Appendix A

Flight Hazard Reports

(Note: Following Hazard Reports Reflect As Signed Versions with exception of Document Revision Letter)

PAYLOAD FLIGHT HAZARD REPORT				a. NO:	AMS-02-F01
b. PAYLOAD	Alpha Magnetic Spectrometer-02 (AMS-02)			c. PHASE:	III
d. SUBSYSTEM:	Structures	e. HAZARD GROUP:	Collision, Injury	f. DATE:	January 21, 2011
g. HAZARD TITLE:	Structural Failure of Hardware			i. HAZARD CATEGORY:	CATASTROPHIC X CRITICAL
h. APPLICABLE SAFETY REQUIREMENTS:	NSTS 1700.7B and the ISS Addendum, 200.2, 208.1, 208.2, 208.3				
j. DESCRIPTION OF HAZARD:	Failure of AMS-02 Structures could injure crewmembers or damage the STS, ISS or other payloads. This hazard does not address non-structural pressure systems or sealed/vented container failures.				

k. CAUSES *(list)*

1. Inadequate structural strength for worst-case loads during all mission phases.
2. Improper Material Selection (including Stress Corrosion Cracking)
3. Initiation of propagation of flaws or crack-like defects.
4. Use of counterfeit, substandard or inadequate fasteners.
5. Loosening of safety critical fasteners.
6. Loss of structural integrity of welds.
7. Improper manufacture and/ or assembly.
8. Improper preload or creeping of the Cryomagnet support system straps.
9. Damage to composite structural components during manufacturing, assembly operations, ground handling, and/or ground transportation.
10. Degradation of composite structural components by atomic oxygen.
11. Improper Preload of PAS
12. Reconfiguration of Mechanical Components
13. Failure of Rotating Equipment

o. APPROVAL	PAYLOAD ORGANIZATION	SSP/ISS
PHASE I		
PHASE II		
PHASE III		

PAYLOAD FLIGHT HAZARD REPORT	a. NO: AMS-02-F01
b. PAYLOAD Alpha Magnetic Spectrometer-02 (AMS-02)	c. PHASE: III

l. HAZARD CONTROL (CONTROL), m. SAFETY VERIFICATION METHODS (SVM), n. STATUS OF VERIFICATIONS (STATUS)	OPS CONTROL
1. CAUSE: Inadequate structural strength for worst-case loads during all mission phases. These loads include, but are not limited to: differential temperature, thermal extremes, differential pressure, depressurization and repressurization, acoustics, ground transportation and handling, on-orbit (including transfer operations from the Orbiter to the ISS and crew induced) and magnet forces.	

1.1 CONTROL: The AMS-02 hardware is being designed to have positive margins of safety during all mission phases (Note exception in Control 1.4). All metallic structures will be tested or analyzed to show margin to the appropriate factors of safety (FOS) that have been coordinated with the Structures Working Group and ISS Structures and Mechanisms Group. In all cases all items have been analyzed to Shuttle and ISS on-orbit loads and results documented in AMS-02 Structural Verification Plan. (Note: Any exceptions to this control are documented in Control 1.4) Attached Table indicates FOS used and margins for structural components.

1.1.1 SVM: Review and approval of the AMS-02 Structural Verification Plan (SVP) (JSC 28792), which includes the requirements in NSTS 14046, by the JSC Structures Working group (SWG). Individual test plans derived from the SVP will be submitted to the JSC SWG.

1.1.2 SVM: Structural analysis will be performed to the appropriate factors of safety for all load conditions. Submittal of the AMS-02 Stress Analysis Reports to the JSC SWG and ISS Structures and Mechanisms Group.

1.1.3 SVM: Static strength and strength model verification tests for the AMS-02 payload will be performed. The AMS-02 Static Correlation Report will be submitted to the JSC SWG.

1.1.4 SVM: Model Correlation. Modal test on the AMS-02 payload and sine sweep test of the Structural Test Article (STA) will be performed for dynamic math model verification. Submittal of the AMS-02 Modal Correlation Report and STA Sine Sweep Correlation Report to the JSC SWG.

1.1.5 SVM: <Deleted with pressure equalization of VC in design>

1.1.6 SVM: <Deleted with pressure equalization of the VC>

1.1.7 SVM: <Deleted with removal of the Cryomagnet>

1.1.8 SVM: <Deleted with removal of Cryomagnet and non-linear support straps>

1.1.9 SVM: <Deleted>

1.1.10 SVM: Sine sweep, "smart -hammer" or modal testing, or analysis (by subsystem) will be performed to verify the first natural frequency of any secondary structure with a global mode that is below 50 Hz. Submittal of the Sine

Sweep, "Smart -Hammer" or Modal Test Plan, analysis methodology (part of the SVP) and Test Report to the JSC SWG.

1.1.11 SVM: Static verification tests of the Payload Attach System (PAS) and Interface Verification Test (IVT) of the PAS to ISS S3 Zenith Inboard Active PAS 2 were performed. Review and approval of the Static Test Report and IVT verification memorandum by the ISS Structures Team.

1.1.12 SVM: Other subdetector items in the AMS-02 SVP will be verified by letters of certification per SVP.

1.1.1 STATUS: Closed. ESCG Document, ESCG-4460-10-LODY-DOC-0001, "Review of the Alpha Magnetic Spectrometer - 02 Structural Verification Plan and Model Correlation Report," dated October 5, 2010.

1.1.2 STATUS: Closed. AMS-02 Stress Report, ESCG-4005-05-AMS-0039-A, “Revised Strength and Stability Assessment of the Alpha Magnetic Spectrometer-02 (AMS-02) Unique Support Structure (USS-02), Vacuum Case, Payload Attach System (PAS) and STS and ISS Integration Hardware, and X-Structure Components,” September 2010

1.1.3 STATUS: Closed. ESCG Memorandum/Document, ESCG-4460-09-LODY-MEMO-0313, "Post-test Analysis fr the Alpha Magnetic Spectrometer (AMS-02) Static Test," dated November 2009.

1.1.4 STATUS: Closed. ESCG Memorandum/Document, ESCG-4460-09-LODY-MEMO-0312, "Post-test Analysis fr the Alpha Magnetic Spectrometer (AMS-02) Modal Test," dated November 2009.

1.1.5 STATUS: <Deleted>

1.1.6 STATUS: <Deleted>

1.1.7 STATUS: <Deleted>

1.1.8 STATUS: <Deleted>

1.1.9 STATUS: <Deleted>

1.1.10 STATUS: Closed. ESCG Memorandum ESCG-4460-10-LODY-DOC-0218, "Summary of the Fundemental Frequencies for Components of the Alpha Magnetic Spectrometer (AMS)-02, Revision A, dated September 17, 2010

1.1.11 STATUS: Closed. PAS Static Test Plan (LMSEAT 34105) reviewed and approved by ISS Structures and Mechanisms Team. IVT Test Preparation Sheet (BCP-S3-T037), PAS Test Report (53103), and IVT Test Report (53103A) provided to ISS Structures and Mechanisms Team for review. Final approval via email acceptance of final Thermal Testing by JSC ES5 Hung Nguyen sent January 8, 2008 to JSC EA1 Stephen Porter titled “Re:AMS PAS Test”.

1.1.12 STATUS: Closed. ESCG Memorandum ESCG-4460-10-LODY-DOC-0218, "Summary of the Fundemental

PAYLOAD FLIGHT HAZARD REPORT	a. NO: AMS-02-F01
b. PAYLOAD Alpha Magnetic Spectrometer-02 (AMS-02)	c. PHASE: III

Frequencies for Components of the Alpha Magnetic Spectrometer (AMS)-02, Revision A, dated September 17, 2010

1.2 CONTROL: <Deleted with removal of Cryomagnet Support System>

1.3 CONTROL: EVA Sites and translation paths have been assessed for compatibility with EVA contact loads, specifically EVA kick loads of 125 pounds. All structures that can be contacted have been assessed to have a positive margin considering a factor of safety of 2.0.

1.3.1 SVM: Structural Analysis

1.3.1 STATUS: Closed. ESCG Memorandum ESCG-4460-09-LODY-MEMO-0280, "Assessment of Alpha Magnetic Spectrometer (AMS)-02 Hardware for Compatibility with Extravehicular Activity (EVA) Worksites and Translation Corridors," dated September 10, 2009

1.4 CONTROL: Structural joints, the junction of structural members, have been assessed for maintaining the preload of all joint fasteners under worst case loading conditions, a transient condition during launch loading. The loss of preload in these fasteners, either collectively or individually, can lead to "gapping" of a joint. This is not a structural failure, no structural member approaches ultimate in these conditions. It is desired that the appropriate margin of safety used for structural member failure be used to assure that preload is not lost, that is, if during launch the FOS of 1.4 is used against ultimate for a structural member failure, that same value is used against the transient elongation (as a spring) of a fastener. Failure to meet this criteria is reported to the Structures Working Group for special attention. This condition is not a violation of NSTS 1700.7B paragraph 208.1 as ultimate factors of safety for the individual structural elements are not exceeded. Current analyses indicate that there are limited locations where this gapping in a portion of a joint may occur (not the entire joint). No yielding or loss of structural integrity occurs at these locations. A fracture control impact assessment has been conducted as this "gapping" does increase the load cycles that the fastener and portion of the joint will experience, this assessment has shown the design and fracture analysis more than adequate cycling life for flight. The AMS-02 has demonstrated and defended this design condition to the Structures Working Group and shown that it is safe for flight with no detrimental loss of structural integrity or load carrying capability. NOTE: This control does not address any structural members as having negative margins, all structural members maintain a positive margin to the required ultimate factor of safety.

1.4.1 SVM: Documentation of all occurrences of structural interface joints negative margins against gapping (documented in Stress Report) in structural joints and submit to the JSC Structures Working Group.

1.4.1 STATUS: Closed. AMS-02 Stress Report, ESCG-4005-05-AMS-0039-A, "Revised Strength and Stability Assessment of the Alpha Magnetic Spectrometer-02 (AMS-02) Unique Support Structure (USS-02), Vacuum Case, Payload Attach System (PAS) and STS and ISS Integration Hardware, and X-Structure Components," September 2010

1.5 CONTROL: All vented containers and volumes present in the Orbiter Payload Bay have been assessed against ICD 2-19001, paragraph 10.6.1 for adequate venting capability or structural margins sufficient to sustain a full atmosphere pressure load without compromising the integrity (with appropriate margins) of the container of volume.

1.5.1 SVM: Review of design to demonstrate compliance with ICD 2-19001 paragraph 10.6.1

1.5.1 STATUS: Closed. ESCG Memo ESCG-4390-07-SP-MEMO-0014, dated October 18, 2007, "Review of AMS-02 Vented Containers". ESCG Memo ESCG=4390-07-SP-MEMO-0013, "Stress Analysis of the USS-02 Hollow Members" dated October 17, 2007. ESCG Memorandum ESCG-4295-10-ADV SY-MEMO-0014, "Venting of the AMS-02 Vacuum Case," dated July 9, 2010.

1.6 CONTROL: The TTCS piping routed to the radiator mounted TTCS Condensers require redundant heater systems along their length for proper operations. The nature of the routing also puts the carbon fiber struts that support the radiators in the same heaters area of effect. To preclude a runaway of both heater systems exceeding the thermal limits of the carbon fiber struts and reducing their load carrying capabilities, two thermostatic controls are in place, on in the source line and the other in the return. As neither heater system individually can cause the temperature excursion, each heater string is supplied with independent single fault tolerance, thus it would take four failures for both heater strings to fail on.

1.6.1 SVM: Thermal Analysis of Heater Fault Condition

1.6.2 SVM: Review of heater control circuitry

1.6.3 SVM: Inspection of as built design for incorporation of proper thermostatic control devices.

1.6.1 STATUS: Closed. NLR (National Lucht- en Ruimtevaartiaboratorium) document AMSTR-NLR-TN-061, "AMS Tracker Thermal Control Subsystem TTCS Liquid line health heater calculations," Issue 1 dated November 19, 2009. ESCG Memorandum ESCG-4295-10-ADV SY-MEMO-0024, "TTCS Design Review," July 20, 2010

1.6.2 STATUS: Closed. NLR (National Lucht- en Ruimtevaartiaboratorium) document AMSTR-NLR-TN-061, "AMS Tracker Thermal Control Subsystem TTCS Liquid line health heater calculations," Issue 1 dated November 19, 2009. ESCG Memorandum ESCG-4295-10-ADV SY-MEMO-0024, "TTCS Design Review," July 20, 2010

1.6.3 STATUS: Closed. AIDC document AMSTR-AIDC-PR-037, "AMS Tracker Thermal Control Subsystem Thermal Switch and Sensor Gluing Integration Procedure," dated January 2008 and Sun Yat-Sen University document TTCS-SYSU-TEST-TRP-016, "TTCBQM Test Report for 2nd Micro-G Loop Performance Test,"10/7/2009. ESCG Memorandum ESCG-4295-10-ADV SY-MEMO-0024, "TTCS Design Review," July 20, 2010

1.7 CONTROL: Design of the heaters on the Tracker plane 1N carbon fiber support structure will be design such that they cannot runaway and overheat the composite material.

1.7.1 SVM: Thermal Analysis of Heater Fault Condition

1.7.2 SVM: Review of heater control circuitry

1.7.3 SVM: Inspection of as built design for incorporation of proper thermostatic control devices.

1.7.1 STATUS: Closed. Thermal Analysis Documented in "AMS Tracker Plane 1NThermal Control" presentation, June 15, 2010

1.7.2 STATUS: Closed. ESCG Memorandum ESCG-4295-ADV Sy-MEMO-0015, “Plane 1NS Thermostats,” dated July 12, 2010

1.7.3 STATUS: Closed. Closed. ATS CABLE100701-003, “Plane 1NS Heater, Thermostat and DTS Installation,” closed June 30, 2010

2. CAUSE: Improper Material Selection (including Stress Corrosion Cracking)

2.1 CONTROL: AMS-02 materials will be selected to meet the requirements of MSFC-STD-3029. Materials with high resistance to stress corrosion cracking will be used where possible. Materials with moderate or low resistance to stress corrosion cracking have MUAs that have been/will be approved for each application. Identified materials to be covered in MUAs are attached to this hazard report.

2.1.1 SVM: Stress Corrosion Evaluation of materials list and drawings.

2.1.2 SVM: ES4/Material and Processes Branch Certification for materials usage.

2.1.1 STATUS: Closed. AMS Approved MUAS for SCC. 7050-T7451/T7452 Parts in USS, VC, PAS, and ROEU of Alpha Magnetic Spectrometer- 02 (AMS-02), Usage Agreement AG 577. Al 5083-H111 and 5083-H321 Parts Used in Helium Tank of Alpha Magnetic Spectrometer- 02 (AMS-02), Usage Agreement AG 594. JSC Materials and Fracture Control Certification, REF: MATL-09-036, Alpha Magnetic Spectrometer (AMS-02) Data Interface hardware. Utilization of Aluminum Alloy 7175 T 7351, MUA PI-217. Electromagnetic Calorimeter (ECAL), Alpha Magnetic Spectrometer-02 (AMS-02), MUA ESCG/ISS-256. Al 7050-T7451 Parts in Transition Radiation Detector (TRD) Gas Supply System, AMS-02, MUA ESCG/ISS-257.

