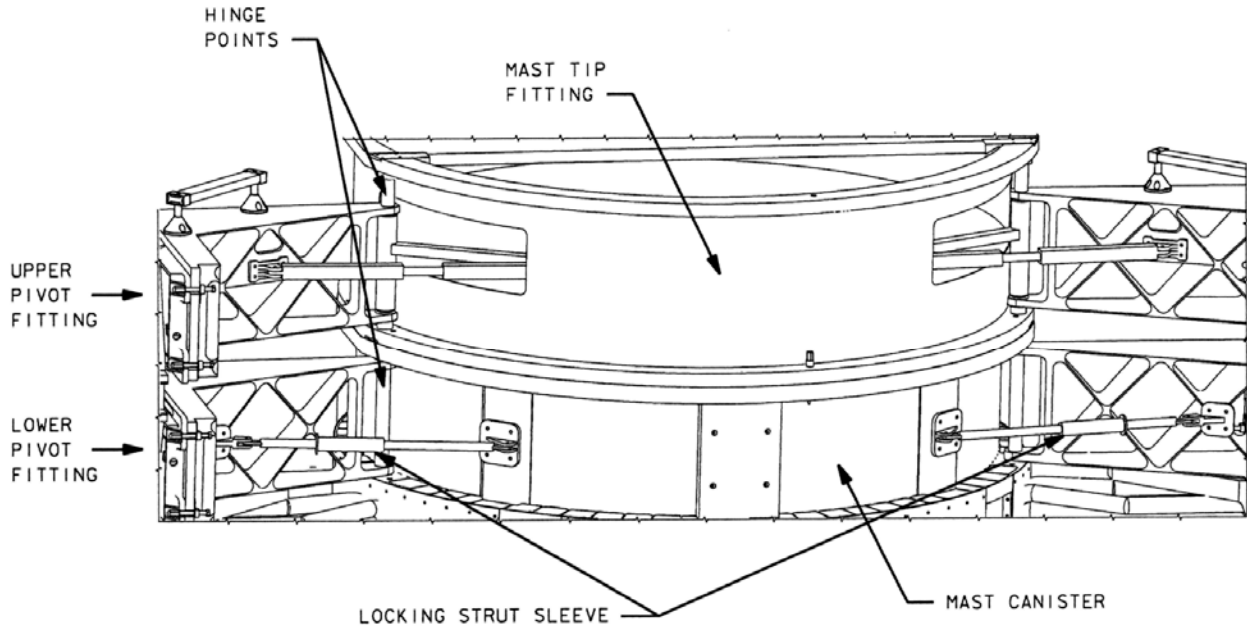


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**Figure 3-16. Keel pin rotation**

### 3.5.1.1.6 Solar Array Blanket Box Unstowed

The next task for the EVA crew is to unstow the SABBs 1B and 3B from their launch positions. Note that the SABB launch restraints must be removed and the IEA keel pin must be rotated to provide clearance for the port SABB. The SABB interfaces to the mast canister tip fitting and mast canister via the upper and lower pivot fittings, respectively. The upper and lower pivot fittings are restrained from rotational movement by swing arms that are pip pinned into the top of the mast canister tip fitting. See Figure 3-17.

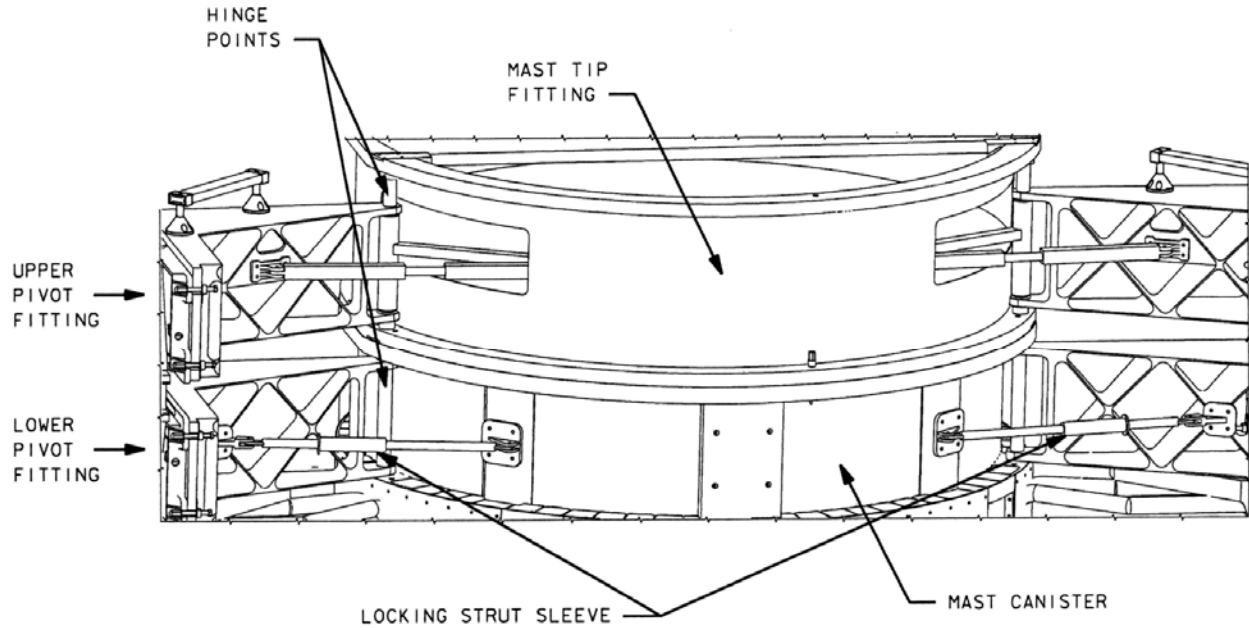


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**Figure 3-17. SABB swing arms and pip pins**

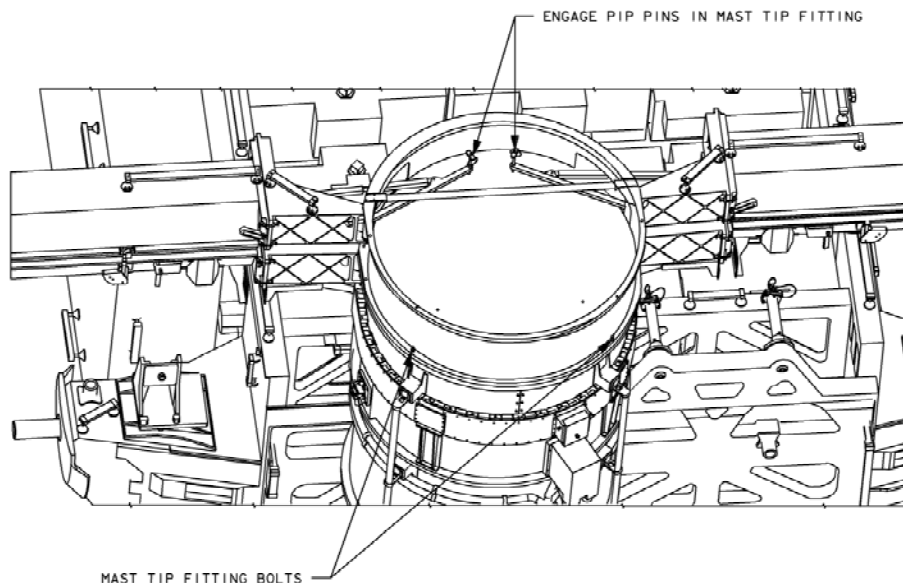
To unstow the SABBs, the EVA crew first removes the pip pins from the lock arm assembly, disengaging it from the tip fitting, and then manually swings the SABB outward  $\pm 90^\circ$ . The pip pins are then reinstalled through the lock arm assembly into the mast tip fitting at new locations to secure the SABBs in the unstowed position. See Figure 3-18.

At this point, each SABB upper pivot fitting is restrained from motion by pip pins inserted through lockout arms into the tip fitting itself. The lower pivot fitting is restrained from rotation because the upper and lower fittings are latched together. However, when the SABB latches are released for SAW deployment, the lower pivot fitting of each SABB is no longer restrained from rotation. To prevent lower pivot fitting rotation, the lower pivot fitting has a strut and sliding sleeve that locks the lower pivot fitting into place during the initial SABB unstow operations (Ops). This design is shown in Figure 3-19.



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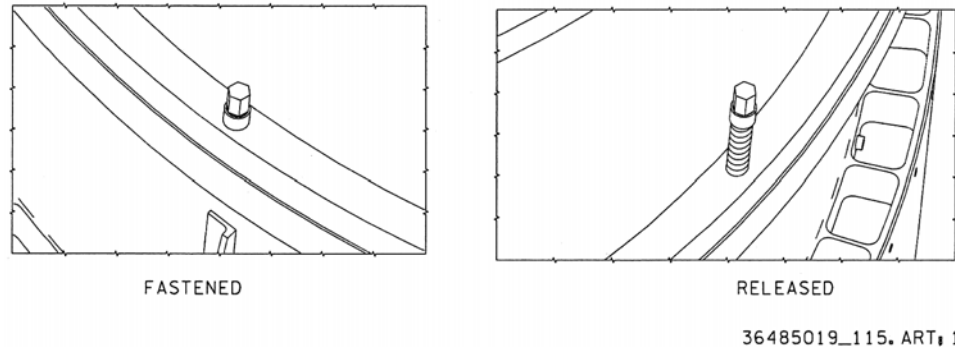
**Figure 3-18. SABB locking strut sleeve (SABB unstowed)**



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**Figure 3-19. SABB (unstowed configuration)**

After unstowing the SABBs, the EVA crew releases the mast tip fitting bolts in preparation for SAW deployment. The mast tip fitting bolts secure the mast tip to the canister via three 7/16-inch captive bolts equally spaced around the circumference of the mast canister. Figure 3-20 shows the fastened vs. released position of the mast tip fitting bolts.



**Figure 3-20. Mast tip fitting bolts**

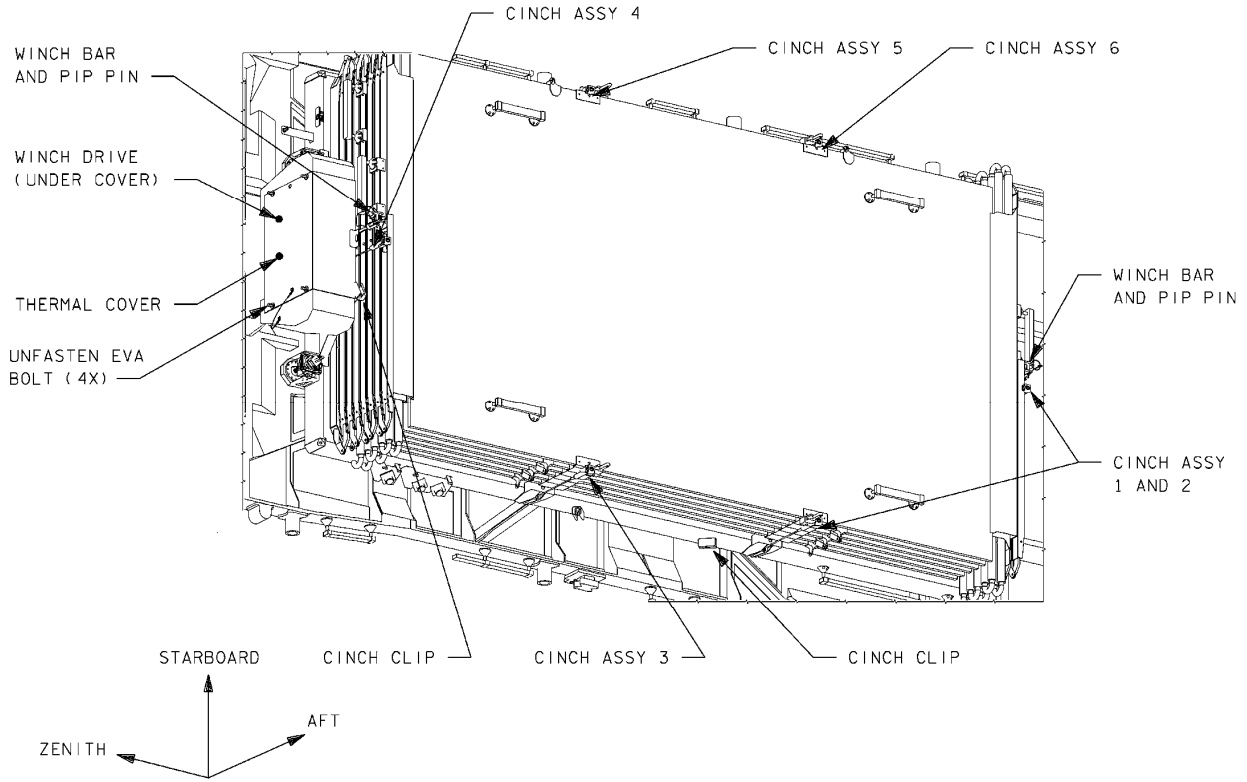
#### 3.5.1.1.7 Release S6 Radiator Cinches/Winch

The next task is to deploy the S6 PVR. The cinches and winch bars on the S6 PVR must be released prior to radiator deploy. Both EVA crewmembers work to remove these cinches and winches while the other EVA crewmember working on the aft and side cinches and winches. After releasing the cinches, the crew modes the ISS to Free Drift to preclude loading the radiator once all restraints are removed, then both crewmembers remove the winch bar Push In Pull (PIP) pins, freeing the radiator for deployment.

The locations of these mechanisms are shown in Figure 3-21.

The cinches serve as launch restraints for the PVR, and are simple cables with nut assemblies on the end. One end of the cable is permanently attached to the PVR baseplate, and the opposite end contains an adjustable nut assembly that slides into a receptacle on the outermost PVR panel. The nut is tightened to increase the tension on the cable and secure the PVR for launch. The EVA crew uses a PGT on the nut assembly to release the tension in the cable, removes the cable nut assembly from its receptacle on the PVR, and attaches the cinch to a clip on the PVR baseplate. (See Figure 3-22).





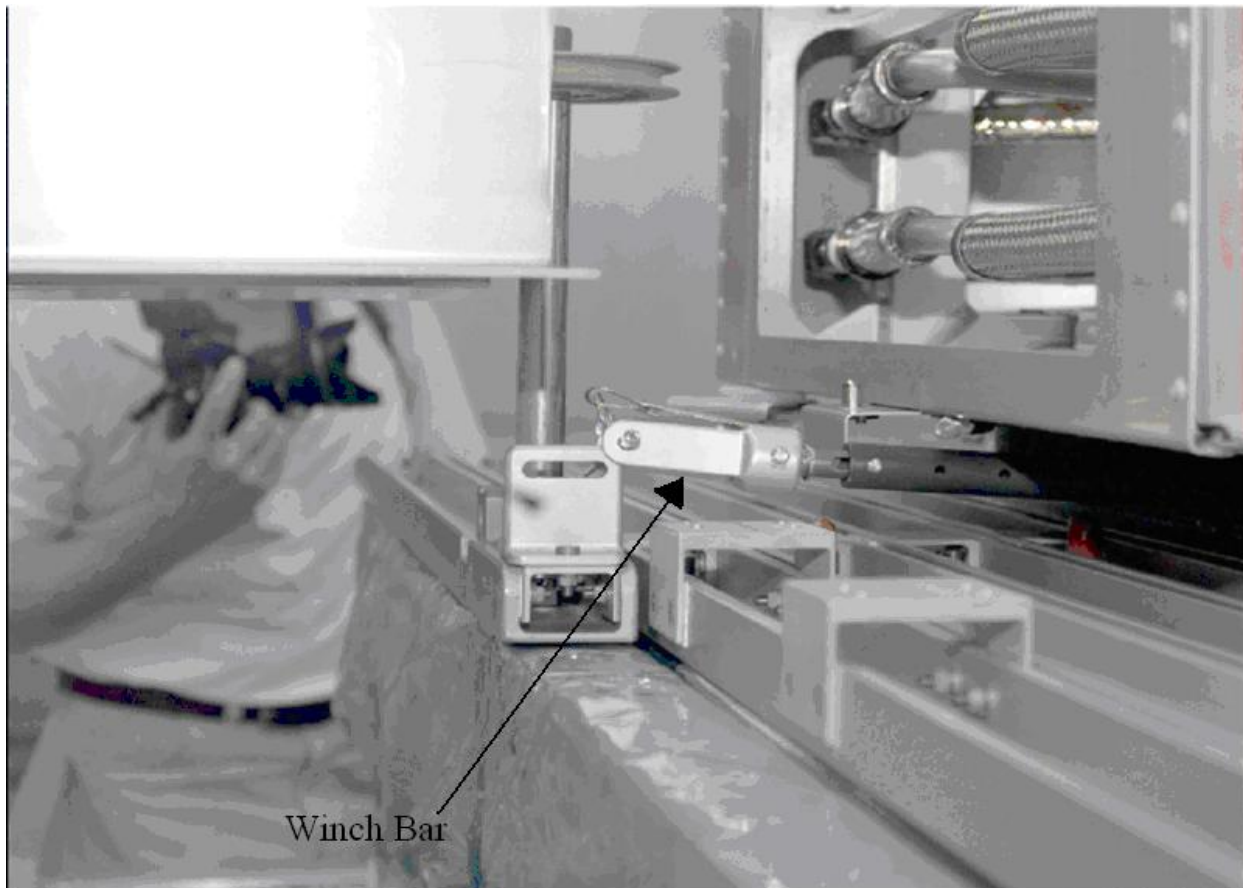
**Figure 3-21. PVR launch restraints**



**Figure 3-22. PVR cinch (left view – cinch receptacle; right view – secured in the on-orbit clip)**

**Verify that this is the correct version before use**

The next task is to release the winch bar from the PVR. The purpose of the winch drive system is to retract and secure the PVR back into its launch configuration. The winch motor extends and retracts a winch bar that is PIP pinned to the PVR. The EVA crew drives the winch in the deploy direction to relieve the tension on the winch bar and then removes the PIP. After the winch bar is released from the PVR, the pip pin is reinstalled into the winch bar, and the winch bar is retracted to its stowed configuration, clear of the PVR. The interface of the PVR to the winch bar is shown in Figure 3-23.

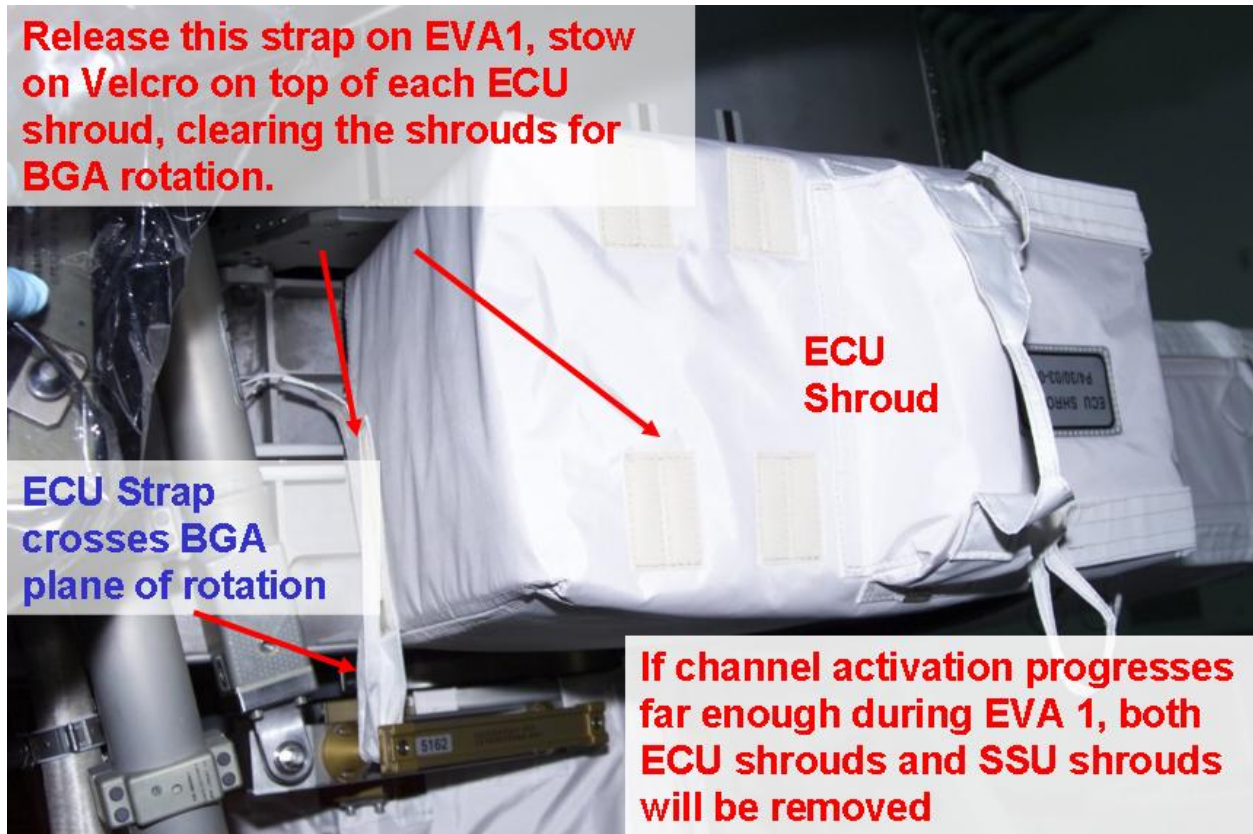


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**Figure 3-23. Winch bar (released from PVR)**

#### **3.5.1.1.8 Remove SSU and ECU Blankets**

There are four thermal blankets on the S6 element, one on each S6 power channel SSU and ECU. These blankets can be removed no earlier than 1 hour prior, or no later than 3 hours after activation of these ORUs. The blanket removal is the last activity for the EVA 1 crew. To avoid having to reinstall the blankets, blanket removal should not be performed until after the ORUs are activated. After removal, these blankets are stowed in the S6 stowage bin. Figure 3-24 shows a picture of the ECU shroud.



*Figure 3-24. ECU shroud removal*

### 3.5.1.2 EVA 2

EVA2 is performed on FD07. Table 3-2 *on the next page* outlines all of the EVA 2 activities.

**Table 3-2. EVA 2 Timeline**

PET HR : MIN	IV/SSRMS	15A EVA 2 EV1 – Swanson	EV3 – Acaba	PET HR : MIN
00:00		<u>EVA 2 POST DEPRESS, EGRESS &amp; SETUP</u> (00:50) • Post Depress/Egress (00:25) • Setup (00:30)	<u>EVA 2 POST DEPRESS, EGRESS &amp; SETUP</u> (00:50) • Post Depress/Egress (00:25) • Setup (00:30)	00:00
01:00		<u>P6 BATTERY PREP</u> (01:10) • APFR Install • Gap Spanner Install • Break Torque on P6 Batteries	<u>P6 BATTERY PREP</u> (01:10) • APFR Install • Gap Spanner Install • Break Torque on P6 Batteries	01:00
02:00		<u>P3 NADIR UCCAS</u> (01:15)	<u>P3 NADIR UCCAS</u> (01:15)	02:00
03:00		<u>P1 RBVM MLI</u> (00:15)	<u>P1/P3 FLUID JUMPER</u> (00:30)	03:00
		<u>P1 FHRC P-CLAMPS</u> (00:50)	<u>P1 FHRC P-CLAMPS</u> (00:50)	
04:00				04:00
		<u>S3 OUTBOARD/ZENITH PAS</u> (01:00)	<u>S3 OUTBOARD/ZENITH PAS</u> (01:00)	
05:00		<u>TOOL STANCHION RELOCATE</u> (00:25)	<u>APFR RETRIEVE</u> (00:25)	05:00
06:00		<u>EVA 2 CLEANUP &amp; INGRESS</u> (00:40) • Cleanup (00:15) • Ingress (00:25)	<u>EVA 2 CLEANUP &amp; INGRESS</u> (00:40) • Cleanup (00:15) • Ingress (00:25)	06:00
-06:30	EVA 1 PET = 06:30 hr	<u>PRE-REPRESS</u> (00:05)	<u>PRE-REPRESS</u> (00:05)	-06:30

### 3.5.1.2.1 P6 Battery Prep

The P6 Battery Prep assists the STS-127 crew for the P6 Battery Remove and Replace (R&R) scheduled for mission 2J/A. The 15A crew *uses the ratchet wrench to* break torque on *all six of the P6 battery* bolts, then re-torques them to ensure the batteries are tight enough to stay attached to the P6 truss, but *loose* enough so the 2J/A crew does not have problems removing them.

### 3.5.1.2.2 P3 Nadir UCCAS Deploy

The Unpressurized Cargo Carrier Attach System (UCCAS) deploy is necessary for Flight ULF3 to install the Express Logistics Carrier (ELC) 1 onto the P3 UCCAS with the SSRMS and SRMS. The EV crew only has to perform the following structural reconfigurations on the UCCAS:

1. Swivel deploy clevis bracket/release pins using the PGT.
2. Install GAP spanner.
3. Release yoke Adjustable Diameter Pin (ADP) and PIP pin using the preinstalled wire ties. The crew may need to loosen the clevis bracket bolts with the PGT to release the yoke PIP pin and ADP.
4. Remove the two hinge line ADPs (one outboard and one inboard).
5. Reposition the diagonal braces to support the removal of the clevis bracket.
6. Deploy PAS detent and reposition gap spanner.
7. Reinstall the stow clevis bracket. This step must be done before the PAS is moved from its detent to final deploy.
8. Reposition diagonal brace into the reinstall position. This step also needs to be done after detent and before final deploy. This step is required for undocking.
9. Reinstall deploy clevis bracket. This step also needs to be done after detent and before final deploy.
10. Move UCCAS from detent to its final position.
11. Perform UCCAS clean up steps.

The EV crew also performs the same procedure on the PAS deploys scheduled for EVA 4. Figure 3-25 displays the UCCAS deploy.

### **3.5.1.2.3 P1 RBVM MLI Repair**

*This is a 15-minute job for EV1. Following the UCCAS deploy, EV translates to the P1 outboard Radiator Beam Valve Module (RBVM) and goes zenith to bay 18. From that location, EV1 reinstalls the FQD MLI on M1/F151 and installs a wire tie around the MLI. A WVS survey is performed followed by EV1 translating to the next task.*

### **3.5.1.2.4 P1/P3 Fluid Jumper Install**

During this task, one EV crewmember performs the P1/P3 Fluid Jumper Install in parallel with the other performing *the P1 RBVM MLI repair*. *This task is* performed as Part 1 of a two-part task to connect ammonia lines from the TCS to the P4 PVTCS. Part 2 of the task is connecting the P3 to P4 Fluid jumpers to perform at a later date. Once Part 2 of the task is complete, the PVTCS has a line to draw ammonia from the TCS in the contingency that an ammonia leak occurs on the PVTCS.

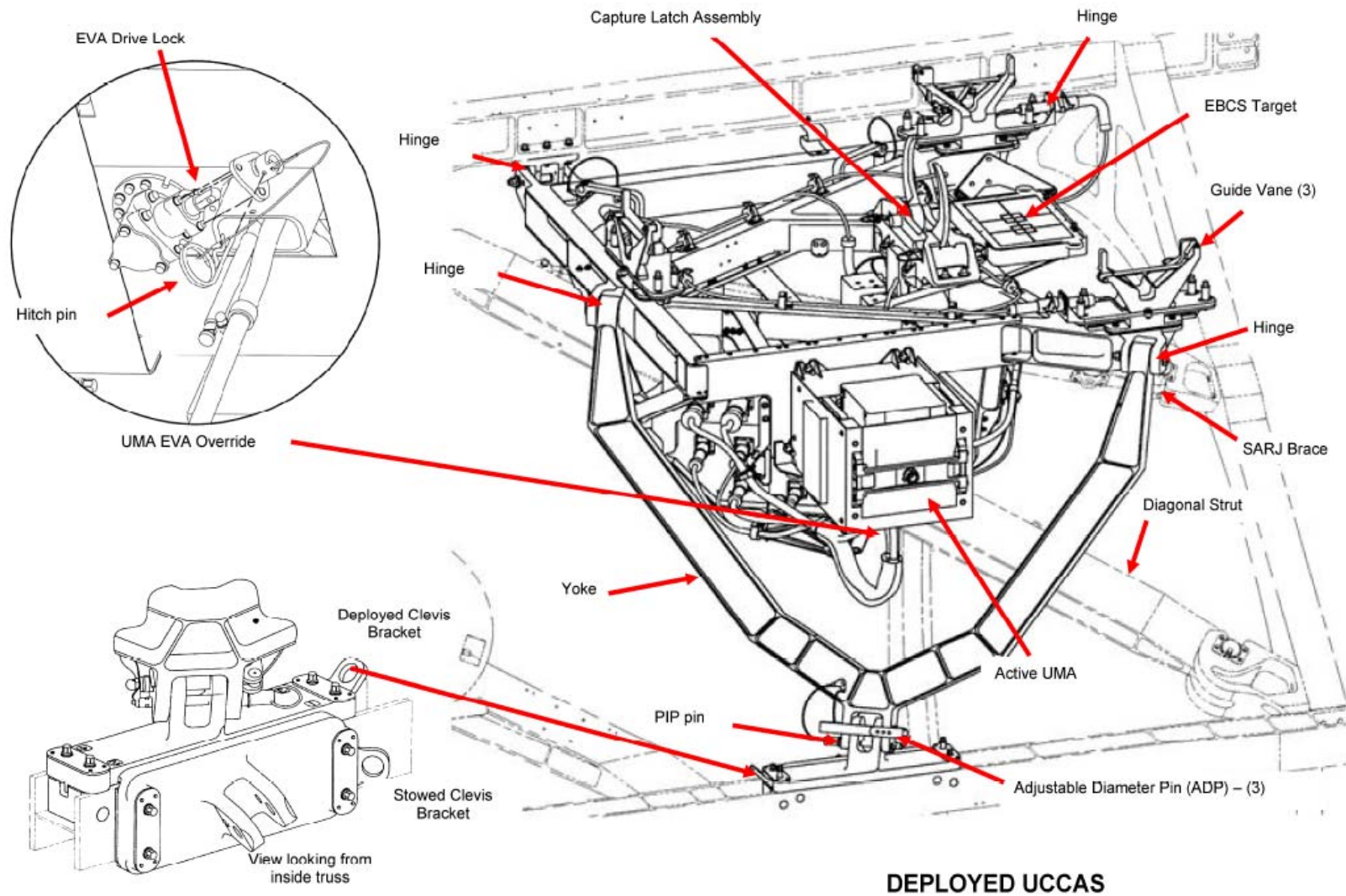
First, the EV goes to the P1 nadir umbilical tray and demates the Quick Disconnects (QDs) for F186 and F187 on M1 panel A504, then mates QD F186 to M3 on P1 panel A503, and opens the valve. Once complete, the EV essentially does the same steps to mate F187 to M1 on P3 panel A501 and opens the valve. The EV finishes the task by reinstalling a FQD MLI on M1/F151, before translating to the P1 FHRC P-Clamp worksite.

### **3.5.1.2.5 P1 FHRC P-Clamp Release**

The Flex Hose Rotary Coupler (FHRC) P-clamp releases are performed as a get-ahead prior to an FHRC failure to keep an FHRC R&R within two EVAs. Without performing the P-clamp removals, an FHRC R&R may require 3 EVAs, which exceeds the two contingency EVAs per stage requirement specified in Flight Rules and Generic Groundrules, Requirements and Constraints (GGR&C).

The P1 FHRC release is a 45 minute task that requires the crew to release the torque on the Box P-clamps illustrated in Figure 3-26 below. One EV crewmember translates to the outboard hose box and the other translates to the inboard stinger. Both EV crewmembers use the PGT and/or the ratchet wrench to release the P-clamps.





**Figure 3-25. PAS – (UCCAS shown here for reference)**

**Verify that this is the correct version before use**

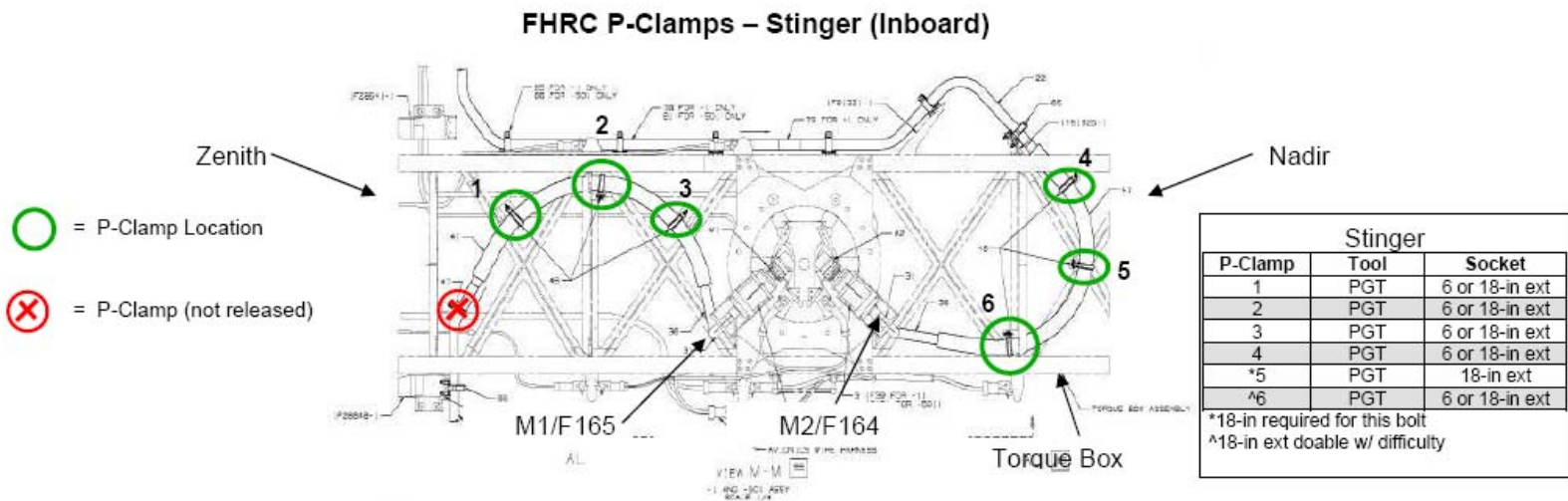
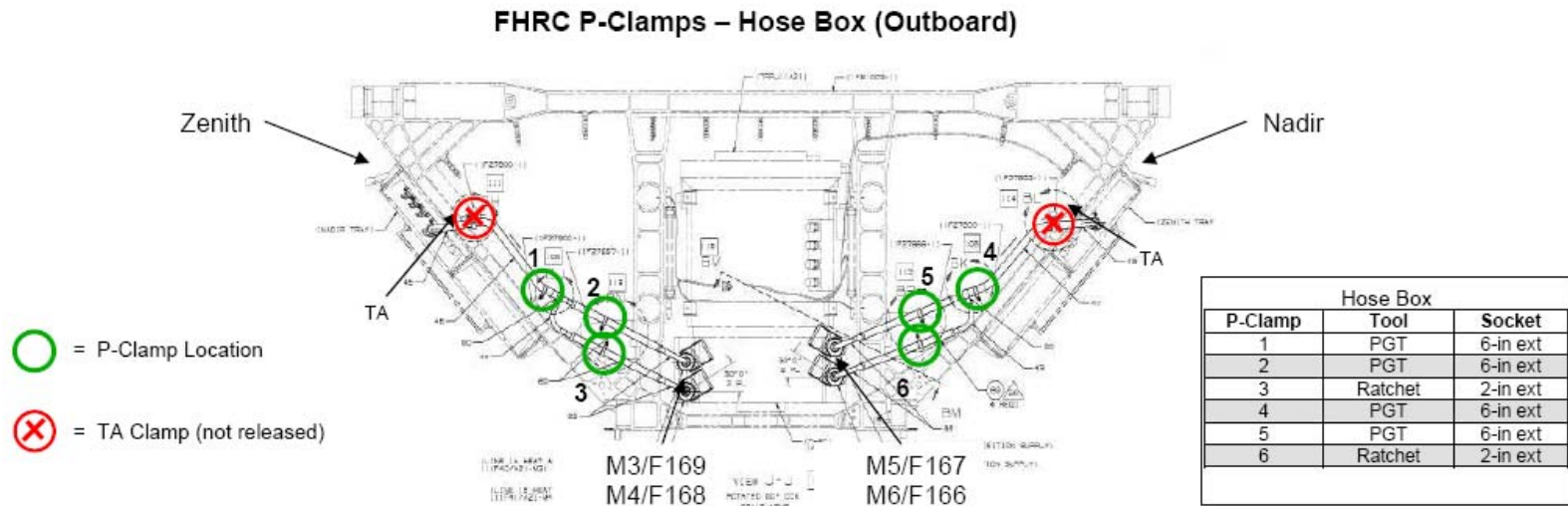


Figure 3-26. FHRC P-clamp locations

Verify that this is the correct version before use



### **3.5.1.2.6 S3 Outboard Zenith PAS Deploy**

The PAS Deploy is necessary for Flight ULF3 to install the ELC 1 onto the P3 PAS with the SSRMS and SRMS. The PAS Deploy procedure is exactly the same as the P3 Nadir UCCAS deploy mentioned in Section 3.5.1.2.3. The only difference is that this deploy requires RPCMs S34B\_E and S33A\_E RPCs 1 - 4 on both RPCMs to be opened and close commands inhibited.