2.1.2 STATUS: Closed. AMS Approved MUAS for SCC. 7050-T7451/T7452 Parts in USS, VC, PAS, and ROEU of Alpha Magnetic Spectrometer- 02 (AMS-02), Usage Agreement AG 577. Al 5083-H111 and 5083-H321 Parts

PAYLOAD FLIGHT HAZARD REPORT	a. NO: AMS-02-F01
b. PAYLOAD Alpha Magnetic Spectrometer-02 (AMS-02)	c. PHASE: III
Used in Helium Tank of Alpha Magnetic Spectrometer- 02 (AMS-02), Usage Agreement AG 594. JSC Materials and Fracture Control Certification, REF: MATL-09-036, Alpha Magnetic Spectrometer (AMS-02) Data Interface hardware. Utilization of Aluminum Alloy 7175 T 7351, MUA PI-217. Electromagnetic Calorimeter (ECAL), Alpha Magnetic Spectrometer-02 (AMS-02), MUA ESCG/ISS-256. Al 7050-T7451 Parts in Transition Radiation Detector (TRD) Gas Supply System, AMS-02, MUA ESCG/ISS-257.	
2.2 CONTROLS: Joints and junctions of dissimilar metals will be avoided when possible and where dissimilar metals will come into contact the materials and processing of the joints and junctions have been selected to limit detrimental galvanic corrosion over the life of the AMS-02 mission (11 years). 2.2.1 SVM: Material Compatibility Assessment 2.2.2 SVM: Approval of material use and MUAs by JSC ES4/Materials and Processes Branch 2.2.1 STATUS: Closed. JSC Materials and Fracture Control Certification MATL-11-009, "Alpha Magnetic Spectrometer -02 (AMS-02) Payload Assembly," Approved December 10, 2010 2.2.2 STATUS: Closed. JSC Materials and Fracture Control Certification MATL-11-009, "Alpha Magnetic Spectrometer -02 (AMS-02) Payload Assembly," Approved December 10, 2010	
3. CAUSE: Initiation or propagation of flaws or crack-like defects.	
3.1.1 CONTROL: The AMS-02 project will use JSC-25863A to implement the fracture control requirements of NASA-STD-5003 and SSP-30558C. See attached table for fracture classification of each structural element. 3.1.1 SVM: Compliance with the fracture control requirements of NASA-STD-5003 and SSP-30558C will be verified by approval of fracture control summary by JSC ES4/Materials and Processes Branch. 3.1.1 STATUS: Closed. JSC Materials and Fracture Control Certification MATL-11-009, "Alpha Magnetic Spectrometer -02 (AMS-02) Payload Assembly," Approved December 10, 2010	
4. CAUSE: Use of counterfeit, substandard or inadequate fasteners.	
4.1 CONTROL: All fasteners, including safety critical fasteners contained in components supplied by subcontractors, #8 (~3 mm) and larger are selected and tested in accordance with JPR 8730.2. Structural fasteners that are safety critical (structurally) are selected to be size #8 or larger. 4.1.1 SVM: AMS-02 Chief Engineer will collect all Certification documentation (including documentation for safety critical fasteners contained in components supplied by subcontractors) to verify that all structural fasteners will be #8 or larger and lot testing has been performed by JSC personnel to verify compliance with strength and	

PAYLOAD FLIGHT HAZARD REPORT		a. NO: AMS-02-F01
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chemical composition requirements of JPR 8730.2. Chief Engineer's Report on Completion will close action. 4.1.1 STATUS: Closed. JSC Memorandum EA3-09-031, "AMS Safety Verification Log," dated November 30, 2009. JSC Memorandum EA3-10-030, "AMS Safety Verification Log Update," dated August 5, 2010		
4.2 CONTROL: All hardware that is capable of releasing a mass of 0.25 lbs. or larger due to fastener(s) failure will be attached with #8 or larger fasteners. 4.2.1 SVM: Review of design by AMS-02 Project to ensure compliance. 4.2.2 SVM: Inspection of as built design. 4.2.1 STATUS: Closed. JSC Memorandum EA3-09-031, "AMS Safety Verification Log," dated November 30, 2009. JSC Memorandum EA3-10-030, "AMS Safety Verification Log Update," dated August 5, 2010 4.2.2 STATUS: Closed. JSC Memorandum EA3-09-031, "AMS Safety Verification Log," dated November 30, 2009. JSC Memorandum EA3-10-030, "AMS Safety Verification Log Update," dated August 5, 2010		
5. CAUSE: Loosening of safety critical fasteners.		
5.1 CONTROL: Safety-critical fasteners, including safety critical fasteners contained in components supplied by subcontractors, inadvertent back-off will be prevented by the use of locking inserts/nuts, self-locking bolts, safety wire and fastener preload/torque. 5.1.1 SVM: Certification documentation (including documentation for safety critical fasteners contained in components supplied by subcontractors) that appropriate back off prevention methods were used. 5.1.1 STATUS: Closed. JSC Memorandum EA3-09-031, "AMS Safety Verification Log," dated November 30, 2009. JSC Memorandum EA3-10-030, "AMS Safety Verification Log Update," dated August 5, 2010		
5.2 CONTROL: For applications where small fasteners are used that utilized chemical thread lock (e.g. "Loctite", "Vibratite") to prevent backout, fasteners will be contained within the structure of the AMS-02 or its subelements. This controls the potential release of mass while on the ISS truss. 5.2.1 SVM: Review of Design 5.2.1 STATUS: Closed. JSC Memorandum EA3-09-031, "AMS Safety Verification Log," dated November 30, 2009. JSC Memorandum EA3-10-030, "AMS Safety Verification Log Update," dated August 5, 2010		
5.3 CONTROL: In limited applications small fasteners capable of being released and not contained by AMS-02 Structures or its subelements and too small to utilize approved backout prevention methodologies have implemented a		

potting/embedding of the fastener head within an epoxy (type) compound to contain the fastener. This implementation requires complete encapsulation of the fastener head (nut where applicable) in a space qualified adhesive material. 5.3.1 SVM: Inspection of fastener potting/embedding. (Cumulative report will close this verification.) 5.3.1 STATUS: Closed. JSC Memorandum EA3-09-031, "AMS Safety Verification Log," dated November 30, 2009. JSC Memorandum EA3-10-030, “AMS Safety Verification Log Update,” dated August 5, 2010	
6. CAUSE: Loss of structural integrity of welds.	
6.1 CONTROL: The welds (heritage Permanent Magnet) will have positive margins of safety during all mission phases, for the factors of safety specified in Control 1.1. 6.1.1 SVM: Structural Analysis demonstrating positive margin of safety 6.1.1 STATUS: Closed. AMS-02 Stress Report, ESCG-4005-05-AMS-0039, “Strength and Stability Assessment of the Alpha Magnetic Spectrometer-02 (AMS-02) Unique Support Structure (USS-02), Vacuum Case, Payload Attach System (PAS) and STS and ISS Integration Hardware,” July 2009	
6.2 CONTROL: Previously approved Heritage welds on the permanent magnet were welded to approved standards and will be inspected prior to reflight. 6.2.1 SVM: Welds will be inspected. 6.2.1 STATUS: Closed. CERN EN/ME/MM/J. M. Dalin, Weld inspection report (No Number)for R/ Becker/AMS, dated May 28, 2010	
7. CAUSE: Improper manufacture and/ or assembly.	
7.1 CONTROL: Approved drawings and procedures, including tool control, will be used for manufacturing and assembly. 7.1.1 SVM: Certification documentation will be provided to verify proper manufacturing/assembly of AMS-02 hardware (including all composite materials). 7.1.1 STATUS: Closed. JSC Memorandum EA3-09-031, "AMS Safety Verification Log," dated November 30, 2009	
8. CAUSE: <Deleted with Removal of Cryomagnet Support System (Non-Linear Straps)	
8.1 CONTROL: <Deleted>	
9. CAUSE: Damage to composite structural components during manufacturing, assembly operations, ground handling, and/or ground transportation.	

PAYLOAD FLIGHT HAZARD REPORT	a. NO: AMS-02-F01
b. PAYLOAD Alpha Magnetic Spectrometer-02 (AMS-02)	c. PHASE: III

9.1 CONTROL: Each supplier/developer of composite structures will provide special handling procedures and requirements which are developed into work instructions for manufacturing, assembly operations, ground handling and/or ground transportation. Quality assurance representatives oversee the implementation of these work instructions to protect the composite structures.

9.1.1 SVM: QA review of procedures and certification of procedure completion.

9.1.1 STATUS: Closed. ESCG Memorandum ESCG-4295-10-ADV SY-MEMO-0035, “Composite Structural Elements,” Dated August 29, 2010

10. CAUSE: Degradation of composite structural components by atomic oxygen.

10.1 CONTROL: All composite structures are covered with thermal blankets, structures and/or coatings to assure non-metallic components are not in a direct line of sight of atomic oxygen.

10.1.1 SVM: Review of design.

10.1.2 SVM: Inspection of as built hardware.

10.1.1 STATUS: Closed. Design of all load bearing composite structures indicate no line of sight to atomic oxygen. Memorandum ESCG-4390-06-SP-MEMO-0005, “Composite Structural Elements,” dated 13 March 2006, AMS-02 Chief Engineer Chris Tutt. ESCG Memorandum ESCG-4295-ADV Sy-MEMO-0016 “Composite Strutural Element on AMS-02,” dated July 12, 2010

10.1.2 STATUS: Closed. Photographic Survey inspection performed by ESCG/P. Mott, 7/21/2010

11. CAUSE: Improper Preload of PAS

11.1 CONTROL: In order to establish the proper stiffness and preload of the AMS-02 when grappled by the ISS active PAS the AMS-02 is designed to have an adjustable configuration on the AMS-02 PAS element. The stiffness has been established to meet the requirement of SSP 57003.

11.1.1 SVM: Structural Analysis (for Stiffness)

11.1.2 SVM: Interface testing on S3 Truss with AMS-02 Flight PAS.

11.1.3 SVM: Inspection of Flight hardware to confirm proper configuration of adjustment prior to flight.

11.1.1 STATUS: Closed. Jacobs Sverdrup Memo ESCG-4390-06-SP-MEMO-0001, “Mechanical Design of the Payload Attach System (PAS)”, Dated 8 January, 2006 from AMS-02 Chief Engineer.

11.1.2 STATUS: Closed. Memo ESCG-4390-05-SP-MEMO-0012, “Functional Testing of the Payload Attach

System" dated 28 December 2005, from AMS-02 Chief Engineer Chris Tutt.

11.1.3 STATUS: Closed. JSC TPS 2A1020268, "Inspection of AMS-02 PAS for Flight Safety Verifications," closed October 20, 2010

12. CAUSE: Reconfiguration of Mechanical Components

12.1 CONTROL: The EVA release of the PAS mechanism is structurally capable of enduring Orbiter return loads with a positive margin of safety regardless of return configuration (fully reinstalled with preload release screws returned to hardstop configuration or disengaged). If after PAS/CAS site electrical and EVA operations fail to secure or release the AMS-02 and the AMS-02 release bar must be extracted, the bar can not be reinstalled for some reason it is capable of sustaining orbiter landing loads, but it may strike other structure or hardware causing potential damage (EBCS enclosure). Analysis shows that EVA restraint is possible (with the inability to immediately reinsert the bar into the AMS PAS) using EVA restraints currently in inventory to secure the extended bar to the Lower USS to preclude its movement during entry. Operation of this mechanism is contingency response only to failures of ISS Payload Attach Site Mechanism. Note: Shuttle and ISS both retain the option to jettison the AMS-02 if they establish the need arises.

12.1.1 SVM: Structural Analysis

12.1.1 STATUS: Closed. ESCG Memorandum ESCG-4460-09-LODY-MEMO-0064, "AMS-02 Contingency Landing with PAS Capture Bar Handle in Extended Position," dated June 2, 2009

12.2 CONTROL: <DELETED ROEU Folding Bracket has been fixed and is no longer folds.>

13. CAUSE: Failure of Rotating Equipment

13.1 CONTROL: Rotating equipment meets criteria of NASA-STD-5003 for obvious containment.

13.1.1 SVM: Fracture Control Analysis

13.1.1 STATUS: Closed. ESCG Memo ESCG-4390-07-SP-MEMO-0003, Titled "Rotational Energy Assessment of the AMS-02 Pumps", dated 29 June 2007 from Chris Tutt.

Notes:

ACRONYMS	
1-D – one dimensional	lbf – pounds force
ACC – Anticoincidence Counter	lbs – Pounds
AIAA – American Institute of Aeronautics and Astronautics	LMSEAT – Lockheed Martin Science Engineering and Test Contract
AIDC – Aerospace Industrial Development Corporation (Taiwan)	LT – Lower Time of Flight
Al – Aluminum	LTOF – Lower Time of Flight
AMICA - Astro Mapper for Instruments Check of Attitude	MUA – Material Usage Agreement
AMS-02 – Alpha Magnetic Spectrometer 02	MIT – Massachusetts Institute of Technology
ANSI- American National Standards Institute	mm – Millimeter
ARDE – Company Name, Arde' Inc.	NDE – Non-Destructive Examination
ASR – AMS-02 Support Rods	PAS – Payload Attach Site (ISS Component, e.g. Active PAS)
ASTM – American Society for Testing and Materials	PAS – Payload Attach System (AMS-02 component)
ASTS – AMS Star Tracker Support Structure	PCB – Printed Circuit Board
ATR – AMS-02 Tracker Rods	PMT – Photomultiplier Tube
CERN - *Conseil Européen pour la Recherche Nucléaire* (European Council for Nuclear Research)	Ops - Operations
CFRP – Carbon Fiber Reinforced Panel	QA – Quality Assurance
C of C – Certificate of Compliance	RAV –
Comp – Compressive	RICH – Ring Imaging Cherenkov Counter
CMA – Contract Management and Administration	ROEU – Remotely Operated Electrical Umbilical
CO2 – CO_2, Carbon Dioxide	RT – Race track
CRISA - *Computadores, Redes e Ingeniería, S.A (Division of*	RTEF – Race track End Frame