### **3.5.1.3 EVA 3**

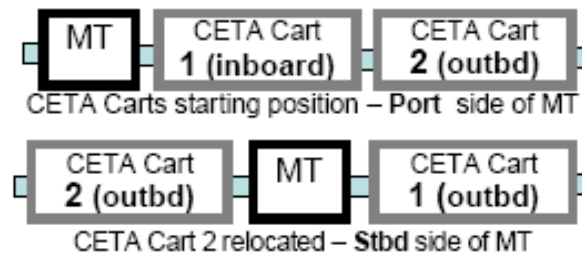
EVA 3 has a Phase Elapsed Time (PET) time of 6:30. The tasks for this EVA include the relocation of two CETA carts from the port side to the starboard side of the MT, SPDM ORU and Tool Changeout Mechanism (OTCM) cover reconfiguration and EP1 cover removal, Latching End Effector (LEE) B Repair, the R&R of RPCMs P11A-A and S01A-D, and a couple S1 tasks. Table 3-3 has the EVA 3 Task List.

**Table 3-3. EVA 3 Task List**

PET HR : MIN	IV/SSRMS	15A EVA 3 EV2 – Arnold	EV3 – Acaba	PET HR : MIN
00:00	EV2 – Acaba (SSRMS) for CETA Cart Ops	<u>EVA 3 POST DEPRESS, EGRESS &amp; SETUP</u> (00:50) <ul style="list-style-type: none"> <li>Post Depress/Egress (00:30)</li> <li>Setup (00:20)</li> </ul> Egress w/Med ORU Bag [Crewlock Bags (3) inside]	<u>EVA 3 POST EGRESS &amp; SETUP</u> (00:50) <ul style="list-style-type: none"> <li>Post Depress/Egress (00:30)</li> <li>Setup (00:20)</li> </ul> Egress w/APFR, EVA Camera, WIF adapter	00:00
01:00		<u>CETA CART RELOCATION</u> (01:00) <ul style="list-style-type: none"> <li>CETA Cart (01:00)</li> </ul>	<u>CETA CART RELOCATION</u> (01:00) <ul style="list-style-type: none"> <li>CETA Cart (01:00)</li> </ul>	01:00
02:00	EV2 – Arnold (SSRMS) for SPDM & LEE B Lube	<u>SPDM COVERS</u> (01:30) <ul style="list-style-type: none"> <li>OTCM Cover Reconfiguration (00:25)</li> <li>EP1 Cover Removal (00:25)</li> <li>SPDM Cover Cleanup (00:25)</li> </ul>	<u>S1 TASKS</u> (02:10) <ul style="list-style-type: none"> <li>S1/S3 SSAS BBC PNL RECONFIG (00:30)</li> <li>S3 FLUID QD JUMPER INSTALL (00:35)</li> <li>S1 FHRC P CLAMP RELEASE (01:05)               <ul style="list-style-type: none"> <li>Torque Box (00:30)</li> <li>Hose Box [Stinger] (00:25)</li> <li>FHRC Cleanup (00:10)</li> </ul> </li> </ul>	02:00
03:00		EV2 – Arnold Egresses SSRMS prior to LEE LUBE	<u>LEE B REPAIR</u> (01:45) <ul style="list-style-type: none"> <li>LEE B Snare Repair (01:15)</li> <li>LEE B Cleanup (00:30)</li> </ul>	
04:00			<u>S0 1A DRPCM R&amp;R</u> (00:45)	04:00
05:00		<u>CLEANUP AND INGRESS</u> (00:50)	<u>P1 1A ARPCM R&amp;R</u> (00:45)	05:00
			<u>CLEANUP AND INGRESS</u> (00:25)	
06:00	EVA 3 PET = 06:00 hr	<u>PRE-REPRESS</u> (00:05)	<u>PRE-REPRESS</u> (00:05)	06:00
--06:30--				--06:30--

### 3.5.1.3.1 Relocation of CETA Carts from Port Truss to Starboard Truss

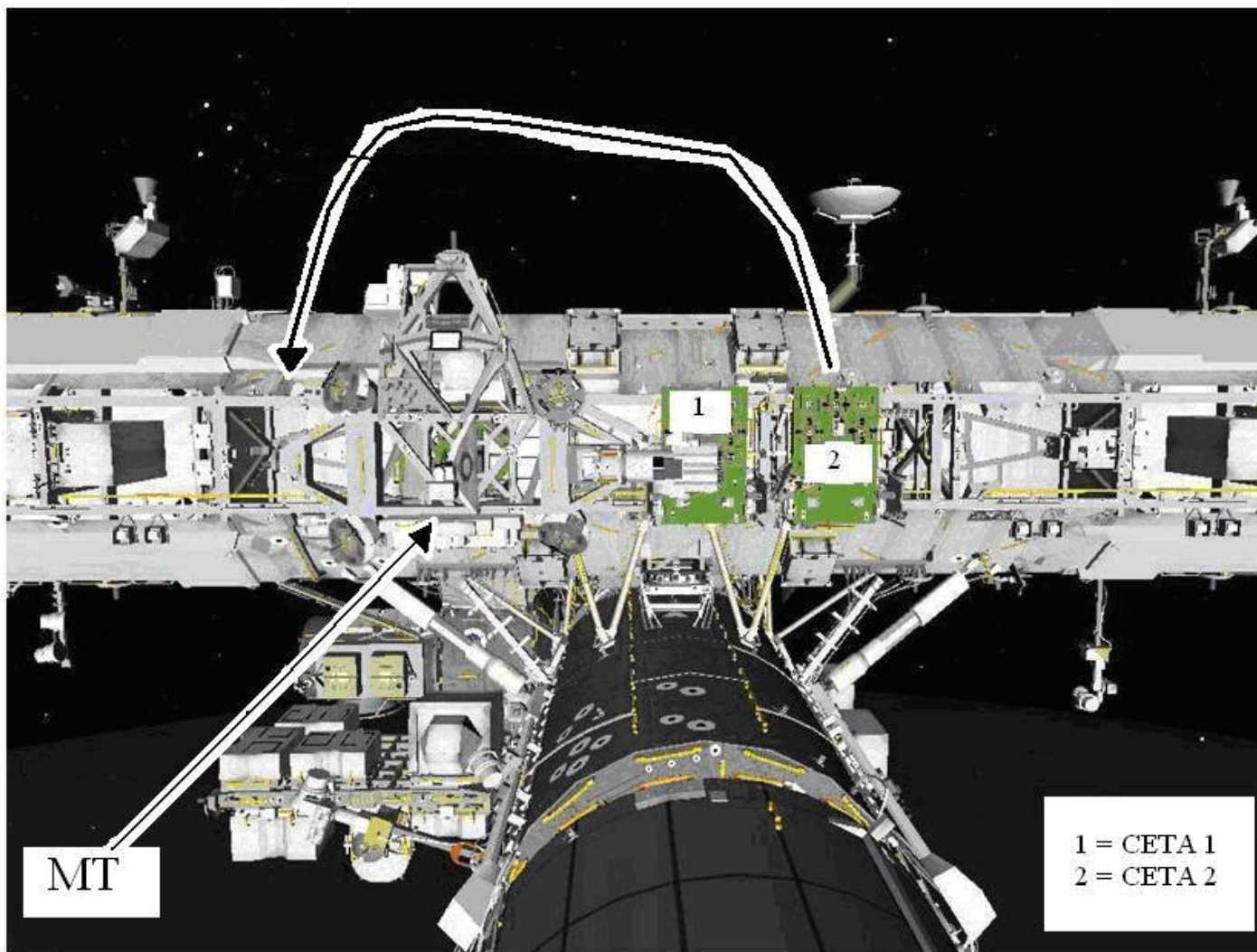
Prior to flight 15A, both CETA carts are located on the port side of the MT, which was required for the S3/S4 truss segment installation on Flight 13A. This configuration is also required for transferring the MT to worksite number 1 for S6 truss segment install to avoid locking the SARJ. The CETA Cart relocation activity is a prep activity for the STS-127/2JA mission that needs the *outboard* CETA Cart moved in order for the MT to reach Worksite (WS) 8 to perform the P6 Battery R&R. Figure 3-27 shows the CETA Cart locations before and after the EVA.



**Figure 3-27. CETA cart positions**

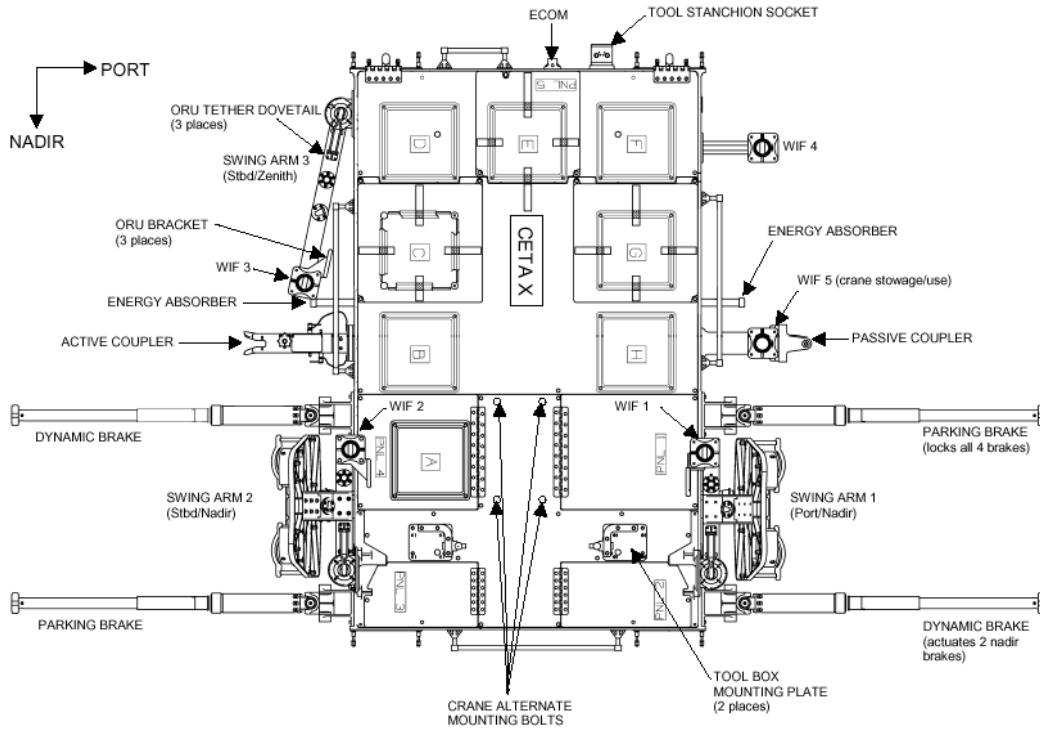
During EVA 3, CETA cart 2 (shown in Figure 3-29) is relocated from the port side of MT to the starboard side and coupled to the MT. This relocation is planned as a two-man task with one EV in FF and the other EV on the SSRMS APFR. An EV ingresses the SSRMS APFR, tethers to the CETA cart, and holds it at grids D and G. Once there is a good hold, the EV crewmember on the SSRMS gives a GO to the other EV crewmember to uncouple the CETA from the MT and disconnect the CETA wheel bogies (see Figure 3-30) from the MT rails. Next, the SSRMS EV holds the CETA cart while the arm translates to the install location, and the other FF EV translates to the same location. The SSRMS EV can then install CETA 2 on the truss with the assistance of the SSRMS and the FF EV.

Once the CETA is installed, the FF EV rotates and locks the wheel bogies (all four) (see Figure 3-30) into the MT rail, verifies that the brake handles are in the up position, and then locks the CETA cart coupler (see Figure 3-31) into the MT. Essentially, the same process is repeated for the other CETA cart. The second CETA cart is coupled to the first CETA cart instead of the MT. Figure 3-28 shows the CETA cart relocation areas.

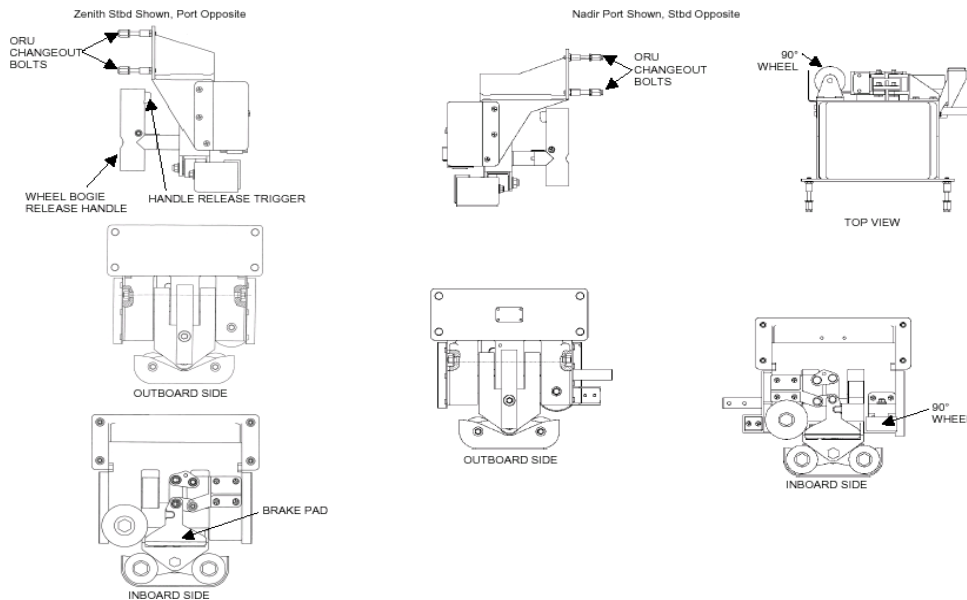


*Figure 3-28. CETA cart relocation*

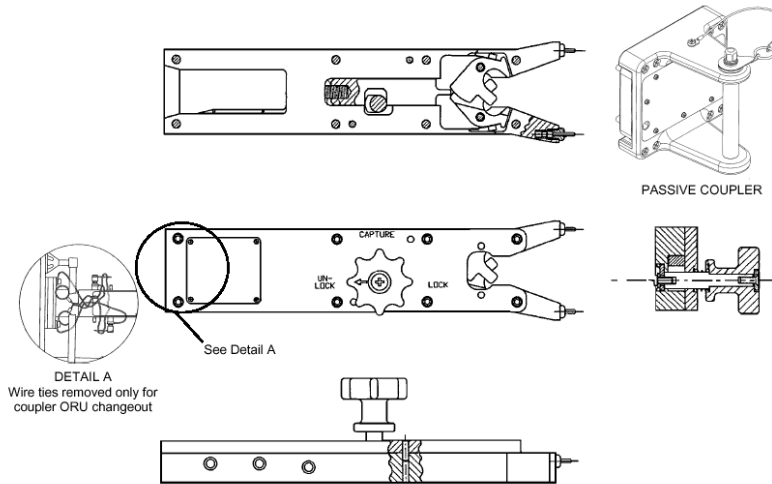
**Verify that this is the correct version before use**



**Figure 3-29. CETA cart**



**Figure 3-30. CETA cart wheel bogies**



**Figure 3-31. CETA cart couplers**

### 3.5.1.3.2 SPDM Covers

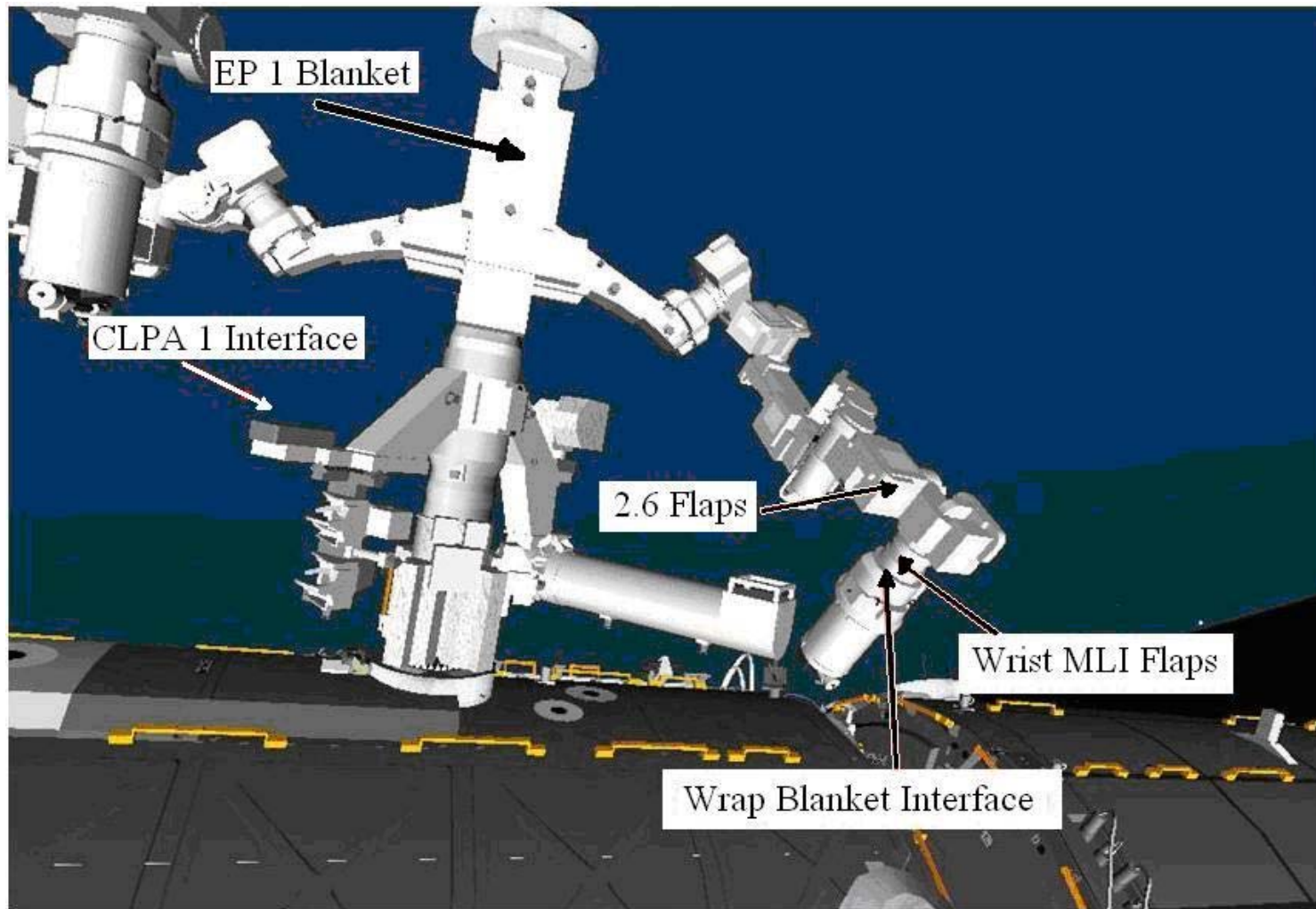
The SPDM cover and LEE B repair activities are performed by one EV in parallel with the other EV performing the S1 tasks *and the S0\_1A\_D and P1\_1A\_A RPCM R&Rs.*

The SPDM cover removal is performed because it is broken down into ORU Tool Changeout Mechanism (OTCM) Cover Reconfiguration, EP1 Cover Removal, and Cover Cleanup steps. Figure 3-32 shows all the SPDM cover locations.

The SPDM cover configuration operations require the SSRMS EV crewmember. The first step is to move the SSRMS EV crewmember to the 2.6 Flaps access location. The EV crewmember mates the two 2.6 Flaps to the corresponding Velcro patches. Once complete, the EV crewmember gives the M1/M2 a GO to maneuver the SSRMS to the Wrist Flaps location. The EV crewmember mates the four Wrist MLT Flaps to the corresponding Velcro patches. Lastly, the EV crew gives the M1/M2 a GO to maneuver to the Wrap Blanket location and the EV pulls out the Wrap Blanket that is rolled under itself. Figure 3-33 show pictures of all three SPDM OTCM covers.

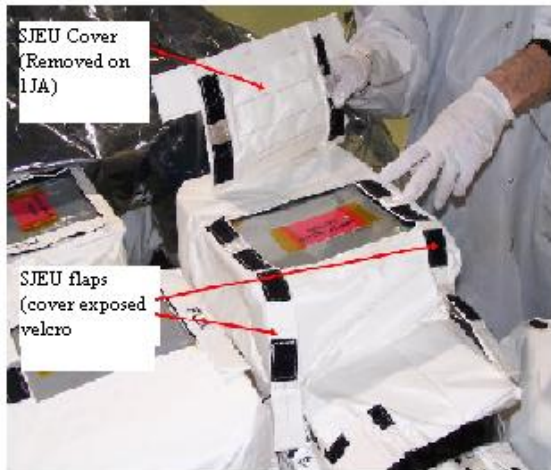
Once the OTCM covers are reconfigured, the EV gives the M1/M2 a GO to maneuver the SSRMS to the EP1 for the thermal blanket removal. The EP1 is close to the Zenith of the SPDM, where the EV removes 14 quarter turn fasteners, lifts tabs, removes the blanket, and stows it behind the Maintenance Workstation (MWS). Lastly, the EV folds over the five Velcro tabs to cover the five thermal blanket grounding patches. Figure 3-34 shows the EP1 covers.





*Figure 3-32. SPDM cover locations*

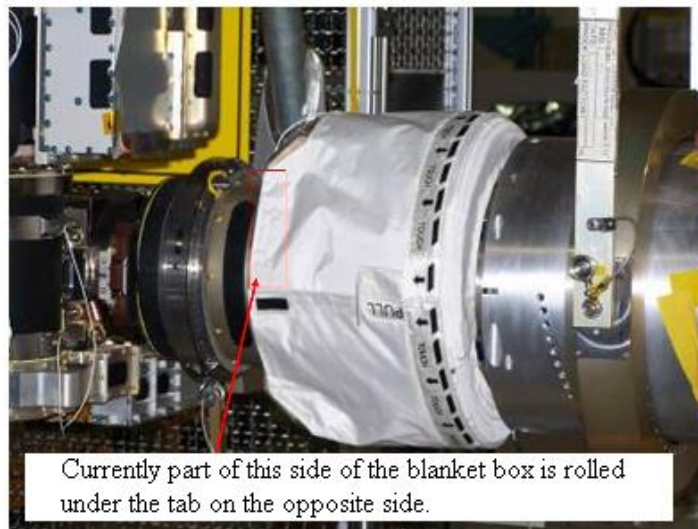
SJEU Flaps



Wrist MLI Flaps

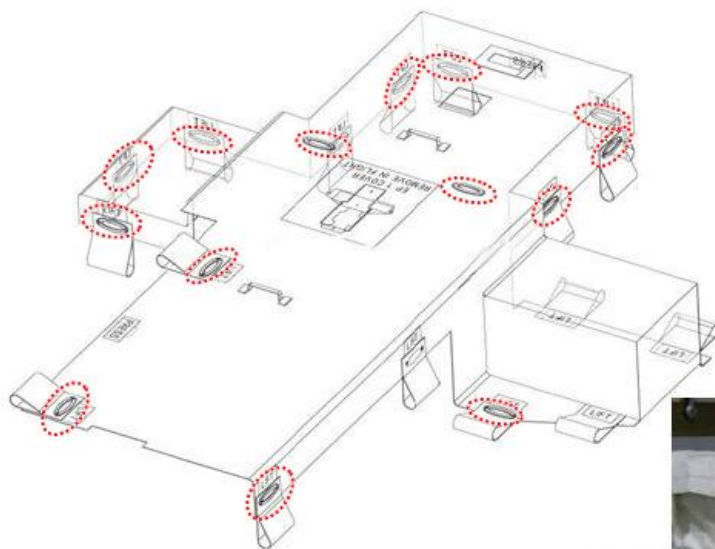


Wrap Blanket



**Figure 3-33. The 3 SPDM OTCM covers**






EP 1 Cover - View 1

**EP1 Cover 1/4-Turn Fasteners**  
1/4-Turn Fasteners (14) - Rotate to release EP Cover

Note: Fasteners may require effort to complete the rotation to the 90 deg. release orientation

 = indicates 1/4-turn fastener location



EP 1 Cover - View 2

**Figure 3-34. EP1 covers**

### 3.5.1.3.3 LEE B Repair

The EV first ingresses the SSRMS APFR and takes pictures of the six bearings and the overall LEE, followed by a snare checkout. The EV crewmember calls down the snare condition, bearing mobility, and resistance to pushing snares into groves. Once the calldowns are complete, the EV preps the grease gun and applies grease to all six of the bearings and to the bearings rod-end/fork. Then, the EV tests the changes in motion after greasing each of the three sets of bearings and reports the results to the Intravehicular (IV) and Mission Control Center (MCC). If required, the EV uses the gap gauge to pack excess grease into the bearing.

The LEE B cleanup requires the EV to take pictures of all of the bearings, egress the APFR, perform a tool inventory, wipe the grease gun and secure it. Figure 3-35 shows all the locations of the LEE B repair. The bearing sets are marked 1 & 2, 3 & 4, and 5 & 6. Figure 3-36 is a photograph of the work area.

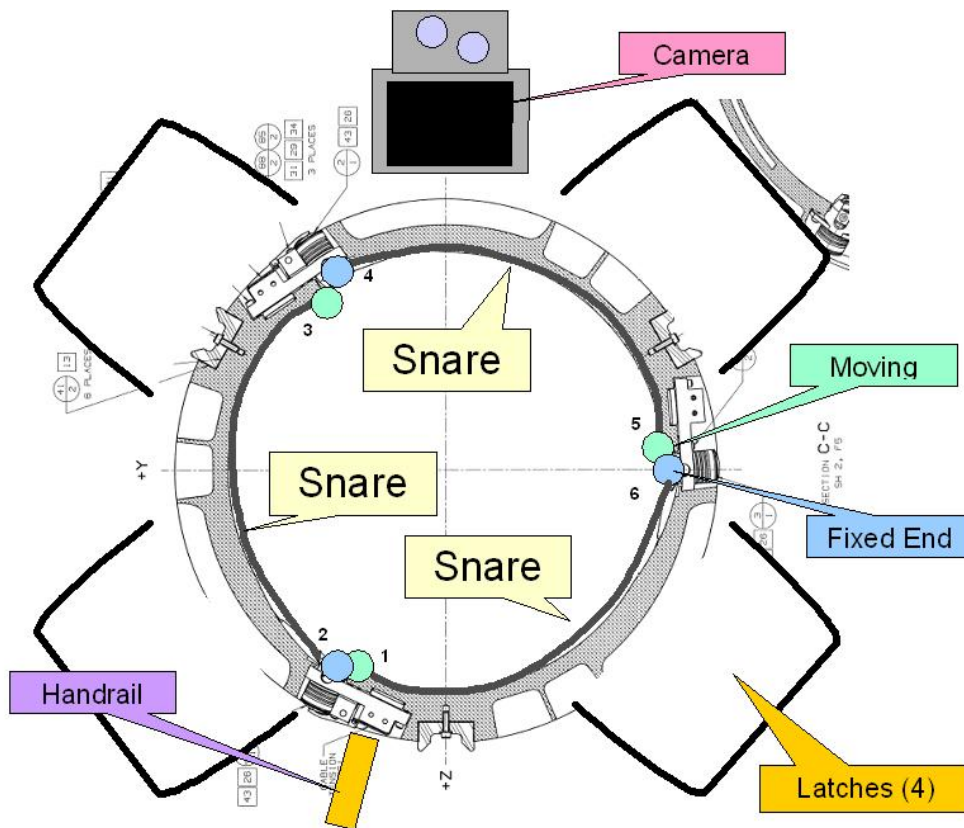
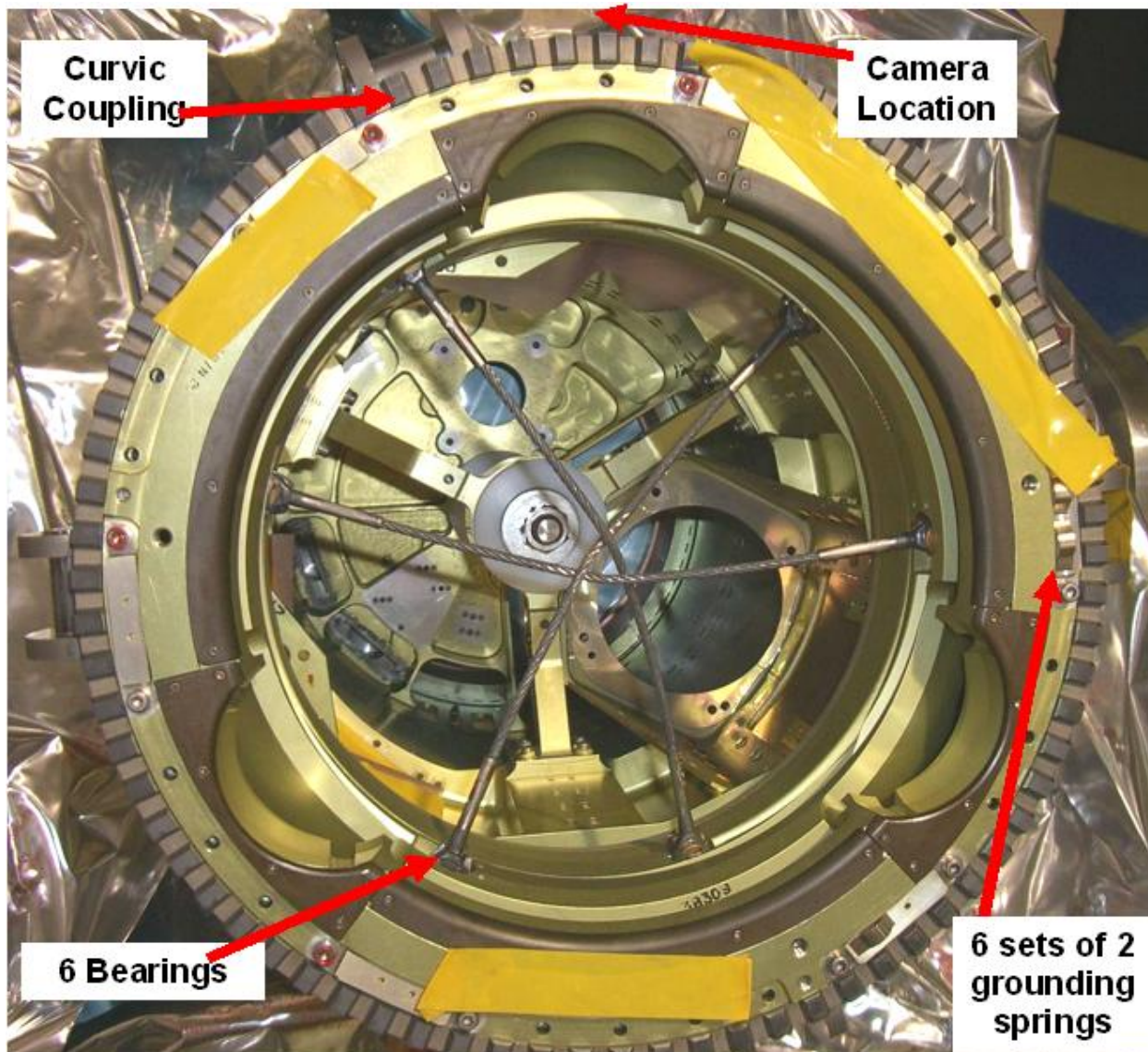


Figure 3-35. LEE B repair



**Figure 3-36. LEE B repair work area**

#### **3.5.1.3.4 S1 Tasks**

The S1 tasks include S1/S3 SASS BBC PNL Reconfiguration, S1/S3 Fluid QD Jumper Install, and S1 FHRC P clamp release. During the EVA, one EV performs those tasks while the other EV performs the SPDM covers and LEE B repair. The SASS BBC PNL Reconfiguration and S1/S3 Fluid QD Jumper Install tasks are performed as part 1 of a two part task to connect ammonia lines from the TCS to the S4 PVTCS. Part 2 of the task is connecting the S3 to S4 Fluid jumpers to be performed at a later date. Once part 2 of the task is complete, the PVTCS has a line to draw ammonia from the TCS in the contingency that an ammonia leak occurs on the S4 PVTCS.



*During* the S1/S3 SASS Panel BBC Reconfiguration, *the EV* essentially translates to panel A102 and disconnects P116 from J116 and reconnects P116 to J195. The EV translates to panel A103 and disconnects P121 from J121 and mates P121 to J196. Once complete, the EV translates to the S1/S3 Fluid Jumper task worksite.

The S1/S3 Fluid QD Jumper Install and the S1 FHRC P-clamp release is essentially the same task as the P1 Fluid QD Jumper Install and P1 FHRC P-clamp release tasks performed in EVA 2. For more information on how these tasks are performed, please go to Sections 3.5.1.2.4 and 3.5.1.2.5.

The FHRC P-clamp releases are performed as a get-ahead prior an FHRC failure to keep an FHRC R&R within two EVAs. Without performing the P-clamp removals, an FHRC R&R may require three EVAs, which exceeds the two contingency EVAs per stage requirement specified in Flight Rules and GGR&C.

#### **3.5.1.3.5 S0 1A\_D and P11A\_A RPCM R&Rs**

On GMT 2007/328, RPCM S01A\_D RPC 2 failed to respond to a THOR RPC Close command. This failure resulted in the loss of ETCS Loop B Umbilical Tray Heaters and Node 3 IFHX valves. This RPCM needs to be R&R'd before Mission STS-130/20A (Node 3 install).

On GMT 2008/95, RPCM P11A-A RPC 16 tripped. The RPC was troubleshot and re-tripped again on GMT 2008/102. Currently, the RPC is open with the Open/Close Command inhibited. This RPC supplies power to the Video Part 8 WETA Htr 2.

Prior to the start of the task, EPS 1.252 S0 DDCU S01A Powerdowns are implemented. Powerup of S0 DDCU S01A does not start until after the task is complete. *EV3 performs both RPCM R&Rs*. The EV translates to the S0 RPCM location. Using the PGT, the EV releases the drive screws on the RPCM until the status indicator is unlocked, and then removes the old RPCM. The EV stows the failed RPCM and replaces it. Once the new RPCM is in place, the EV uses the PGT to screw in the drive screws until the status indicator states LOCK. The EV reports the torque and turns required to lock the RPCM. The EV repeats the steps to replace the P11A\_A RPCM.

Lastly, the crew performs clean up steps and ingresses the ISS Airlock.

#### **3.5.1.4 EVA 4**

EVA 4 has a scheduled PET of 06:30. All the activities for EVA 4 are deemed to fit within the existing EVA timeline. If the EVA falls behind schedule, the EVA is not extended to complete any of the tasks. The task list for EVA 4 is below in Table 3-4.

**Table 3-4. EVA 4 Task List**

PET HR : MIN	IV/SSRMS	15A EVA 4 EV1 – Swanson	EV2 – Arnold	PET HR : MIN
00:00		<u>EVA 4 POST DEPRESS &amp; EGRESS</u> (00:25)	<u>EVA 4 POST DEPRESS &amp; EGRESS</u> (00:25)	00:00
		<u>JLP GPS ANTENNA B INSTALL</u> (01:00)	<u>S1/P1 RADIATOR IMAGING</u> (01:30)	
01:00		<u>Z1 PATCH PANEL</u> (00:30)		01:00
		<u>S3 TASK SETUP</u> (00:30)	<u>S3 TASK SETUP</u> (00:30)	
02:00		<u>CP1 WETA INSTALL</u> (00:40)	<u>CP1 WETA INSTALL</u> (00:40)	02:00
		<u>S3 OUTBOARD/NADIR PAS</u> (01:15)	<u>S3 OUTBOARD/NADIR PAS</u> (01:15)	
03:00				03:00
		<u>S3 INBOARD/ZENITH PAS</u> (01:15)	<u>S3 INBOARD/ZENITH PAS</u> (01:15)	
04:00				04:00
		<u>EVA 4 CLEANUP &amp; INGRESS</u> (00:40) • Cleanup (00:25) • Ingress (00:15)	<u>EVA 4 CLEANUP &amp; INGRESS</u> (00:40) • Cleanup (00:25) • Ingress (00:15)	
05:00				05:00
	EVA 4 PET = 06:20 hr	<u>PRE-REPRESS</u> (00:05)	<u>PRE-REPRESS</u> (00:05)	
06:00				06:00
--06:20--				--06:20--

### 3.5.1.4.1 JLP GPS Antenna Install

ULF-2 was supposed to install String A and String B JEM JPS antennas. Since ULF-2 was only able to complete the Sting A GPS antenna, String-B install has been added to STS-119/15A. The JEM GPS is not an ISS navigation system, it is used for HTV operations.

Out of the Airlock, EV1 will translate to the JLP to perform the GPS antenna install to further expand the ISS GPS capabilities. During the GPS antenna install, the EV opens the GPS antenna connector, mates the antenna to the connector, and reattaches the MLI covers. Once complete, the EV gives MCC a "GO" to checkout the antenna.

### 3.5.1.4.2 S1/P1 Radiator Imaging

This task was not completed during the STS-126/ULF-2 mission and has been moved to STS-119/15A. It takes approximately 90 minutes to complete. Out of the Airlock, EV2 translates to PMA w, configures to the WIF, and ingresses the APFR. Once set, the EV uses an IR camera and records a 150-frame movie of each side of each radiator. This imagery gives insight into the structural health of the TCS radiators.

Figure 3-37 shows the video paths of each radiator.

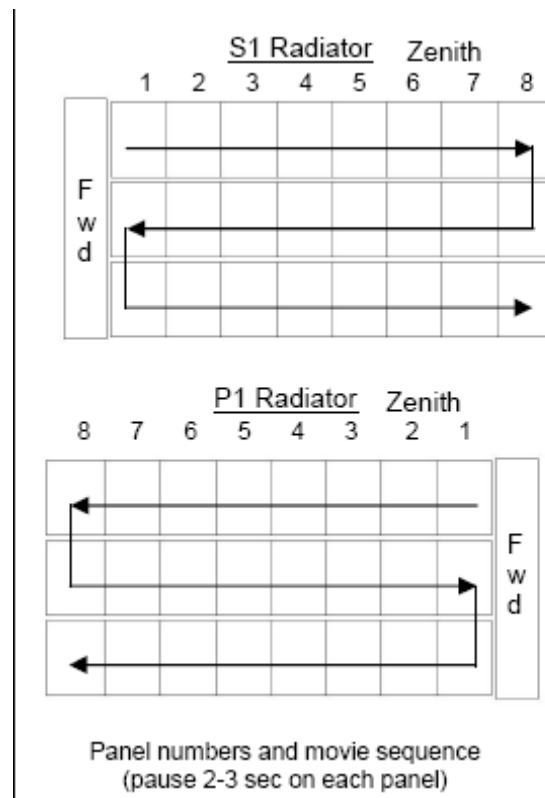


Figure 3-37. Video paths of each radiator

### 3.5.1.4.3 Z1 Patch Panel

The Z1 Patch Panel task reconfigures CMG2 power from RPCM Z13B-B to RPCM S02B-D. CMG2 was originally configured to RPCM S02B-D. During UF-1, RPCM S02B-D failed, resulting in loss of power to CMG2. To recover CMG2, an EVA crew reconfigured it to draw power from RPCM Z13B-B. RPCM Z13B-B also feeds power to CMG3. In the current configuration, if RPCM Z13B-B fails, power is lost to both CMG2 and CMG3. RPCM S02B-D has been R&R and is fully functional, but CMG2 was never reconfigured back to RPCM S02B-D.

First, RPC 18 of the Z13B RPCM and RPC 17 of the S02B RPCM must be opened with the close command inhibits in place. Once in place, the EV crew translates to the Z1 patch panel and demates the P2 connector from the J4 receptacle and connects it back into the J2 receptacle. *Figure 3-38* shows a picture of the Z1 patch panel. Drawing 3.1, Sheet 1 shows the current configuration of CMG 2.



**Figure 3-38. Z1 Patch Panel**

### 3.5.1.5 S3 Task Setup and Wireless Video System External Transceiver Assembly System Install

*This task was scheduled for STS-124/1J. The 124/1J EV crew did not have time to complete this task. The 119/15A crew has to retrieve the Wireless Video System External Transceiver Assembly (WETA) from the ISS Airlock and translate to S3. Using the PGT, one EV crewmember removes the dummy box and installs the WETA by sliding it in the stanchion. The other EV crewmember mates the electrical and data umbilicals.*

### **3.5.1.5.1 S3 Outboard Nadir PAS Deploy and S3 Inboard Zenith PAS Deploy**

The PAS *deploys are* get-aheads for Flight ULF3 to install the ELC 1 on the P3 PAS with the SSRMS and SRMS. The S3 Inboard Zenith *and Outboard Nadir PAS deploys are* identical to the P3 UCASS Deploy on EVA 2. For the procedure details, go to Section 3.5.1.2.3. This task is to configure ISS so future missions that require the PAS to stow external payloads and ISS spare parts. Prior to starting *each PAS deploy, MCC must inhibit RPCMs and give the EV a GO to perform. After the tasks are complete, the EVs* clean up, ingress, and repress *the ISS Airlock*.

### **3.5.2 Unscheduled and Contingency EVA Tasks**

The crew provisions support the performance of seven two-crewmember EVAs to accomplish the scheduled, unscheduled, and/or contingency EVA tasks. Orbiter consumables support the performance of five two-crewmember EVAs with consumables for the two contingency EVAs taken from the consumables budgeted for the contingency hole in the cabin (GN2) and the two orbiter contingency and weather avoidance days (O2). For worse-case consumables planning, assume four two-crewmember EVAs are conducted from the ISS Airlock and two two-crewmember EVAs from the Shuttle Airlock.

EVAs are conducted from the orbiter airlock (note that currently, no EVAs are actually scheduled to operate from the shuttle airlock).

The following is a definition of unscheduled and contingency EVAs:

1. One unscheduled EVA, if required, to perform the following tasks:
  - (a) Tasks as defined in NSTS 21510, International Space Station 15A Mission Integration Plan.
  - (b) Open Payload Retention Latch Actuators (PRLAs) (deployable payloads/elements only).
  - (c) Deploy Manipulator Positioning Mechanism (MPM).
  - (d) Release SRMS shoulder brace.
2. Two orbiter-based contingency EVAs, if required, to perform the following contingency tasks (any of these tasks may replace scheduled or unscheduled EVAs):
  - (a) Close and/or latch the PLBDs.
  - (b) Stow radiators.
  - (c) Realign the Ku-band antenna gimbals.



- (d) Perform an SRMS joint alignment, an SRMS tie down, an OBSS assisted latching, or an MPM stow.
- (e) Manually release the SRMS or SSRMS grapple fixture.
- (f) Manually separate the ODS from the ISS along the 96-bolt interface plane.
- (g) Release ODS capture latches.
- (h) Inspect and/or repair orbiter Thermal Protection System (TPS).
- (i) Close PRLAs (deployable payloads/elements only).

The flight-specific unscheduled EVA activities (as defined in the MIP) are listed in Table 3-5. This table contains listings of unscheduled and contingency EVA tasks for Flight 15A, which may be required to respond to failure(s) of systems or station hardware that impact the planned operations on Flight 15A.

**Table 3-5. *Unscheduled/contingency EVAs for STS-119/15A***

Class 1 – All procedures, timelines, and training are developed and certified to support an EVA response within 24 hours.

<b>EVA tasks</b>	<b>Description</b>
1.	Manually override the Blanket Box MDA to support SAW Blanket Tensioning
2.	Manually override the Mast MDA. Deploy or retract the SAW on S6
3.	Use the Payload Retention Devices (PRDs) to bring the truss segments together in the event of gapping due to RTAS capture latch failure
4.	Complete RTAS mating using EVA contingency bolts
5.	Manual assist of S6 4-Bar linkage deployment
6.	Manual release of the SABB Restraint Pins
7.	Install SABB Locking Strut Aids on S6
8.	R&R SSU on any PV Module
9.	R&R DCSU on any PV Module
10.	R&R MBSU on S0
11.	R&R PVCU on any PV Module
12.	EVA release of PRLAs for S6 unberth
13.	EVA release of S6 Grapple Fixture (GF) for failed SRMS End Effector (EE)
14.	EVA release of SSRMS LEE from S6 GF
15.	R&R SSRMS Arm Control Unit (ACU)
16.	Installation of spare FQDC detent button
17.	Manually deploy or retract the S6 PVR
18.	Rewinch and recinch S6 PVR

**Table 3-5. *Unscheduled/contingency EVAs for STS-119/15A (continued)***

Class 2 – For contingencies occurring during the docked timeframe, an EVA response is available on a subsequent EVA based on reprioritization of the mission tasks. Published procedures and timelines are developed but may require real-time updates to match the flight-specific failure.

EVA tasks	Description
1.	Manually override the Blanket Box MDA to support SAW deployment/stowage
2.	Manually override the Beta Gimbal Antirotation Latch
3.	Manually release and jettison a SAW
4.	Perform DLA Backoff
5.	Manually release and jettison PV Radiator
6.	Remove and temporarily stow the BCDU onto an adjacent battery ORU for any PV Module
7.	R&R PVR PFCS on any PV Module
8.	R&R S0, S1, P1 or any PV Module's Direct Current-to-Direct Current Converter Unit-External (DDCU-E)
9.	R&R Remote Power Control Module (RPCM)
10.	R&R Node1 Multiplexer/Demultiplexer (MDM)
11.	R&R S0 External MDM
12.	R&R S0 MDM
13.	R&R P3 or S3 MDM
14.	Position any PV Module's BGA to orient the SAW to support docking/undocking loads if SAWs already deployed
15.	Fill any PV Module PVTCS with ammonia from ammonia servicer
16.	R&R SARJ Rotary Joint Motor Controllers (RJMCs) on P3 or S3
17.	R&R ECU on any PV Module
18.	Respool Solar Array Tension/Guide Wires

**Table 3-5. *Unscheduled/contingency EVAs for STS-119/15A (concluded)***

Class 3 – For contingencies related to first-flight hardware that are not time critical, skeleton EVA procedures are developed preflight to support a Class 3 EVA. The EVA response time can be greater than 2 weeks and can be deferred to the Stage or next available mission. The ISSP has determined that additional resources are not applied to further refine the training and integrated planning until the failure occurs. Subsequent flight listings for these hardware items are contained in the ISS GGR&C document.

EVA tasks	Description
	R&R SARJ Trundle Bearing on P3 or S3

### 3.5.3 Stage EVA Tasks

There are no scheduled stage EVAs for 15A.

## 3.6 SSRMS ACTIVITIES

Flight 15A has extensive Robotics Activities. On top of the standard early and late inspections and viewing positions, 15A requires a double handoff and a SSRMS walk off to install the S6 Truss segment. The SSRMS activities for EVA are mentioned in the EVA sections of the AOH.

### 3.6.1 S6 Double Hand Off Overview and S6 install

A double handoff of S6 is required due to clearance issues between SRMS and the JEM module. The S6 truss is unberthed from the orbiter PLB with the SSRMS based on MBS PDGF 1 with the MT at WS6. The SSRMS then handoffs the truss to the SRMS. The MT then translates from WS6 to WS1, the SRMS maneuvers to the second handoff position where the S6 truss is handed back from the SRMS to the SSRMS and maneuvered to the overnight park position, and the SRMS maneuvers to the S6 install viewing position.

## 3.7 TRANSFER ACTIVITIES

Mission 15A is primarily an ISS Assembly flight, the mission priorities focus on the installation of the S6 truss segment and SAW deploy. The weight and mass of the S6 truss segment limits the amount of items we can transfer to ISS. Transfer Ops for critical supplies remain a requirement for the mission.

Mission 15A resupplies items required for stage crew and P/L activities. Resupply items include on-orbit spares for ISS maintenance activities, fresh medical supplies and equipment, crew care packages, PCS, and food. Returning items include P/L hardware and samples, and items no longer needed on the ISS.

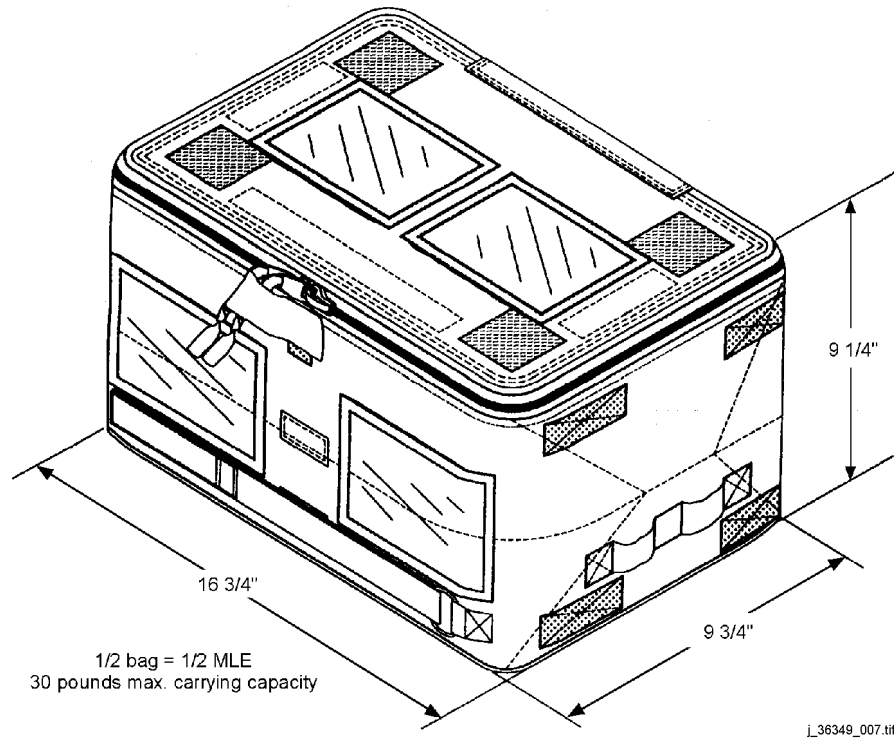
### 3.7.1 Cargo Transfer Bags

Cargo Transfer Bags (CTBs) are white Nomex, flexible, soft-sided bags. CTBs are available in half, single, double, and triple Middeck Locker Equivalent (MLE) sizes. See Figure 3-39 through Figure 3-42.

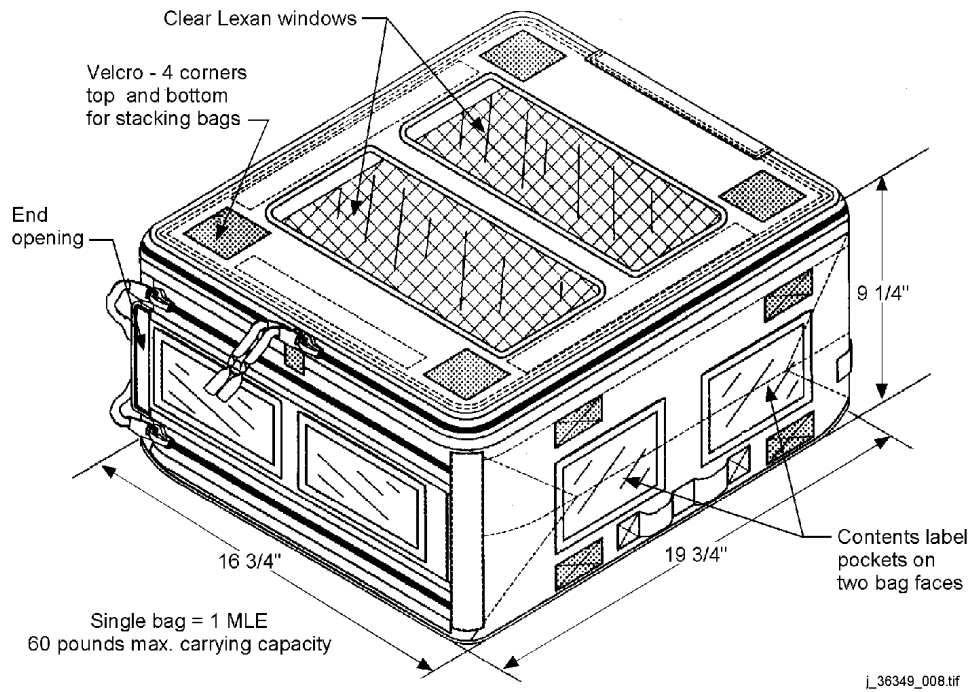
Table 3-6 gives the outer and inner dimensions of the CTBs. Half and double bags have zipper tops. Triple bags have zipper fronts. Single bags have both front and top zippers. All bags are solid Nomex, except the single bags, which are also available with a clear top. All bags have 1/4-inch foam built into all sides for some padding. Additional foam dividers (1/4-inch thick) are available in various sizes for use inside the CTBs, primarily to divide the bag into different compartments, but also to provide additional padding. All bags have at least one adjustable strap handle and several fixed handles. The adjustable strap handle can be wrapped around a handrail and used to temporarily secure the bag. Hook Velcro is on all sides of the bag, except the top which has pile Velcro. This allows the bags to interface with each other, the FGB walls, the floor and ceiling, and the Spacehab bulkhead mounting plates.

**Table 3-6. CTB dimensions**

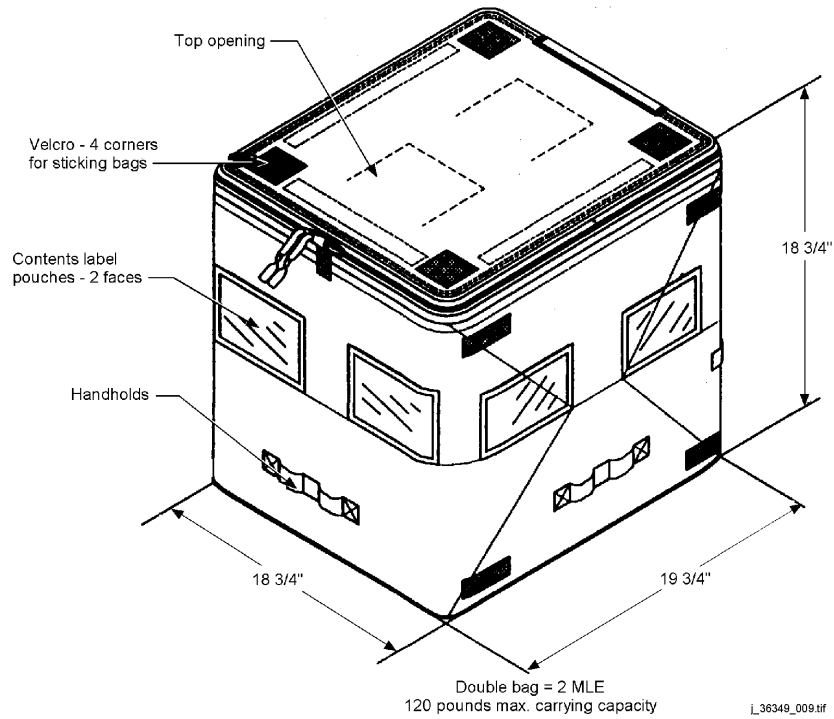
<b>Bag size</b>	<b>Outer dimensions (in.)</b>	<b>Inner dimensions (in.)</b>
Half	9.75 x 16.75 x 9.25	9.25 x 16.25 x 8.75
Single	19.75 x 16.75 x 9.25	19.25 x 16.25 x 8.75
Double	19.75 x 16.75 x 18.75	19.25 x 16.25 x 18.25
Triple	19.75 x 16.75 x 28.0	19.25 x 16.25 x 27.5



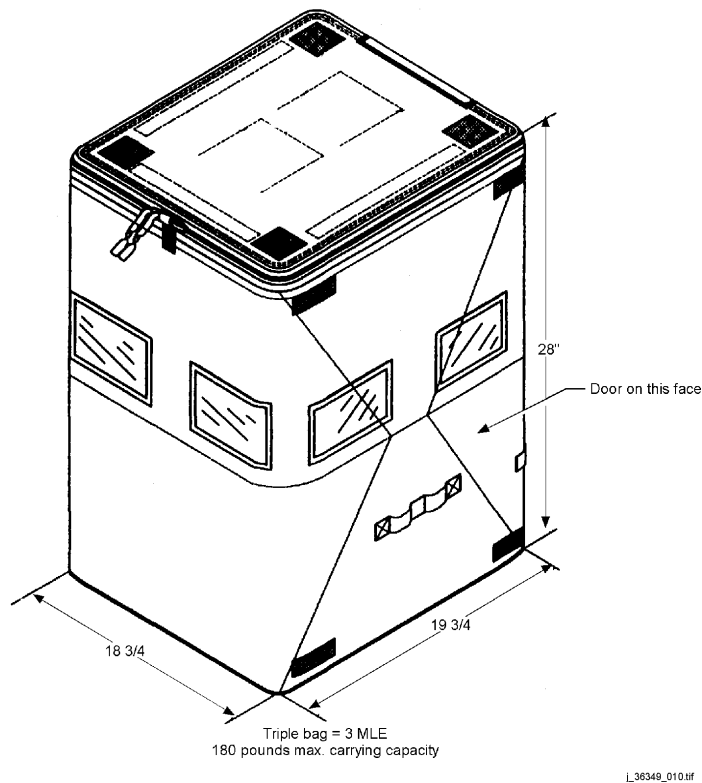
**Figure 3-39. Half bag**



**Figure 3-40. Single bag (with window)**



**Figure 3-41. Double bag**



**Figure 3-42. Triple bag**

## 3.8 TRANSFER PAYLOADS

Mission 15A launches several payloads that are transferred to the ISS during joint operations. Other payloads are transferred from the ISS to the orbiter for return to Earth on STS-119.

### 3.8.1 Glacier

The Glacier operates in the orbiter middeck as a continuously powered, rear-breathing cryogenic freezer designed to provide transportation and preservation capability for cryogenic experiment samples. STS-119/15A is the second flight of Glacier. Two Glacier units flew on STS-126/ULF2; one powered in the middeck and one unpowered unit mounted in EXPRESS Rack 6 in the MPLM, then transferred to the U.S. LAB.

Glacier is a double Middeck Locker (MDL)-sized cryogenic freezer to be used in conjunction with other ISS/middeck experiments. The primary function of Glacier is to provide cryogenic preservation of samples from experiments on-orbit, per the baselined cold storage plan. Glacier is designed to support experiments that require thermal control between +4° and -160° C. For STS-119/15A orbiter middeck operations, Glacier operates on air cooling with its thermal control system set to -95° C.

Glacier is continuously powered by the nominal 28 V dc 20-amp source from Middeck Utility Panel (MUP) in the orbiter middeck. Power outage for preservation of samples should be limited to 120 minutes. Door openings for preservation of samples should be limited to the minimal amount possible, not exceeding 2 minutes. Sample transfer is a time-critical operation and individual samples may have mission-specific time constraints.

The crew is required to perform a temperature status check starting the day of launch prior to crew sleep, then twice a day each day following. The desired separation of these status checks is 8 to 12 hours. A status check is required within two hours after the door opening to verify the Glacier is ramping toward the set-point temperature.

Other nominal crew operations include hardware preparation for sample transfers, sample removal/insertion, swapping the shuttle middeck Glacier unit with the Glacier unit located on ISS in EXPRESS Rack 6, and hardware configuration for landing.

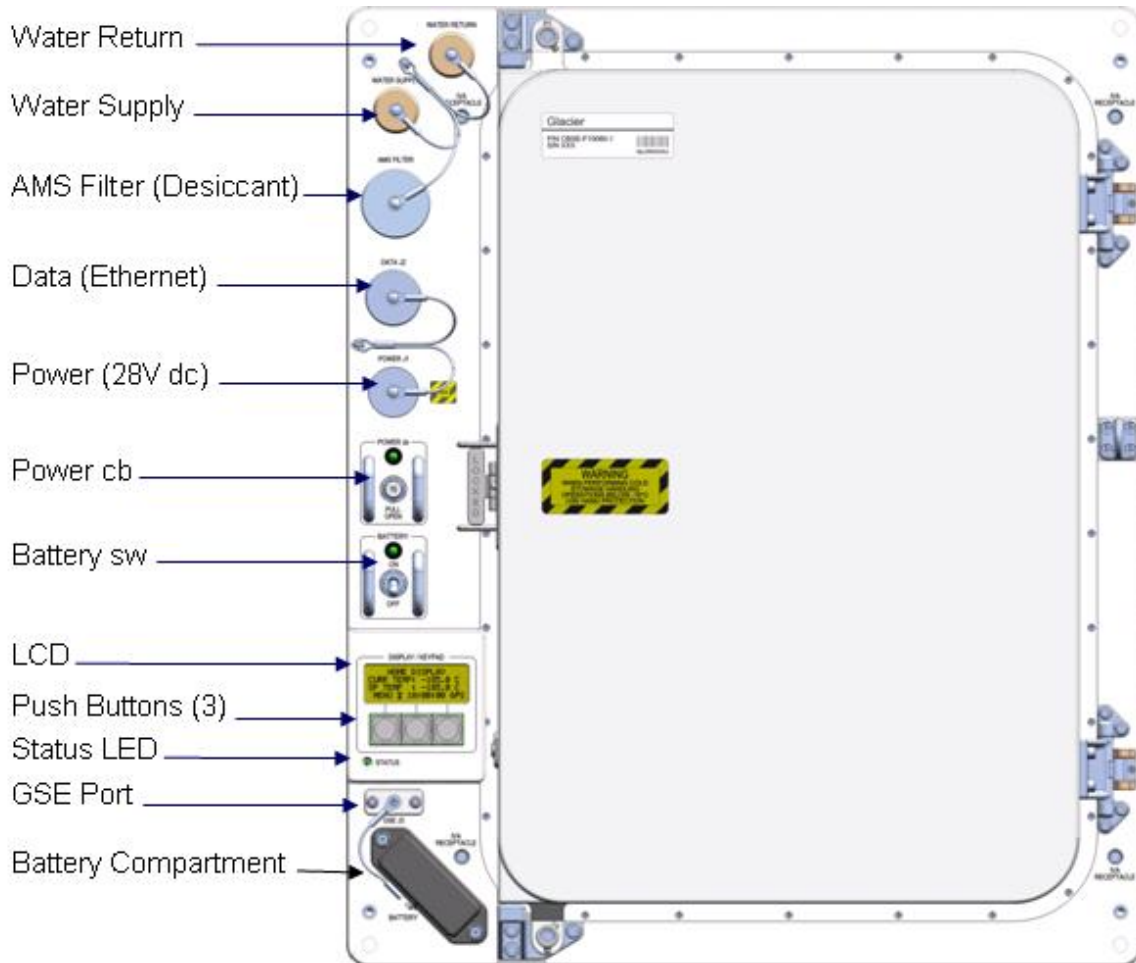
The Glacier front panel is shown in Figure 3-43.

#### 3.8.1.1 Mechanical and Structural Interface

Glacier interfaces to the middeck wiretray through mounting panels. Glacier nominally uses dual Vented Payload Mounting Panels (VPMPs) (see Figure 3-44), but can be configured to use one VPMP and one Payload Mounting Panel (PMP). The two mounting panels must be preinstalled in the middeck prior to Glacier installation. Tool guide access is provided for the four mounting panel captive fasteners located in the corners of Glacier. The Glacier interface to these hard-mounting locations is through a nickel-plated aluminum backplate. For ease of mounting, Glacier comes equipped with

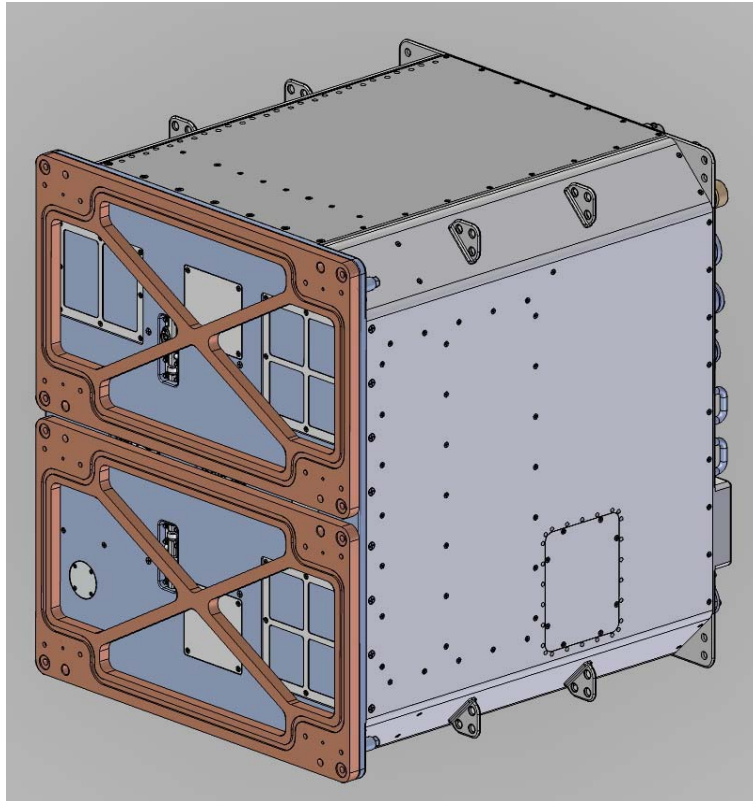


interface fasteners at the four corners of the backplate. These fasteners are captive to the Glacier backplate. The fasteners are equipped with locking patches to prevent unintentional fastener back off. They also provide approximately 0.030 inches of radial float to accommodate potential misalignment. These captive fasteners were analyzed for three standard installation torque cycles and two additional installations, if necessary, for a total of five torque cycles. Therefore, these four captive fasteners are replaced prior to each flight to limit the torque cycles on the locking patch below the manufacturer's suggested limits.



**Figure 3-43. Glacier front panel**

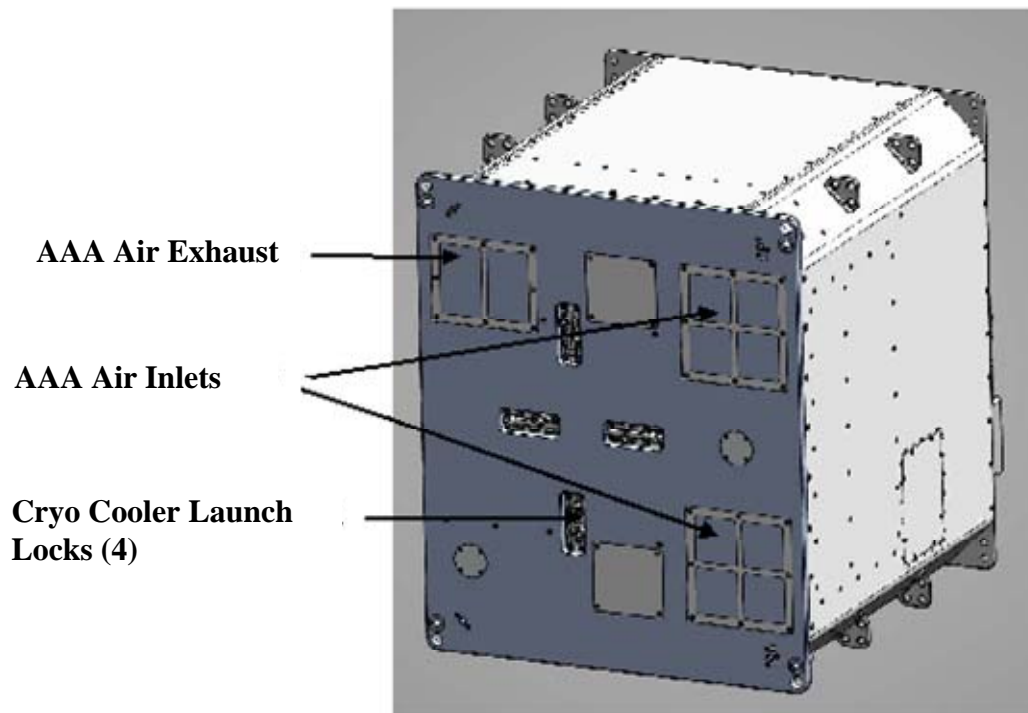
Glacier is compatible with the envelope, weight, and center of gravity requirements of the middeck. Glacier is designed to accommodate 14.3 pounds (6.5 kg) of sample mass/support hardware installed within the cold volume. For STS-119/15A, the configuration is four Type V sample trays with support hardware.