ACRONYMS	
EADS Astrium)	
CSIST – Chung-shan Institute of Science and Technology	RWTH – *Rheinisch-Westfälische Technische Hochschule (Rhenish-Westphalian Technical University)*
DCLA – Design Coupled Loads Analysis	SCL – Space Cryomagnetics Laboratory (Now Scientific Magnetics)
Deg - Degrees	SFHe – Superfluid Helium
EADS – European Aeronautics Defense and Space Company	Si – Silicon
ECAL – Electromagnetic Calorimeter	SM – Scientific Magnetics (Formerly SCL)
E-Crate – Electronics Crate	STA – Structural Test Article
EVA – Extravehicular Activity	SVM – Safety Verification Method
FEM – Finite Element Method	SVP – Structural Verification Plan
FOS – Factor of Safety	TCS – Thermal Control System
FS – Factor of Safety	TOF – Time of Flight
He – Helium	TRD – Transition Radiation Detector
HV – High Voltage	ult – Ultimate
Hz – Hertz	UPS – Uninterruptible Power Supply
I/F – Interface	USS – Unique Support Structure
in – inch	UT – Upper Time of Flight
INFN - *Istituto Nazionale di Fisica Nucleare*	UTOF – Upper Time of Flight
ISATEC – Company Name	VC – Vacuum Case
ksi – thousand pounds per square inch	VCM – Volatile Condensable Material
L – Launch	Xe – Xenon
LFCR – Laser Fiber Coupler	XPD – Generic Power Distribution Box (First letter changed to designate specific subsystem)

AMS-02 Structural Margin Tables

Margin of Safety Summary of Permanent Magnet

Item	Drawing Number	Material and temper	Material allowable stress (ksi)	Max. applied tensile stress (ksi)	Margin of Safety (ult) FS =2.0	Comments
Upper/Lower Flange		Al 2014	51.	12.7		From AMS-01 PVLR
Integral Frame		Al 2014	51.	9.1		From AMS-01 PVLR
Semi-frame		Al 2014	51.	9.1		From AMS-01 PVLR
Inner Shell		Al 2014	40. (weld)	1.9		From AMS-01 PVLR
Outer Shell		Al 2014	64.	3.0		From AMS-01 PVLR
Interface Support Pad		Al 7075	71.	8.3		From AMS-01 PVLR
Z-stringer		Al 2024	61.	5.0		From AMS-01 PVLR

Margin of Safety Summary of X-structure and Magnet Support Struts

Item	Drawing Number	Material and temper	Material allowable stress (ksi)	Max. applied tensile stress (ksi)	Margin of Safety (ult) FS =3.0	Comments
X-structure frame	2316-1.0001-A05	Al 7075 T7351 AMS-QQ-A 250/12	57.	6.9	1.7	Per ISAtec
Clevis to x-structure	2316-1.0002-A03	Al 7075 T7351 AMS-QQ-A 250/12	57.	14.2	0.3	Per ISAtec
Clevis to outer ring	2316-1.0003-A05	Al 7075 T7351 AMS-QQ-A 250/12	57.	8.0	1.3	Per ISAtec
Clevis adapter in outer ring	2316-1.0004-A03	Al 7075 T7351 AMS-QQ-A 250/12	57.	18.5	0.03	Per ISAtec
Struts	2316-1.0005-A05	Ti6Al4V AMS 4928	130.	5.4	7.0	Per ISAtec
Shear pins	2316-1.0010-A02	Ti6Al4V AMS 4928				

Margin of Safety Summary of Vacuum Case Conical Flange

Item	Drawing Number	Material and temper	Material allowable stress (ksi)	Max. applied tensile stress (ksi)	Margin of Safety (ult) FS =1.4	Comments
Upper conical flange, PM vacuum case	SDG39137911	Al 2219-T62 AMS-QQ-A-250/30	54.	28.0	0.38	Section 3.1.1, Note 26
Lower conical flange, PM vacuum case	SDG39137912	Al 2219-T62 AMS-QQ-A-250/30	54.	28.0	0.38	Section 3.1.1, Note 26

Margin of Safety Summary of Tracker Plane 1 Assembly

Item	Drawing	Material and temper	Material	Max. applied	Margin of	Comments

	Number		allowable stress (ksi)	tensile stress (ksi)	Safety (ult) FS =3.0	
Bracket		Al 7075 T7351	57.	13.1	0.44	Per ISAtec
Composite skins		T700S + EP	53.3	1.1	14.8	Per ISAtec
Honeycomb Core		Aluminum	0.11	0.02	0.84	Per ISAtec
C-Channel		T300 + EP	58.	1.03	17.7	Per ISAtec
GPS Antenna Bracket		Al 7075 T7531	57.	5.9	2.2	Per ISAtec

Margin of Safety Summary of Tracker Plane 6 Assembly

Item	Drawing Number	Material and temper	Material allowable stress (ksi)	Max. applied tensile stress (ksi)	Margin of Safety (ult) FS =3.0	Comments
Support Arms (interface bracket)		AL 7075 T7351	57.	5.9	2.2	Per ISAtec
Composite Skins		Carbon Fiber/Cyanite Ester M55/CE	27.6	3.9	1.3	Per ISAtec
Honeycomb Core		Aluminum	0.11	0.03	047	Per ISAtec

Margin of Safety Summary for Transition Radiation Detector (TRD) Structure

Item	Drawing number	Material and temper	Material allowable stress (ksi)	Max. applied stress (ksi)	Margin of Safety (ult) FS=2.0	Comments
TRD Support						
M structure	1811/60 0002 1 V1	7075-T7351	62	15.4	1.02	Page 31 Note 1
Corner brackets	1811/60 0001 V1	7075-T7351	57	22.9	0.24	Page 12, Note 30
Upper bracket right	1811/60_0003-01_V1	7075-T7351	60	22.8	0.32	Page 14, Note 30
Upper bracket left	1811/60_0004-01_V1	7075-T7351	60	22.8	0.32	Page 14, Note 30
TRD Octagon						
Octagon panels	ams1912i-3d-02 ams1912p	Carbon fiber skin Al. 5056 core 1/8 in cell	145	72.3	0.002	Page 20, Note 30
Octagon panel flanges	ams 02 1912p Detail U,V	Carbon fiber skin Al. 5056 core 1/8 in cell	145	43.7	0.66	Page 24, Note 1
Upper flange reinforcement ring	ams 02 1996 f	T33 Tenax Fabric	116	-27.7	1.10	Page 25, Note 1
Upper cover	ams 02 1942g	Carbon fiber skin Al. 5056 3/16 cell	116	-32.2	0.80	Page 27, Note 1

Margin of Safety Summary for Transition Radiation Detector (TRD) Gas System Structure

Item	Drawing number	Material and temper	Material allowable stress (ksi)	Max. applied stress (ksi)	Margin of Safety (ult) FS=2.0	Comments
Box S plate		7050-T7451	66.1	30.6	0.08	Page 21, Note 2
Xe tank bracket		6061-T6	42	4.6	1.4	Page 21 Note 2
Lower bracket		7050-T7451	66.1	12.3	1.69	Page 21, Note 2
Box C base plate		6061-T6	49.3	20.3	0.21	Page 15 Note 3
Valve bracket		6061-T6	49.3	13.2	0.86	Page 15 Note 3

Margin of Safety Summary of AMS-02 Upper Time of Flight (UTOF)

Item	Drawing number	Material and temper	Material allowable stress (ksi)	Max. applied stress (ksi)	Margin of Safety (ult) FS=2.0	Comments
Upper brackets	ams TOF 08-01-006 UT	7075-T7351	64	31.4	0.02	Page 57, Note 4
Lower brackets	ams TOF 08-01-001 UT	7075-T7351	64	16.1	0.98	Page 57, Note 4
Extensions	ams TOF 08-01-008 UT	7075-T7351	64	16.1	0.98	Page 57, Note 4
Honeycomb skins	ams TOF 08-02-002 UT	2024-T81	62.9	18.3	0.72	Page 57, Note 4
Secondary Brackets	ams TOF 02-01-005 UT	7075-T7351	64	8.1	2.92	Page 57, Note 4
Sensor Boxes	ams TOF 09-001 UT	CFRP T300 fabric	X = 115.9 Y = 115.9 XY =14.3	X=4.9 Y=7.4 XY=4.6	0.51	Page 58, Note 4, Margin of safety Note 5
Scintillator Supports		CFRP T 300 fabric	X = 115.9 Y =115.9 XY= 14.3	X=22.2 Y=25.7 XY=3.8	0.11	Page 58, Note 4, Margin of safety Note 5
PMT Boxes supports	ams TOF 05-05-001 UT	CFRP T 300 fabric	X =115.9 Y =115.9 XY = 14.3	X=10.4 Y=9.75 XY=2.4	1.70	Page 58, Note 4, Margin of safety Note 5

Margin of Safety Summary of AMS-02 Lower Time of Flight (LTOF)

Item	Drawing number	Material and temper	Material allowable stress (ksi)	Max. applied stress (ksi)	Margin of Safety (ult) FS=2.0	Comments
Beam A	ams TOF 04-01-001 LT	7075-T7351	64	30.6	0.05	Page 76, Note 6
Beam B	ams TOF 04-01-002 LT	7075-T7351	64	29.8	0.07	Page 76, Note 6
Corner beam	ams TOF 04-01-	7075-T7351	64	11.0	1.9	Page 76, Note 6

	003 LT					
Upper bracket	ams TOF 04-01-021 LT	7075-T7351	64	10.7	1.98	Page 76, Note 6
Lower bracket	ams TOF 04-01-020 LT	7075-T7351	64	10.0	>2.0	Page 76, Note 6
Internal bracket	ams TOF 04-01-018 LT	7075-T7351	64	13.30	1.4	Page 76, Note 6
Struts	ams TOF 04-01-01-001 LT	7075-T7351	64	14.60	1.18	Page 76, Note 6
Sensor Boxes Bracket	ams TOF 04-01-008 LT	7075-T7351	64	17.84	0.79	Page 76, Note 6
Sensor Boxes	ams TOF 02-001 LT	CFRP T300 Fabric	X = 115.9 Y = 115.9 XY = 14.3	X=-9.7 Y=9.8 XY=3.9	1.56	Page 77, Note 6 Margin of safety Note 7
Boxes/PMT Support	ams TOF 05-05-001 LT	CFRP T300 Fabric	X = 115.9 Y = 115.9 XY = 14.3	X=13.9 Y=-17.4 XY=-3.5	1.17	Page 77, Note 6 Margin of safety Note 7
Scintillator supports		CFRP T300 Fabric	X = 115.9 Y = 115.9 XY = 14.3	X=17.4 Y=30.5 XY=5.9	0.12	Page 77, Note 6 Margin of safety Note 7

Margin of safety Summary of AMS-02 Ring Imaging Chernkov Counter (RICH)

Item	Drawing number	Material and temper	Material allowable stress (ksi)	Max. applied tensile stress (ksi)	Margin of Safety (ult) FS=2.0	Comments
External Structure						
Primary beam	13-RICSYS-00.001	7075-T7351	64	13.2	1.42	Page 54, Note 8
Secondary Internal beam	13-RICSYS-00.004	7075-T7351	64	14.6	1.18	Page 54, Note 8
Internal Structure						
Structural members	12-RICSYS-10-001	7075-T7351	64	11.4	1.8	Page 54, Note 8
Structural members	12-RICSYS-20-002	6061-T6	39.5	13.5	0.46	Page 54, Note 8
Reflector Support	12-RICSYS-40-001	7075-T7351	64	11.3	0.74	Page 54, Note 8
Reflector	13-RICSYS-00-008	CFRP M55J EX-1515	73	Failure Index 0.074	>2.0	Page 50, Note 8, Margin of safety Note 9

Margin of Safety Summary of AMS-02 Electro Magnetic Calorimeter (ECAL)

Item	Drawing number	Material and temper	Material allowable stress (ksi)	Max. applied stress (ksi)	Margin of Safety (ult) FS=1.4	Comments
Honeycomb Face plate	ECAL0-10-Je	2024-T4 (2A12-T4)	61	16.0	1.73	Page 27, Note 10
Honeycomb I frame	ECAL0-11-Je	2014-T6 (2A14-T6)	65.3	21.3	1.19	Page 27, Note 10
Side panels	ECAL0-20-Je ECAL0-30-Je	2014-T6 (2A14-T6)	65.3	21.9	1.13	Page 27, Note 10
Bracket	ECAL0-41-Je	7050-T7451	69.9	21.0	1.37	Page 27, Note 10
Support beam	ECAL0-42-Je	7050-T7451	69.9	41.2	0.21	Page 27, Note 10

Margin of Safety Summary of AMS-02 Star Tracker

Item	Drawing number	Materials and temper	Material allowable stress (ksi)	Max. limit stress (Ksi)	M.S. (ult) FS=2.0	Comments
Upper bracket		CFRP M55J ACGLTM110	154	43	0.41	Page 13, Note 11, M.S. Note 11a
Lower bracket		CFRP M55J ACGLTM110	154	31.6	0.11	Page 13, Note 11, M.S,. Note 11a
Baffle to M structure bracket		7075-T7351	59	29.2	0.01	Page 11, Note 12

Margin of Safety Summary of AMS-02 Silicon Tracker Structure

Item	Drawing number	Material and temper	Material allowable stress (ksi)	Max. applied tensile stress (ksi)	Margin of Safety (ult) FS=2.0	Comments
Tracker Outer Planes						
Sandwich facing	AMS II 154 A0 AMS II 155 A0	Carbon fiber M60 J Cyanate Ester	50.7	fx=0.536 fy=0.826 fxy=0.276	>2.0	Page 22 Note 13
Sandwich core	AMS II 154 A0 AMS II 155 A0	Hexcel Honeycomb 3/16 in. Al. 5056	0.11	0.004	16	Page 22 Note 13
Tracker Inner Planes						
Sandwich core		Hexcel Honeycomb 3/8 in Al. 5056	0.025	0.011	0.12	Page 27 Note 13
Sandwich facing		Carbon fiber M60 J Cyanate Ester	72.5	fx=4.06 fy=3.33 fxy=1.65	4.8	Page 27 Note 13
Insert ring core		Hexcel Honeycomb 3/16 in. Al. 5056	0.11	0.024	1.26	Page 27 Note 13
Tracker feet		Ti-6Al-4V	130	56.4	0.14	Page 5, Note 14

Margin of Safety Summary of AMS-02 Anti Coincidence Counter (ACC)

Item	Drawing Number	Material and temper	Material allowable stress (ksi)	Max. applied stress (ksi)	Margin of Safety (ult) FS = 2.0	Comments
ACC Clamps	ams-02-03 1024	7075-T7351	56	25.8	0.09	Page 13, Note 19
ACC cylinder	ams-02 1626	CFRP Tenax J UMS2526	211	0.074	>2.0	
ACC panels	ams-02 1771c	Bicron BC 414 Polyvinyl Toluene	4.5	0.22	>2.0	
Connector support	1812/60_ 0004_I_VI	7075-T7351	68	22	0.54	Page 17, Note 31
ACC PMT support	1812/60_ 0010_I_VI	7075-T7351	67	0.13	>2.0	Note 19

Margin of Safety Summary of Main and Tracker Radiator

Item	Drawing Number	Material and temper	Material allowable stress (ksi)	Max. applied tensile stress (ksi)	Margin of Safety (ult) FS =2.0	Comments
Main radiator panel heat pipes	21-AMS-000.00.XY &22-AMS-000.00.XY	6063-T5	25.35	7.7	0.54	Page 198, Note 22. Combined inertia and pressure loads. (Ref. Page 193)
Tracker radiator panel heat pipes	25-AMS-000.00.XY	6063-T5	25.35	12.82	0.39	Page 199, Note 22. Combined On-Orbit and Pressure loads. (Ref. Page 197)
Main / Tracker radiator bracket	24-AMS-330.08 .XY	7075-T7351	62.97	27.46	0.15	Page 200, Note 22
Tracker radiator rod 4		Carbon fiber	1022 lbf	265.8 lbf	0.92	Page 199, Note 22
Main Radiator Skin	21_AMS-000.00.XY, 22-AMS-000.00.XY	2024-T81	62.97	17.68	0.78	Page 198, Note 22
Tracker radiator skin	25-AMS-000.00 01,25-AMS-000-00.02	2024-T81	62.97	27.63	0.14	Page 199, Note 22

Margin of Safety Summary of AMS-02 Electronic Crates and Radiator Brackets

Item	Drawing Number	Material and temper	Material allowable stress (ksi)	Max. applied tensile stress (ksi)	Margin of Safety (ult) FS =2.0	Comments
XPD structure	24- AMS-120.AB.XY	7075-T7351	58.29	26.73	0.09	Page 200, Note 22

Crate structure	24- AMS-110.AB.XY	7075-T7351	58.29	28.22	0.03	Page 200, Note 22
XPD board stiffeners	24- AMS-121.03.XY	6061-T651	39.36	21.77	0.21	Page 200, Note 22, Plastic bending analysis used. Ref. page 173
Links	24- AMS-130.01.XY	7075-T7351	53.58	20.16	0.33	Page 200, Note 22
Top bracket	24- AMS-310.02.XY	7075-T7352	53.58	24.55	0.09	Page 198, Note 22
Mid bracket	24- AMS-320.02.XY	7075-T7351	53.58	25.47	0.05	Page 198, Note 22
Lower bracket Plate	24- AMS-330.AB.XY	7075-T7351	56.41	9.15	>2.0	Page 198, Note 22

Margin of Safety Summary of High Voltage (HV) Bricks

Item	Drawing Number	Material and temper	Material allowable stress (ksi)	Max. applied tensile stress (ksi)	Margin of Safety (ult) FS =2.0	Comments
ECAL and RICH HV Bricks						
Bracket		7075-T7351	63.8	14.7	1.17	Page 125, Note 23
Frame		7075-T7351	59.2	11.8	1.5	Page 125, Note 23
Cover		6061-T62	39.5	6.8	1.88	Page 125, Note 23
Lateral walls		7075-T7351	63.8	23.8	0.34	Page 125, Note 23
TOF HV bricks						
Frame		7075-T7351	63.8	11.6	1.75	Page 126, Note 23
Cover		6061-T62	39.5	14.0	0.41	Page126, Note 23
Vertical Stand off		7075-T7351	63.8	11.9	1.68	Page 126, Note 23

Margin of Safety Summary of AMS-02 Vacuum Case Components

Item	Drawing number	Material and temper	Material allowable stress (ksi)	Max. applied stress (ksi)	Margin of Safety (ult) FS=1.4	Comments
Outer Cylinder	SDG39135779	7050-T7451 Forging	67	25.0	0.76	Sect. 3.2.1-5, Note 26
Upper Support rings	SDG39135786	7050-T7452 Forging	66	29.1	0.069	Sect. 3.4-26, Note 26
Lower Support rings	SEG39135785	7050-T7452 Forging	66	27.5	0.29	Sect. 3.5-13, Note 26 Stresses are much lower than the Upper support Ring and is enveloped by the Upper support Ring
Upper I/F plate assy.	SDG39135788	7050-T7451 Plate	68	9.5	3.69	Sect. 3.6-5, Note 26
Lower I/F plate assy.	SDG39135789	7050-T7451 Plate	68	14.0	2.19	Sect. 3.7-5, Note 26
Clevis Plate	SDG39135790	A 286 CRES	85 (yield)	Pax=4366 lbf Ptr =11798 lbf	2.37 (yield)	Sect. 3.8-8 , Note 26

Margin of Safety Summary of AMS-02 USS-02 Components

Item	Drawing number	Material and temper	Material allowable stress (ksi)	Max. applied tensile stress (ksi)	Margin of Safety (ult) FS=1.4	Comments
Sill Trunnion	SDG39135732	Custom 455 H1000	185 (yield)	77.2	1.34(yield)	Sect. 2.1.5-16, Note 26
Keel Trunnion	SDG39135772	Custom 455 H1000	185 (yield)	121.3	0.344(yield)	Sect. 2.3.4-12 Note 26
Upper VC Joint	SDG39135727	7050-T7451 Plate	69	22.5	0.46	Sect.2.1.1-10, Note 26
Lower VC Joint	SDG39135737	7050-T7451 Plate	67	21.4	0.38	Page 2.1.9-13, Note 26
Sill joint primary secondary	SDG39135730	7050-T7451 Plate	66	24.2	0.72	page.2.1.3-10 Note 26
Diagonal strut end fitting	SEG39135743	7075-T73511	37(Shear)	12.0	0.60 (Thread shear)	Sect. 2.1.13.2-5, Note 26
Diagonal strut tube	SEG39135742	6061-T6511	75343 lbf	29651 lbf	0.65 (buckling)	Sect. 2.1.13.1-5, Note 26
Lower center body joint	SDG39135759 SDG39135760	7050-T7451 Plate	70	27.6	0.67	Sect. 2.2.1-14, Note 26
Sill elbow joint	SDG39135734	7050-T7451 Plate	66	12.0	2.40	Sect.2.1.7-22, Note 26
Keel block	SEG39135770	7050-T7451 Plate	67	29.5	0.54	Sect.2.3.2-13, Note 26
Diagonal sill bracket clevis	SEG39135740	7050-T7451 Plate	Pbru=88484 lbf Ptbru=32342 lbf	Pax=4366 lbf Ptr=11797 lbf	0.50	Sect. 2.1.12-13, Note 26
Sill bracket	SEG39135738	7050-T7451 Plate	66	20.0	1.21	Sect. 2.1.10-8, Note 26
Lower USS to Upper USS joint	SDG39135762	7050-T7451 Plate	66	20.4	0.52	Sect 2.2.4-16, Note 26

Margin of Safety Summary for AMS-02 Payload Attach System (PAS)

Item	Drawing number	Material and temper	Material allowable stress (ksi)	Max. applied stress (ksi)	Margin of Safety (ult) FS=2.0	Comments
Vertex Bracket	SDG39135813	7050-T7451 Plate	65	38.502	0.02(FS=1.5)	Sect. 4.1-13, Note 26, Min. principal stress, ultimate
Aft Bracket	SDG39135814	7050-T7451 Plate	65	29.332	0.01	Sect. 4.2-13, Note 26, Min. principal stress, ultimate
PAS platform	SDG39135817	7050-T7451 Plate	73	26.339	0.27	Sect 4.3-7, Note 26, Tension ultimate
Guide Pins	SDG39135818	7050-T7451 Plate	43 (Shear)	1.117	17.67	Sect.4.4-10, Note 26, Shear ultimate
Bridge beam	SDG39135837	7050-T7451 Plate	43 (Shear)	18.949	0.04	Sect 4.6-16, Note 26, Shear ultimate
Bearing Housing	SEG39135845	15-5-PH H1025	155	125.45	0.20	Sect 4.10-14, Note 26, Tension Ultimate
Capture bar	SEG39135850	A 286 CRES bar	140	66.52	0.01	Sect. 4.11.1-7, Note 26, Tension Ultimate

Margin of Safety Summary of AMS-02 E-Crates						
Item	Drawing number	Material and temper	Material allowable stress (ksi)	Max. applied stress (ksi)	Margin of Safety (ult) FS=2.0	Comments
Bottom plate		7075-T7351	62.9	13.5	1.34	Page 50, Note 25
Lateral wall		7075-T7351	62.9	8.9	2.53	Page 50, Note 25

Margin of Safety Summary of Power Distribution System (PDS)						
Item	Drawing Number	Material and temper	Material allowable stress (ksi)	Max. applied tensile stress (ksi)	Margin of Safety (ult) FS =2.0	Comments
Structure (shell)	10-AMS02PDS-000.04	7075-T7351	64	10.53	2.03	Page 75, Note 32
Structure (bars)	10-AMS02PDS-000.09	7075-T7351	64	7.6	3.2	Page 75, Note 32
Electronics	11-AMS02PDS-700.00	Polyimide	27.5	1.94	6.08	Page 75, Note 32

Margin of Safety Summary of Tracker Thermal Control System Box (TTCB)						
Item	Drawing Number	Material and temper	Material allowable stress (ksi)	Max. applied tensile stress (ksi)	Margin of Safety (ult) FS =2.0	Comments
Base Plate		7475-T7351	70	5.3	5.6	Page 49 Note 33
Side Plate		7475-T7351	70	8.05	3.35	Page 50, Note 33
Start up radiator		7075-T7351	68	1.18	27.9	Page 52, Note 33
APS Bracket		7475-T7351	70	3.76	8.32	Page 53, Note 33
DPS Bracket		7475-T7351	70	4.05	7.65	Page 54, Note 33
Cover		2024-T72 clad	56	2.7	9.37	Page 55, Note 33

Margin of Safety Summary of Tracker Thermal Control System (TTCS) Accumulator						
Item	Drawing Number	Material and temper	Material allowable stress (ksi)	Max. applied tensile stress (ksi)	Margin of Safety (ult) FS =2.0	Comments
Accumulator		316LN stainless steel	94.3	36.98	0.02(FS=2.5)	Page 118 Note 34
Peltier Copper saddle		Copper	31.9	11.4	0.40	Page 67, Note 34
Fixed bracket, clamp collar and wedge		316L stainless steel	79.8	14.1	1.82	Page 119, Note 34
Sliding bracket		7075-T7351	68	8.6	2.95	Page 120, Note 34
Heat pipe		316L stainless steel	79.8	9.31	1.14 (FS=4.0)	Page 122, Note 34
Peltier Pipe fix		316L stainless steel	79.8	18.1	1.2	Page 123, Note 34
Peltier Heat exchanger spring support		316L Stainless steel	79.8	9.38	3.25	Page 124, Note 34
Heat exchanger press		316L stainless steel	79.8	21.9	0.82	Page 126, Note 34

Margin of Safety Summary of UMA

Item	Drawing Number	Material and temper	Material allowable stress (ksi)	Max. applied tensile stress (ksi)	Margin of Safety (ult) FS =2.0	Comments
UMA Bracket	SDG39136121 SDG39135858	6061-T651	40	18.15	0.003	Page 5.1-10, Note 26

Margin of Safety Summary of PVGF

Item	Drawing Number	Material and temper	Material allowable stress (ksi)	Max. applied tensile stress (ksi)	Margin of Safety (ult) FS =2.0	Comments
PVGF Bracket	SDG39135860	7075-T7351	63	25.32	0.082	Page 5.2-13, Note 26

Margin of Safety Summary of FRGF

Item	Drawing Number	Material and temper	Material allowable stress (ksi)	Max. applied tensile stress (ksi)	Margin of Safety (ult) FS =2.0	Comments
FRGF Bracket	SDG39135861	7050-T7451	66	17.18	0.498	Page 5.4-12, Note 26

Margin of Safety Summary of ROEU

Item	Drawing Number	Material and temper	Material allowable stress (ksi)	Max. applied tensile stress (ksi)	Margin of Safety (ult) FS =2.0	Comments
ROEU Clevis assy.	SEG39137677	7050-T7451	67	4.38	6.64	Page 5.5.1-19, Note 26
PDA Bracket	SDG39135866					

Margin of Safety Summary of Interface Panel A

Item	Drawing Number	Material and temper	Material allowable stress (ksi)	Max. applied tensile stress (ksi)	Margin of Safety (ult) FS =2.0	Comments
Interface Panel A	SEG39137684	7075-T73	67	25.95	0.136	Page 5.13-19, Note 26

Margin of Safety Summary of Scuff Plate

Item	Drawing Number	Material and temper	Material allowable stress (ksi)	Max. applied tensile stress (ksi)	Margin of Safety (ult) FS =2.0	Comments
Scuff Plate	SDG39135867	7050-T7451	68	21.36	0.449	Page 5.8-11, Note 26

Margin of Safety Summary of EVA Connector Panel

Item	Drawing Number	Material and temper	Material allowable stress (ksi)	Max. applied tensile stress (ksi)	Margin of Safety (ult) FS =2.0	Comments
FRGF Bracket	SEG39136085	6061-T651	40	16.0	0.162	Page 5.9-14, Note 26

Margin of Safety Summary of Debris Shield Port Side

Item	Drawing Number	Material and temper	Material allowable stress (ksi)	Max. applied tensile stress (ksi)	Margin of Safety (ult) FS =2.0	Comments
External Bumper	SDG39137853	7075-T73	67	29.93	0.07	Page 5.10.1-20, Note 26
Inner plate	SDG39137858	7075-T73	67	17.79	0.81	Page 5.10.1-23, Note 26
Interface joint bracket	SEG39137851	7075-T73	67	31.42	0.008	Page 5.10.1-35, Note 26

Margin of Safety Summary of TRD Gas Ballistic Shield

Item	Drawing Number	Material and temper	Material allowable stress (ksi)	Max. applied tensile stress (ksi)	Margin of Safety (ult) FS =2.0	Comments
Outer Skin	SLG39137916	6061-T6	27 (Shear)	8.61 (shear)	0.50	Page 5.10.3-18, Note 26
Standoff Bracket “A”	SDG39137917	7075-T7351	38 (Shear)	16.77	0.09 (Shear)	Page 5.10.3-24, Note 26
Interface joint bracket	SEG39137851	7075-T73	67	31.42	0.008	Page 5.10.1-35, Note 26
GPS Antenna Support	40-AMS02TCS-200.00.01	7075-T7351	68	27.6	0.23	Page 98, Note 20

NOTE:

1) Ref. Transition Radiation Detector (TRD), Structural Verification Presentation, Rev.3, 11 April 2005
2) Ref. TRD Gas System Box S Mechanical structure AMS-02, Rev_1, 27 June 2005, INFN Rome and MIT
3) Ref. TRD Box C Finite element analysis, MIT @CERN, June 11, 2004
4) Ref. Upper Time of Flight structural Analysis Report, RICSYS-CGS-013, issue 1, 29 June 2004
5) Tsai-Hill equation shown in Ref. note 4, Page 38. Margin of safety is (1/ Failure Index)-1
6) Ref. Lower Time of flight (LTOF) structural Analysis Report, RICSYS-RP_CGS-012 issue1, 29 June 2004
7) Tsai-Hill equation shown in Ref. note 6, page 44. Margin of safety is (1/ Failure index)-1.
8) Ref. RICH Structural Analysis Report, RICSYS-RP-CGS-009, issue2, 11/9//2008, Carlo Gavazzi Space
9) Tsai-Wu equation shown in Ref. Note 8 page 39. Margin of safety = (1/SFu. Failure index)-1
10) Ref. Flight ECAL Stress analysis after weight saving, 7 April 2004
11) Ref. AMS-02 AMICA Star Tracker Support Design, Rev. 1 INFN Rome, 27 June 2005
11a) Tsai-Hill equation shown in report note 11 page 12. Margin of safety = (1/FSult Failure index)-1
12) Ref. Baffle Support design, INFN Rome, Rev1 27 June 2005
13) Ref. AMS Silicon Tracker Support Plates Analysis Report Extension AMS-ANR-002, Contraves Space, 19 November 1999.
14) Ref. AMS 02 Tracker Support Feet, Rev. 1 Structural Verification Document, ISATEC, 16 June 2004
15) <Deleted>
16) <Deleted>
17) <Deleted>
18) <Deleted>
19) Ref. AMS-02 Anti Coincidence Counter Structural Verification Document, Rev. 1, ISATEC, 9 Dec. 2004