**Figure 3-44. Glacier with VPMP mounted**

### 3.8.1.2 Thermal Interface

For middeck operations, Glacier operates in an air-cooled only mode. Once Glacier is installed in the U.S. Lab Express Rack 6 (ER6), Glacier utilizes the Avionics Air Assembly (AAA) system for air cooling inside the rack and the TCS Moderate Temperature Loop (MTL) to reject heat from Glacier and to achieve the cryogenic temperatures necessary to support experiment samples. The backplate incorporates cutouts that are aligned with the AAA air inlet and outlet in the Express Rack 6 (LAB1O4) (see Figure 3-45). Glacier may be configured to receive air through the top inlet only or through a combination of the top and bottom inlets while utilizing the top exhaust in either configuration. Air flows into the Glacier system from the AAA and is ducted across air heat exchangers located on the cryocoolers and back into the AAA. Glacier utilizes two software-controlled axial fans that provide 36 Cubic Feet per Minute (CFM) of airflow across the Glacier heat exchanger. The system is closed to the remainder of the Glacier system, thereby preventing mixing of AAA air and cabin air. Thermistors are also located at the Glacier air inlet and outlet to provide direct feedback on cooling air temperatures for Glacier.



**Figure 3-45. Glacier backplate**

### 3.8.1.3 Power Interface

Glacier is powered by nominal 28 V dc with a 20A power resource from the orbiter Middeck. *The STS-Glacier has an estimated peak power consumption of 160 W and an over current trip of 15A. Glacier steady-state power consumption is rated at 160 W (7.6 A). The Inc 18 Glacier is being internally limited to a peak power draw of 220 W with an over trip current of 18 A. Like the STS-Glacier, the Inc 18 Glacier has a steady state power consumption of 160 W (7.6 A). Prior to the Glacier swap, the UAB Glacier ground team commands the Inc 18 Glacier to the shuttle power ratings of 160 W steady state and 160 W peak (15A over current trip).*

All electrical connections to Glacier are made with the connectors unpowered; and these hazards are controlled via the crew procedures. Once the power connection has been made to J1, and +28 V dc applied, Glacier is turned On by closing the Power circuit breaker on the front panel. A green Light Emitting Diode (LED) turns on to indicate that main power has been applied. To enable battery-backed data logging, the battery switch is toggled to the On position. The data logger continuously lights up a separate green LED when the battery voltage is good and the main power is on. The battery LED flashes when the main power circuit breaker is open or upstream power is not available, and the unit is logging data on battery power.

When 28 V dc power is interrupted, Glacier uses two disposable 9 V alkaline batteries to provide up to 96 hours of temperature data logging capability. The battery power circuit is fused at 1 A (1/2 A per battery). Battery logging backup is enabled by turning on the battery toggle switch on the front panel. No battery charging is performed for the batteries and replacement of the 9 V batteries is not planned for the STS-119/15A flight.

Glacier has one circuit breaker located on the front panel for main power. The breaker is engaged when pushed in (Closed). When the breaker is disengaged, or has tripped, it is in the pulled out (Open) position and a white band shows around the base of the breaker. The main circuit breaker controls the main power feed from the power source to the unit. The breaker serves both as over current protection and as an On-Off switch. The main circuit breaker is rated at 15 and does not reset automatically.

To ensure that Glacier remains within its power resource limitations and to monitor operation, the current draw from the main input is continuously measured. The Glacier microcontroller reads the current value and reduces the Cryocooler stroke length if the current is above the nominal value for the current mounting location. Also, the main input voltage is measured at the power distribution board, and reported in the health and status data.

#### **3.8.1.4 Command Interface**

For Mission 15A, the Glacier flight unit is manually controlled and operated by the crew through the use of the front panel Liquid Crystal Display (LCD) and pushbuttons (see Figure 3-46).

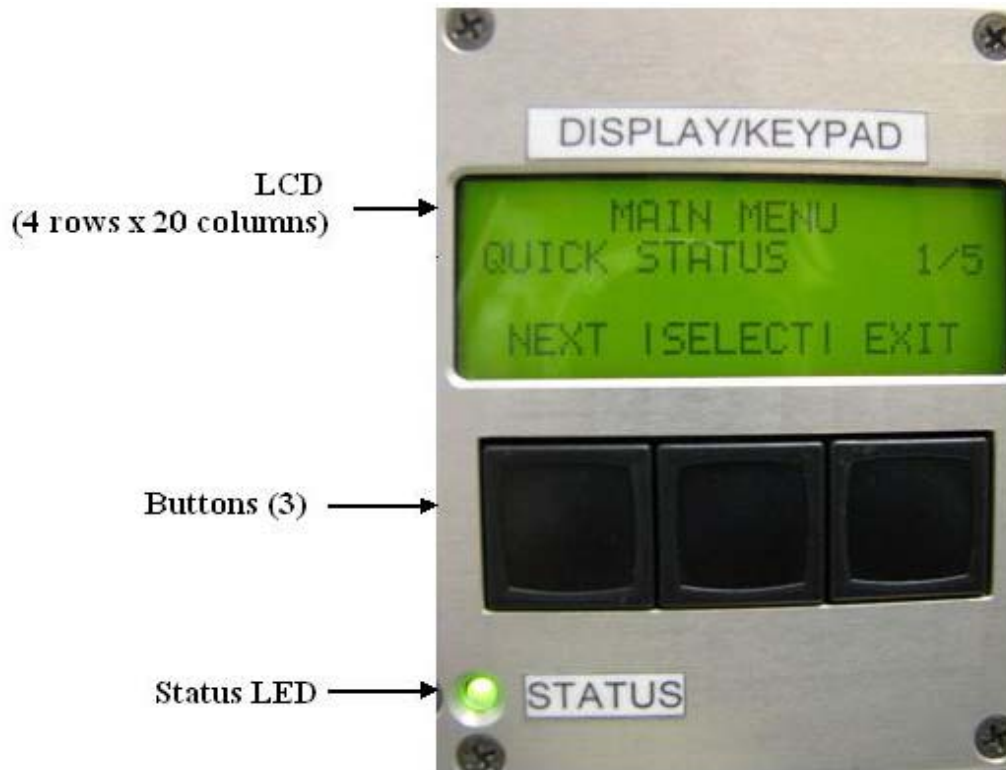
The three front panel pushbuttons are located below a 4-row by 20-column LCD. Pushbuttons operating in conjunction with the LCD are aligned with the LCD so that each button corresponds with the software command option located on the bottom row of the LCD. These buttons provide a soft tactile click when pressed. These are used to issue commands, as well as to monitor Glacier.

LEDs on the front panel provide visual indication of power status (main power and battery) and command activity. The Status LED is off and is blinking when there is an error detected.

The main software functions of Glacier are thermal control, air management, health and status, communication, command, and control.

#### **3.8.1.5 Data Connections**

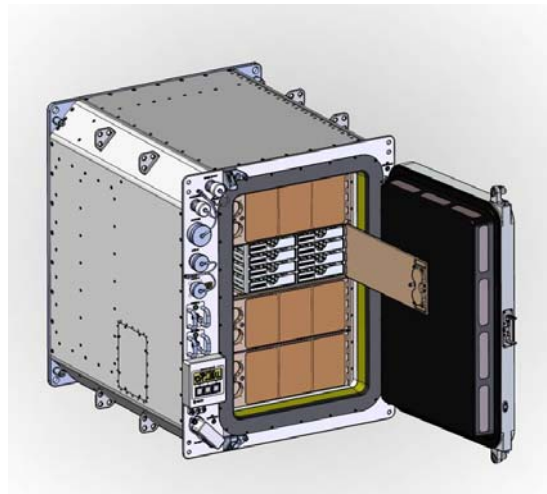
There are no data connections for the STS-119/15A middeck configuration.



**Figure 3-46. Crew command interface**

### 3.8.1.6 Cold Volume

The core of Glacier is the cold volume, which is used for sample storage. The cold volume provides a controlled environment to store experiment samples. Sample temperature within the cold volume is maintained by circulating dry air over the samples in the cold volume and removing heat from the sample into the air stream. The air is then circulated through the heat exchangers located within a vacuum jacket at the rear of the cold volume. Access to the samples is obtained through an outer door that provides sample volume insulation and four inner aperture doors that are used to isolate segments of the cold volume during sample access. The Glacier outer door also provides structural load bearing capability for the cold volume support structure and for crew-applied loads. Figure 3-47 shows details of the outer door configuration and inner aperture doors.



**Figure 3-47. Glacier internal doors**

Three temperature detectors are located within the cold volume of Glacier to indicate the temperature of the sample environment. One is located at the heat exchanger inlet, one at the heat exchanger outlet, and one in the cold volume air flow. One or more of these may be selected as feedback sensors for cold volume temperature control.

A sensor in the outer door is used to detect door position. When the sensor detects the door open position, the internal impeller shuts off to reduce the amount of heat leaked into the system.

The cold volume is maintained with a dry air environment to prevent the formation of ice. Periodically, it is necessary to replenish the dry air environment due to air losses to the cabin during cabin pressure changes, cold volume temperature changes, door openings, and system idle scenarios. This replenishment is accomplished by incorporating pumps, valves, a humidity sensor, a pressure sensor, a delta pressure sensor, filters, and desiccant into a closed-loop system. The system monitors the moisture content and replenishes the system by cleaning the environment present inside the Glacier and using the AAA air supply as necessary. The desiccant particles which fill the desiccant canister are 2 mm in diameter and are contained within a canister with filter paper at the air entrance and exit. These filters trap particles down to the micron range to control release into the crew environment. Since the 15A Glacier is powered at turn over, the replenishment of the dry air environment is not a nominal activity for this shuttle flight.

The crew is required to wear personal protection equipment (gloves) for sample insertion and removal as the temperature is below  $-18^{\circ}\text{C}$ .



### 3.8.1.7 Glacier Mechanisms

Glacier utilizes five types of mechanisms; a failure to the first four (door latch, door captive locks, door hinges, and the VPMP/Locker Captive Fasteners that attach the Glacier to the hard mounting locations and cryocooler launch/landing locks) is considered catastrophic and the Cryocooler launch/landing locks is considered necessary for mission success.

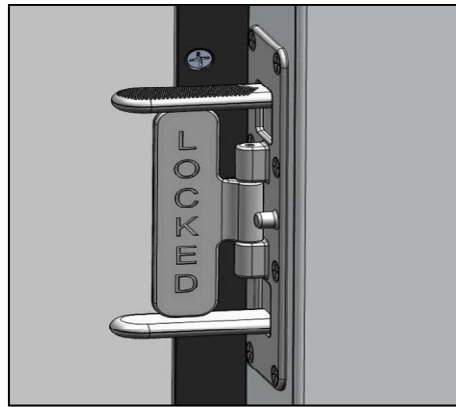
The following description provides an overview of the Glacier mechanisms:

#### **Door Latch**

The Glacier door latch (see Figure 3-48) consists of the system necessary to gain access to the experiment volume contained within the Glacier and to secure its contents during launch and landing environments. The door latch is designed to support the weight of the samples in the cold volume in the x-axis during launch and landing and to provide thermal isolation during on-orbit operations by maintaining the door in the closed position. The latch is engaged prior to turnover for flight and is operated by the crew during on-orbit activities. The door latch is located on the left side of the front panel between the door and circuit breakers.

When the crewmember is ready to open the front door, the latch lock plate must be rotated to an unlocked position. The door latch mechanism is activated by compressing two handles between the thumb and index finger. This movement compresses a spring that is installed and contained between the two handles, thereby allowing the handles to retract the latch mechanism to the unlatched position. The door latch mechanism is intended to be engaged for launch, landing, and on-orbit operations. This mechanism should remain in the closed position, except for those times when Glacier is accessed for sample insertion or removal.

For STS-119/15A, the crew is required to use the door latch to access the inner doors during sample transfer. The crew is required to verify this latch is locked prior to landing.

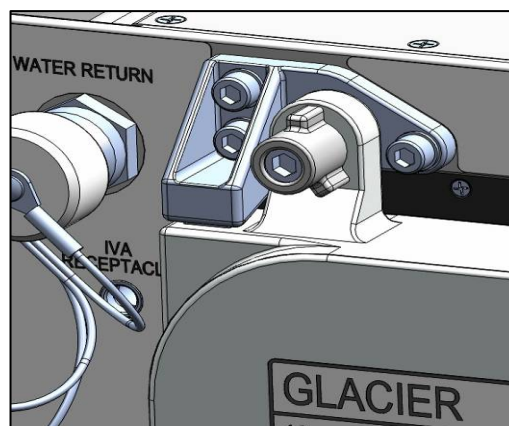


**Figure 3-48. Glacier door latch**

### **Door Captive Locks**

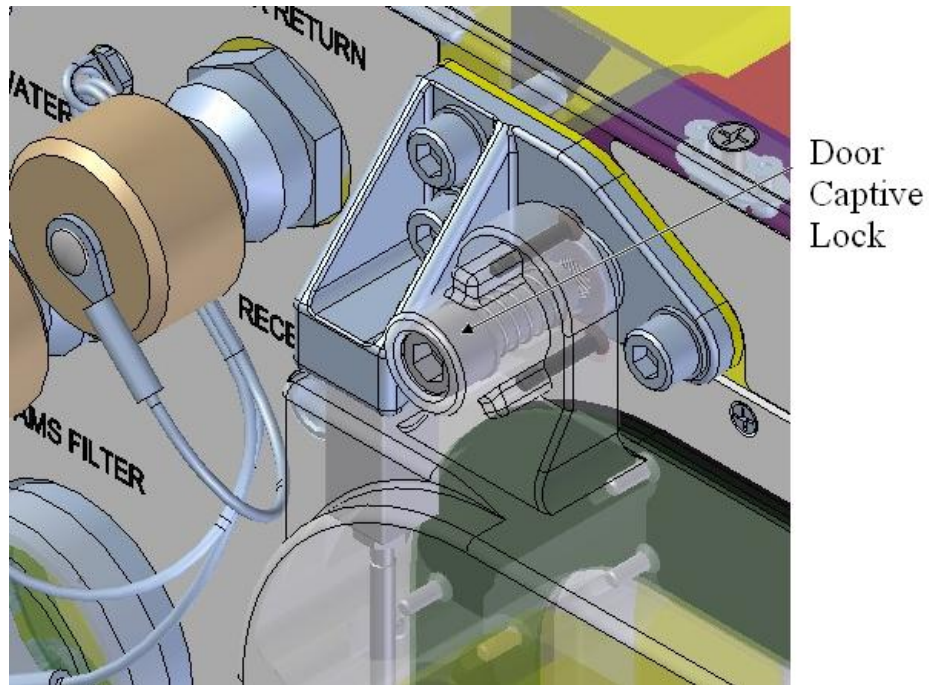
The Glacier door also contains two captive locks (see Figure 3-49), located at the top and bottom of the door on the latch side. Figure 3-50 shows the Captive Lock Position for the on orbit transfer. Figure 3-51 shows the Captive Lock Position for Ascent and Descent. These fasteners are used to provide redundancy only during launch and landing. Captive fasteners are replaced after each mission. The captive locks are operated by inserting a tool into the hex drive.

For STS-119/15A, the crew is required to unlock the door captive locks prior to sample transfer, and lock these prior to landing.

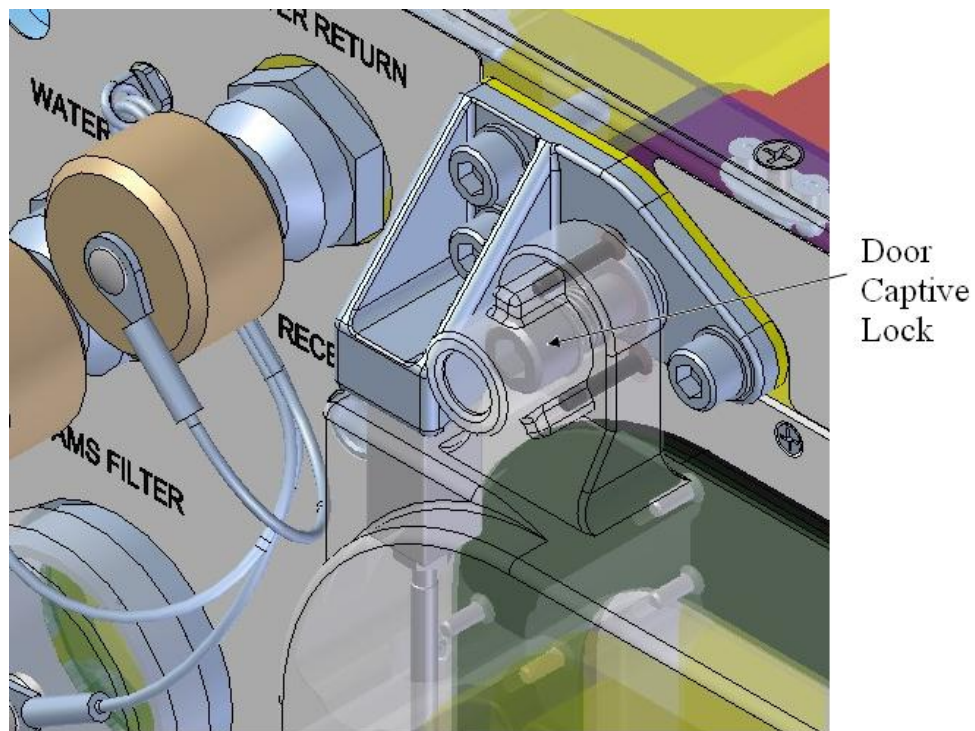


**Figure 3-49. Door captive lock (qty 2)**





**Figure 3-50. Glacier door captive lock positioned for on-orbit sample transfer**



**Figure 3-51. Glacier door captive lock positioned for ascent and descent**

**Verify that this is the correct version before use**

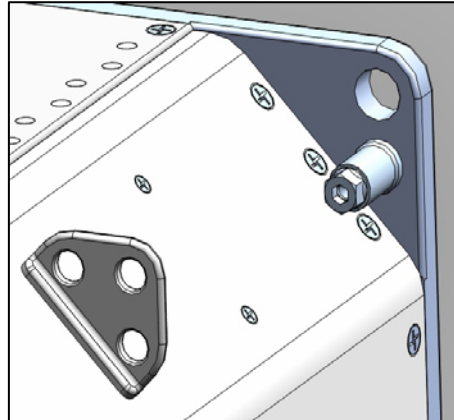
## **Door Hinge**

The Glacier door hinge provides a means of rotating the door into an open position for sample insertion and rotating back to the closed position. There are two hinges incorporated into the door design, one at the top of the door and one at the bottom of the door. The only structural load applied to the hinges is created by sample restraint during launch and landing.

The door hinge mechanism is utilized to provide positive retention of the door in the open position during microgravity operations. The front panel incorporates a door retention spring, retention spring cover, and a retention spring shim for each hinge. As the door rotates into the open position, the small protrusion on the door hinge engages the door retention spring at the 90° point. Once the door goes past that point, it is prevented from returning to the closed position without active crew intervention.

## **VPMP/Locker Captive Fasteners**

For launch and landing in the middeck, Glacier attaches to two mounting panels, in two places on each panel, by means of four captive fasteners (see Figure 3-52). Glacier utilizes these captive fasteners for all structural attachments, and they are required to be installed before launch or landing. The captive fasteners are replaced after each flight.

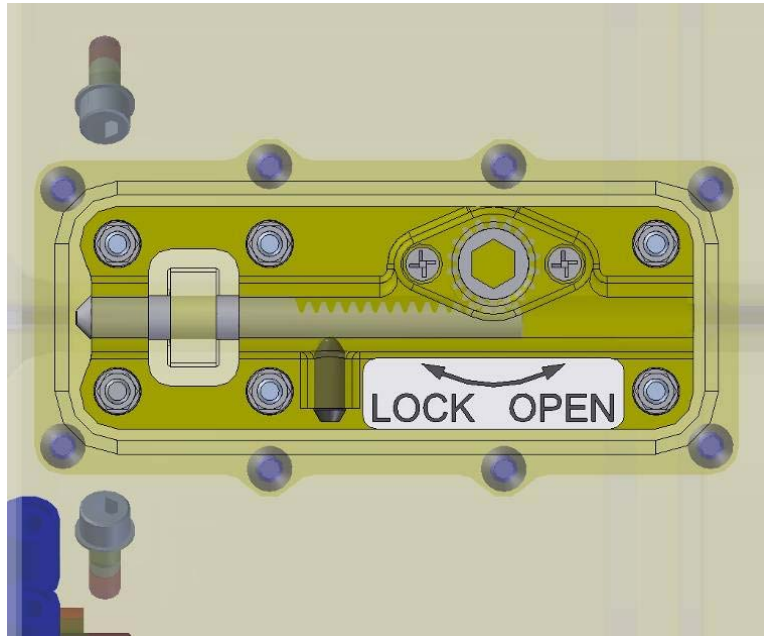


***Figure 3-52. Locker captive fasteners (qty 4)***

## **Cryocooler Launch/Landing Locks**

Cryocooler launch/landing locks (see Figure 3-53) are used in the Glacier design to provide for vibration isolation of the cryocoolers during on-orbit operations while securing Glacier during launch and landing. There are a total of four locks, two that restrain x-y motion and two that restrain x-z motion within the wire tray coordinate system. The locks are important to mission success; however, failures associated with the launch locks do not present catastrophic or critical hazards. Prelaunch procedures

require that the locks be engaged for launch. The locks are also to be engaged for descent/landing. In the event of failure to close the latches, the cryocoolers are contained by the back plate, cold volume, and within foam packaged around the cryocoolers.



**Figure 3-53. Cryocooler launch/landing locks**

### **Glacier Intravehicular Activity Handle Assembly**

A Glacier Intravehicular Activity (IVA) handle, Figure 3-54, is provided to support IVA transfers between shuttle and ISS. The IVA handle attaches to the Glacier front panel by inserting the handle ball-lock pins into the corners of Glacier. The Glacier IVA handle is a single assembly which collapses for easy stowage.

#### **3.8.1.8 Malfunctions**

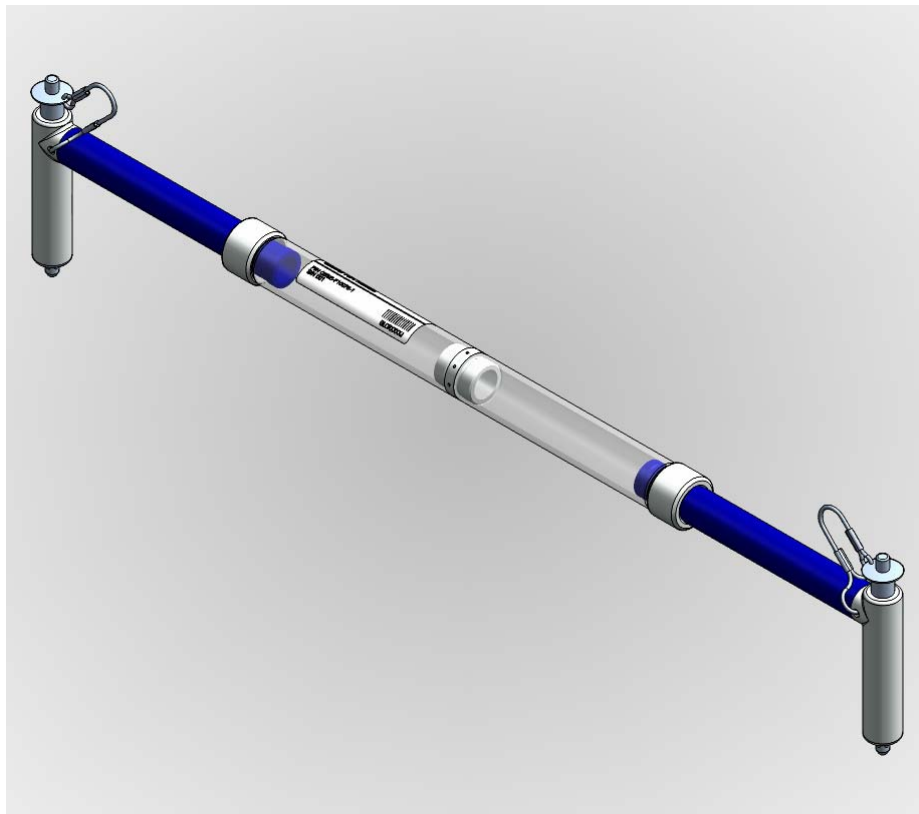
If the crew experiences an off-nominal situation during a status check or sample insert or removal, the procedures direct them to the Glacier Error Message malfunction procedure. In the event of further off-nominal situations, the ground can direct the crew to one of the following malfunction or contingency procedures: Glacier Fail to Repower, Glacier LCD Blank, Glacier Fail to Hold Set Point, Glacier Power Cycle, Glacier Shutdown, Glacier Reboot, Glacier Manual Reconfigure, or Glacier Record Diagnostic Data.

If a temperature is out of range  $\pm 10^{\circ}$  C off the set point ( $-95^{\circ}$  C for 15A ascent), the Glacier software indicates an **\*\*Error Pending\*\*** message. The Middeck status check contains a step to check that the CURR TEMP is  $-95^{\circ} \pm 5^{\circ}$  C. So, the crew would call

down any temperature outside of this range and may need to run the Error Message procedure without the **\*\*Error Pending\*\*** indication.

Other Error Pending messages are enunciated for the following errors:

- a. Water flow or water temp is out of range of set point.
- b. AAA temp is out of range of set point.
- c. Voltage reading is out of range of set point.
- d. Current reading is out of range of set point.
- e. Rack Interface Controller (RIC) Comm Loss error occurs if Glacier is configured to communicate to the EXPRESS Rack and data is lost between them.



**Figure 3-54. Intravehicular activity handle assembly**

### 3.8.2 Dome Gene

The Dome Gene sortie payload investigates the effects of microgravity on amphibian cells at the gene expression level with particular interest in the possibility of expression of unidentified genes from microgravity cultivation.

STS-119/15A is the first flight for JAXA's Dome Gene payload. Three large and three small cylinders, large and small prefixation apparatuses, fixation sticks, buffer cassettes, culture chambers and Cell Experiment Units (CEUs) launch at ambient temperature.

The Dome Gene has a late-load requirement of Launch (L) -24 hours due to living cells. There is also an early retrieval requirement of Return (R)+4 for the Large Fixation Cylinder stowed in the returning Glacier at -95° C on STS-119/15A descent.

The Dome Gene sortie operations are performed prior to docking. The Dome Gene ISS experiment hardware is transferred to ISS, where operations are performed in the JEM.

### **3.8.2.1 Dome Gene Sortie**

The sortie samples are the experiment control group to quantify the launch vibration effect for cultured cells. The sortie operation must be performed in the orbiter before docking, within 24 to 72 hours after turnover. The sortie operation is currently scheduled for Flight Day 2 (FD02).

### **3.8.2.2 Operations**

Two Large Culture Chambers of A-6 amphibian cell are launched in the Prefixation Apparatus ready for washing by a buffer solution at ambient temperature. A crewmember is required for a 45-minute activity to operate the Prefixation Apparatus. The handle is squeezed 15 times to wash out the medium by a buffer solution. The crewmember switches an air/buffer exchange valve to the air side and squeezes 10 times to exchange the buffer with air inside the chambers. Then, the two Large Culture Chambers are removed from the Prefixation Apparatus and put into a Large Fixation cylinder. Two large fixation sticks are inserted into the Large Fixation cylinder to inject fixative into the Culture Chambers. The Fixation Cylinder has fixative syringes inside and the fixation sticks are used to push the fixative into the chambers from syringes inside the Fixation Cylinder. After activation, the Large Fixation Cylinder is immediately transferred to Glacier to freeze at -95° C for return on STS-119/15A.

On FD02 the Dome Gene is activated and stowed in the Shuttle Glacier. During docked ops, the Shuttle Glacier unit is swapped with the Glacier unit on ISS in EXPRESS Rack 6. Later in the docked time frame, the Dome Gene is swapped back to the Shuttle Glacier in a Double Cold Bag (DCB).

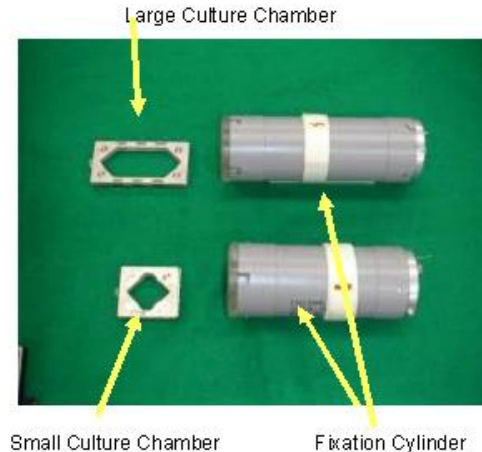
The Dome Gene sortie hardware consists of the following:

- a. Prefixation Apparatus (see Figure 3-55)
- b. Large and Small Culture Chambers (see Figure 3-56)
- c. Cell Exp Large and Small Fixation Cylinder





**Figure 3-55. Prefixation apparatus**



**Figure 3-56. Culture chambers and fixation cylinders**

### 3.8.2.3 Interfaces

There are no data, power, or thermal interfaces for Dome Gene.

### 3.8.2.4 Safety

The Large Fixation Cylinder contains Toxicity Hazard Level (THL)3 fixative, named Isogen, and the cylinder maintains a triple level of containment at all times during operation. A few operational controls are required and are covered by the procedure. The sortie procedure directs the crewmember to verify that no scar or distortion exists on the triple O-rings before closing the transparent cover and to verify that the cover is engaged with the cylinder after closing. The crewmember marks a check on the cylinder after operation not to open the cylinder again.

### 3.8.2.5 Dome Gene ISS

The remaining Dome Gene hardware is transferred from the shuttle to the JEM. During docked operations, two large and two small cylinders are transferred to Minus Eighty Laboratory Freezer for ISS (MELFI) (+2° C) before the start of incubation of the CEUs in the Cell Biology Experiment Facility (CBEF). One small cylinder is transferred to ISS for ambient stowage. CEU-A and CEU-B are placed in the CBEF within 72 to 144 hours of hardware turnover (L + 2 - 5 days) for incubation. After incubation, Culture Chambers from CEU-A are removed first for observation and fixation followed by the removal of

CEU-B Culture Chambers. CEU-B must be removed from the CBEF for fixation within 24 hours of CEU-A fixation.

After CEU-A incubation, the crew retrieves the two large and two small Fixation Cylinders from MELFI. The crew removes the Culture Chambers from two CEU-A in the CBEF, places Culture Chambers into one large and one small Fixation Cylinder, and fixes samples. These large and small Fixation Cylinders are inserted into MELFI (-95° C), immediately, no later than 2 hours after activation.

The crew removes the other Culture Chambers from the remaining two CEU-A in the CBEF and observes samples using the Clean Bench (CB) microscope. The crew retrieves samples from the CB, places the Culture Chambers into the remaining large and small Fixation Cylinders, and fixes samples. These large and small Fixation Cylinders are also inserted into MELFI (-95° C), immediately, no later than 2 hours after activation.

Within 24 hours of CEU-A Culture Chamber fixation, the crew removes the Culture Chambers from the CEU-B in the CBEF, places the Culture Chambers into the ambient Small Fixation Cylinder, and fixes samples. This small Fixation Cylinder is reinserted into MELFI (+2° C) as soon as possible, no later than 2 hours after activation. The crew performs remaining closeout and deactivation activities.

During Flight 2J/A docked ops, all cylinders are removed from MELFI and packed in DCBs for return.

### **3.8.3 PCDF-PU**

The Protein Crystallization Diagnostics Facility (PCDF) is an ESA multiuser facility to investigate crystal growth mechanisms in proteins or other macromolecules under microgravity. It provides all means to conduct crystallization experiments according to different crystallization methods (dialysis or batch), and is capable of observing the crystallization process with various optical means as video observation, interferometry, and dynamic light scattering. For experiment sessions, PCDF is hosted in the European Drawer Rack (EDR) in the Columbus Module on the ISS.

PCDF has the following two major units:

- a. The Electronics Unit (EU) – For the control of the overall performance; it is an integral part of EDR as launched Mission 1E.
- b. The Process Unit (PU) – It contains the experiment itself and the diagnostic instruments (optical, interferometer, dynamic light scattering).

The shuttle middeck locker is used for launch and return, and PCDF is transferred to the Columbus Module during the dock phase of the mission. Prior to the PCDF-PU transfer, the Columbus Rack needs to be configured for install. The PCDF-PU must be

powered down, transferred and powered up within 100 minutes. STS-119/15A is the first flight of the PCDF-PU.

The Advanced Protein Crystallization Facility (APCF), the precursor to PCDF, was also an MDL payload and has been flown several times before (e.g., SpaceHab1, International Microgravity Laboratory (IML)-2, United States Microgravity Laboratory (USML)-2, Life and Microgravity Spacelab (LMS), ISS, and Increment 3). The PCDF-PU is the only part of PCDF that is the subject of flight in the orbiter middeck; therefore, the following hardware description is focused on this item and its middeck operation.

PCDF-PU is continuously powered by the nominal 28 V dc 10-A source from the orbiter middeck. Continuous power maintains the constant temperatures required by the protein crystallization experiments. The maximum time without power is limited to 100 minutes.

The PCDF-PU operates autonomously during its ascent in the orbiter middeck. The unit is in keep-alive mode for the experiments until it is transferred to ISS. The crew is required to perform a status check once a day before transferring the PCDF-PU to the EDR in Columbus. In the event of an off-nominal condition, the PCDF Off Nominal Recovery procedure is performed.

The PCDF-PU installed in an ISS locker is shown in Figure 3-57.

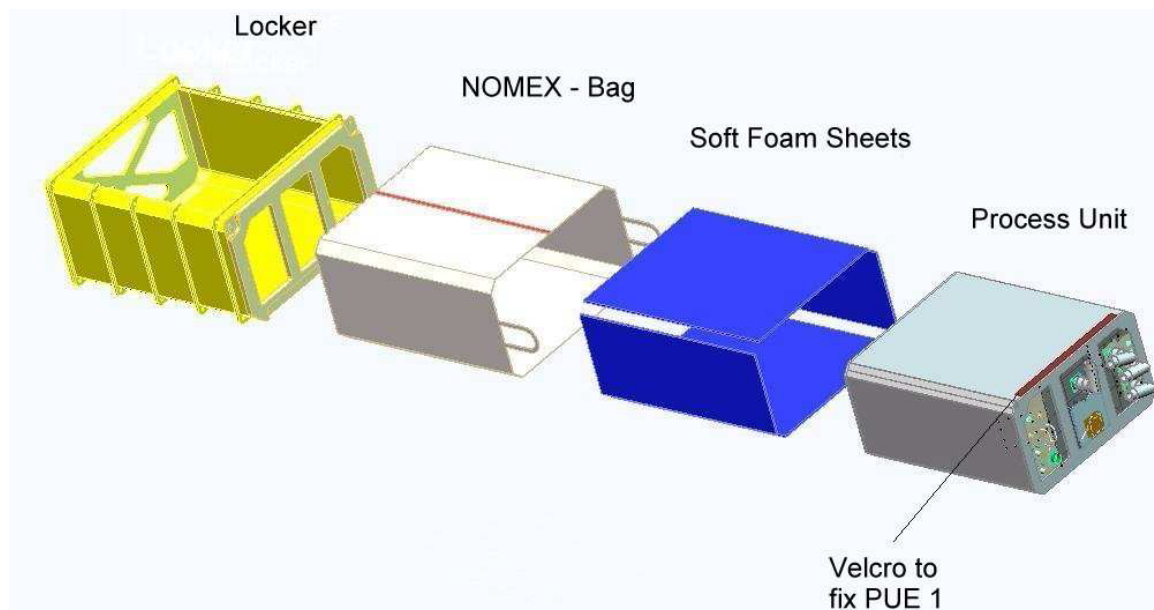


**Figure 3-57. PCDF-PU installed in an ISS locker**



### 3.8.3.1 Mechanical Structural Interface

The integral part of the PU is the layers of thermal isolation and packing foam that are covered by a NOMEX bag, as shown in Figure 3-58. This assembly is compliant to MDL internal dimensions and fits into the locker as an MDL insert. No trays or additional packing foam inside the locker are required. The crew handles the whole assembly as one single piece covered by the Nomex bag during transfer to ISS.



**Figure 3-58. Principle of PCDF-PU installation into MDL**

The whole PCDF-PU assembly, including the Nomex bag, must be accommodated in an MDL with the door panels removed to facilitate front panel access and cutouts at the locker rear to use the VPMP of the shuttle middeck.

The PU is transferred from the orbiter to ISS/EDR, as soon as the EDR is ready to host the PU. The outer layer of the PU is a Nomex bag with slings as shown in Figure 3-58. Using these slings, the PU is extracted from the middeck locker, transferred to the ISS, and installed into the EDR/ISS locker, including the Nomex bag. The empty MDL and a few hard foam pieces on the back side of the locker door remain in the orbiter.

### 3.8.4 PCDF-PU Front Panel

Figure 3-59 shows the PU front panel. It contains the following:

- A circuit breaker in combination with the Power On/Off switch
- Electrical power supply connector, J01
- LEDs for status indication that have to be operated during middeck activities

- d. Two quick disconnects for cooling water inlet and outlet (used in EDR only)
- e. Two light fiber connectors (used in EDR only)
- f. Further electrical connectors, J02 through J05, for connection to PCDF Electronics Unit (used in EDR only)
- g. Fire port for the portable fire extinguisher



**Figure 3-59. PCDF-PU front view after installation into MDL**

In the standalone operation in the orbiter middeck, the status of the PCDF-PU is displayed by five LEDs.

- a. EDR Power On LED is On – External power outlet is providing power and PU is switched on
- b. Power On LED is On – Secondary power of PU is on
- c. Contr Failure LED is Off – Microcontroller watchdog is operational

- d. Nominal Process Temp LED is On – Experiment sample temperature is within appropriate range
- e. Standalone Mode LED displays operations mode either standalone or connected to and controlled by EU

#### **3.8.4.1 Power Interfaces**

Due to protein sample life limitations, the PU must be installed in the shuttle middeck as a late-access payload at Launch-28 (L-28) hours. From late-access load to transfer to the ISS, electrical power of *90 W (140 W peak)* must be provided from orbiter to the PCDF-PU via front panel connector (Power J01).

The PCDF-PU is continuously powered by the nominal 28 V dc 10-A source from the orbiter middeck. The only planned period without power is the transfer from the shuttle to the ISS/Columbus. The maximum time without power is limited to *100* minutes at 25° C maximum cabin temperature.

#### **3.8.4.2 Thermal Interfaces**

The PCDF-PU is a rear-breather, and internal heat dissipation is conducted via its internal ammonia heat pipes to the rear heat exchangers.

The PCDF-PU has two thermal interfaces to the orbiter.

- a. PUE1 fan on the front panel, rejecting about 7W of heat to cabin air
- b. Rear-breather interface to rear air panel air flow, at air flow rate of 17 L/s (36 CFM with temperatures <27° C, maximum heat rejection of 133 W)

#### **3.8.4.3 Structural Interfaces**

The PU is inserted into an MDL using packing foam that is an integral part of the facility. The fully packed locker is then fixed to the orbiter via the four standard locker fasteners. The PU accommodation has to be such that before launch, the front panel is looking to the opposite of the orbiter nose to keep the heat pipes properly working before reaching the microgravity environment.

A summary of the orbiter interfaces is given in Table 3-7.

**Table 3-7. PCDF interfaces**

<b>Power Interfaces</b>	<b>Thermal Interfaces</b>	<b>Command/Telemetry Interfaces</b>	<b>Structural Interfaces</b>
Connector Power J01 is the interface to the power outlet 10-A 28 V dc (max. 140 W)	Front panel fan 7 W to cabin air	Power On - Off switch Operated manually by crew	The four captive Milson fasteners of the middeck locker
	To rear locker panel air flow 140 W	LEDs show status of facility	
		Telemetry I/F none	

### 3.8.5 Data Connections

There are no data connections for the STS-119/15A middeck configuration.

During standalone operations, a set of housekeeping data is stored periodically in nonvolatile memory for later read-out via the electronics of the EU. There is no required data communication with the orbiter foreseen.

The Data J02 and J05 connectors, as well as the Power J03 and J04 connectors are not connected to the orbiter as they provide the electrical EU-PU connection inside EDR.

### 3.8.6 Safety

The safety of the PCDF is discussed in Safety Data Package (SDP) (PCDF-DP-DO-01, issue H). During phase III review, the related hazard reports were approved and signed.

The following hazards are of specific interest for the PCDF-PU in the orbiter (operations and hazard controls in Columbus/EDR are covered elsewhere):

- a. PCDF-01: Rupture/leakage of heat pipes (Ammonia heat pipes)
- b. PCDF-03: Release of sample material

- c. PCDF-05: Structural failure (verification 2.1 crew procedures during transfer)
- d. PCDF-STD-14.2.3 switch off upstream power during power cable mating (CAUTION)

### 3.8.6.1 ISS Interfaces that Affect PCDF-PU Transfer Operations

The PCDF-PU is transferred from the shuttle middeck to the Columbus Module and installed in the EDR. The entire PU is transferred, including its NOMEX bag, leaving its locker shell behind in the middeck as the EDR locker is already housed in Columbus.

The EDR configuration, with installed PCDF, is shown in Figure 3-60.

After mechanical insertion of the PCDF-PU into the EDR locker, the following connections must be made:

1. Connect PCDF-PU to EDR power outlet (10-A at 28 V dc).
2. Install power/data harness (J02 through J05) between PCDF-PU and Electronics Unit (more details in Figure 3-61).
3. Install fiber-optic cables between PCDF-PU and Electronics Unit.
4. Connect PU to EDR water cooling loop.
5. Install the coolant water hose between EU and PU.

When the PCDF-PU is installed in the EDR, it receives its power (10 A at 28 V) from EDR via the same connector at the PU front panel as was used in the middeck.

Disregard the EU and PU labels (status before ISS Payload Label Approval Team (IPLAT) approval)

PCDF heat rejection inside EDR

- a. EU and PU reject more than 90 percent of their heat via the moderate water cooling loop provided by EDR, requiring a water flow of 32.4 l/h (at 16° to 20° C). The PCDF coolant water supply (Quick Disconnect) is at the PU front panel, the water is then routed by the PCDF coolant water hose to the EU, and then returned to EDR at the EU coolant water return (Quick Disconnect).
- b. The electronics on the PU front side is cooled – as in the orbiter middeck – by forced air convection to cabin

The rear air cooling feature of the PU is no longer used in EDR.

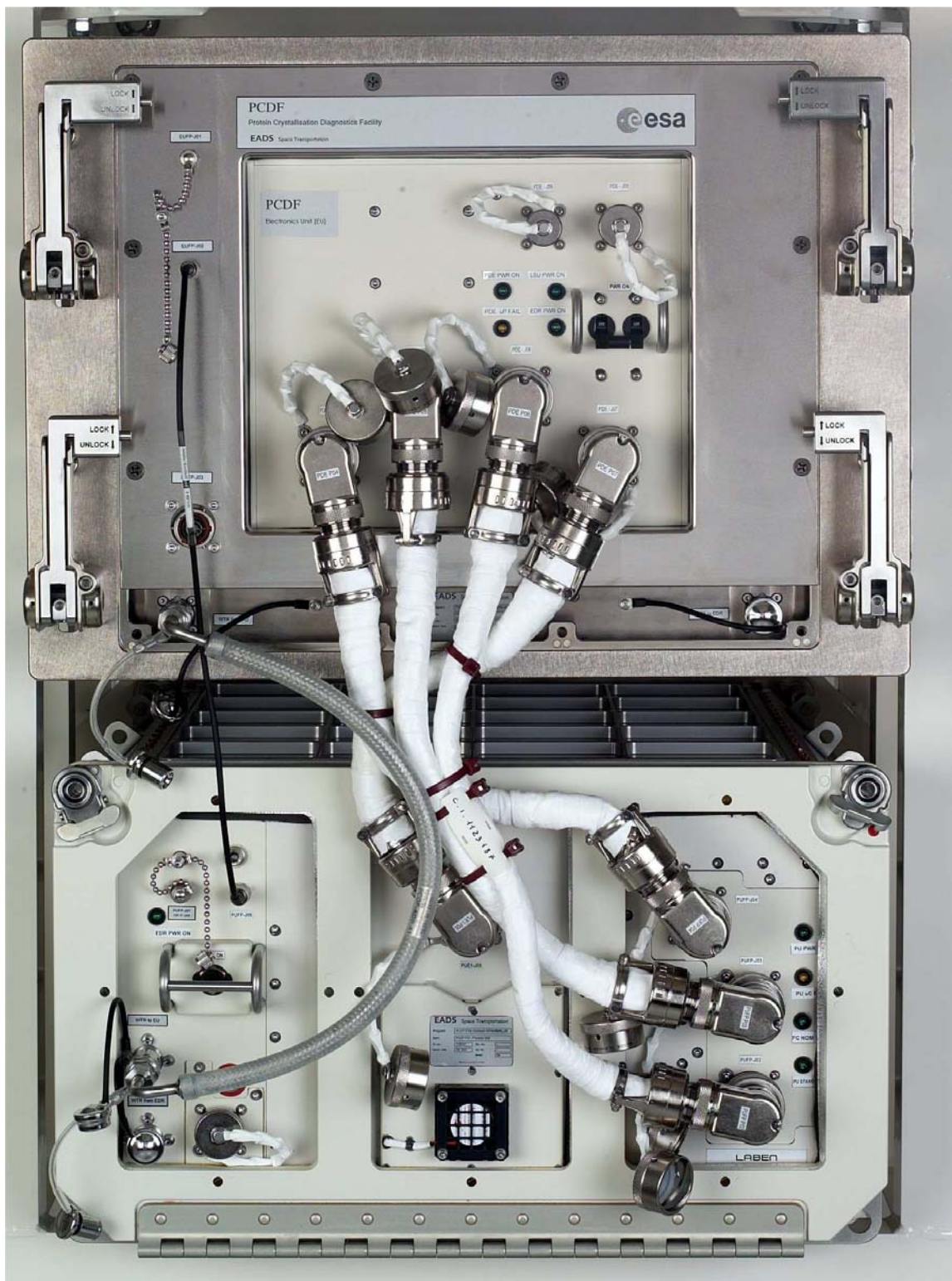
After integration in the rack, the Data/Command/Telemetry Interfaces are controlled by EDR via the PCDF electronics, which are connected to the PU and switched on during the installation sequence. These interfaces are listed in Table 3-8.



**Figure 3-60. EDR, including PCDF in isometric view**

**Verify that this is the correct version before use**





**Figure 3-61. PCDF front panel connections**

**Verify that this is the correct version before use**

**Table 3-8. PCDF-EDR interfaces**

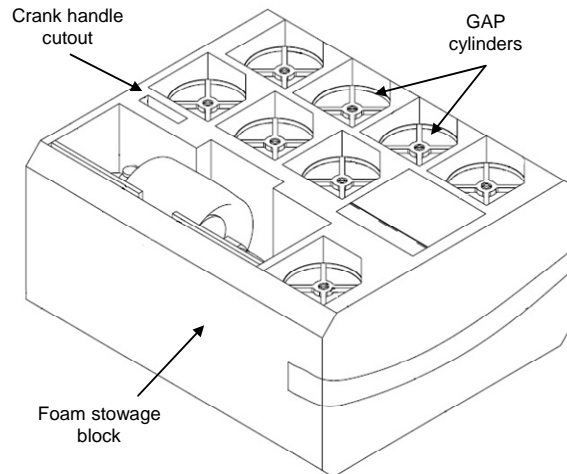
<b>Power Interfaces</b>	<b>Thermal Interfaces</b>	<b>Command/ Telemetry Interfaces</b>	<b>Structural Interfaces</b>	<b>Other Interfaces</b>
Connector Power J 01 is the interface to power outlet 10 A 28 V dc of EDR Upper Utility Panel	Front panel fan 7 W to cabin air	Front panel connections to PCDF Electronics Unit provide Command/telemetry capabilities via EDR/Columbus	Nomex bag with packing foam; no rigid I/F to preinstalled EDR ISS locker	
	Quick disconnects reject heat to EDR coolant water loop	Fiber-optic connections		

### **3.8.7 National Lab Pathfinder-Vaccine 3 (NLP-Vaccine 3)**

The purpose of the National Lab Pathfinder (NLP)-Vaccine payload is to investigate the effect of spaceflight on microbial gene expression, virulence, and drug resistance. This information is used to improve the microbial risk assessments to decrease infectious disease risk to the crew and could also be used to create new approaches to vaccines used on earth.

NLP-Vaccine is an unpowered payload, flown at ambient temperature in a single Middeck locker. The NLP Vaccine-3 payload consists of eight Group Activation Packs (GAPs) and one hand crank. The GAPs and hand crank are flown inside a foam insert (see Figure 3-62), which are stowed inside a locker in the orbiter middeck.





**Figure 3-62. GAPs and hand crank in foam stowage block**

Each GAP (labeled 1 through 8) contains eight Fluid Processing Apparatuses (FPAs). Each FPA contains a growth medium and a microbial culture suspended in stasis medium. One of the GAPs contains a HOBOTM temperature recorder to collect thermal profiles the flight samples are exposed to. The GAPs and FPAs have previously flown on numerous missions; most recently on ULF-2.

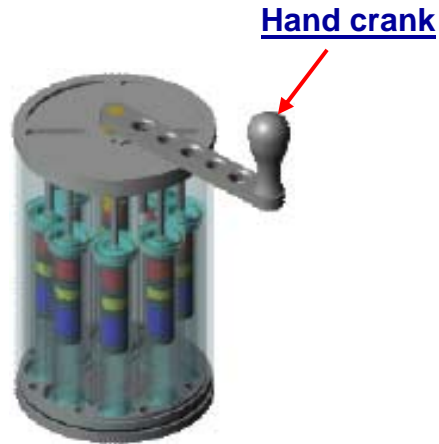
### **HOBOTM Data Recorder**

The HOBOTMs are autonomous data (temperature) recorders, powered by small internal Manganese Dioxide Lithium battery (1x CR2032). These data recorders are routinely flown aboard the STS/ISS. The HOBOTM data recorders were flown aboard STS-95, 93, 106, 100, 110, 112, 115, 15S. Batteries are not accessible on orbit and cannot be replaced by the crew. HOBOTM data is stored in nonvolatile memory and, therefore, battery life does not constitute the “operational life” of the payload.

### **Group Activation Pack**

The GAP is designed to contain eight FPAs. It consists of a clear polycarbonate cylinder with aluminum end caps. The GAP is a sealed container and, therefore, the FPAs located inside do not experience any pressure differentials caused by depressurization or pressurization. The GAPs are rated to vacuum exposure in the case of cabin depressurization.

The crew manually operates the GAPs by attaching the provided 1/4-inch drive crank handle to turn the lead screw, which causes the GAP-internal pressure plate to depress the FPA plungers (Figure 3-63). All eight FPAs in a single GAP are activated and terminated simultaneously.



**Figure 3-63. GAP with hand crank attached**

Alignment marks on the outside of the clear GAP cylinder indicate the proper activation and termination positions (see Figure 3-64). The procedure directs the crew to shake each GAP after activation and termination. The crew immediately calls down the Mission Elapsed Times (METs) of activations and terminations so the ground control units can be activated or terminated accordingly.



**Figure 3-64. GAP with alignment marks**

## Fluid Processing Apparatus

The FPA (shown in Figure 3-65), first flown aboard STS-77, is a series evolved hardware from the original FPA (STS-50). Each FPA contains an experiment sample, a media solution, and may or may not contain a fixative solution. There are three different FPA configurations to choose from: no gas exchange membranes, one Gas Exchange (GE) membrane, or two GE membranes.

As an example, in the FPA configuration that was used for NLP-Vaccine-1A and 1B, which flew on STS-123 and STS-125 respectively, the last rubber septum of chamber A (shown in Figure 3-65, circled in blue) was an Ultem insert. The insert had three holes drilled through it and was sealed within the glass barrel by an O-ring. A hydrophobic polytetrafluoroethylene (PTFE) membrane with 0.02 $\mu$ m pore size was attached to the insert and allowed the passage of gases into or out of the A chamber, without allowing liquids to pass (gas-permeable, watertight). This membrane served as the first level of liquid containment (inside the glass barrel) even at very high pressures.

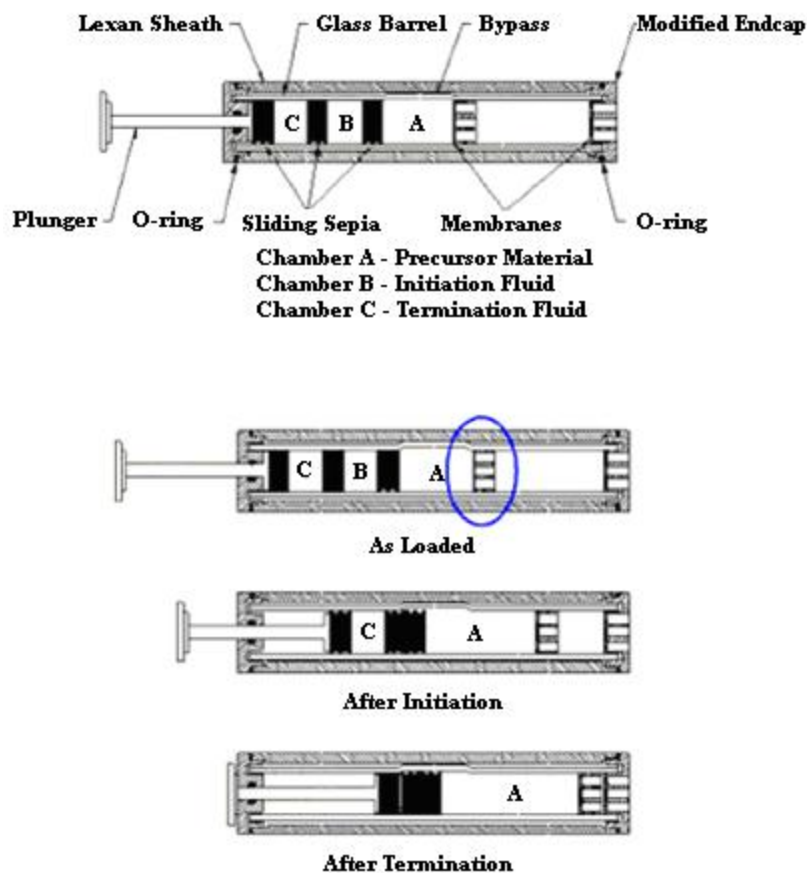


Figure 3-65. FPAs

The FPAs in Figure 3-65, contain two GE membranes. The PTFE membranes allow for active gas exchange between the interior of the FPA and the sealed volume of the GAP, as well as providing two levels of liquid containment. The GAP polycarbonate enclosure provides an additional third level of fluid containment and one level of vapor containment for all internal experimental samples.

The second level of liquid containment, in case the first level is breached (glass barrel failure, membrane failure), is provided by O-rings at the bottom end cap, the plunger end cap, and at the plunger penetration.

### Interfaces with Shuttle

NLP-Vaccine does not require any power, thermal, or data interfaces to shuttle.

### Safety

NLP-Vaccine contains biosafety level one and two organisms and toxicology level one and two agents. These hazards are separated from the crew by three levels of containment. See Table 3-9.

**Table 3-9. GAP levels of containment**

Level of containment	Method of Containment
1	Glass barrel + Membrane
2	Lexan Sheath
3	GAP Outer Container

Each level of containment requires different responses in the event a breach of containment occurs. Crew responses are as follows:

- a. For a first level breach in two or less glass barrels, GAP may be activated or terminated and then placed into Ziplock bag for containment.
- b. For a two level breach (glass barrel and FPA Lexan sheath) in any FPA, GAP is immediately bagged and not used. Likewise, a breach of the primary GAP polycarbonate enclosure requires the crew to immediately seal the entire unit in a Ziplock bag. Crew should report any observed leakage to MCC-H.

### Operations

- a. Two nominal procedures
  1. GAP Activation: one crew for approximately 15 minutes
  2. GAP Termination: one crew for approximately 15 minutes

- b. No off-nominal procedures.
- c. NLP-Vaccine has Late Stow and Early Access of L-28 and R+6 hours, respectively.

### **3.9 PAYLOADS OF OPPORTUNITY**

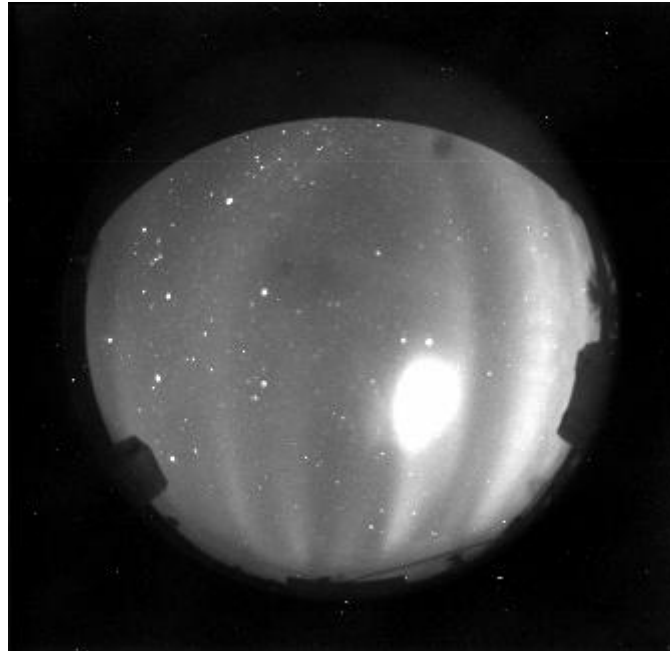
A payload of opportunity is one that is only performed when conditions become favorable for the successful operation of the payload. STS-119/15A attempts to accommodate the three following payloads: Maui Analysis of Upper-atmospheric Injections (MAUI), Shuttle Ionospheric Modification with Pulsed Localized Exhaust (SIMPLEX), and Shuttle Exhaust Ion Turbulence Experiments (SEITE). All three are Department of Defense (DoD) experiments designed to analyze the orbiter's thruster firings for purposes of improving space surveillance and space asset characterization. No hardware is flown to support the payloads, as existing ground and in-space resources are already in place to record data. No additional propellant is flown for the payloads of opportunity.

The DoD Representative (Rep) is responsible for and provides support to the MAUI, SEITE, and SIMPLEX payloads. The DoD Rep is located in the DoD Payload Operations Control Center (POCC) (building 30M, room 336, at JSC). The DoD Rep coordinates with Assembly Checkout Officer (ACO) on the Prime Ops loop and ACO Data on the PL Conf loop. The DoD POCC phone numbers are 281-483-3510 and 281-244-5305. The DoD Rep coordinates with ACO Data for shuttle trajectory information as needed for planning.

#### **3.9.1 Maui Analysis of Upper-atmospheric Injections**

MAUI is designed to observe the orbiter exhaust plumes via the optical telescopes at the Air Force Maui Optical and Supercomputing Site (AMOS) located on Maui, Hawaii. An example of an Orbital Maneuvering System (OMS) burn viewed from the ground is shown in Figure 3-66. The images and data taken by the telescope system are analyzed to better understand the interaction between spacecraft plumes and the upper atmosphere. AMOS is capable of capturing data from both RCS and OMS burns. Two other MAUI ground sites are available to capture OMS burns only and are located on the Kwajalein Atoll and Christmas Island.

Minimum science for MAUI requires viewing a sequence of four Primary RCS (PRCS) burns at 0°, 90°, 180° and 45° Angles-of-Attack (AOA) relative to the velocity vector, three Vernier RCS (VRCS) burns at 0°, 90°, and 45° AOA, and at least one OMS burn (retrograde preferred). For MAUI to observe the minimum required burns, it is planned for multiple shuttle flights.



**Figure 3-66. Low resolution all-sky imagery from OMS burn**

### 3.9.1.1 Operations

MAUI has no upmass, but the requirements are fairly limiting. The orbiter must execute a specific burn or series of burns within a restrictive viewing range of the MAUI ground site while the ground site is in darkness and the orbiter is in either twilight or darkness. In the case of performing RCS burns, the orbiter has to be in a predefined attitude to correctly align the thrusters used for the experiment relative to the velocity vector. Because the crew is involved, it must also occur while they are awake. The crew should be scheduled for approximately 30 minutes to perform the burn(s).

MAUI requires the orbiter to complete three types of engine firings or maneuvers. The PRCS and VRCS data takes involve viewing burns using telescopes at AMOS. The telescopes require the orbiter to be at an elevation  $\geq 30^\circ$  to the AMOS site located at geodetic latitude  $+20.708^\circ$ , longitude  $-156.258^\circ$ , and altitude  $+1.6513$  n. mi. AMOS also has all-sky imagers to capture the OMS burn data for MAUI. MAUI can also acquire just the OMS burn data using all-sky imagers from the Kwajalein Atoll and Christmas Island when the orbiter elevation is  $\geq 30^\circ$  from each site. The Kwajalein Atoll site is located at geodetic latitude  $+9.3954^\circ$ , longitude  $+167.479^\circ$ , and altitude  $+0.01619$  n. mi. The Christmas Island site is located at geodetic latitude  $+2.01^\circ$ , longitude  $-157.4^\circ$ , and altitude  $+0.00539$  n. mi.

PRCS burn sequence is the highest priority, followed by a VRCS burn sequence, and finally the OMS burns. The PRCS and VRCS burn sequences can be combined during a single overflight. The entire sequence of seven PRCS and VRCS burns requires 30 minutes to prepare for but only 1 minute 50 seconds to complete the burn sequence

during the overflight. The burns are performed by the commander and pilot using a predefined procedure developed by the Guidance, Navigation, and Control (GNC) group.

To date, MAUI has captured two OMS burns, one during STS-120 and the other STS-122, both over Kwajalein. A PRCS burn sequence of four burns was observed on STS-120; however, the weather conditions (clouds) obscured two of the burns in the sequence and MAUI has requested another observation.

### **3.9.1.2 Post-Flight Analysis**

The results of the experiments are used to improve sensors and plume models used for space surveillance. MAUI requires orbiter state vector data, orbiter attitude data, and RCS jet firing history to perform analysis on the data, and this is obtained from the Orbiter Data Reduction Complex (ODRC) after the mission.

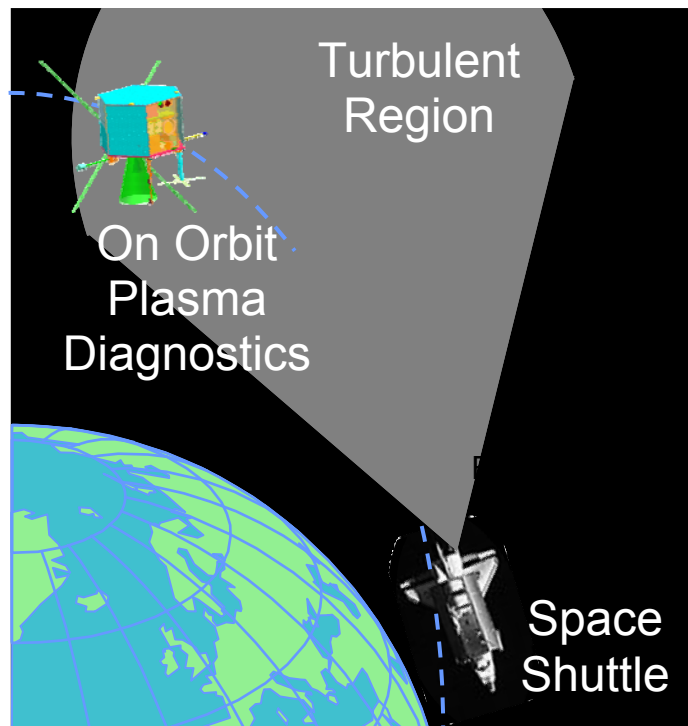
### **3.9.2 Shuttle Exhaust Ion Turbulence Experiments**

SEITE uses space-based sensors to investigate plasma turbulence in the ionosphere utilizing the firing of the orbiter's OMS engines while within range of the available diagnostic satellite, as shown in Figure 3-67. Various sensors provide data on neutral flows, electron and ion distributions, electric fields, plasma waves, and radio scintillations. Furthermore, the data obtained through SEITE enables development of quantitative models of the plasma disturbance, which degrades tracking and imaging radars.

The satellites that *are* used during STS-119/15A *are* the Communications/Navigation Outage Forecasting System (C/NOFS) *and STPSat-1*. Conjunctions between the satellite and the orbiter are rare, thus, it is important for SEITE to be manifested on as many shuttle missions as possible to increase the chances for obtaining the desired data.

Another diagnostic satellite that carries the required sensors for data collection for future shuttle missions is the Enhanced Polar Outflow Probe/Cascade SmallSat and Ionospheric Polar Explorer (ePOP/CASSIOPE) from the Canadian Space Agency (CSA), which is expected to launch in *November* 2009. A third diagnostic satellite, FalconSat-3, is currently on orbit but unavailable as it is tumbling.





**Figure 3-67. Satellite diagnostics of artificial plasma turbulence**

### 3.9.2.1 Operations

During a conjunction with one of the above satellites, the crew performs an OMS burn at a specified time provided by the Principal Investigator (PI). Ideally, it would be a 10-second, 400-lb dual OMS burn fired retrograde, but can be downgraded to a 10-second, 200-lb single OMS burn, depending on the characteristics of the conjunction. Approximately 30 minutes of crew time is required to prepare and perform the burn. The burn is performed by the commander and pilot. A still photo taken by another crewmember of the OMS burn near-field plume is required to capture any burn asymmetry. The photo requirement can be met by using a PLB video camera.

The OMS engine firings could be specific to SEITE, or a required burn that could be rescheduled to occur at an opportune time during a conjunction. One possibility is that an orbital adjust burn performed to set up for landing opportunities could be planned during a C/NOFS conjunction to lessen impact to propellant usage.

Two OMS burn observations, one sunlit and one in darkness, are required to satisfy the minimum science objectives for SEITE. SEITE first flies on STS-125, followed by STS-126/ULF2.

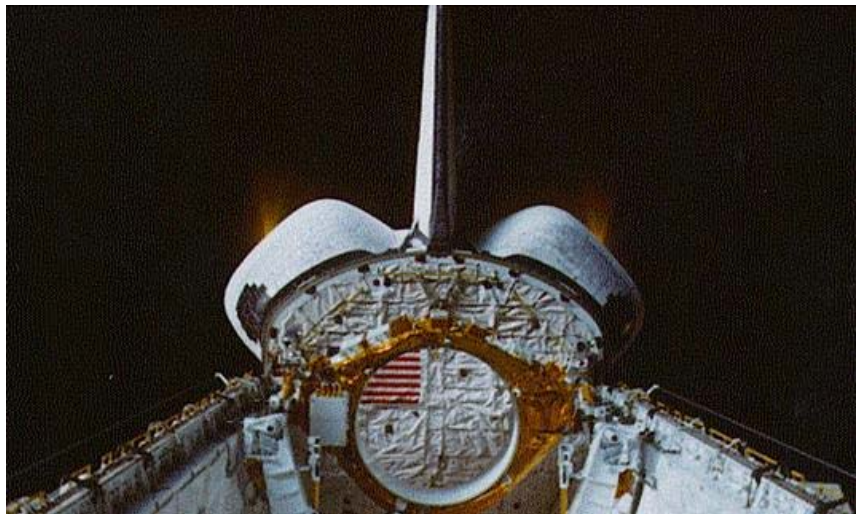


### 3.9.2.2 Post-Flight Analysis

The results of the experiments provide direct measurements of exhaust flow sources and provide in-situ observations of density and electric field disturbances. SEITE requires orbiter state vector data, orbiter attitude data, and OMS engine firing history to perform analysis on the SEITE data collected; this is obtained from the ODRC after the mission. Any photo or video documentation during the OMS burns is also required for postflight analysis.

### 3.9.3 Shuttle Ionospheric Modification with Pulsed Localized Exhaust

The objective of SIMPLEX payload of opportunity is to determine the source of Very High Frequency (VHF) radar echoes resulting from the orbiter OMS engine firings. Figure 3-68 shows a dual OMS burn. There is no payload hardware, rather, SIMPLEX uses six ground-based radar and radio telescope installations to record the ionospheric distortions caused by the OMS burns.



*Figure 3-68. Symmetrical dual-OMS burn during orbital daylight*

#### 3.9.3.1 Operations

Once in orbit, the crew performs OMS engine firings over one of the six SIMPLEX groundsites. The burn, or burns, may be required as part of the nominal mission plan but may be rescheduled to occur within range of a SIMPLEX site, or a dedicated firing for SIMPLEX. The locations of the groundsites, along with the field-of-view and scheduling timeframe, is provided in Table 3-10. The estimated crew time involved is approximately 30 minutes. The commander and pilot are required to perform the burn, and a third crewmember is required to take a few still photos of the near-field plume to capture any asymmetry. The photo requirement can be met by using a payload bay video camera.

**Table 3-10. SIMPLEX groundsites**

<b>Radar or Radio Telescope (VLA)</b>	<b>Central Location</b>	<b>Viewing Cone Angle or Range</b>	<b>Facility Lead Time</b>
Millstone Hill, Massachusetts	42.62° N 71.49° W	60° from zenith	1 week
Arecibo, Puerto Rico	18.35° N 66.75° W	15° from zenith	2 weeks
Jicamarca, Peru	11.96° S 76.87° W	7° from zenith	2 weeks
Roi Namur, Kwajalein, Marshall Islands	9.40° N 167.46° E	60° from zenith	2 weeks
Very Large Array (VLA), Near Socorro, New Mexico	34.04° N 107.37° W	60° from zenith	2 weeks
Alice Springs, Australia	12° S 132° E	3000 km from center	1 week

The following three burns are required to complete the minimum science objectives for SIMPLEX and are in priority order.