20) Ref. Cryo TCS and Support beams Structural Analysis Report AMSTCS-TN-CGS-011, iss.1, 3/31/2008
21) <Deleted>
22) Ref. Main and Tracker Radiator Structural Analysis Report, AMSTCS-TN-CGS-007, issue1, 3/25/2008, Carlo Gavazzi Space
23) Ref. HV Bricks Structural analysis Report, AMS-02-RP-CGS-007, issue 1, November.22, 2004
24) Ref. UPS Box Redesign Structural Analysis Report, CSIST Taiwan, December 28, 2005
25) Ref. Report AMS-02 RP-CGS-003, issue 2, 4 August 2005, Carlo Gavazzi Space
26) Revised Strength and Stability Assessment of the Alpha Magnetic Spectrometer-02 (AMS-02) Unique Support Structure (USS-02), Vacuum Case, Payload Attach System (PAS), STS and ISS integration Hardware, and X-structure Components, Report ESCG-4005-05-AMS-0039-A, September 2010.
27) <Deleted>
28) <Deleted>
29) <Deleted>30) Ref. Transition Radiation Detector (TRD), Structural Verification Presentation, Rev.5, 7 March 2007
31) Ref. ACC Connector Support, Documentation of Margin of Safety, 8 March 2007
32) Ref. PDS Structural Analysis report, PDS-TN-CGS-010, issue1, 3/25/2008, Carlo Gavazzi Space
33) Ref. TTCB structural Analysis Report TTCS-SYSU-MECH-AN-009-4.0, issue 4, 12 December 2008
34) Ref. Accumulator Structural Analysis Report TTCS-SYSU-MECH-AN-004-3.0, issue 3, 17 December 2008

AMS-02 FASTENERS MARGIN OF SAFETY

TRD Fasteners						
Item	Drawing number	Material and temper	Material allowable stress (ksi)	Applied Load (lbf)	Margin of Safety (ult) FS=2.0	Comments
Corner bracket to upper VC joint	SEG39135720	NAS1958C 0.50-20, A286	180	Tension = 2295 Shear = 1130	0.095	Total tension yield, 2.4.1.3-13, Note 10
Upper bracket to M structure		1/4-28, A286	160	Tension = 1167 Shear = 0	0.02	Joint separation, Note 1, Load case 1008
Corner bracket to M structure		5/16-24, A286	200	Tension = 2656 Shear = 84	0.04	Joint separation, Note 1, Load case 4058
Upper brackets to upper cover		1/4-28, A286	140	Tension = 900 Shear = 6	0.01	Total tension yield, Note 1, Load case 1008
Upper cover to octagon		5/16-24, A286	140	Tension = 155 Shear = 237	0.08	Total tension yield, Note 1, Load case 1008
GPS Antenna support to TRD	Joint 4	NAS1351N4 A286 0.250-28	160	tension = 523.7 Shear = 102.4	0.23	Joint separation Note 15, Page 121
GPS Antenna to Antenna support	Joint 5	DIN 965 M3-16 A2-70	101.5	tension = 12.5 Shear = 26.8	0.46 (yield)	Total tension yield Note 15, Page 124
TRD Gas System Fasteners						
Item	Drawing number	Material and temper	Material allowable stress (ksi)	Applied Load (lbf)	Margin of Safety (ult) FS=2.0	Comments
Box S/BoxC plate to USS upper I/F bolts		NAS1954 0.25-28 A-286	180	Tension = 148 Shear = 978	0.01	Total tension yield, Note 2 page 13
Box S Xe bracket to plate bolts		NAS1351N 0.375-24 A-286	160	Tension = 816 Shear = 698	0.01	Total tension yield, Note 2, page 19
Box C mounting of cylinder to bracket		NAS1351N 0.190-32, A-286	160	Tension = 24 Shear = 48	0.04	Total tension yield, Note 3, Page 5
Box C mounting of valve bracket to holder		NAS135N1 0.190-32, A-286	160	Tension = 44 Shear = 85	0.01	Total tension yield , Note 3, Page 12
AMS-02 Upper Time of Flight (UTOF) Fasteners						
Item	Drawing number	Material and temper	Material allowable stress (ksi)	Applied Load (lbf)	Margin of Safety (ult) FS=2.0	Comments
USS I/F bolts	Joint 1	A-286, 0.3125-24 EWB-0420-5	200	Tension = 2646 Shear = 0	0.10	Total tension yield , Note 4
Bracket extension	Joint 3	A-286,	160	Tension = 465	0.04	Combined tension and

bolts		NAS1351N4 0.25-28,		Shear = 961		Shear, Note 4
Upper to lower bolts	Joint 4	A-286, NAS1351N4, 0.25-28	160	Tension = 337 Shear = 232	0.16	Total tension yield , Note 4
AMS-02 Lower Time of Flight (LTOF)Fasteners						
Item	Drawing number	Material and temper	Material allowable stress (ksi)	Applied Load (lbf)	Margin of Safety (ult) FS=2.0	Comments
Bracket to ring bolts	Joint 1	A-286, NAS1351N5 0.3125-24	160	Axial = 633 Shear = 1179	0.01	Combined tension and Shear, Note 4
USS to Upper bracket bolts	Joint 2	A-286, NAS1351N6 0.375-24	160	Axial = 2788 Shear = 107	0.03	Joint separation , Note 4
USS to Lower bracket bolts	Joint 3	A-286, NAS1351N3 0.190-32	160	Axial = 108 Shear = 158	0.15	Total tension yield, Note 4
Ring to Honeycomb bolts	Joint 4	A-286, NAS1351N4 0.25-28	160	Axial = 130 Shear = 283	0.16	Total tension yield, Note 4
Rod end	Joint 6	NAS 6706 DU 0.375-24	160	Axial = 0 Shear = 2280	0.07	Combined tension and Shear, Note 4
AMS-02 Ring Imaging Chernkov Counter (RICH) Fasteners						
Item	Drawing number	Material and temper	Material allowable stress (ksi)	Applied Load (lbf)	Margin of Safety (ult) FS=2.0	Comments
External Structure bolts	Joint 1	A-286, NAS1351N4 0.25-28	160	Tension = 86 Shear = 1018	0.11	Combined tension and Shear, Page 75,Note 24
External to Internal structure bolts	Joint 2	A4-70 0.118-44 (3 mm)	101.5	Tension = 89 Shear = 64	0.19	Joint Separation, Page 75, Note 24
External Structure bolts	Joint 3	A-286, NAS1351N5 0.3125-24	160	Tension = 113 Shear = 824	0.34	Combined tension and Shear, Page 75, Note 24
External Structure Hi-lok	Joint 4	A-286 CR7620(06)	95	Tension = 259 Shear = 525	0.72	Combined tension and Shear, Page 75, Note 24
External Structure to Reflector bracket	Joint 5	A-286, NAS1351N3 0.190-32	160	Tension = 23 Shear = 228	0.56 (yield)	Total tension yield Page 75, Note 24
Reflector bracket to	Joint 6	A-286,	160	Tension = 58	0.54 (yield)	Total tension yield, Page 75

reflector		NAS1351N3 0.190-32		Shear = 12		Note 24
External structure to debris shield bracket	Joint 7	A-286 NAS1351N3 0.190-32	160	Tension = 57 Shear = 26	0.52 (yield)	Total tension yield, page 75 Note 24
Debris shield bracket to debris shield	Joint 8	A-286 NAS1351N3 0.190-32	160	Tension = 15 Shear = 28	0.53 (yield)	Total tension yield, Page 75 Note 24
AMS-02 Electro Magnetic Calorimeter (ECAL) Fasteners						
Item	Drawing number	Material and temper	Material allowable stress (ksi)	Applied Load (lbf)	Margin of Safety (ult) FS=1.4	Comments
Support beam to bracket (Joint 1)	ECAL0-0E	A-286 0.3125-24 NAS 6705U7, 8	160	Tensile = 2728 Shear =0.0	0.081	Total tension yield, Negative MS for Joint separation, Note 8
Bracket to side panels (joint 2)	ECAL0-0E	A-286 0.25-28 NAS 1954C6	180	Tensile = 3201 Shear = 264	0.042	Total tension yield, Negative MS for Joint separation, Note 8
I Frame to bracket bolts (joint 3)	ECAL0-0E	A-286 0.3125-24 NAS 6705HU10	160	Tensile = 358 Shear = 0.0	0.20	Total tension yield, Note 8
I Frame to honeycomb reinforcing and side panels 1 and 2 bolts (joint4)	ECAL0-0E	A-286 0.25-28 NAS1004-2	140	Tensile = 156 Shear = 1287	0.08	Combined tension and shear, Note 8
I Frame to side panel 1 bolts(Joint 5)	ECAL0-0E	A-286 0.25-28 NAS1004-9	140			Bolts were overtorqued. This joint is removed from model to re-evaluate bolt loads
I-Frame to side panels 1 and 2 (joint 6)	ECAL0-0E	A-286 0.3125-24 NAS1005-1,-2	140	Tensile = 335 Shear = 563	0.165	Total tension yield, Note 8
I-Frame to honeycomb reinforcing and side panels 1 and 2 (Joint 7)	ECAL0-0E	A-286 0.3125-24 NAS1005-1	140	Tensile = 887 Shear = 601	0.141	Total tension yield, Note 8
Support beam to USS (Joint 8)	ECAL0-0E	A-286 0.625-18 NAS 1960C30	140	Tensile = 4389 Shear = 1270	0.171	Total Tension yield, Note 8
AMS-02 Star Tracker Fasteners						
Item	Drawing number	Material and temper	Material allowable stress (ksi)	Applied Load (lbf)	Margin of Safety (ult) FS=2.0	Comments
Upper bracket to tracker plane 1 bolts		A286, 0.39 (M10)	160	Tension = 67 Shear = 268	0.005	Total tension Yield, Note 5, page V
Upper bracket to lower bracket bolts		A286, 0.190-32	160	Tension = 125 Shear =116	0.009	Total tension Yield , Note 5, Page IX

Lower bracket to tracker conical flange		A286, 0.118 (M3)	160	Tension = 8 Shear = 112	0.03	Total tension Yield, Note 5. page XIII
Baffle bracket Baffle side to Baffle bolts		A286 0.190-32	160	Tension = 38 Shear = 14	0.03	Total tension Yield, Note 6, page XIV
AMS-02 Silicon Tracker Structure Fasteners						
Item	Drawing number	Material and temper	Material allowable stress (ksi)	Applied Load (lbf)	Margin of Safety (ult) FS=2.0	Comments
Tracker feet to vacuum case (Joint1)		A4-70, 0.3125-24 UNF	101.5	Tension = 1072 Shear = 0	0.02	Joint separation, Note 17, page 2.1-4
Tracker feet to Tracker shell (Joint2)		A-286 10-32 UNF	200	Tension = 1196 Shear = 0	0.03	Total tension yield, Negative MS on Joint separation, Note 17, page 2.2-4
Conical Flange to tracker shell (Joint3)		A-286, M4x33	200	Tension = 327 Shear = 333	0.01	Combined tension and shear, Note 17, page 2.3-4
Tracker shell to tracker shell (Joint 4)		A4-70 0.138-32 UNC	101.5	Tension = 59 Shear = 0	0.07	Total tension yield, Note 17, page 2.4-4
Inner plane to tracker shell (Joint 5)		A4-70, M4x12	101.5	Tension = 49 Shear = 60	0.08	Total thread shear ultimate, Note 17, page 2.5-4
Outer plane to conical flange, long flange (Joint 6)		A4-70, M4x40	101.5	Tension = 29 Shear = 80	0.16	Total thread shear ultimate, Note 17, page 2.6-4
Outer plane to conical flange, short flange (Joint 7)		A4-70, M4x40	101.5	Tension = 29 Shear = 80	0.05	Total thread shear ultimate, Note 17, page 2.7-4
Fasteners Anti Coincidence Counter (ACC)						
Item	Drawing number	Material and temper	Material allowable stress (ksi)	Applied Load (lbf)	Margin of Safety (ult) FS=2.0	Comments
ACC clamps to VC flange bolts		A-286, 0.190-32	200	Tension = 545 Shear = 0	0.012	Total tension yield, Note 13
PMT supports to Vacuum Case		A-286, 0.190-32	160	Tension = 246 Shear = 273	0.023	Total tension yield, Note 14
Fasteners AMS-02 Main and Tracker Radiators (WAKE and RAM)						
Item	Drawing number	Material and temper	Material allowable stress (ksi)	Applied Load (lbf)	Margin of Safety (ult) FS=2.0	Comments
USS to top Bracket	Joint 1a	A 286 0.25-28 NAS1351N4	160	Tension = 274.7 Shear = 1145.5	0.011	Combined tension and shear, Page 207, Note 20