- a. Arecibo – One day burn (prefer Ram-directed burn)
- b. Millstone Hill – One night burn (prefer Ram-directed burn)
- c. Kwajalein or Jicamarca – One 90° out-of-plane burn either day or night

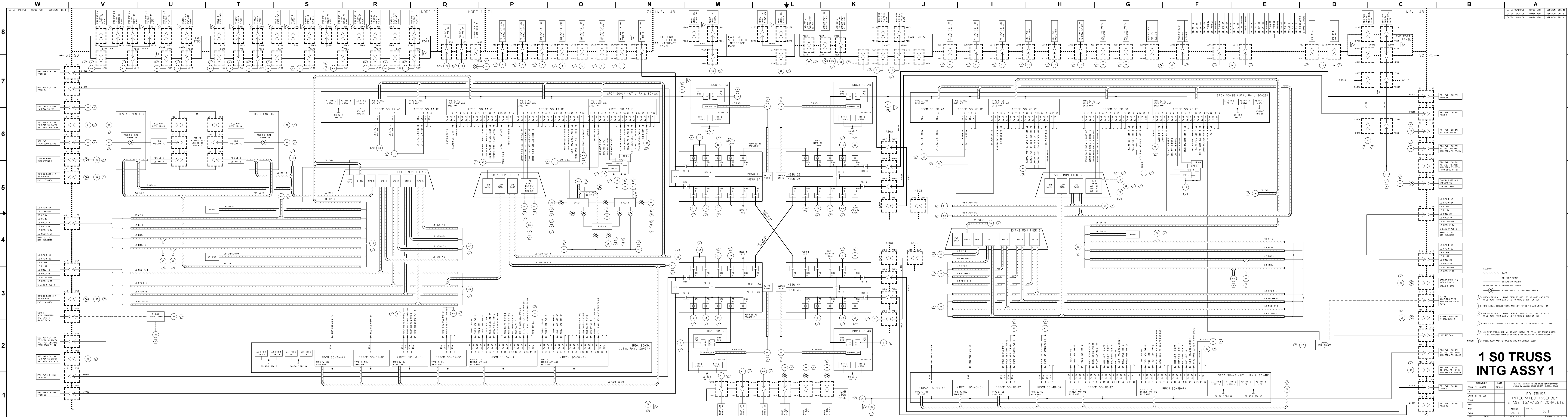
In addition to the three required burns above, the following two burns are highly desired for secondary SIMPLEX Science objectives and are in priority order.

- a. Alice Springs – One day or night burn
- b. Very Large Array – One day or night burn

### **3.9.3.2 Postflight Analysis**

The PI examines the collected data for the effects of orbital kinetic energy on ionospheric irregularities and to understand the processes that take place with the venting of exhaust materials. SIMPLEX requires orbiter state vector data, orbiter attitude data, and OMS engine firing history to perform analysis on the SIMPLEX data collected; this is obtained from the ODRC after the mission. Any photo or video documentation during the OMS burns is also required for postflight analysis.

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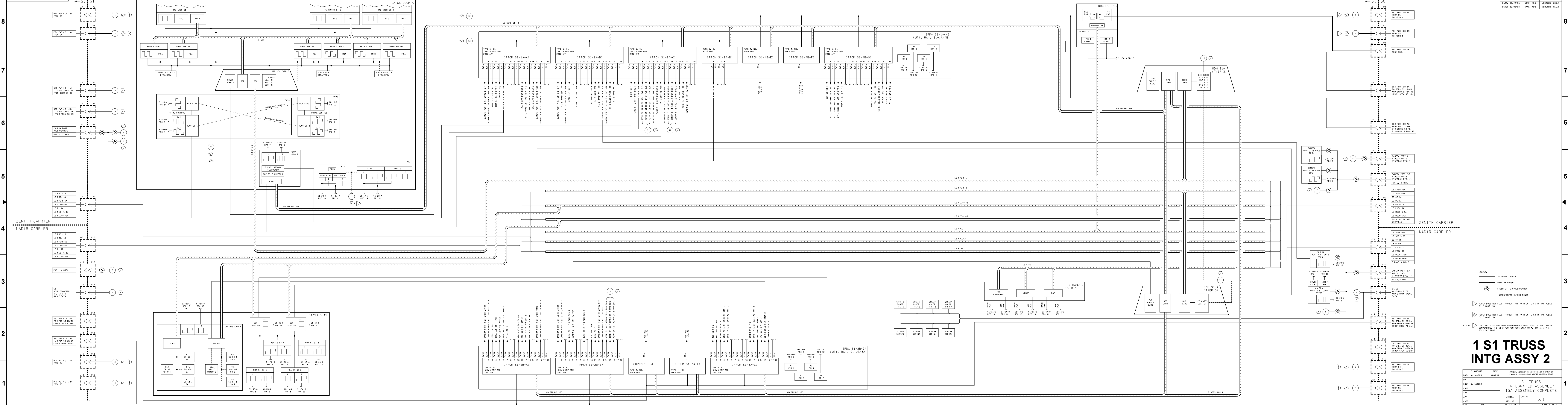


- LEGEND**
- DATA
  - PRIMARY POWER
  - SECONDARY POWER
  - INSTRUMENTATION
  - FIBER OPTIC (VIDEO/SYNC/HD)
  - VIDEO P230 WILL MOVE FROM SO J831 TO SO J363 AND P201 WILL MOVE FROM LAB J119 TO NODE 2 J701 ON 10A
  - VIDEO P236 WILL MOVE FROM SO J239 TO SO J276 AND P202 WILL MOVE FROM LAB J118 TO NODE 2 J702 ON 10A
  - UNBILICAL CONNECTIONS ARE NOT MATED TO LAB UNTIL 10A
  - UNBILICAL CONNECTIONS ARE NOT MATED TO NODE 2 UNTIL 10A
  - J26P5 W148 AND W149 ARE INSTALLED TO ALLOW TRUSS LOADS TO BE POWERED FROM LABS AND LABS DROCK IN A CONTINGENCY
  - P250/J250 AND P240/J240 ARE NO LONGER USED

## 1 50 TRUSS INTG ASSY 1

SIGNATURE	DATE	NATIONAL INSTRUMENTS (NIN) DRAWING APPROVALS
DR	08/03/08	UNION W. GORDON SPACE CENTER DIVISION, 1549
ENGR D. KEISER		
APP		
CADD		
LTR		

SO TRUSS  
 INTEGRATED ASSEMBLY -  
 STAGE 15A-ASSY COMPLETE  
 APP: ADM15A  
 DWG NO: 515-119  
 3, 1  
 SHEET 1 OF 7



DATE: 06/20/08	NAME: MDU	VERSION: REL.1
DATE: 11/28/08	NAME: MDU	VERSION: CHG.1
DATE: 12/08/08	NAME: MDU	VERSION: REL.1

**LEGEND**

- Secondary Power
- Primary Power
- Fiber Optic (Video/Sync)
- Instrumentation/SDD Power

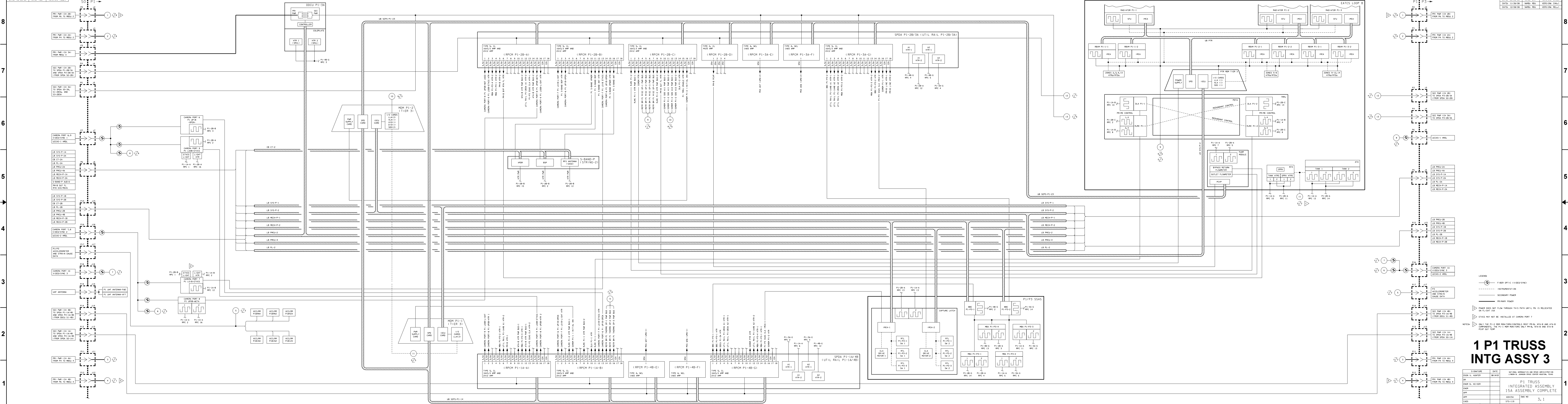
POWER DOES NOT FLOW THROUGH THIS PATH UNTIL S6 IS INSTALLED ON FLIGHT S24

POWER DOES NOT FLOW THROUGH THIS PATH UNTIL S4 IS INSTALLED ON FLIGHT S24

NOTES: ONLY THE S1-1 NON-MON/SPS/CONTROL'S MOST PWA, NTA-A, ATKA PCWP OUT TEMP

# 1 S1 TRUSS INTG ASSY 2

SYNOPSIS	DATE	NATIONAL MEMORIAL FOR SPACE ADMINISTRATION
DR	09/03/03	LYNN W. JOHNSON SPACE CENTER, MIAMI
ENGR	D. KEISER	
ENGR		
APP		
CADD	ADH/SA	DWG NO
LTB	S15-119	3, 1
	126.5 X 54	



**LEGEND**

- FIBER OPTIC (VIDEO-SYNC)
- INSTRUMENTATION
- PRIMARY POWER

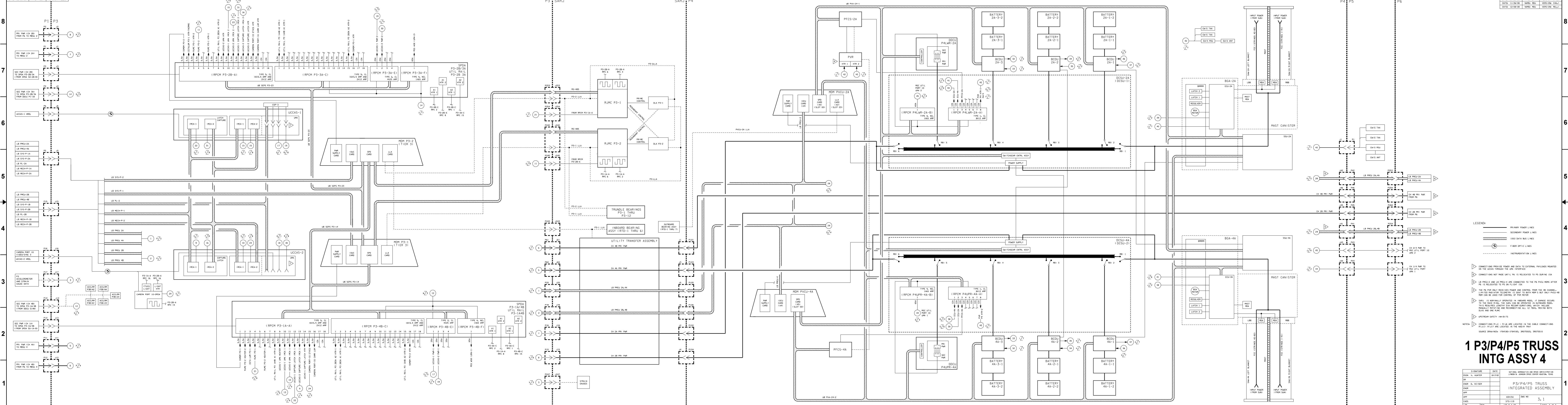
**NOTES**

- POWER DOES NOT FLOW THROUGH THIS PATH UNTIL PG 15 IS RELOCATED ON FLIGHT 15A
- ETVCS MAY NOT BE INSTALLED AT CAMERA PORT 7
- ONLY THE P1-2 MON MONITORS/CONTROLS MOST PRI-B, NTA-B AND ATA-B COMPONENTS. THE P1-1 MON MONITORS ONLY PRI-B, NTA-B AND ATA-B PCVP OUT TERM.

# 1 P1 TRUSS INTG ASSY 3

SIGNATURE	DATE	NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
SSDN V. HUNTER	08/14/03	LYNN B. JOHNSON SPACE CENTER HOUSTON, TEXAS
ENGR D. KEISER		
CDR		
APP	ADH154	DWG NO
CARD	S15-119	3.1
REV	PCN	12/8/08





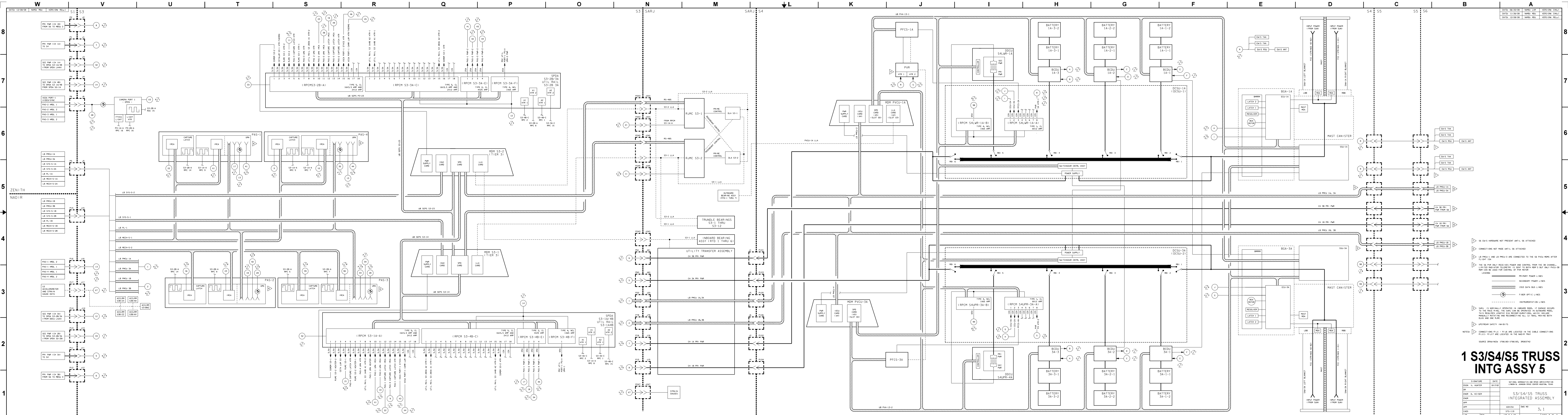
- LEGEND**
- Primary Power Lines
  - Secondary Power Lines
  - ISSD Data Bus Lines
  - Fiber Optic Lines
  - Instrumentation Lines
- CONNECTIONS PROVIDE POWER AND DATA TO EXTERNAL PAYLOADS MOUNTED ON THE UCCAS THROUGH THE UCA INTERFACE
- CONNECTIONS NOT MADE UNTIL PG 15 IS RELOCATED TO PG DURING ISA
- LB PDCU-2 AND LB PDCU-4 ARE CONNECTED TO THE PG PDCU MODS AFTER PG 15 IS RELOCATED TO PG ON FLOW 134
- THE PG PWR ONLY RECEIVES POWER AND CONTROL FROM THE 4B CHANNEL. LIMITED MODATOR TELEMETRY IS SENT TO BOTH MOD 5 BUT ONLY PWR-4B MOD CAN BE USED FOR CONTROL OF PWR MOTOR
- SARJ IS NORMALLY OPERATED IN INBOARD MODE. IF DAMAGE OCCURS TO THE ROCE BRING THE SARJ CAN BE OPERATED IN OUTBOARD MODE. MANUALLY ROTATED AND RECONNECTING ALL 12 BEAMS, MOVING BOTH UPSTREAM SAFETY INHIBITS

- NOTES**
- CONNECTIONS P3-11 TO P3-16 ARE LOCATED IN THE CABLE CONNECTIONS P3/211-2/P3/212 ARE LOCATED IN THE 1200H TRAY
- SOURCE DRAWINGS: 184640-184648, 380750S, 380751S

**1 P3/P4/P5 TRUSS INTEGRATED ASSEMBLY**

SIGNATURE	DATE	NATIONAL INSTRUMENTS (IN THE SPACE PROVIDED)
ENGR. V. HUNTER	10/13/02	ENGR. D. KEISER
APP.		APP.
CDS	ADH15A	ENG NO.
LTB	S15-119	3, 1
	128.5 X 54	SHEET 4 OF 7





DATE: 04/20/08	NAME: LHM	VERSION: CHG1
DATE: 11/28/08	NAME: MDU	VERSION: CHG1
DATE: 12/08/08	NAME: MDU	VERSION: REL1

- ▶ S6 EHS HARDWARE NOT PRESENT UNTIL S6 ATTACHED
- ▶ CONNECTIONS NOT MADE UNTIL S6 ATTACHED
- ▶ LB PNCU-1 AND LB PNCU-3 ARE CONNECTED TO THE S6 PWR MDMS AFTER ELIGHT 13A
- ▶ THE S6 PWR ONLY RECEIVES POWER AND CONTROL FROM THE 3B CHANNEL. LIMITED RADAR/TELEMETRY IS SENT TO BOTH MDMS BUT ONLY PNCU-3R CAN BE USED FOR CONTROL OF PWR MOTOR

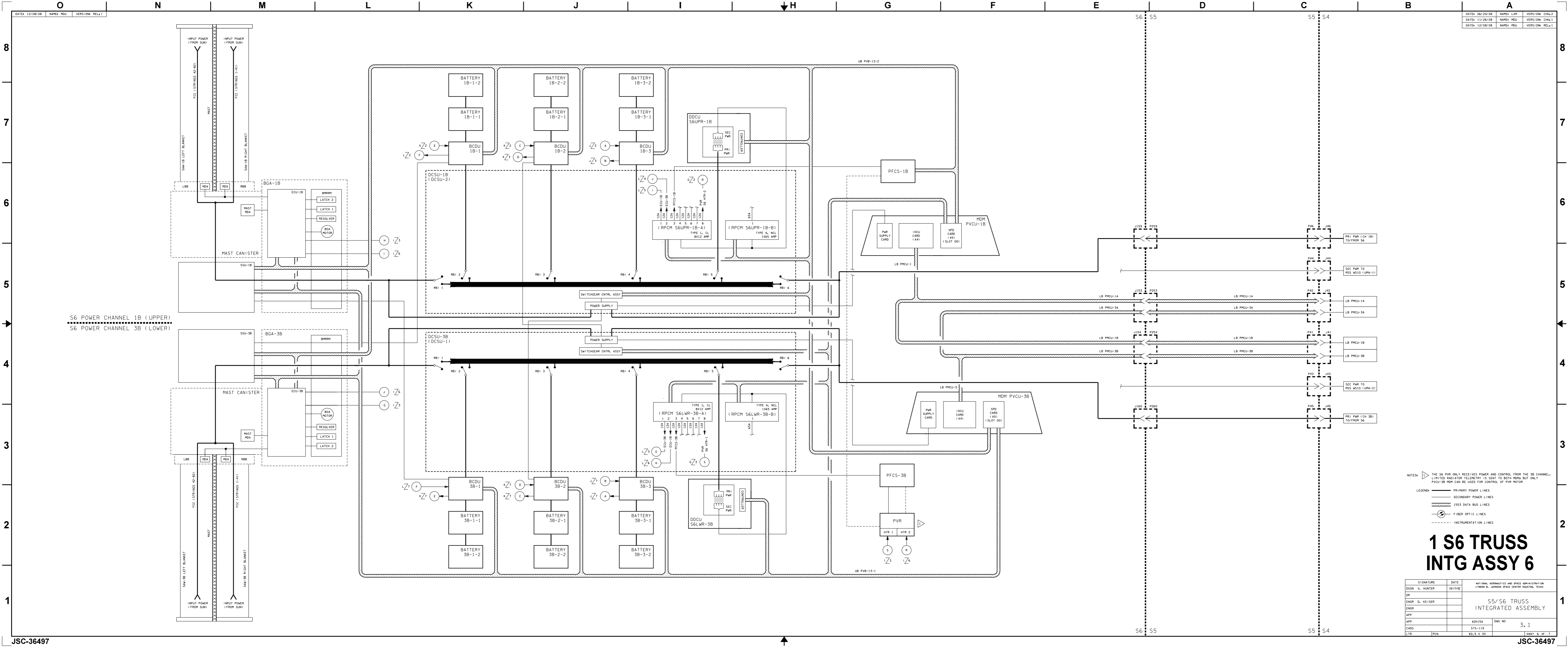
- ▶ SARU IS NORMALLY OPERATED IN INBOARD MODE. IF DAMAGE OCCURS TO THE FACE RING, THE SARU CAN BE OPERATED IN OUTBOARD MODE. THIS REQUIRES LENGTHY EHS RECONFIGURATION, WHICH INCLUDES MANUALLY ROTATING AND RECONNECTING ALL 12 TRAIL MOVING BOTH SLAS AND ONE RJC
- ▶ UPSTREAM SAFETY INHIBITS

NOTES: ▶ CONNECTIONS P/J1 - P/J48 ARE LOCATED IN THE CABLE CONNECTIONS P/J11 - P/J217 ARE LOCATED IN THE NADIR TRAY

SOURCE DRAWINGS: 1786180-1786185, 18083142

# 1 S3/S4/S5 TRUSS INTEGRATED ASSY 5

SIGNATURE	DATE	NATIONAL INSTRUMENTS OR THE TRADE REPRESENTATIVE
DR	10/13/02	UNION & JOHNSON SPACE CENTER, MISSION, TEXAS
ENGR. D. KEISER		
APP.		
APP.		
CADS	ADH15A	DWG NO
LTB	S15-119	3, 1
	12/5, V. 54	



S6 POWER CHANNEL 1B (UPPER)  
S6 POWER CHANNEL 3B (LOWER)

- NOTES: THE S6 PWR ONLY RECEIVES POWER AND CONTROL FROM THE 3B CHANNEL. LIMITED RADIATOR TELEMETRY IS SENT TO BOTH MDMs BUT ONLY PVCU-3B MDM CAN BE USED FOR CONTROL OF PVR MOTOR.
- LEGEND:
- PRIMARY POWER LINES
  - SECONDARY POWER LINES
  - 1553 DATA BUS LINES
  - FIBER OPTIC LINES
  - INSTRUMENTATION LINES

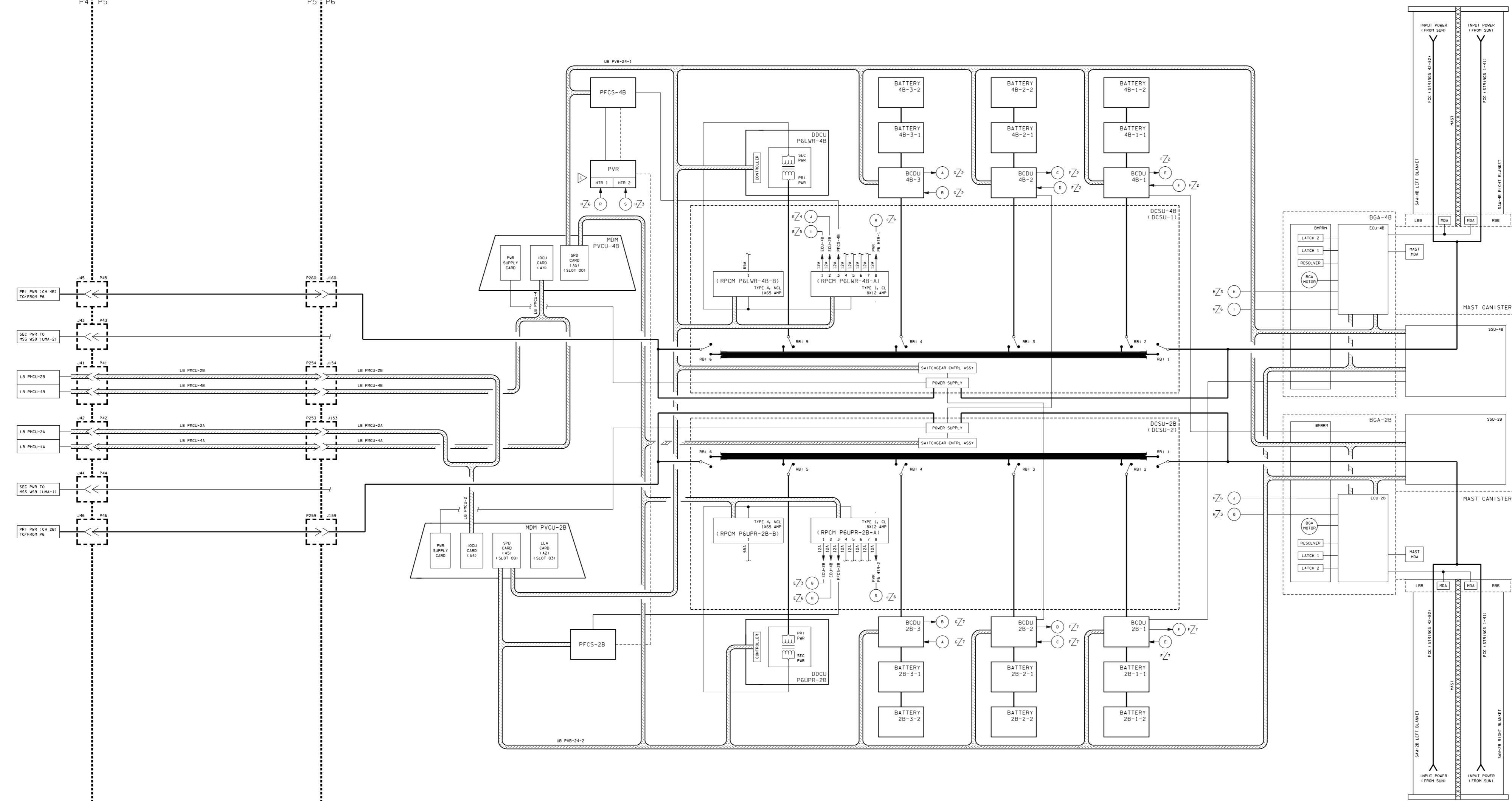
# 1 S6 TRUSS INTG ASSY 6

SIGNATURE	DATE	NATIONAL AERONAUTICS AND SPACE ADMINISTRATION LINDON B. JOHNSON SPACE CENTER HOUSTON, TEXAS
DR ENGR D. KEISER	10/19/02	
APP		
CADS	ADHJSA	DWG NO 575-119
LTR	PCN	82.5 X 34

S5/S6 TRUSS  
INTEGRATED ASSEMBLY

3.1

SHEET 6 OF 7

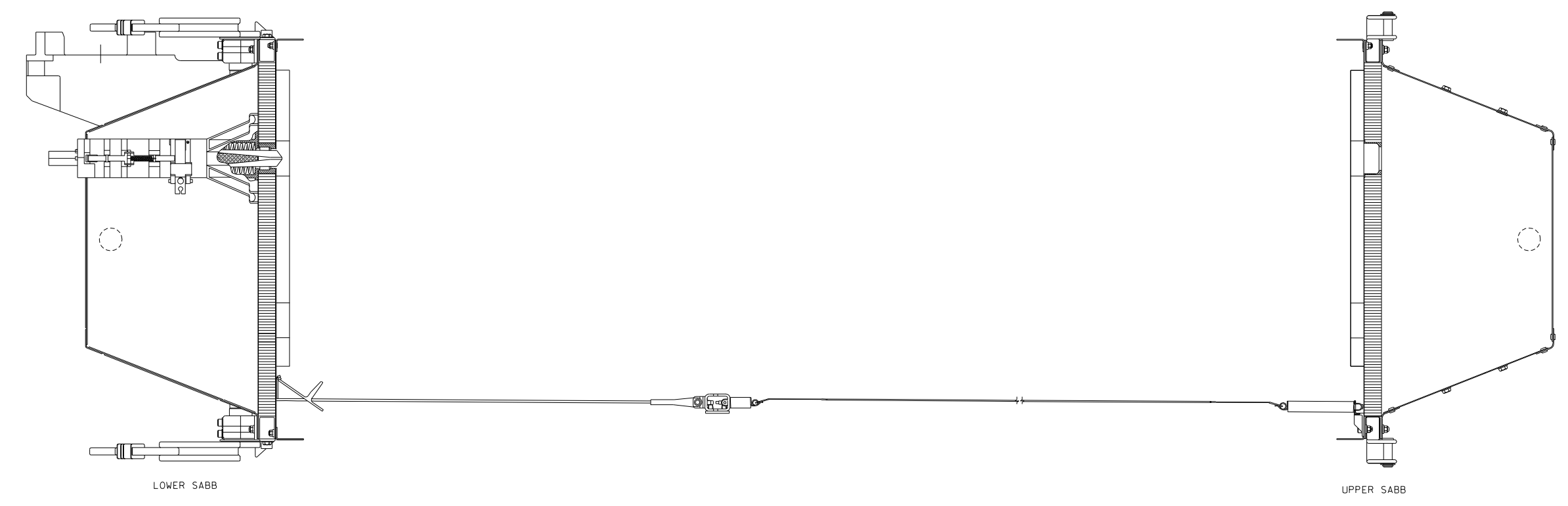


P6 POWER CHANNEL 4B (LOWER)  
 P6 POWER CHANNEL 2B (UPPER)

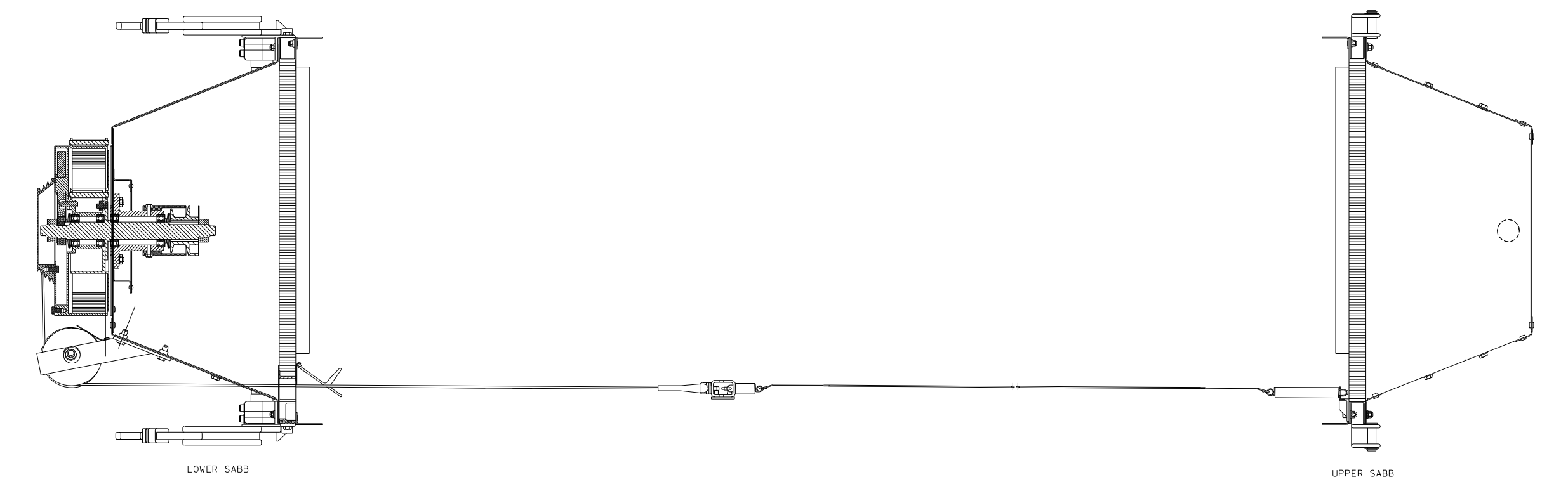
- NOTES
- THE P6 PVR ONLY RECEIVES POWER AND CONTROL FROM THE 4B CHANNEL.
  - LIMITED RADIATOR TELEMETRY IS SENT TO BOTH MDU'S BUT ONLY PVCU-4B MDU CAN BE USED FOR CONTROL OF PVR MOTOR
- LEGEND
- PRIMARY POWER LINES
  - SECONDARY POWER LINES
  - 1553 DATA BUS LINES
  - FIBER OPTIC LINES
  - INSTRUMENTATION LINES

# 1 P6 TRUSS INTG ASSY 7

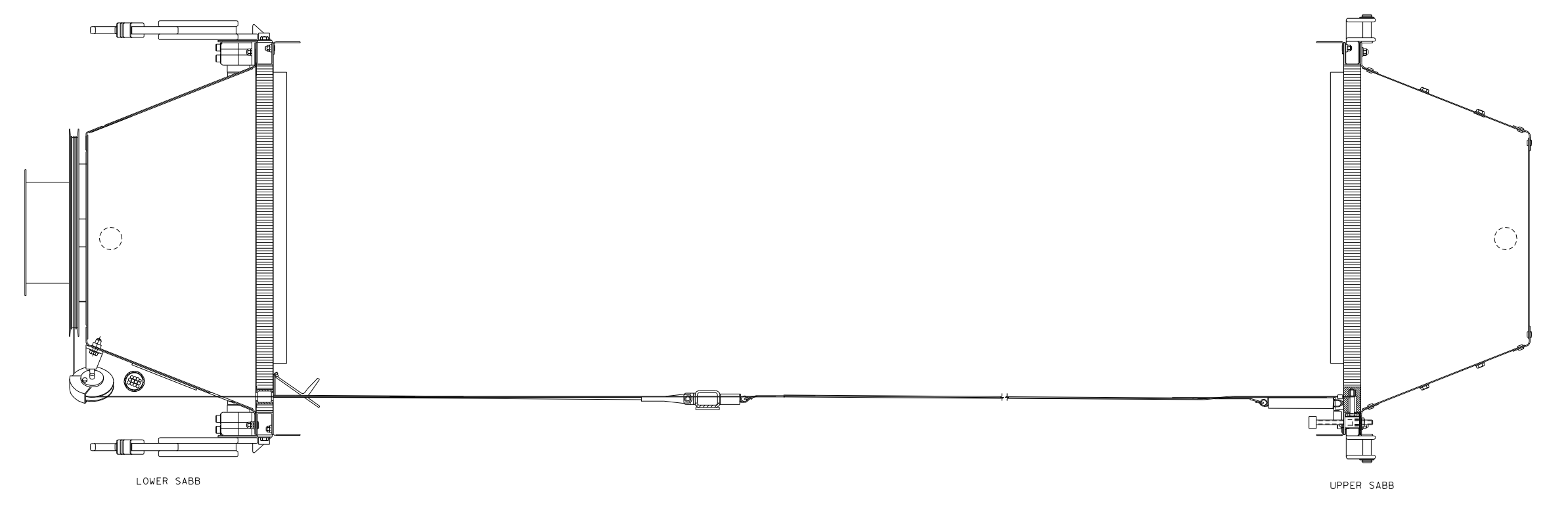
SIGNATURE	DATE	NATIONAL AERONAUTICS AND SPACE ADMINISTRATION L'ROON R. JOHNSON SPACE CENTER HOUSTON, TEXAS
DR	10/19/02	
ENGR	D. KEISER	
APP		
APP		
CADS	515-119	3. 1
LTR	PCN	82.5 X 34



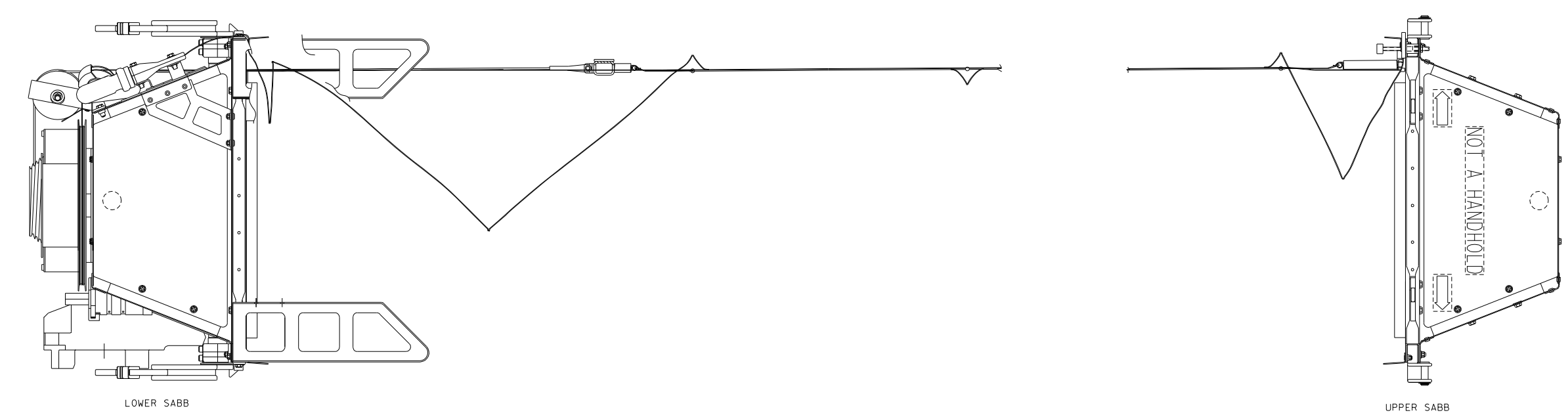
DEPLOYED CONFIG OF BRS/STORAGE ASSY



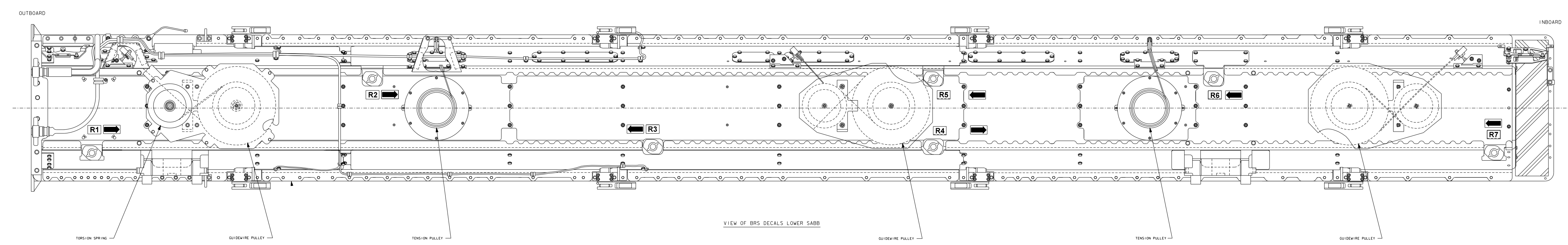
VIEW OF BLANKET TENSIONING SYSTEM (2 UMB)



VIEW OF GUIDEWIRE SYSTEM (3 WIRES)



OUTBOARD VIEW WITH FCC RIBBON



VIEW OF BRS DECALS LOWER SABB

SOURCE DRAWING: SRS2975

## 2 SABB

SIGNATURE	DATE	NATIONAL AERONAUTICS AND SPACE ADMINISTRATION L'ROUN IN ORIGIN SPACE CENTER HOUSTON, TEXAS
ESON, E. DYSARZ	06/20/08	
DR		
ENGR. D. KEISER		
ENGR		SOLAR ARRAY
APP		BLANKET BOX (SABB)
APP		
APP	ADHISA	ENG NO
CADS	S15-119	3, 2
LTR	PCN	126L5 V 54

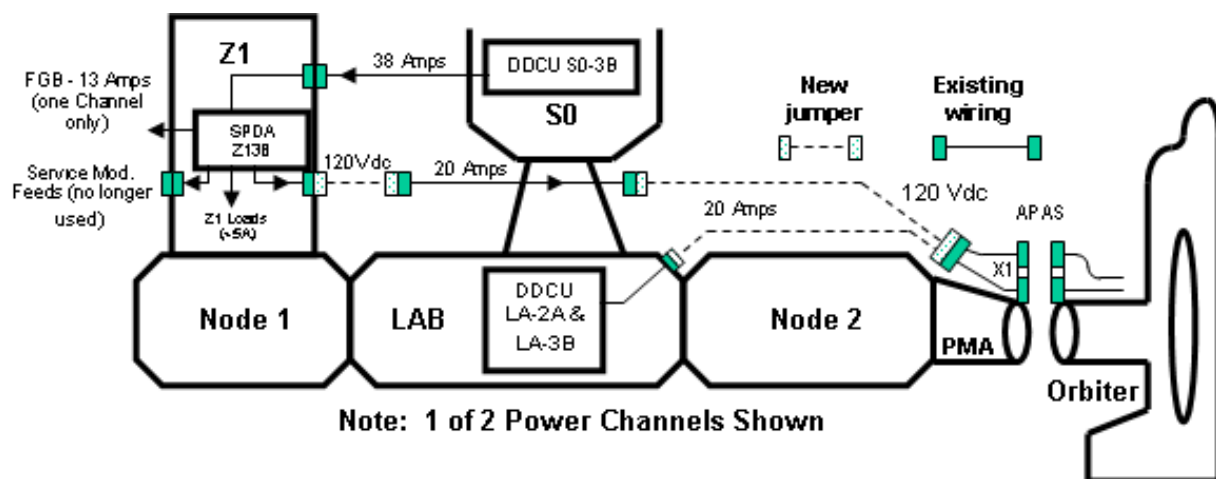
## 4.0 FLIGHT SPECIFIC UNIQUE INTERFACES AND SYSTEMS

### 4.1 ORBITER SYSTEMS

Many of the orbiter systems are critical to the tasks required to assemble the ISS. This section is intended to provide an overview of the units that are integral in the assembly tasks for Flight 15A. A general description of each system is provided along with information on the orbiter interfaces and flight-specific configurations. The systems that are discussed in detail in this section are the Station-Shuttle Power Transfer System (SSPTS) and the PDRS, as they pertain directly to the activities of STS-119/15A.

#### 4.1.1 Station-Shuttle Power Transfer System

SSPTS is an orbiter ORU that provides the capability to convert 120 V dc ISS power to 28 V dc orbiter power. This ability to convert power allows for a longer mission duration for increasingly complex assembly missions (see Figure 4-1).



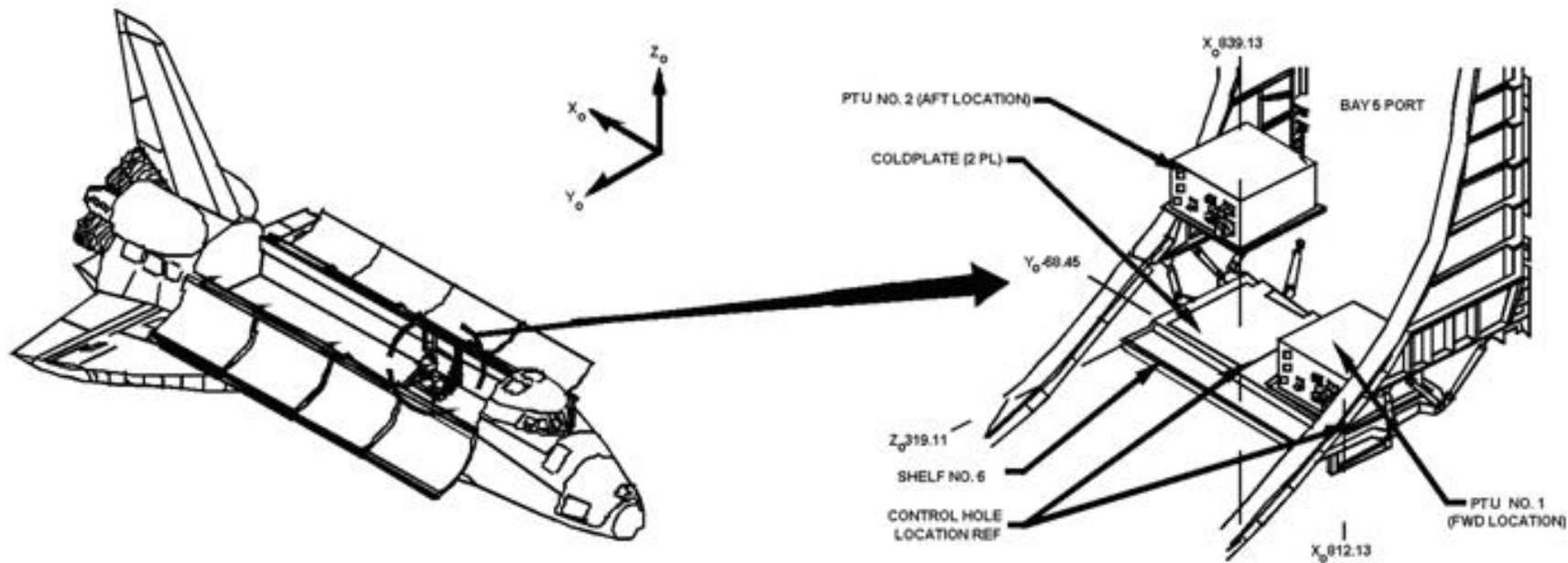
**Figure 4-1. SSPTS architecture (OV-103 and -105)**

##### 4.1.1.1 Hardware and Configuration

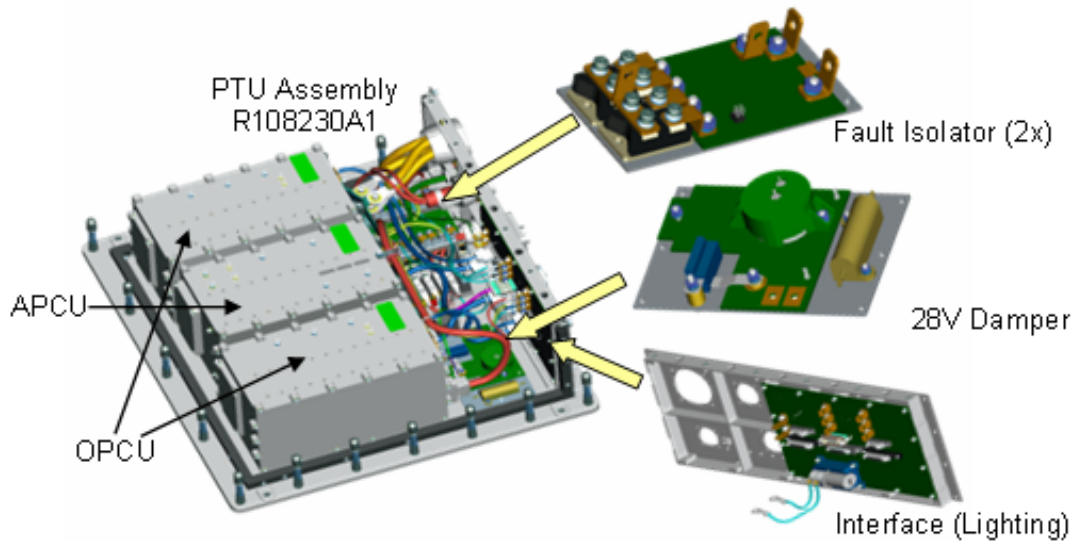
The SSPTS system has two principal components: the Power Transfer Units (PTUs), and the wiring to provide power through the APAS X-connectors to two of the three orbiter main busses. The capability of the Assembly Power Converter Units (APCUs) to provide power to ISS has been eliminated due to the removal of the return feeds through the X-connectors to the ISS. The PTUs are installed under the liner in the payload bay in the same locations previously occupied by the original APCUs (Figure 4-2). The new configuration applies only to space shuttle Orbiters Discovery and Endeavour, Orbiter Vehicles 103 (OV-103) and 105, respectively. The Orbiter Atlantis, OV-104, is not a SSPTS vehicle and still carries the original APCUs.

Each PTU includes one APCU and two Orbiter Power Converter Units (OPCUs) in a single Line Replacement Unit (LRU) (see Figure 4-3).

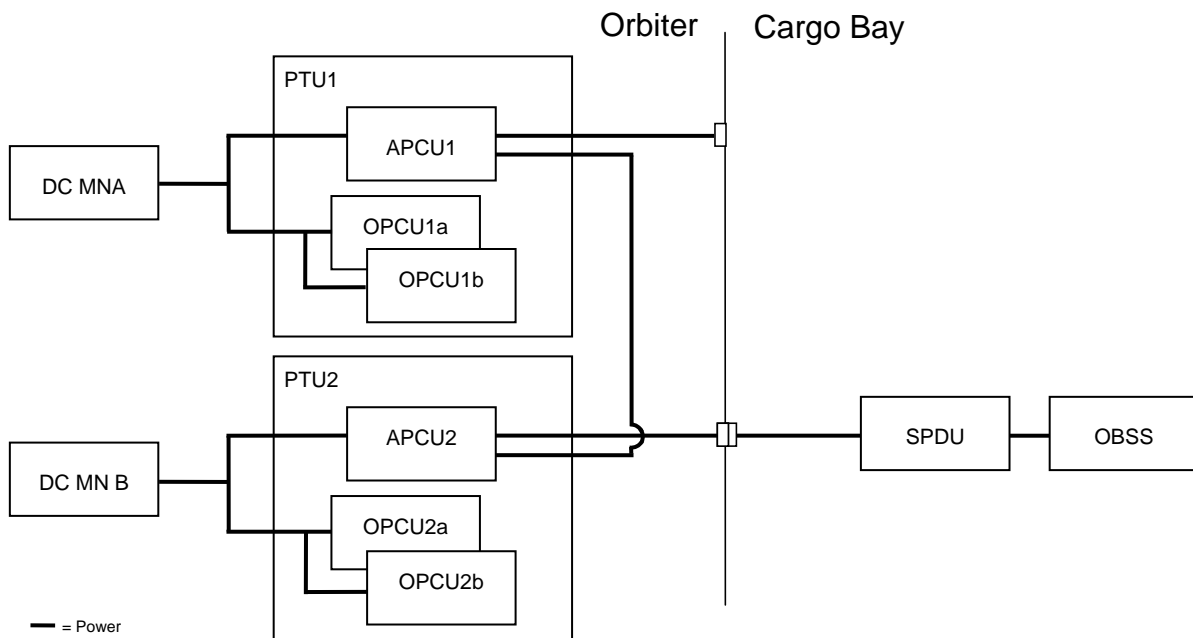
ITS S6 launches unpowered in the PLB and does not require power from either APCU. APCU2 powers the OBSS camera inspection equipment. APCU2 is activated on FD02 after OBSS unberth to provide power to OBSS heaters (see Figure 4-4 for power configuration). Each APCU activation/deactivation takes 5 minutes, plus roughly another 5 minutes for crew translation time to the A15 panel and for bringing up the appropriate Specialist (SPEC) Function page.



**Figure 4-2. PTU installation locations**



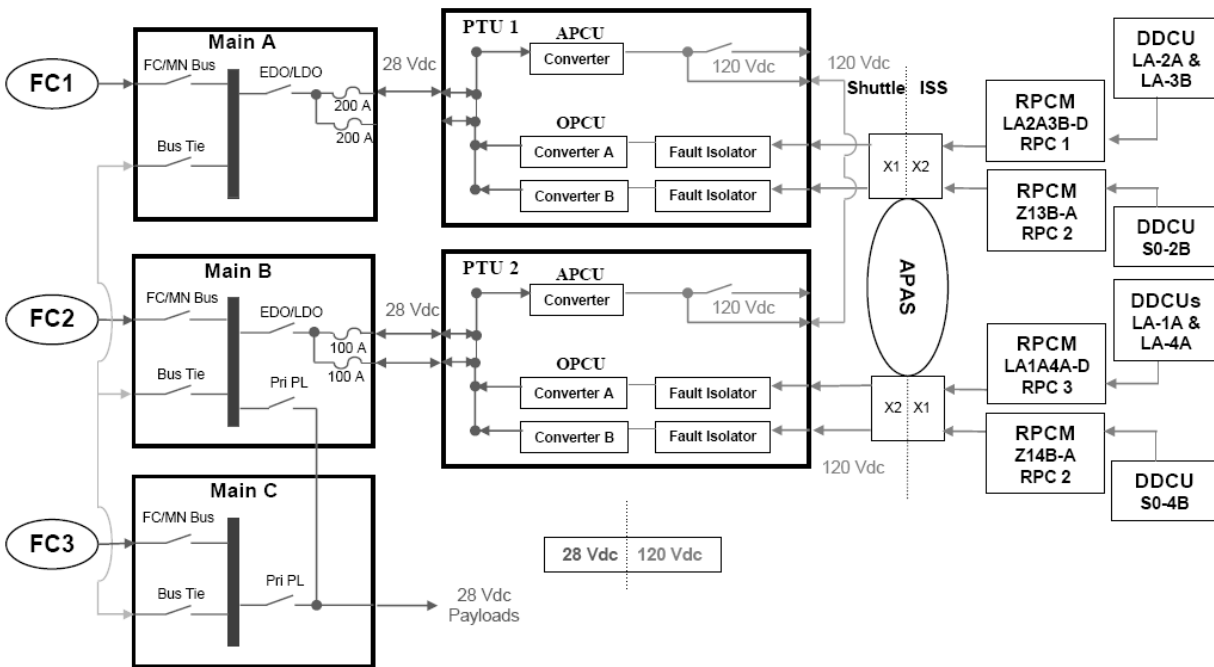
**Figure 4-3. Integrated PTU with additional hardware**



**Figure 4-4. APCU configuration**



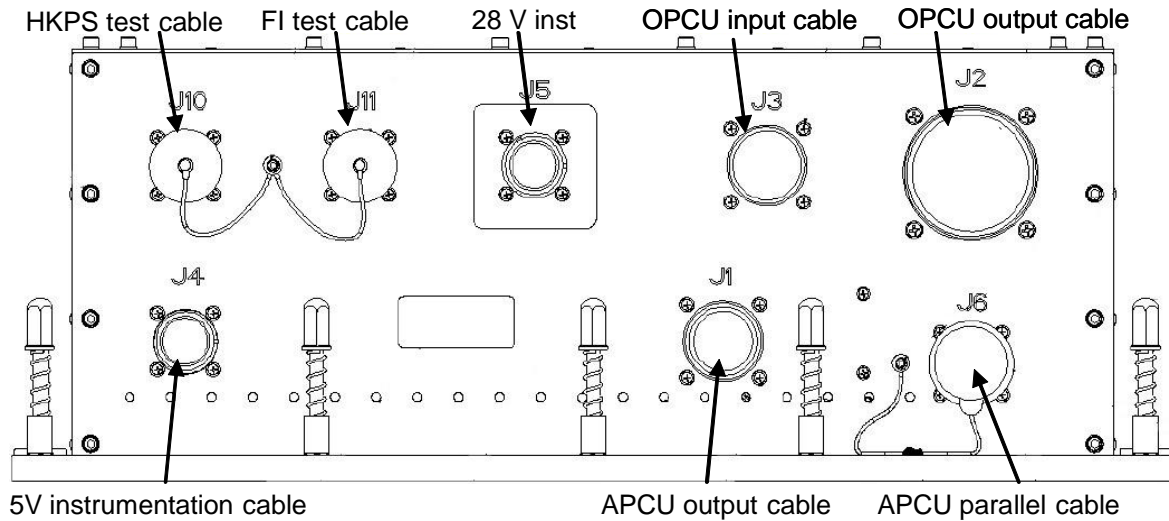
The OPCU has the sole function of converting 124 V dc ISS secondary power to 28 V dc power. Each OPCU converter draws 2.2 kW of 124 V dc power from station Remote Power Controllers (RPCs) and converts it to 2kW of 28V dc orbiter-usable power. There are four OPCU converters total (two per OPCU): 1a/1b and 2a/2b, thus supplying a total of 8 kW of power, should all four OPCU converters operate simultaneously. Due to ISS power limitations, only three converters are likely to be on at any time. The OPCU 1 converters are directly connected to the orbiter bus Main A (MNA), via Fuel Cell 1 (FC1), and OPCU 2 converters to Main B (MNB), via FC2 (see Figure 4-5). Whichever bus has two OPCU converters activated is bus-tied to orbiter bus Main C (MNC) to allow better power transfer capability; therefore, if OPCU converters 2a/2b are on, the bus-tie is MNB-C. If OPCU converters 1a/1b are on, then the bus-tie is MNA-C. With SSPTS operating at full capacity, the docked mission duration can be extended by approximately 3 days, depending on overall orbiter power usage.



**Figure 4-5. Bus wiring for return power to orbiter**

#### 4.1.1.2 Interface and Controls

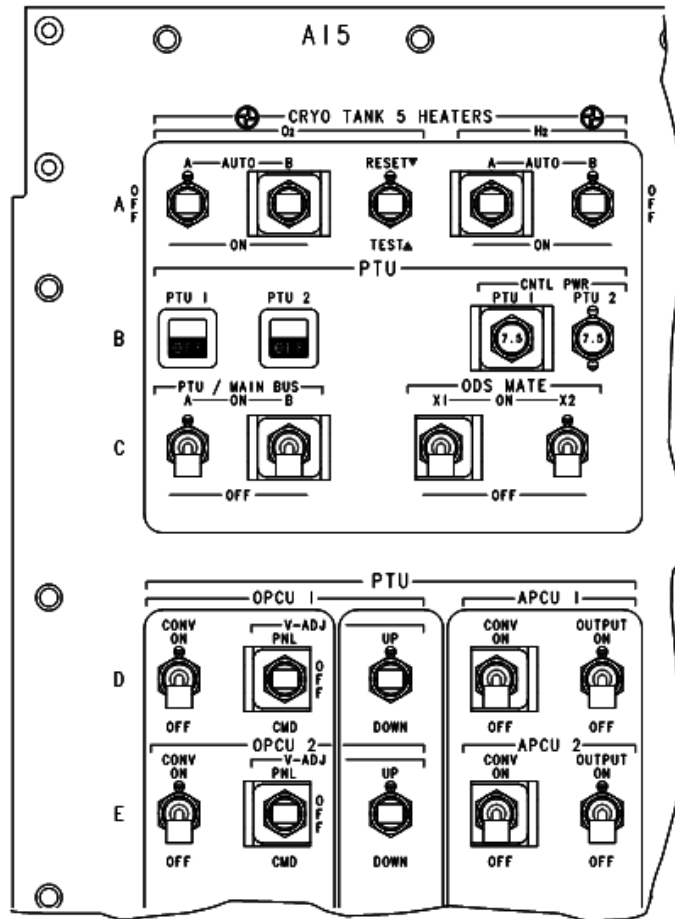
The front panel of the PTU (see Figure 4-6) has input and output connectors for the OPCU and APCU converters, as well as connectors for control power and others for Ground Support Equipment (GSE) test equipment. Once installed, only the test cables are left disconnected.



**Figure 4-6. SSPTS PTU front panel connections**

#### 4.1.1.3 Crew Interfaces

The PTUs have crew interfaces in the form of switches on panel A15 and system insight via crew displays. The switches on panel A15 replace those previously found on the SSPs and controls for the APCU. The APCU controls remain unchanged from previous missions, converter and output ON/OFF for both APCUs. The OPCU controls include converter ON/OFF and a PNL/CMD switch to allow ground commanding to the system (see Figure 4-7). See Section 4.2.6.2 for the Power Transfer SPEC page.



**Figure 4-7. A15 Panel switches for PTUs**

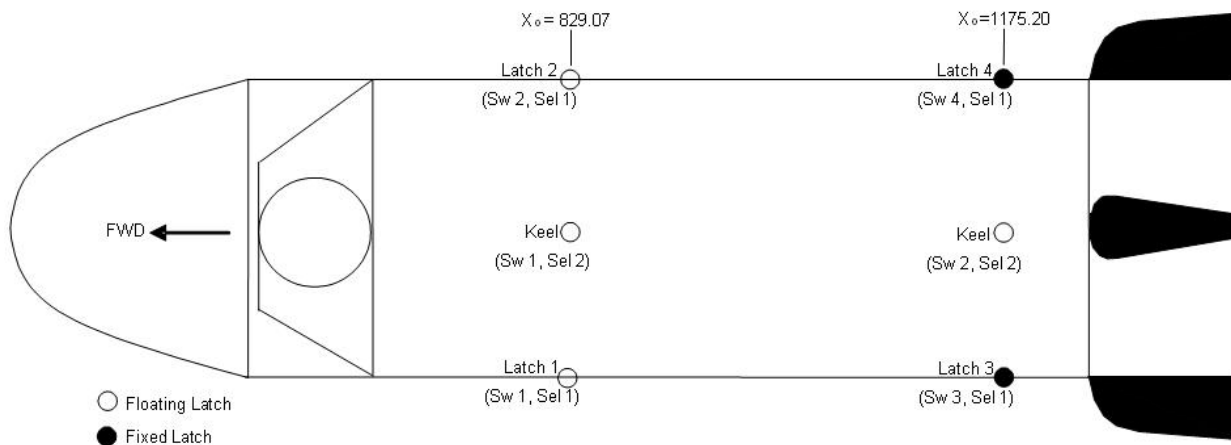
#### 4.1.2 Payload Deployment and Retrieval System

The orbiter PDRS utilizes the SRMS, the Payload Retention Latch Assemblies (PRLAs), the Manipulator Positioning Mechanism (MPM)/Manipulator Retention Latches (MRLs), Payload (P/L) handling aids and guides, the Closed-Circuit Television (CCTV) system, and the General Purpose Computers (GPCs). This section of the AOH concentrates on the SRMS and the PRLAs as they apply to ISS assembly during Mission 15A. Further details, including descriptions of the other PDRS elements, can be found in other sources (e.g., training documents, and the JSC-11174, Space Shuttle Systems Handbook (SSSH)).

SRMS operations for 15A include inspections (early, focused and late) using the OBSS and for the double handoff required to install S6 truss segment. The SRMS unberths the OBSS on FD02 for initial inspection. On FD06, the SSRMS unberths the OBSS and hands it off to the SRMS for focused inspection. Final inspection occurs after undock, with the SRMS again unberthing the OBSS on FD13.

On FD04, the SSRMS unberths S6, then hands it off to the SRMS. The Mobile Tracker (MT) then translates with the SSRMS from worksite 6 to worksite 1, in order to reach the installation site. Once translation is complete, the SRMS hands S6 back to the SSRMS. The truss remains on the SSRMS overnight, with installation occurring on FD05 as part of EVA 1.

S6 is secured in the orbiter PLB by six latches, two latches located each on the starboard and port longerons, and the keel. The motorized latches can be opened and closed by the crew on orbit. The keel latches are used to take the side loads of the P/L and help center the P/L in the cargo bay. If the S6 is returned to or relatched in the PLB, the keel latches must be closed first to center the P/L before closing the longeron latches, as the keel latches do not have the force to overcome the longeron latches. The switches that control the six S6 PRLAs are located on the A6 panel. S6 is released by placing the Payload Select (PL SEL) switch in positions 1 (starboard/port latches) and 2 (keel latches) and activating each latch associated with the specific PL SEL position. The locations of the latches on the PLB are shown in Figure 4-8.



**Figure 4-8. PRLA latch locations**

## 4.2 CREW INTERFACES

This section describes interfaces that are used in the assembly process.

### 4.2.1 Portable Computer System

The ISS contains several different types of computers for the crew to interface with the various ISS systems. Rather than using an overwhelming number of hardware switches, the ISS is designed to be controlled with software switches. Direct commands originate from graphical displays on the interface computers, which then use the C&DH buses to route the commands to the appropriate system. Most of the interface computers are portable IBM ThinkPad laptop computers that plug into Utility Outlet Panels (UOP) at fixed locations throughout the ISS. Two printers (one USOS, one RS)

are available onboard the ISS, but MCC does not have the capability to print to them. The printers interface with the laptops using RS-232 serial cables and plug into the UOPs. A key advantage to using laptops is that they can be upgraded easily as computer technology advances. A standard UOP located in the standoffs between the racks has two Portable Computer Receptacles (PCR). The PCR can provide both a power and a data link with the same connection, with the exception of the node PCRs, which provide a power connection only. The two most important crew-interface computer systems are the Portable Computer System (PCS) and the Station Support Computers (SSCs).

#### **4.2.2 ISS Homepage Display**

The homepage is the top-level display on the PCS and on displays seen in MCC-H (see Figure 4-9). The homepage provides the primary C&W information, including alarm type, alarm message, and graphical indication of affected subsystems and locations. The homepage also provides navigational paths to more detailed displays of elements or subsystems via the icons on the right of the display.

##### **4.2.2.1 System Displays**

System displays can be found by clicking on one of the icons on the right side of the ISS homepage display. The system displays give more detailed descriptions of specific systems and modules shown on that display.

#### **4.2.3 PCS Software**

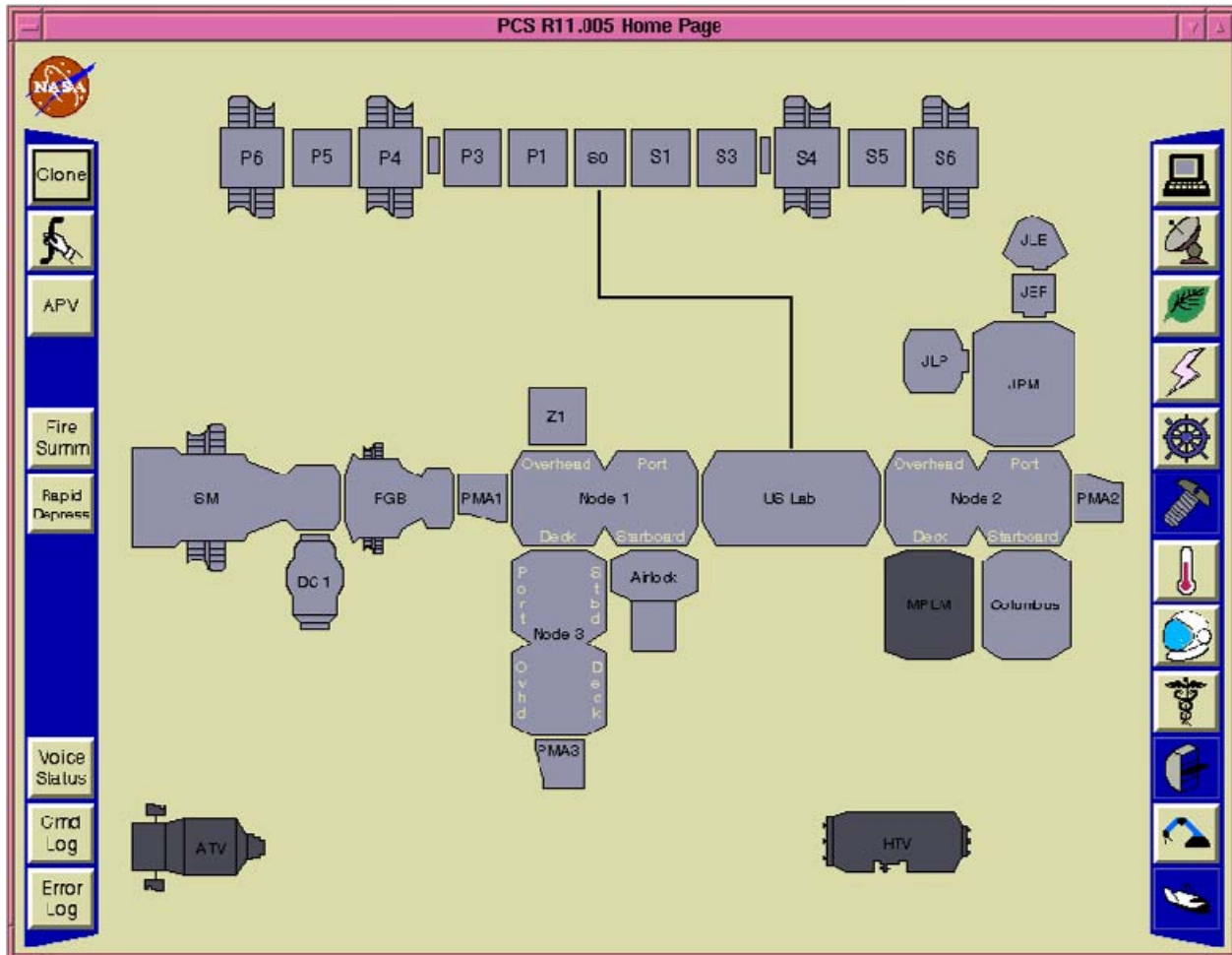
The software on the U.S. laptop provides C&C of the systems to the crew and C&W information for the vehicle. All the developed software runs under the Red Hat Linux operating system.

#### **4.2.4 RS PCS**

Section 12 of JSC-36460, Data Book: Service Module (SM), has an extensive writeup on Russian PCS machines. The SM and the FGB also support two NASA PCS connection points each to RS Bus 7 (CB GNC-1) and RS Bus 8 (CB GNC-2).

#### **4.2.5 Station Support Computer**

There is no assembly mission-specific SSC for the 15A mission.



**Figure 4-9. ISS homepage**

#### 4.2.6 Multifunctional CRT Display System

The Multifunction Cathode-Ray Tube Display System (MCDS) provides a crew interface to ISS systems and support hardware, independent of the PCS units used on the Aft Flight Deck (AFD). The arrival/departure moding display allows the shuttle crew to perform attitude moding Ops for docking or undocking using the Ultrahigh Frequency (UHF) link to the ISS. The ISS C&W display allows the shuttle crew to see C&W annunciations from the ISS, complementing the subset that is passed through to the orbiter C&W system.

##### 4.2.6.1 SPEC 205 - Arrival/Departure Moding

The arrival/departure moding display (see Figure 4-10) allows the orbiter crew to command the ISS to free drift upon contact, or to active attitude control upon separation. The primary method for moding the ISS attitude control system at orbiter docking and undocking is the automatic Attitude Control System Manager (ACSM) software that resides in the C&C MDM. SPEC 205 is a tertiary or redundant method.