USS to mid bracket	Joint 1b	A 286 0.25-28 NAS1351N4	160	Tension = 931.9 Shear = 705.2	0.08	Joint Separation, Page 209, Note 20
USS to lower bracket	Joint 1c	A 286 0.25-28 NAS1351N4	160	Tension = 365.9 Shear = 367.5	0.46 (yield)	Total tension yield, Page 211, Note 20
Upper Brackets to Electronic boxes	Joint 2a	A 286 0.190-32 NAS1351N3	160	Tension =401.3 Shear = 440.1	0.143	Combined tension and shear , Page 215, Note 20
Mid Brackets to Electronic boxes	Joint 2b	A 286 0.25-28 NAS1351N4	160	Tension =250.1 Shear = 208.8	0.47 (yield)	Total tension yield, Page 217, Note 20
Main Radiator/Electronic boxes Joints	Joint 3 b	A 286 0.25-28 NAS1351N4	160	Tension = 60.3 Shear = 829.4	0.28	Combined tension and shear, Page 224, Note 20
Links to electronic boxes	Joint 4	A 286 0.190-32 NAS1351N3	160	Tension = 412.9 Shear = 170.6	0.11	Combined shear, tension and bending, Page 231, Note 20
Crates and XPD wall joints	Joint 5a	A 286 0.164-32 NAS1352N08	160	Tension = 166 Shear =58	0.10	Total tension yield, page 233, Note 20
TPD wall Joints	Joint 5b	A 286 0.164-32 NAS1351N08	160	Tension = 102 Shear = 28	0.12	Total tension yield, Page 235, Note 20
Upper T crate wall Joints	Joint 5c	A 286 0.190-32 NAS1351N3	160	Tension = 855 Shear = 376	0.01	Total tension yield, Page 237, Note 20
Lower Bracket bolt	Joint 6	A-286 0.4375-20 NAS6307	160	Tension = 703 Shear = 1	0.13 yield	Combined axial, bending and shear, Page 242, Note 20
USS/ tracker Radiator rods Interface brackets	Joint 7	A 286 0.250-28 NAS1351N4	160	Tension = 73 Shear = 794	0.32	Combined Tension and shear Page 247, Note 20,
Tracker radiator to rods Interface brackets	Joint 8	A 286 0.190-32 NAS1351N3	160	Tension = 50 Shear = 147	0.54 (yield)	Total tension yield Page 250, Note 20
Tracker radiator panel condenser plate	Joint 9	MS51957, 0.138-32	80	Tension = 12 Shear = 112	0.15	Combined Tension and shear yield, Page 253, Note 20
Tracker radiator rods to brackets	Joint 10	A 286 0.3125-24 NAS6305	160	Tension = 265 Shear = 254	0.35 (yield)	Combined axial, bending and shear Page 257, Note 20
Main to tracker radiator bracket	Joint 11b	A286 0.190-32 NAS1351N3	160	Tension = 58.3 Shear = 43.9	0.53 (yield)	Total tension yield Page 265, Note 20
Fasteners ECAL and RICH HV Bricks						
Item	Drawing Number	Material and temper	Material allowable stress (ksi)	Applied Load (lbf)	Margin of Safety (ult) FS =2.0	Comments
HV Bricks to USS	Joint 1	A 286 0.25-28 NAS1351N4	160	Tension = 245 Shear = 202	0.18	Total tension yield , Note 4
Lateral wall to bracket	Joint 2	A4 70 0.0984 in (2.5 mm)	102	Tension = 8 Shear = 56	0.11	Total tension yield , Note 19
Frame and bracket	Joint 3	A 4 70 0.1181 in (3	102	Tension = 130	0.02	Tension yield , Note 19

		mm)		Shear = 114		
Fasteners TOF HV bricks						
Item	Drawing Number	Material and temper	Material allowable stress (ksi)	Applied Load (lbf)	Margin of Safety (ult) FS =2.0	Comments
TOF HV bricks to Radiators	Joint 1	A 286 0.25-28 NAS1351N4	160	Tension = 152 Shear = 131	0.16	Total tension yield, Note 4
Lateral wall to Frame	Joint 2	A4 70 0.0984 in (2.5 mm)	102	Tension = 26 Shear = 39	0.10	Total tension yield, Note 19
Vertical stand off to cover	Joint 3	A4 70 0.1181 (3 mm)	102	Tension = 109 Shear = 84	0.07	Total tension yield, Note 19
Fasteners AMS-02 E-Crate						
Item	Drawing number	Material and temper	Material allowable stress (ksi)	Applied Load (lbf)	Margin of Safety (ult) FS=2.0	Comments
E-Crates to USS-02	Joint 1	A 286 0.190-32 NAS1351N3	160	Tension = 601 Shear = 124	0.09	Joint separation, Note 25
Lateral walls to bottom plate	Joint 2	A 286 0.190-32 NAS1351N3	160	Tension = 272 Shear = 339	0.13	Total tension yield, Note 25
Lateral walls	Joint 3	A286 0.164-32 NAS1352N08	160	Tension = 196 Shear = 157	0.12	Total tension yield, Note 25
AMS-02 Tracker Thermal Control System (TTCS) Fasteners						
Tracker Thermal Control System Box (TTCB)						
Item	Drawing number	Material and temper	Material allowable stress (ksi)	Applied Load (lbf)	Margin of Safety (ult) FS=2.0	Comments
TRD lower bracket and Base Plate to USS-02 (shared bolts)		A 286 NAS1351N4 0.25-28,	160	Tension = 120 Shear = 137	0.111 (yield)	Total Tension Yield, Ref. 22
Base Plate to USS-02		A-286 NAS1351N4 0.25-28	160	Tension = 38 Shear = 38.5	0.136 (yield)	Total Tension Yield, Ref.22
Side Plate to USS-02		A-286 NAS1351N4 A-286 0.25-28	160	Tension = 15 Shear = 120	0.08 (yield)	Total Tension Yield, Ref.22
Start up radiator to Base Plate		A-286 NAS1351N3 0.190-32	160	Tension = 13 Shear = 74	0.136 (yield)	Total Tension Yield, Ref.22
Cover to Base Plate		NAS1352N08 A-286 0.164-32	160	Tension = 27 Shear =7	0.047 (yield)	Total Tension Yield, Ref.22
Accumulator bracket to		A-286	160	Tension = 41	0.14 (yield)	Total Tension Yield, Ref.22

Base plate		NAS1351N3 0.190-32		Shear = 39		
Pump bracket to startup Radiator		A-286 NAS1352N06 0.138-32	160	Tension = 21 Shear = 80	0.11 (yield)	Total Tension Yield, Ref.22
Cold orbiter heater to Base Plate		A-286 NAS1352N08 0.164-32	160	Tension = 7 Shear = 27	0.079 (yield)	Total Tension Yield, Ref.22
Pump controller to Base Plate		A-286 NAS1351N3 0.190-32	160	Tension = 25 Shear =9.3	0.122 (yield)	Total Tension Yield, Ref.22
APS/DPS to base Plate		A-286 NAS1352N08 0.164-32	160	Tension = 4.4 Shear =13	0.167 (yield)	Total Tension Yield, Ref.22
Heat exchanger Support to base plate		A-286 NAS1351N3 0.190-32	160	Tension = 59.9 Shear =0.0	0.153 (yield)	Total Tension Yield, Ref.22
Heat exchanger clip to Support		MS24694C52 CRES 300	85	Tension = 42.3 Shear =0.0	0.036 (yield)	Total Tension Yield, Ref.22
AMS-02 Tracker Thermal Control System (TTCS) Fasteners						
Accumulator						
Item	Drawing number	Material and temper	Material allowable stress (ksi)	Applied Load (lbf)	Margin of Safety (ult) FS=2.0	Comments
Accumulator clamp to collar		A 286 NAS1351N08 0.164-36	160	Tension = 3.6 Shear = 12	0.12(yield)	Total Tension Yield, Ref. 23
Pipefix to bracket clamp		A-286 NAS1351N06 0.138-40	160	Tension = 1.6 Shear = 2.2	0.124 (yield)	Total Tension Yield, Ref.23
Press to saddle		A-286 NAS1351N08 0.164-36	160	Tension = 41.5 Shear = 193.8	0.107 (yield)	Total Tension Yield, Ref.23
Fasteners UMA Bracket						
Item	Drawing number	Material and temper	Material allowable stress (ksi)	Max. applied Load (lbf)	Margin of Safety (ult) FS=2.0	Comments
UMA Bracket to lower USS bolts		A-286 0.190-32 NAS 1351N3	160	Tension = 746 Shear = 315.5	0.02	Total tension yield page 5.1-23, Note 9
Fasteners PVGF Bracket						
Item	Drawing number	Material and temper	Material allowable stress (ksi)	Max. applied Load (lbf)	Margin of Safety (ult) FS=2.0	Comments

PVGF bracket to PVGF	SDG39135860	EWB0420 0.375-24	200	Tension =1862 Shear = 0	0.033	Combined tension, shear and bending, page .5.11.2-11, Note 9
PVGF bracket to USS-02 upper trunnion beam	SDG39135860	A 286 0.25-28 NAS1351N4	160	Tension = 1023. Shear = 499.5	0.008	Total tension yield, Page 5.11.3-6, Note 9
Fasteners FRGF Bracket						
Item	Drawing number	Material and temper	Material allowable stress (ksi)	Max. applied Load (lbf)	Margin of Safety (ult) FS=2.0	Comments
FRGF bracket to FRGF	SDG39135861	EWB0420 0.375-24	200	Tension = 1364. Shear = 215	0.02	Combined tension, shear and bending, page .5.11.4-10, Note 9
FRGF bracket to USS-02 upper trunnion beam	SDG39135861	A 286 0.25-28 NAS1351N4	160	Tension = 436 Shear = 253	0.02	Total tension yield, Page 5.11.5-6, Note 9
Fasteners ROEU						
Item	Drawing number	Material and temper	Material allowable stress (ksi)	Applied Load (lbf)	Margin of Safety (ult) FS=2.0	Comments
ROEU clevis plate to Sill joint	SEG39137677	A 286 0.25-28 NAS1351N4	160	Tension = 544 Shear = 80.5	0.199	Total tension yield, Sect. 5.11.6.1-13, Note 9
ROEU PDA Bracket Pin	SEG39137678	56789R8-15DL10C6	190	Fb=13.7 ksi	5.79	Pin bending, Sect. 5.11.6.3-19 Note 9
Harness bracket to mounting bracket	SEG39135865	A 286 0.190-32 NAS1351N3	160	Tension = 409 Shear = 125	0.190	Total tension yield, Sect 5.11.6.4-7 Note 9
Fasteners Scuff Plate						
Item	Drawing number	Material and temper	Material allowable stress (ksi)	Applied Load (lbf)	Margin of Safety (ult) FS=2.0	Comments
Scuff Plate to Sill joint	SGG39137813	A 286 0.250-28 NAS1954C5	180	Tension =408 Shear = 994	0.11	Total tension yield, Sect. 5.11.9-6, Note 9
Fasteners Interface Panel A						
Item	Drawing number	Material and temper	Material allowable stress (ksi)	Applied Load (lbf)	Margin of Safety (ult) FS=2.0	Comments
Base Panel and stiffener to USS-02 beam	SEG39137684	A 286 0.25-28 NAS1004	140	Tension = 31 Shear =752	0.15	Total tension yield, page 5.11.11-7 Note 9
Fasteners AMS-02 Vacuum Case components						
Item	Drawing number	Material and	Material	Applied Load (lbf)	Margin of	Comments

		temper	allowable stress (ksi)		Safety (ult) FS=1.4	
Upper Support ring to conical flange	SEG39135776	EWB 0420 0.25-28	200	Tension = 437 Shear =146	0.074	Total tension yield, Sect. 3.10.1-6 Note 9
Lower Support ring to conical flange	SEG39135776	EWB 0420 0.25-28	200	Tension = 367 Shear =52	0.078	Total tension yield, Sect. 3.10.2-6 Note 9
Upper Support ring to outer cylinder	SEG39135776	EWB 0420 0.25-28	200	Tension = 314 Shear =220	0.089	Total tension yield, Sect. 3.10.3-7 Note 9
Lower Support ring to outer cylinder	SEG39135776	EWB 0420 0.25-28	200	Tension = 1322 Shear = 336	0.030	Total tension yield, Sect. 3.10.4.1-7 Note 9
Upper I/F plate to Vacuum case	SEG39135776	NAS1956C A 286 0.375-24	180	Tension = 2542 Shear = 3069	0.103	Total tension yield, Sect. 3.10.6-11 Note 9
Lower I/F plate to vacuum case	SEG39135776	NAS1956C A 286, 0.375-24	180	Tension = 1086 Shear = 743	0.113	Total tension yield, Sect. 3.10.7.1-11, Note 9
Lower I/F plate to vacuum case	SEG39135776	NAS1958C A 286, 0.50-20	180	Tension = 2169 Shear = 1956	0.110	Total tension yield, Sect. 3.10.7.2-11, Note 9
Clevis plate to Upper support ring	SEG39135776	NAS1958C A 286 0.50-20	180	Tension = 6380 Shear = 6387	0.066	Total tension yield, Sect. 3.10.5-8 Note 9
VSB to Vacuum case rings	Joint 6	NAS1351C6 0.375-24	80	tension = 78.7 Shear = 289.5	0.35 (yield)	Total tension yield Note 15, Page 127
VSB to LHP VSB bracket	Joint 7	NAS1352C08 0.164-32	80	tension = 53.2 Shear = 191.9	0.03	Combined tension and shear Note 15, Page 130
VSB supports to LHP VSB standoffs	Joint 8	DIN 912 M%-12 A2-70	101.5	tension = 18.7 Shear = 21.9	0.40(yield)	Total tension yield Note 15, Page 133
VSB to VSB cover	Joint 9	NAS1351C3 0.190-32	80	tension = 2.6 Shear = 143.8	0.50(yield)	Total tension yield Note 15, Page 136
USS-02 and Keel Fasteners						
Item	Drawing number	Material and temper	Material allowable stress (ksi)	Applied Load (lbf)	Margin of Safety (ult) FS=1.4	Comments
Upper I/F plate to USS-02	SDG39135724	NAS1958C A 286 0.50-20	180	Tension = 2063 Shear = 1557	0.067	Total tension yield, Sect. 2.4.1.1-13 Note 9
Lower I/F plate to USS-02	SDG39135726	NAS1958C A 286 0.50-20	180	Tension = 2656 Shear = 2063	0.060	Total tension yield, Sect. 2.4.1.2-12 Note 9
TRD Corner Bracket to Upper VC Joint	SDG39135720	NAS1958C A 286 0.50-20	180	Tension = 2494 Shear = 881	0.083	Total tension yield, Sect. 2.4.1.3-15 Note 9
Sill bracket to Sill joint	SDG39135726	NAS1958C A 286 0.50-20	180	Tension = 2508 Shear = 27	0.063	Total tension yield, Sect 2.4.1.4-12 Note 9
Lower USS to Upper USS bolts	SDG39135724	NAS1958C A 286 0.50-20	180	Tension = 4307 Shear = 1873	0.053	Total tension yield, Sect. 2.4.2.1-12, Note 9
Lower angle beam to	SDG39135758	EWB0420	200	Tension = 7613	0.051	Total tension yield, Sect.2.4.2.2-12

centerbody box joint		0.50-20		Shear = 366		Note 9
Diagonal sill bracket to sill joint	SDG39135726	EWB0420 0.50-20	200	Tension = 9673 Shear = 1518	0.043	Total tension yield, Sect.2.4.1.5-12 Note 9.
Keel angle joint to lower USS	SEG39135724	EWB0420 0.50-20	200	Tension = 674 Shear = 988	0.122	Total thread shear ultimate, Sect. 2.4.3.1-12, Note 9
Keel Retainer to Keel Trunnion	SEG39135768	NAS8103PU8 A 286, 0.190-32	160	Tension = 388 Shear = 0	0.194	Total tension yield, Sect. 2.4.3.2-8, Note 9
Keel retainer to keel block	SEG39135768	HTH 1978-3 0.190-32	200	Tension = 1000 Shear = 0	0.166	Total tension yield, Sect. 2.4.3.2-14, Note 9
PAS Fasteners						
Item	Drawing number	Material and temper	Material allowable stress (ksi)	Applied Load (lbf)	Margin of Safety (ult) FS=2.0	Comments
Handle to Handle extension	SEG39135849	NAS1351N4 A 286 0.25-28	160	Tension = 802.8 Shear = 0.0	0.091	Total tension yield, Sect. 4.12.2-5 Note 9
Handle extension to Handle base	SEG39135849	NAS1351N4 A 286 0.25-28	160	Tension = 0 Shear = 50	0.213	Total tension yield, Sect. 4.12.3-5 Note 9
Handle base to capture bar	SEG39135849	A 286 CRES	140	Tension = 50 Shear = 0	0.090	Total tension yield, Sect 4.12.4-6 Note 9
Guide Pin to Platform	SEG39135816	NAS1351N6 A 286 0.375-24	160	Tension = 2874 Shear =274	0.03	Total tension yield, Sect. 4.12.5.1-15, Note 9
Vertex bracket to Platform	SGG39135873	NAS1956C30 A286 0.375-24	180	Tension = 3424 Shear = 1218.6	0.01	Joint Separation, Sect.4.12.6.1-9, Note 9
Vertex bracket to Platform shear bolt	SGG39135873	NAS1160-6 A286 0.375-24	160	Tension = 600 Shear = 361	0.01	Total tension yield, sect. 4.12.6.2-6 Note 9
Aft Bracket to Platform	SGG39135873	EWB0420 0.375-24	200	Tension = 3630 Shear = 874	0.05	Total tension yield, Sect.4.12.7.1-9 Note 9
Aft Bracket to Platform shear bolts	SGG39135873	NAS1160-6 A286 0.375-24	160	Tension = 314 Shear = 209	0.01	Total tension yield, Sect.4.12.7.2-6, Note 9
Vertex bracket to lower USS	SDG39135817	NAS1956C7 A286 0.375-24	180	Tension = 704 Shear = 419	0.071	Total tension yield, Sect.4.12.9.1-12, Note 9
Aft Bracket to lower USS	SGG39135873	NAS1956C7 A286 0.375-24	180	Tension = 2323 Shear = 1044	0.10	Total tension yield, Sect.4.1210.1-9, Note 9