XXXX/205/XXX	ARP/DPTR	MODING	XX X	DDD/HH:MM:SS	DDD/HH:MM:SS
US STA MODE	XXXXXXXX	INHIBITS		ENA	INH
GNC MODE	XXXXXXXX	MODE TRANS		1X	6X
HEALTH	XXXXXS	ATT MNVR		2X	X
RS GNC MODE	XXXXXXXX	DSAT REQ		3X	X
TC/RATE STATUS	XXXXXS	ATT CNTL SHTDN		4X	X
DOCK CONFIG	XXXXXS	ARM AUTO CNTL RS			7
		AUTO CNTL RS		5X	8X
DRIFT		ATT CNTL			
MOMENTUM SERVO		RS PREP CMG DSAT		12	
INTL	9	THRSTR AVL DSAT		XXX	
REF FRM	XXXX	ORB UNDOCK CMPLT		XXXX	
MAN CMG DSAT	10	MASS PROP		13	
CMG DSAT PROG	X	DOCK IND		14X	
ORB CPTR	XXXXS	UNDOCK IND		15X	
DAMP	XXXXS				
MODE TO DRIFT	11	MODE TO CMG TA		16	
		ATT HOLD		17	
					(XX)

3649061\_117.CRT, 1

**Figure 4-10. SPEC 205: USOS ARP/DPTR moding**

#### 4.2.6.2 SPEC 179 - Power Transfer

A new display that incorporates system information for both APCUs and OPCUs (SPEC 179) has been incorporated into the orbiter flight software to provide system insight for the crew (see Figure 4-11).

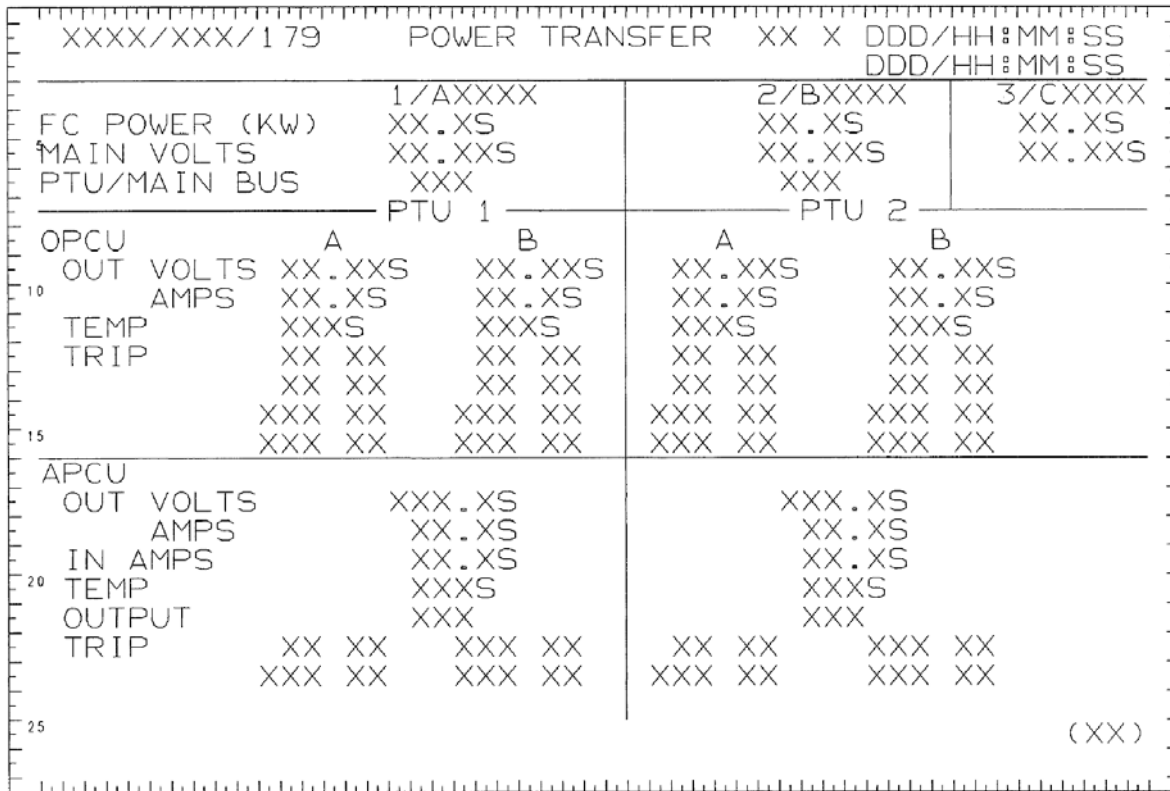
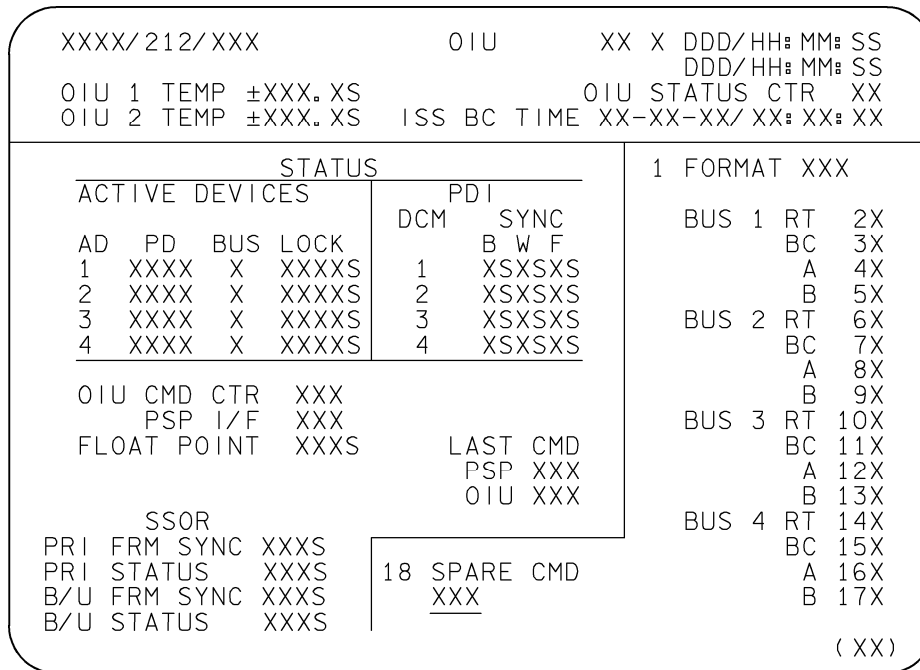


Figure 4-11. SPEC 179 - Power Transfer

#### 4.2.6.3 SPEC 212 - OIU

The OIU display (see Figure 4-12) is used to configure the OIU for cargo element Ops through the OIU 1553 B data buses (ISS MDMs, SSOR, MPLM MDM, etc.), monitor OIU status, and monitor relevant Payload Data Interface (PDI), Payload Signal Processor (PSP), and SSOR status.





3649063\_117.CRT: 1

**Figure 4-12. SPEC 212: OIU**

### 4.3 STANDARD SWITCH PANEL

Standard Switch Panel (SSP) 1 and SSP 2 provide a crew interface for control of flight specific orbiter-installed equipment and payloads. The panel layouts are depicted in Figure 4-13 and Figure 4-14 are the SSP layouts for Flight STS-119.

### 4.4 PAYLOAD DATA INTERFACE PANEL

The STS-119 configurations for Payload Data Interface Panel (PDIP)1 and PDIP2 are shown in Figure 4-15 and Figure 4-16.

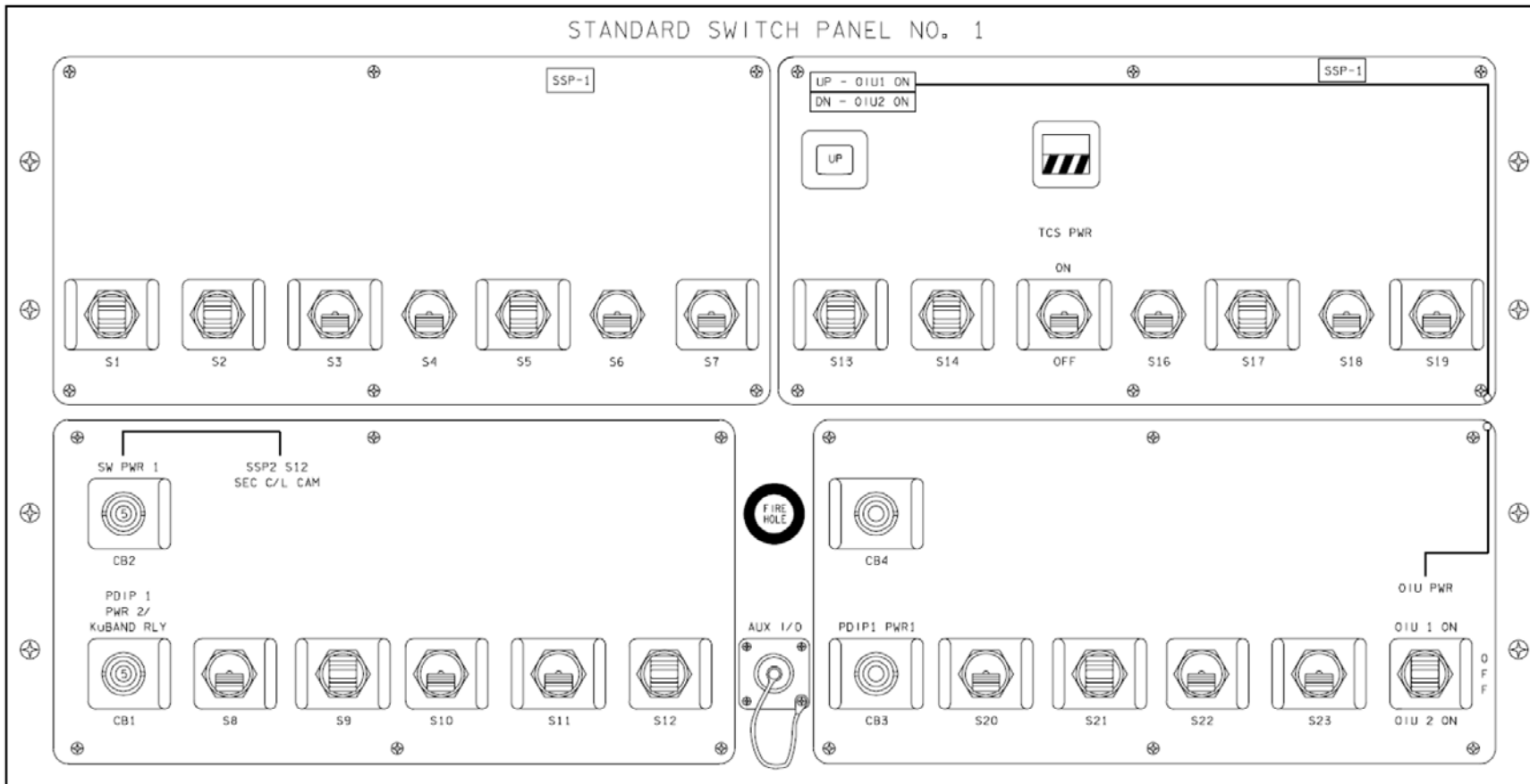


Figure 4-13. SSP 1

Verify that this is the correct version before use

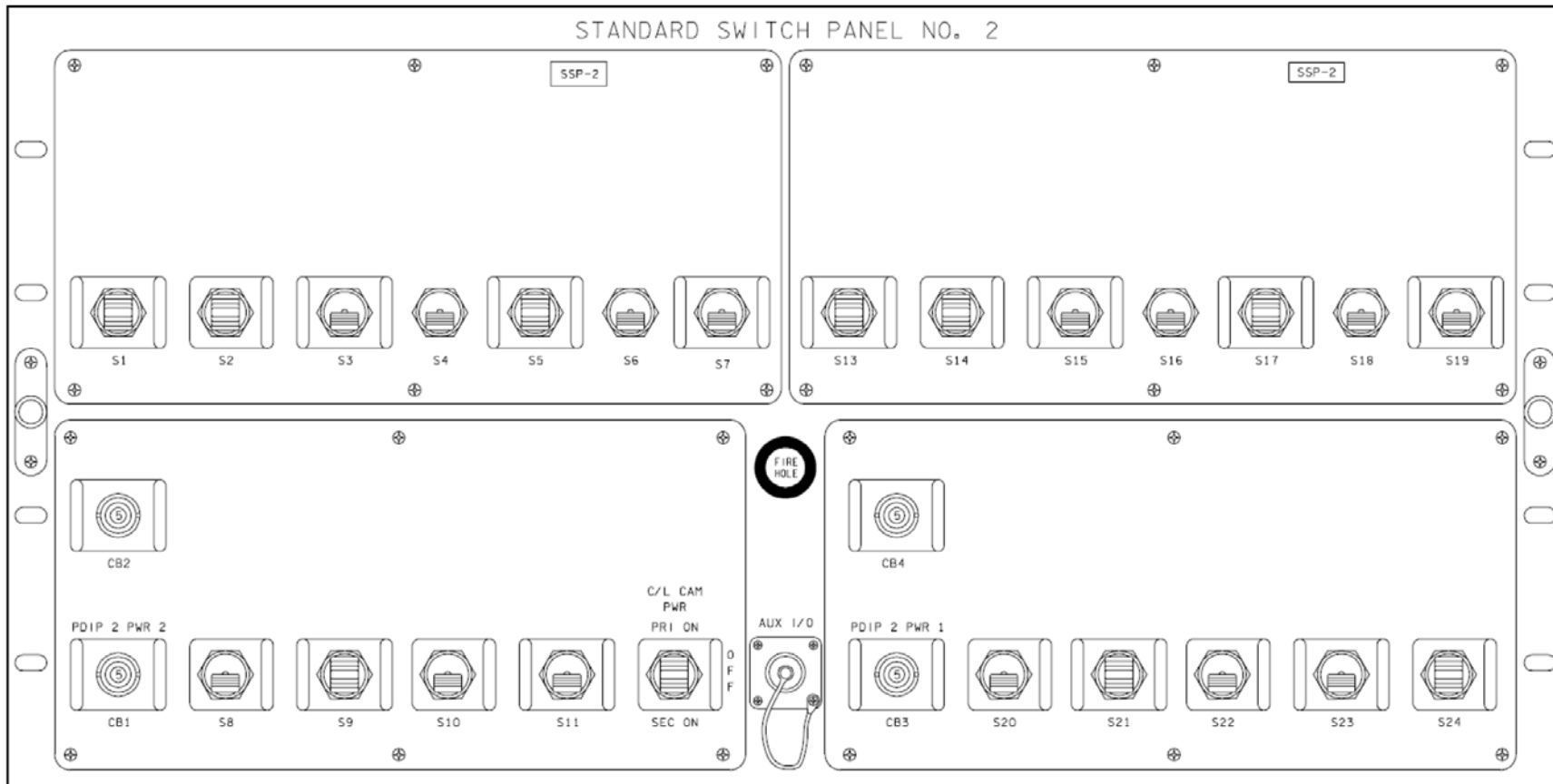
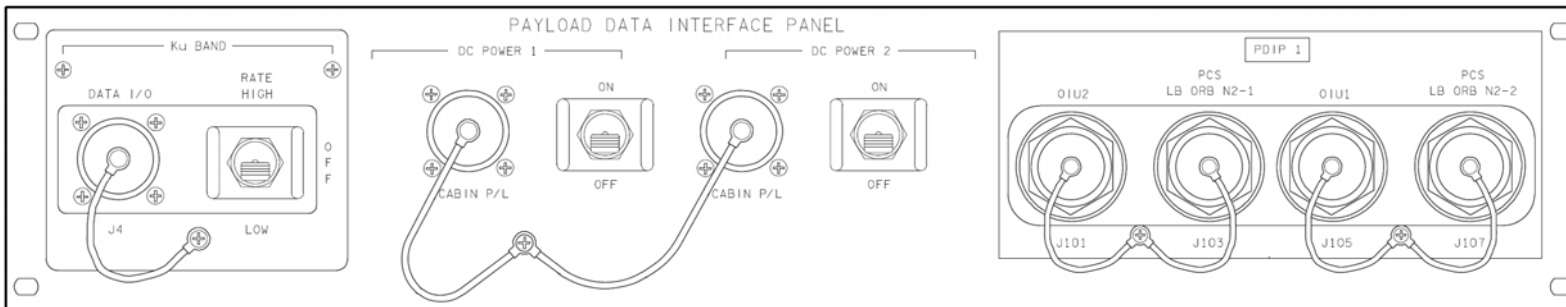
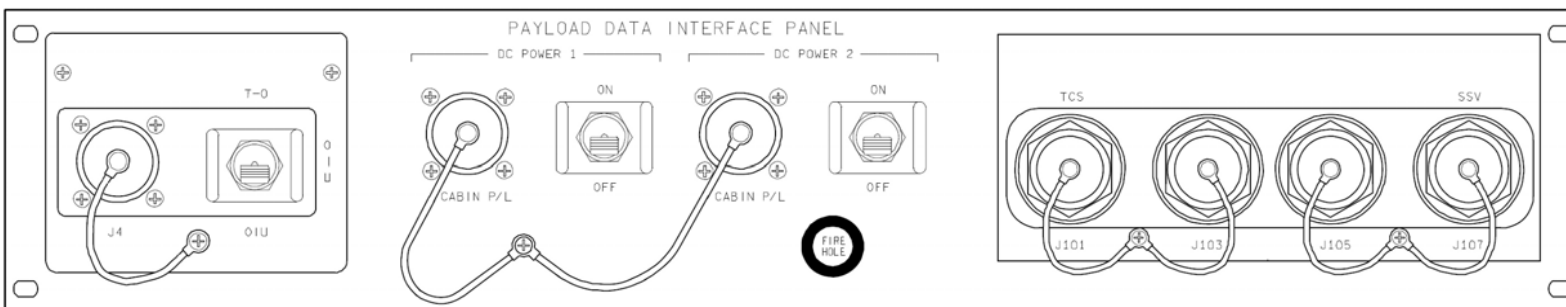


Figure 4-14. SSP 2

Verify that this is the correct version before use



**Figure 4-15. Payload Data Interface Panel 1**



**Figure 4-16. Payload Data Interface Panel 2**

## APPENDIX A ACRONYMS AND ABBREVIATIONS

A/L	Airlock
AA	Antenna Assembly
AAA	Avionics Air Assembly
ACBM	Active Common Berthing Mechanism
ACS	Atmosphere Control and Supply
ACSM	Attitude Control System Manager
ADP	Adjustable Diameter Pin
AFD	Aft Flight Deck
AMOS	Air Force Maui Optical and Super Computing Site
AO	Atomic Oxygen
AOA	Angles-of-Attack
AOH	Assembly Operations Handbook
APAS	Androgynous Peripheral Attachment System
APCF	Advanced Protein Crystallization Facility
APCU	Assembly Power Converter Unit Auxiliary Power Converter Unit
APFR	Articulating Portable Foot Restraint
ARCU	American-to-Russian Converter Unit
ATA	Ammonia Tank Assembly
ATU	Audio Terminal Unit
BBC	Bolt Bus Controller
BCDU	Battery Charge/Discharge Unit Berthing Mechanism Control and Display Unit
BG	Beta Gimbal
BGA	Beta Gimbal Assembly
BGDTS	Beta Gimbal Deployment/Transition Structure
BGHS	Beta Gimbal Housing Subassembly
BGTS	Beta Gimbal Translation Structure
BIA	Bus Interface Adapter
BIT	Built-In Test
BMRRM	Bearing Motor and Roll Ring Module
BOL	Beginning of Life
BRS	Blanket Restraint System
BSCCM	Battery Signal Conditioning and Control Module
C&C	Command and Control
C&DH	Command and Data Handling
C&T	Communication and Tracking
C&W	Caution and Warning
C/L	Crew Lock
C/O	Checkout
CASSIPOPE	Cascade SmallSat and Ionospheric Polar Explorer

CB	Clean Bench Control Bus
CBEF	Cell Biology Experiment Facility
CBM	Common Berthing Mechanism
CCAA	Common Cabin Air Assembly
CCTV	Closed-Circuit Television
CDRA	Carbon Dioxide Removal Assembly
CETA	Crew Equipment Translation Aid
CEU	Cell Experiment Unit
CFM	Cubic Feet per Minute
CHeCS	Crew Health Care System
CHX	Cabin Heat Exchanger
CIOB	Cargo Integration Operations Branch
CLPA	Camera Light Pan Tilt Assembly
CMG	Control Moment Gyroscope
CP	Cold Plate
CR	Change Request
CSA	Canadian Space Agency
CSCI	Computer Software Configuration Item
dc	Direct Current
DC	Docking Compartment
DCB	Double Cold Bag
DCSU	Direct Current Switching Unit
DDCU	DC-to-DC Converter Unit
DDCU-E	DDCU External
DDCU-I	DDCU Internal
deg	degree
DIU	Data Interface Unit
DLA	Drive Lock Assembly
DMC	Data Management Computer
DMS	Data Management System
DMS-R	Data Management System-Russian
DoD	Department of Defense
E/L	Equipment Lock
EATCS	External Active Thermal Control System
ECLSS	Environmental Control and Life Support System
ECU	Electronics Control Unit
EDF	Expanding Diameter Fastener
EDFM	Electronic Data Filter Method
EDR	European Drawer Rack
EDT	Eastern Daylight Time
EE	End Effector
EEPROM	Electrically Erasable Programmable Read-Only Memory
EETCS	Early External Thermal Control System

EF	Exposed Facility
ELC	Express Logistics Carrier
ELM	Experiment Logistics Module
ELM-ES	Japanese Experiment Logistics Module – Exposed Section
EMI	Electromagnetic Interference
EMU	Extravehicular Mobility Unit
EOL	End of Life
EPDS	Electrical Power Distribution System
ePOP	Enhanced Polar Outflow Probe
EPS	Electrical Power System
ER6	Express Rack 6
ES	Exposed Section
ESA	European Space Agency
ETCS	External Thermal Control System
ETE	End-to-End
ETRS	EVA Temporary Rail Stop
EU	Electronic Unit
EV	Extravehicular
EVA	Extravehicular Activity
EWIS	External Wireless Instrumentation System
EXT	External
FAST	Folding Articulated Square Truss
FC	Fuel Cell
FCC	Flat Collector Circuits
FCV	Flow Control Valve
FD	Flight Day
FDF	Flight Data File
FDIR	Fault Detection, Isolation, and Recovery
FE	Flight Engineer
FF	Free Flight
FGB	Functional Cargo Block
FHRC	Flex Hose Rotary Coupler
FOR	Flight Operations Review
	Frame of Reference
FPA	Fluid Processing Apparatus
FQD	Fluid Quick Disconnect
FQDC	Fluid Quick Disconnect Couplings
FRD	Flight Requirements Document
FRR	Flight Readiness Review
FSE	Flight Support Equipment
GAP	Group Activation Pack
GE	Gas Exchange
GF	Grapple Fixture
GFE	Government Furnished Equipment

GGR&C	Generic Groundrules, Requirements and Constraints
GLACIER	General Laboratory Active Cryogenic ISS Experiment Refrigerator
GLONASS	Global Navigational Satellite System
GMT	Greenwich Mean Time
GNC	Guidance, Navigation, and Control
GPC	General Purpose Computer
GPS	Global Positioning System
GSE	Ground Support Equipment
HEPA	High Efficiency Particulate Acquisition
HPR	Heat Pipe Radiator
HX	Heat Exchanger
I/O	Input/Output
IAA	Intravehicular Antenna Assembly
ICS	Interorbit Communication System
ICS-EF	Interorbit Communication System – Exposed Facility
ID	Inner Dimensions
IEA	Integrated Equipment Assembly
IFHX	Interface Heat Exchanger
IMCS	Integrated Mission Control System
IMV	Intermodule Ventilation
IOCC	Input/Output Card Controller
IP	International Partner
IPLAT	ISS Payload Label Approval Team
ISS	International Space Station
ISSP	International Space Station Program
ISSSH	International Space Station Systems Handbook
ITS	Integrated Truss Segment
IV	Intravehicular
IVA	Intravehicular Activity
JAXA	Japanese Aerospace Exploration Agency
JCP	JEM Control Processor
JEF	JEM Exposed Facility
JEM	Japanese Experiment Module
JEM-PM	JEM – Pressurized Module
JLE	Japanese Experiment Logistics Module – Exposed Section
JLP	Japanese Logistics Module – Pressurized Section
JPM	Japanese Pressurized Module
JSC	Johnson Space Center
Kbps	Kilobit per second
kW	Kilowatt
L	Launch
LAB	Laboratory



LB	Local Bus
LCA	LAB Cradle Assembly
LCD	Liquid Crystal Display
LDI	Local Data Interface
LED	Light Emitting Diode
LEE	Latching End Effector
LFDP	Load Fault Detect/Protect
LMC	Lightweight Multipurpose Equipment Support Structure Carrier
LOC	Loss of Control
LP	Long Spacer
LRU	Line Replacement Unit
LTL	Low Temperature Loop
M-RTAS	Modified RTAS
MAUI	Maui Analysis of Upper Atmospheric Injections
Mb	Megabit
Mbps	Megabit per second
MBS	Mobile Base System
MBSU	Main Bus Switching Unit
MCA	Major Constituent Analyzer
MCC	Mission Control Center
MCC-H	Mission Control Center – Houston
MCC-M	Mission Control Center – Moscow
MCDS	Multifunction Cathode-Ray Tube Display System
MDA	Motor Drive Assembly
MDL	Middeck Locker
MDM	Multiplexer/Demultiplexer
MDP	Management Data Processor
MELFI	Minus Eighty Laboratory Freezer for ISS
MET	Mission Elapsed Time
MIP	Mission Integration Plan
MKAM	Minimum Keep Alive Monitor
MLE	Middeck Locker Equivalent
MLI	Multilayer Insulation
MMC	Mission Management Computer
MMOD	Micrometeoroid/Orbital Debris
MNA	Main A
MNB	Main B
MNC	Main C
MOD	Mission Operations Directorate Modulator
MPLM	Multipurpose Logistics Module
MPM	Manipulator Positioning Mechanism
MPV	Manual Procedure Viewer
MRL	Manipulator Retention Latch
ms	Millisecond

MSS	Mobile Servicing System
MT	Mobile Tracker
MTL	Moderate Temperature Loop
MUP	Middeck Utility Panel
MWS	Maintenance Workstation
N <sub>2</sub>	nitrogen
n. mi.	nautical mile
NASA	National Aeronautics and Space Administration
NET	No Earlier Than
NH <sub>3</sub>	ammonia
NLP	National Lab Pathfinder
NOFS	Navigation Outage Forecasting System
NTA	Nitrogen Tank Assembly
OCAS	Operator Commanded Automatic Sequence
OD	Outer Dimensions
ODRC	Orbiter Data Reduction Complex
ODS	Orbiter Docking System
OIU	Orbiter Interface Unit
OMS	Orbital Maneuvering System
OPCU	Orbiter Power Converter Unit
Ops	Operations
ORCA	Oxygen Recharge Compressor Assembly
ORU	Orbital Replacement Unit
OSE	Orbital Support Equipment
OTCM	ORU and Tool Changeout Mechanism
OTP	ORU and Tool Platform
OV	Orbiter Vehicle
P6	Portside Truss Structure, Segment 6
P/L	Payload
P/S	Power/Supply
P/TV	Photo/Television
PAMA	PDGF Attachment Mounting Assembly
PAS	Payload Attachment System
PCA	Pressure Control Assembly
PCDF	Protein Crystallization Diagnostics Facility
PCN	Page Change Notice
PCR	Portable Computer Receptacle
PCS	Portable Computer System
PCU	Power Control Unit
PDB	Power Distribution Box
PDGF	Power and Data Grapple Fixture
PDH	Payload Data Handling unit
PDI	Payload Data Interface

PDIP	Payload Data Interface Panel
PPDRS	Payload Deployment Retrieval System
PDU	Power Distribution Unit
PET	Phase Elapsed Time
PFCS	Pump Flow Control Subassembly
PFR	Portable Foot Restraint
PGT	Pistol Grip Tool
PI	Principal Investigator
PIB	Power Interface Box
PIP	Push In Pull
PIT	Preintegrated Truss
PLB	Payload Bay
PLC	Pressurized Logistics Carrier
PL SEL	Payload Select
PM	Pressurized Module
PMA	Pressurized Mating Adapter
PMAD	Power Management and Distribution
PMCA	Power Management Controller Application
PMCU	Power Management Control Unit
PMP	Payload Mounting Panel
POA	Payload ORU Accommodation
POCC	Payload Operations Control Center
PPA	Pump Package Assembly
PPL	Pre-Positioned Load
PPS	Primary Power System
PRCS	Primary Reaction Control System
PRD	Payload Retention Device
PRLA	Payload Retention Latch Assembly
PSP	Payload Signal Processor
PTCS	Passive Thermal Control System
PTFE	polytetrafluoroethylene
PTR	Port Thermal Radiator
PTU	Pan/Tilt Unit
	Power Transfer Unit
PU	Process Unit
PV	Photovoltaic
PVAA	Photovoltaic Array Assembly
PVCA	Photovoltaic Controller Application
PVCU	Photovoltaic Controller Unit
PVM	Photovoltaic Module
PVR	Photovoltaic Radiator
PVTCS	Photovoltaic Thermal Control System
PWR	Power
QD	Quick Disconnect

R	Return
R&R	Remove and Replace
RACU	Russian American Converter Unit
RBI	Remote Bus Isolator
RBVM	Radiator Beam Valve Module
RCS	Reaction Control System
Rep	Representative
RFHX	Radiant Fin Heat Exchanger
RGA	Rate Gyro Assemblies
RIC	Rack Interface Controller
RJMC	Rotary Joint Motor Controller
RMS	Remote Manipulator System
ROS	Russian Orbital Segment
RPC	Remote Power Controller
RPCM	Remote Power Controller Module
RPDA	Remote Power Distribution Assembly
RPM	Roll Pitch Maneuver
RS	Russian Segment
RTAS	Rocketdyne Truss Attachment System
RTE	Run Time Environment
RTL	Ready-to-Latch
RWS	Robotics Workstation
S6	Starboard Six
SA	Solar Array
SABB	Solar Array Blanket Box
SARJ	Solar Alpha Rotary Joint
SASS	Segment-to-Segment Attach System
SAW	Solar Array Wing
SCA	Switchgear Controller Assembly
SDMS	Structural Dynamic Measurement System
SDP	Safety Data Package
SDS	Sample Distribution System
SEDA	Space Environment Data Acquisition equipment
SEDA-AP	Space Environment Data Acquisition equipment – Attached Payload
SEITE	Shuttle Exhaust Ion Turbulence Experiments
SiO	silicon oxide
SIMPLEX	Shuttle Ionospheric Modification with Pulsed Localized Exhaust
SLT	Station Laptop Terminal
	System Laptop Terminal
SM	Service Module
SODF	Station Operations Data File
SPC	Standard Portable Computer
SPD	Serial Parallel Digital
SPDA	Secondary Power Distribution Assembly
SPDM	Special Purpose Dextrous Manipulator

SPDU	Station Power Distribution Unit
SPEC	Specialist
SPM	Solar Power Module
	Space Power Module
SRMS	Shuttle Remote Manipulator System
SSAS	Segment-to-Segment Attach System
SSC	Station Support Computer
SSMDM	Space Station Multiplexer/Demultiplexer
SSOR	Space-to-Space Orbiter Radio
SSP	Space Shuttle Program
	Standard Switch Panel
SSPTS	Station/Shuttle Power Transfer System
SSRMS	Space Station Remote Manipulator System
SSSH	Space Shuttle Systems Handbook
SSU	Sequential Shunt Unit
STR	Starboard Thermal Radiator
STS	Space Transfer System
TA	Thruster Assist
TCCS	Trace Contaminant Control System
TCCV	Temperature Control and Check Valve
TCS	Thermal Control System
TEA	Torque Equilibrium Attitude
THC	Temperature and Humidity Control
	Translational Hand Controller
THL	Toxicity Hazard Level
TMA	Russian vehicle designation
TOCA	Total Organic Carbon Analyzer
TPS	Thermal Protection System
TRRJ	Thermal Radiator Rotary Joint
TUS	Trailing Umbilical System
TVC	Television Camera
U.S.	United States
U.S. Lab	United States Laboratory
UAS	User Application Software
UCCAS	Unpressurized Cargo Carrier Attach System
UHF	Ultra High Frequency
UMA	Umbilical Mating Adapter
UOP	Utility Outlet Panel
USA	United Space Alliance
USOS	United States On-Orbit Segment
VDS	Video Distribution System
VHF	Very High Frequency
VLA	Very Large Array

VPMP	Vented Payload Mounting Panel
VRCS	Vernier Reaction Control System
VSC	Video Signal Connector
WETA	Wireless Video System External Transceiver Assembly
WOOV	Water On-Off Valve
WPA	Water Pump Assembly
WRS	Water Recovery System
WS	Worksite
	Workstation

**APPENDIX B  
SUPPLEMENTARY DATA**

No supplementary data are currently identified.

## **APPENDIX C CHANGE CONTROL**

### **INTRODUCTION**

#### **Purpose**

The purpose of this appendix is to delineate change control procedures for the AOH. This ensures the proper coordination of changes and provides a record of proposed changes with rationale and disposition.

#### **Effectivity**

September 2006

### **CHANGE PROCEDURES**

#### **Submission of Changes**

Proposed changes are solicited from any individual or organization having a valid input. Changes should be submitted to the AOH book manager, Dustin Keiser, at mail code DO5, NASA/Johnson Space Center, Houston, Texas 77058.

Persons desiring to submit a change should complete all applicable items on the AOH Change Request (CR) Form shown on Page C-3. This form should be typed or neatly printed. Additional pages may be used if the space provided is not adequate. Then, the original complete form should be forwarded to the AOH book manager.

The AOH book manager evaluates the proposed change and makes modifications as required. The originator is advised of any such changes.

#### **Disposition**

#### **Coordination**

The AOH book manager obtains formal concurrence and comments from the necessary personnel. All proposed modifications to the CR are coordinated with all necessary personnel prior to disposition.

#### **Signoff**

Upon obtaining the required concurrences, the AOH book manager presents the proposed change to National Aeronautics and Space Administration (NASA) management for final disposition.



## **Postdisposition**

If a change is disapproved or modified, the AOH book manager returns the CR to the originator. A copy, however, is retained by the AOH book manager for future reference.

## **REVISIONS/PCNs**

### **Development**

The AOH book manager compiles all approved changes and any typographical errors and incorporates them into a Revision or Page Change Notice (PCN) to the document.

Pen-and-ink changes may be used to correct typographical errors if there are no other changes on the page concerned.

### **Approval**

Any revisions to this document are approved by the appropriate USA management.

### **Publication**

### **Schedule**

Revisions/PCNs are made on an as-required basis.

### **Distribution**

Revisions/PCNs are printed and distributed to the standard distribution list.

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AOH Title _____ NUMBER _____	
SECTION(S) AFFECTED:	
WAS:	
IS:	
RATIONALE FOR CHANGE:	
<u>ORIGINATOR</u> NAME _____  ORGANIZATION _____  TELEPHONE _____	<u>CONCURRENCE</u> _____ LEAD ACO DATE
<u>BOOK MANAGER</u> NAME _____ DATE _____  RECOMMENDATION _____  INCORPORATED _____ DATE _____	<input type="checkbox"/> APPROVE <input type="checkbox"/> DISAPPROVED  <input type="checkbox"/> APPROVED WITH CHANGES  _____ NASA GROUP LEAD DATE

JSC Form 1337 (March 31, 2000) (MS Word March 2000)

**Figure C-1. AOH Change Request Form sample**

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