NOTE:
1) Ref. TRD fastener analysis summary Excel tables, 6/8/2005
2) Ref. Box S May_2004_Rev1_doc, Appendix 2
3) Ref. C_Box _FEM Analysis, Appendix 1, June 10, 2004

4) Ref. AMS-02 Bolt Analysis_ Update_v4(1), Excel tables, 8/14/2005
5) Ref. ASTS_July 2004_Rev1.doc, Appendix 2, INFN Rome
6) Ref. Baffle report April 2005_rev 1.doc, appendix 1, INFN Rome
8) Ref. Report ESCG-4450-05-STAN-DOC-0131, Table 3-15, January 2006
9) Ref. Revised Strength and Stability Assessment of the Alpha Magnetic Spectrometer-02 (AMS-02) Unique Support Structure (USS-02), Vacuum Case, Payload Attach System, STS and ISS Integration Hardware, and X-structure Components, ESCG-4005-05-AMS-0039-A, September 2010
10) <Deleted>
11) Ref. PAS analysis report
12) Ref. Cryomagnet Avionics Box Mechanical Analysis, CAB-AN-CRS-0055, issue 2, 22 Sept.2006
13) Ref. ACC-Clamps, Mathcad analysis, 7/15/2005
14) Ref. PMT-Supp, Mathcad analysis, 7/15/2005
15) Ref. Cryo TCS and Support beams Structural Analysis Report AMSTCS-TN-CGS-011, issue 1, March 31, 2008
16) Ref. Main Radiator Structural analysis Report, AMS-02-RP-CGS-005, issue 4, April 5, 2007
17) Ref. AMS-02 Tracker Bolt analysis Memo, University of Geneva, 1/26/2006
18) Ref. UPS Box Redesign Structure Analysis Report, 28 December, 2005, Mathcad analysis update 16 January 2006, CSIST Taiwan
19) Ref. AMS-02-DC-CGS-001, issue 1, Page 3
20) Main and Tracker Radiators Structural Analysis Report, AMSTCS-TN-CGS-007, issue.1, March 25, 2008
21) PDS FM Structural Analysis, PDS-TN-CGS-010, issue.1, March 25, 2008
21) RICH structural Analysis report, RICSYS-RP-CGS-009, issue 2, November 9, 2005
22) Ref. TTCB Bolts Mathcad Analysis, Rev.04, January 2009
23) Ref. TTCS Accumulator Rev.3.0, Mathcad files, January 2009
24) Ref. RICH Structural Analysis Report, RICSYS-RP-CGS-009, issue2, 11/9//2008, Carlo Gavazzi Space
25) Ref. Report AMS-02 RP-CGS-003, issue 2, 4 August 2005, Carlo Gavazzi Space

Fracture Classification for TRD Structure

Item	Drawing number	Material and temper	Fracture Classification	Rationale	Comments
M structure	1811/60_0002_1_V1	7075-T7351	Low risk	Note 2	Page 31, Note 4
Corner brackets	1811/60_0001_1_V1	7075-T7351	Low risk	Note 2	Page 12, Note 12
Upper bracket right	1811/60_0003_01_V1	7075-T7351	Low risk	Note 2	Page 14, Note 12
Upper bracket left	1811/60_0004_01_V1	7075-T7351	Low risk	Note 2	Page 14, Note 12
Octagon panels	ams1912i-3d-02 ams1912p	Carbon fiber skin Al. 5056 core 1/8 in. cell	Low risk	Note 6	Page 20, Note 12
Octagon panel flanges	ams 02 1912p Detail U,V	Carbon fiber skin Al. 5056 core 1/8 in. cell	Low risk	Note 6	Page 24, Note 4
Upper flange reinforcement ring	ams 02 1996f	T300 EP fabric	Low risk	Note 6	Page 25, Note 4
Upper Cover	ams 02 1942g	Carbon fiber skin Al. 5056 core 3/16 cell	Low risk	Note 6	Page 27, Note 4
Item	Drawing number	Material and temper	Fracture classification	Rationale	Comments
Upper bracket to M structure		A286, 1/4-28	Fail-safe	Note 3	Joint Separation, Note 9, Load case 1008
Corner bracket to M structure		A286, 5/16-24	Fail-safe	Note 3	Total thread shear, Note 9, Load case 4058
Upper brackets to Upper Cover		A286, 1/4-28	Fail-safe	Note 3	Joint Separation, Note 9, Load case 1008
Upper cover to Octagon		A286, 5/16-24	Fail-safe	Note 3	Combined shear and tension, Note 9, Load case 1008
Corner bracket to Upper VC joint	SDG39135720	NAS1958C A286, 1/2-20	Fail-safe	Note 3	Combined tension and shear, Note10, page 2.4.1.3-21

Fracture Classification of TRD Gas System structure

Item	Drawing number	Material and temper	Fracture Classification	Rationale	Comments
Box S plate		7050-T7451	Low risk	Note 2	Page 21, Note 5
Xe tank bracket		6061-T6	Low risk	Note 2	Page 21, Note 5
Lower bracket		7050-T7451	Low risk	Note 2	Page 21, Note 5
Box C base plate		6061-T6	Low risk	Note 2	Page 15, Note 7
Valve bracket		6061-T6	Low risk	Note 2	Page 15, Note 7
Item	Drawing number	Material and temper	Fracture Classification	Rationale	Comments
Box S/Box C plate to USS upper I/F bolts		NAS1954 0.25-28 A-286	Fail-safe	Note 3	Combined tension and shear, Note 8, page 10
Box S Xe bracket to plate bolts		NAS1351N6 0.375-24 A-286	Fail-safe	Note 3	Combined tension and shear, Note 8, page 20
Box C mounting of cylinder to bracket		NAS1351N3 0.190-32 A-286	Fail-safe	Note 3	Combined tension and shear Note 11, Page 6,
Box C mounting of valve bracket to holder		NAS1351N3 0.190-32 A-286	Fail-safe	Note 3	Combined tension and shear Note 11, Page 15

Notes: (TRD Structure and Gas System)

1) The components will be classified as per JSC25863A, August 1998 to comply with NASA-STD-5003, October 1996 and SSP 30558 Rev. B, June 1994.

2) The component will be classified as low risk as per section 5.1.L.1, 5.1.L.2.A and 5.1.L.2.B.3 of JSC 25863A and will be shown that the component possesses acceptable durability (Possesses acceptable resistance to crack growth)
3) The component will be classified as fail-safe as per section 5.1.c of JSC 25863A
4) Ref. Transition Radiation Detector (TRD) Structural Verification Presentation Rev. 3, 11 April 2005
5) Ref. TRD Gas system, Box S mechanical Structure AMS-02, Rev_1 27 June 2005, INFN, Rome and MIT
6) The component will be classified as low risk as per section 5.2 d of JSC25863A
7) Ref. Finite Element Analysis for Box-C of TRD Gas System, MIT@CERN, 11 June 2004
8) Ref. Appendix 2_Box_S May_2004_Rev1_doc,
9) Ref. TRD fasteners summary Excel tables , 6/8/2005
10) Ref. Strength and stability analysis report for USS-02
11) Ref. Appendix1, C_box_FEM analysis, June 10, 2004
12) Ref. Transition Radiation Detector (TRD) Structural Verification Presentation , Rev. 5, 7 March 2007

Fracture Classification of AMS-02 Upper Time of Flight (UTOF)

Item	Drawing number	Material and temper	Fracture Classification	Rationale	Comments
Upper brackets	ams TOF 08-01-006 UT	7075-T7351	Low risk	Note 2	Page 57, Note 4
Lower brackets	ams TOF 08-01-001 UT	7075-T7351	Low risk	Note 2	Page 57, Note 4
Extensions	ams TOF 08-01-008 UT	7075-T7351	Low risk	Note 2	Page 57, Note 4
Honeycomb skins	ams TOF 08-02-002 UT	2024-T81	Low risk	Note 2	Page 57, Note 4
Secondary Brackets	ams TOF 02-01-005 UT	7075-T7351	Low risk	Note 2	Page 57, Note 4
Sensor Boxes	ams TOF 09-001 UT	CFRP T300 fabric	Low risk	Note 5	Page 58, Note 4, Margin of safety, Note 6
Scintillator supports		CFRP T 300 fabric	Low risk	Note 5	Page 58, Note 4, Margin of safety, Note 6
PMT Box Supports	ams TOF 05-05-001 UT	CFRP T 300 fabric	Low risk	Note 5	Page 58, Note 4, Margin of safety, Note 6
Item	Drawing number	Material and temper	Fracture Classification	Rationale	Comments
UTOF/TRD I/F bolts	Joint 1	EWB0420-5 0.3125-24	Fail-safe	Note 3	Total thread shear Note 7
Bracket to Ext. bolts	Joint 3	NAS1351N4 A-286 0.25-28	Fail-safe	Note 3	Combined tension and shear, Note 7
Upper to lower bracket bolts	Joint 4	NAS1351N4 A-286 0.25-28	Fail-safe	Note 3	Combined tension and shear, Note 7

Notes:
1) The components will be classified as per JSC 25863 A, August 1998 to comply with NASA-STD-5003, October 1996 and SSP 30558 Rev. B, June 1994
2) The component will be classified as low risk as per section 5.1.L.1, 5.1.L.2.A and 5.1.L 2.B.3 of JSC 25863 A and will be shown that the component possesses acceptable durability (Possesses acceptable resistance to crack growth)
3) The component will be classified as fail-safe as per section 5.1 c of JSC 25863 A
4) Ref. Upper Time of Flight Structural Analysis Report, RICSYS-CGS-013, issue 1 , 29 June 2004
5) The component will be classified as low risk per section 5.2 d of JSC 25863 A
6) Tsai_Hill equation shown in note 4 , page 38. Margin of safety is (1/Failure Index)-1
7) Ref. AMS-02 Bolt Analysis_Update_v4.(1), 8/4/2005

Fracture Classification of AMS-02 Lower Time of Flight (LTOF)

Item	Drawing number	Material and temper	Fracture Classification	Rationale	Comments
Beam A	ams TOF 04-01-001 LT	7075-T7351	Low risk	Note 2	Page 76, Note 4
Beam B	ams TOF 04-01-002 LT	7075-T7351	Low risk	Note 2	Page 76, Note 4
Corner beam	ams TOF 04-01-003 LT	7075-T7351	Low risk	Note 2	Page 76, Note 4
Upper bracket	ams TOF 04-01-021 LT	7075-T7351	Low risk	Note 2	Page 76, Note 4
Lower bracket	ams TOF 04-01-020 LT	7075-T7351	Low risk	Note 2	Page 76, Note 4
Internal bracket	ams TOF 04-01-018 LT	7075-T7351	Low risk	Note 2	Page 76, Note 4
Struts	ams TOF 04-01-01-001 LT	7075-T7351	Low risk	Note 2	Page 76, Note 4
Sensor Boxes Bracket	ams TOF 04-01-008 LT	7075-T7351	Low risk	Note 2	Page 76, Note 4
Sensor Boxes	ams TOF 02-001 LT	CFRP T300 Fabric	Low risk	Note 6	Page 77, Note 4 Margin of safety Note 5
Boxes/PMT Support	ams TOF 05-05-001 LT	CFRP T300 Fabric	Low risk	Note 6	Page 77, Note 4, Margin of safety Note 5
Scintillator supports		CFRP T300 Fabric	Low risk	Note 6	Page 77, Note 4, Margin of safety, Note 5

Item	Drawing number	Material and temper	Fracture Classification	Rationale	Comments
Item	Drawing number	Material and temper	Fracture Classification	Rationale	Comments
Bracket to ring bolts	Joint 1	NAS1351N5 A-286 0.3125-24	Fail-safe	Note 3	Combined tension and shear, Note7
USS to Upper bracket bolts	Joint 2	NAS1351N6 A-286 0.375-24	Fail-safe	Note 3	Total thread shear ultimate, Note 7
USS to L bracket bolts	Joint 3	NAS1351N3 A-286 0.190-32	Fail-safe	Note 3	Total thread shear ultimate, Note 7
Ring to Honeycomb bolts	Joint 4	NAS1351N4 A-286 0.25-28	Fail-safe	Note 3	Total thread shear ultimate, Note 7

Notes:
1) The components will be classified as per JSC 25863A, August 1998 to comply with NASA-STD-5003, October 1996 and SSP 30558 Rev. B, June 1994
2) The component will be classified as fail-safe as per section 5.1.L.1, 5.1.L.2.A and 5.1.L.2.B.3 of JSC 25863 A and will be shown that the component possesses acceptable durability (possesses acceptable resistance to crack growth)
3) The component will be classified as fail-safe as per section 5.1 c of JSC 25863 A
4) Ref. Lower Time of Flight (LTOF) Structural Analysis Report, RICSYS-RP-CGS-012 issue 1, 29 June 2004
5) Tsai-Hill equation shown in report note 4, page 44. Margin of safety is (1/ Failure index)-1
6) The component will be classified as low risk as per sect. 5.2 d of JSC 25863A.
7) Ref. AMS-02 Bolt Analysis_Update_v4.(1), 8/4/2005

Fracture Classification of AMS-02 Ring Imaging Chernekov Counter (RICH)

Item	Drawing number	Material and temper	Fracture Classification	Rationale	Comments
Primary beam		7075-T7351	Low risk	Note 2	Page 47, Note 4
Secondary Internal beam		7075-T7351	Low risk	Note 2	Page 47, Note 4
Structural members	12-RICSYS- 10-001	7075-T7351	Low risk	Note 2	Page 47, Note 4
Structural members	12-RICSYS- 20-002	6061-T6	Low risk	Note 2	Page 47, Note 4
Reflector Support	12-RICSYS- 40-001	7075-T7351	Low risk	Note 2	Page 47, Note 4
Reflector	13-RICSYS- 00-008	CFRP BRYTE EX-1515	Low risk	Note 5	Page 48, Note 4, Margin of safety, Note 6
Item	Drawing number	Material and temper	Fracture Classification	Rationale	Comments
External Structure bolts		NAS1351N4 A-286, 0.25-28	Fail-safe	Note 3	Combined tension and shear, Note 7
External to Internal structure bolts		A4-70 0.118-44 (3 mm)	Fail-safe	Note 3	Combined tension and shear, Note 7
External Structure bolts		NAS1351N5 A-286 0.3125-24	Fail-safe	Note 3	Combined tension and shear, Note 7

Notes:

1) The components will be classified as per JSC25863A, August 1998 to comply with NASA-STD-5003, October 1996 and SSP 30558 Rev. B, June 1994

2) The component will be classified as low risk as per section 5.1.L.1, 5.1.L.2.A and 5.1.L.2.B.3 of JSC 25863A and will be shown that the component possesses acceptable durability (Possesses acceptable resistance to crack growth)

3) The component will be classified as fail-safe as per section 5.1.c of JSC 25863A

4) Ref. RICH Structural Analysis report, RICSYS-RP-CGS-009, issue 1, 29 June 2004

5) The Component will be classified as low risk as per section 5.2 d of JSC 25863 A

6) Tsai-Hill equation shown in report (note 4) page 44. Margin of safety = (1/ Failure index)-1

7) Ref. AMS-02 Bolt Analysis_Update_v4.(1), 8/4/2005

Fracture Classification of AMS-02 Electro Magnetic Calorimeter (ECAL)

Item	Drawing number	Material and temper	Fracture Classification	Rationale	Comments
Honeycomb Face plate	ECAL0-10-Je	2024-T4 (2A12-T4)	Low risk	Note 2	Page 27, Note 4
Honeycomb I frame	ECAL0-11-Je	2014-T6 (2A14-T6)	Low risk	Note 2	Page 27, Note 4
Side panels	ECAL0-20-Je ECAL0-30-Je	2014-T6 (2A14-T6)	Low risk	Note 2	Page 27, Note 4
Bracket	ECAL0-41-Je	7050-T7451	Low risk	Note 2	Page 27, Note 4
Support beam	ECAL0-42-Je	7050-T7451	Low risk	Note 2	Page 27, Note 4
Item	Drawing number	Material and temper	Fracture Classification	Rationale	Comments
Support beam to bracket (Joint 1)	ECAL0-0E	A-286 0.3125-24 NAS 6705U7, 8	Fail-safe	Note 3	Total thread shear, Note 5
Bracket to side panels (joint 2)	ECAL0-0E	A-286 0.25-28 NAS 1954C6	Fail-safe	Note 3	Total Thread shear, Note 5
I Frame to bracket bolts (joint 3)	ECAL0-0E	A-286 0.3125-24, NAS 6705HU10	Fail-safe	Note 6	Fail-safe by Engineering Judgment
I Frame to honeycomb reinforcing and side panels 1 and 2 bolts (joint4)	ECAL0-0E	A-286 0.0.25-28 NAS1004-2	Fail-safe	Note 6	Fail-safe by Engineering Judgment
I Frame to side panel 1 bolts(Joint 5)	ECAL0-0E	A-286 0.25-28 NAS1004-9	Fail-safe	Note 6	Fail-safe by Engineering Judgment
I-Frame to side panels 1 and 2 (joint 6)	ECAL0-0E	A-286 0.3125-24 NAS1005-1,-2	Fail-safe	Note 6	Fail-safe by Engineering Judgment
I-Frame to honeycomb reinforcing and side panels 1 and 2 (Joint 7)	ECAL0-0E	A-286 0.3125-24 NAS1005-1	Fail-safe	Note 6	Fail-safe by Engineering Judgment
Support to USS (Joint 8)	ECAL0-0E	NAS1960C30 A-286 0.625-18	Fail-safe	Note 3	Combined tension and shear, Note 5

Notes:

1) The components will be classified as per JSC25863A, August 1998 to comply with NASA-STD-5003, October 1996 and SSP 30558 Rev. B, June 1994.

2) The component will be classified as low risk as per section 5.1.L.1, 5.1.L.2.A and 5.1.L.2.B.3 of JSC 25863A and will be shown that the component possesses acceptable durability (Possesses acceptable resistance to crack growth)

3) The component will be classified as fail-safe as per section 5.1.c of JSC 25863A

4) Flight ECAL Stress Analysis after weight savings, April 7, 2004

5) Ref. ECAL bolt analysis report ESCG-4450-05-STAN-DOC-0131, February 2006

6) The components will be classified as fail-safe by Engineering Judgment as per section 5.1.c of JSC25863A

Fracture Classification of the AMICA Star Tracker

Item	Drg. No.	Materials and temper	Fracture Classification	Rationale	Comments
Upper bracket		CFRP M55J ACGLTM110	Low risk	Note 4	Page 13, Note 5 Margin of Safety , Note 9
Lower bracket		CFRP M55J ACGLTM110	Low risk	Note 4	Page 13, Note 5, Margin of Safety , Note 9
Baffle to M structure bracket		7075-T7351	Low risk	Note 2	Page 11, Note 6
Item	**Drawing number**	**Material and temper**	**Fracture Classification**	**Rationale**	**Comments**
Upper bracket to tracker plane 1 bolts		A286, 0.3937 (M10)	Fail-safe	Note 3	Total Thread shear, Note 7, page VI
Upper bracket to lower bracket bolts		NAS1351N3 A286, 0.190-32	Fail- safe	Note 3	Total Thread shear, Note 7, page X
Lower bracket to tracker conical flange		A286, 0.118 (M3)	Fail- safe	Note 3	Combined tension and shear , Note 7, page XIII
Baffle bracket baffle side to baffle bolts		NAS1351N3 A286, 0.190-32	Fail-safe	Note 3	Combined tension and shear, Note 8, page 14

Notes:
1) The components will classified as per JSC 25863A, August 1998 to comply with NASA-STD-5003, October 1996 and SSP30558 Rev.B, June 1994
2) The components will be classified as low risk as per sect. 5.1.L.1, 5.1.L.2.A and 5.1.L.2.B.3 of JSC 25863A and will be shown that the component possesses acceptable durability (Possesses acceptable resistance to crack growth)
3) The component will be classified as fail-safe as per sect 5.1.c of JSC 25863A
4) The components will be classified as low risk as per section 5.2 d of JSC 25863A
5) Ref. AMS-02 AMICA Star Tracker Support Design, Rev 1 INFN Rome, 27 June 2005
6) Ref. Baffle Support design, INFN Rome, Rev.1 27 June 2005
7) Ref. ASTS_July2004_Rev1.doc, Appendix 2_ASTS.doc
8) Ref. Baffle_April2005_Rev1.doc, Appendix1_Baffle.doc
9) Tsai-Hill equation shown in report note 5, page 12. Margin of safety = (1/Fsult*Failure index)-1

Fracture Classification of AMS-02 Silicon Tracker

Item	Drawing number	Material and temper	Fracture Classification	Rationale	Comments
Sandwich facing	AMS II 154 A0 AMS II 155 A0	Carbon fiber M60 J Cyanate Ester	Low risk	Note 4	Page 22 ,,Note 5
Sandwich core	AMS II 154 A0 AMS II 155 A0	Hexcel Honeycomb 3/16 in. Al. 5056	Low risk	Note 4	Page 22, Note 5
Sandwich core		Hexcel Honeycomb 3/8 in Al. 5056	Low risk	Note 4	Page 27, Note 5
Sandwich facing		Carbon fiber M60 J Cyanate Ester	Low risk	Note 4	Page 27, Note 5
Insert ring core		Hexcel Honeycomb 3/16 in. Al. 5056	Low risk	Note 4	Page 27, Note 5
Tracker feet		Ti-6Al-4V	Fail-safe	Note 3	Page 5, Note 6
Item	Drawing number	Material and temper	Fracture Classification	Rationale	Comments
Tracker feet to magnet (Joint1)		A4-70, 0.3125-24 UNF	Fail-safe	Note 3	Joint separation, Note 7
Tracker feet to Tracker shell (Joint2)		A-286 10-32 UNF	Fail-safe	Note 3	Combined shear and tension, Note 7 Negative M.S. on joint separation acceptable for fail-safe
Conical Flange to tracker shell (Joint3)		A-286, M4x33	Fail-safe	Note 8	Fail-safe by Engineering Judgment
Tracker shell to tracker shell (Joint 4)		A4-70, 0.138-32 UNF	Fail-safe	Note 8	Fail-safe by Engineering Judgment
Inner plane to tracker shell (Joint 5)		A4-70, M4x12	Fail-safe	Note 8	Fail-safe by Engineering Judgment
Outer plane to conical flange (Joint 6)		A4-70, M4x40	Fail-safe	Note 8	Fail-safe by Engineering Judgment
Outer plane to conical flange (Joint 7)		A4-70, M4x40	Fail-safe	Note 8	Fail-safe by Engineering Judgment

Notes:

1) The components will be classified as per JSC25863A, August 1998 to comply with NASA-STD-5003, October 1996 and SSP 30558 Rev. B, June 1994.

2) The component will be classified as low risk as per section 5.1.L.1, 5.1.L.2.A and 5.1.L.2.B.3 of JSC 25863A and will be shown that the component possesses acceptable durability (Possesses acceptable resistance to crack growth)

3) The component will be classified as fail-safe as per section 5.1.c of JSC 25863A

4) The component will be classified as low risk as per section 5.2d of JSC 25863A

5) Ref. AMS Silicon Tracker Support Plates Analysis Report Extension AMS-ANR-002, Contraves Space, 19 November 1999.

6) Ref. AMS 02 Tracker Support Feet , Rev. 1 Structural Verification Document, ISATEC, 16 June 2004

7) AMS Tracker bolt analysis compliance with NSTS 08307 standards, University of Geneva Memo, 26 January, 2006

8) There are multiple fasteners in this joint and the fasteners are classified as fail-safe by Engineering Judgment as per 5.1.c of JSC 25863A

Fracture Classification of Anti Coincidence Counter (ACC)

Item	Drawing Number	Material and temper	Fracture Classification	Rationale	Comments
ACC Clamps	ams-02-03 1024	7075-T7351	Low risk	Note 2	Page 13, Note 4
ACC cylinder	ams-02 1626	CFRP Tenax J UMS2526	Contained	Note 5	
ACC panels	ams-02 1771c	Bicron BC 414 Polyvinyl Toluene	Contained	Note 5	
Connector support	1812/60- 0004_I_VI	7075-T7351	Low risk	Note 2	Page 17, Note 8
ACC PMT Support	1812/60- 001_I_VI	7075-T7351	Low risk	Note 2	Note 4
Item	Drawing Number	Material and temper	Fracture Classification	Rationale	Comments
ACC clamps to VC flange bolts		A-286 0.190-32	Fail-safe	Note 3	Joint separation, Note 6
PMT support to Vacuum case		A-286 0.190-32	Fail-safe	Note 3	Combined tension and shear, note 7

Notes:

1) The components will be classified as per JSC25863A, August 1998 to comply with NASA-STD-5003, October 1996 and SSP 30558 Rev. B, June 1994

2) The component will be classified as low risk as per section 5.1.L.1, 5.1.L.2.A and 5.1.L.2.B.3 of JSC25863A, and will be shown that the component possesses acceptable durability (Possesses acceptable resistance to crack growth)

3) The component will be classified as fail-safe as per section 5.1.c of JSC 25863A

4) Ref. AMS-02 Anti Coincidence Counter Structural Verification Document, Rev. 1, ISATEC, 9 December 2004

5) The component is classified as contained as per sect. 5.1 g of JSC 25863A

6) ACC- clamps Mathcad analysis 7/15/2005

7) PMT-Support Mathcad analysis 7/15/2005

8) Ref. ACC Connector Support, Documentation of Margin of Safety, 8 March 2007

Fracture Classification for Main and Tracker Radiator

Item	Drawing Number	Material and temper	Fracture Classification	Rationale	Comments
Main radiator panel heat pipes	21-AMS-000.00.XY &22-AMS-000.00.XY	6063-T5	Low risk	Note 2	Pages 189 – 191, Note 4.
Tracker radiator panel heat pipes	25-AMS-000.00.XY	6063-T5	Low risk	Note 2	Pages 192-195, Note 4
Main/Tracker radiator bracket	24-AMS-330.08 .XY	7075-T73	Low risk	Note 2	Page 198, Note 4
Tracker radiator rod 4		Carbon fiber	Low risk	Note 2	Pages 188 & 197 Note 4
Main Radiator Skin	21_AMS-000.00.XY, 22-AMS-000.00.XY	2024-T81	Low risk	Note 2	Page 196, Note 4
Tracker radiator skin	25-AMS-000.00 .01, 25-AMS-000.00.02	2024-T81	Low risk	Note 2	Page 197, Note 4
Item	Drawing Number	Material and temper	Fracture Classification	Rationale	Comments
USS to Tracker Radiator I/F brackets	Joint 7	A 286 0.250-28 NAS1351 N4	fail-safe	Note 3	Page 337, Note 4
Tracker radiator panel to I/F brackets	Joint 8	A 286 0.190-32 NAS1351N3	fail-safe	Note 3	Page 338, note 4
Tracker radiator panel to condenser plate	Joint 9	MS51957 0.138-32	fail-safe	Note 3	Page 339, Note 4
Main to tracker radiator bracket	Joint 11a	A 286 0.190-32 NAS1351N3	fail- safe	Note 3	Page 340, Note 4

Notes:
1) The components will be classified as per JSC25863A, August 1998 to comply with NASA-STD-5003, October 1996 and SSP 30558 Rev. B, June 1994
2) The component will be classified as low risk as per section 5.1.L.1, 5.1.L.2.A and 5.1.L.2.B.3 of JSC25863A, and will be shown that the component possesses acceptable durability(Possesses acceptable resistance to crack growth)
3) The component will be classified as fail-safe as per section 5.1.c of JSC 25863A
4) Ref. Main Radiators Structural Analysis Report AMS-02-RP-CGS-005, issue 4, April 5, 2007

Fracture Classification for Electronic Crates and Radiator Brackets

Item	Drawing Number	Material and temper	Fracture Classification	Rationale	Comments
XPD structure	24- AMS- 120.AB.XY	7075-T7351	Low risk	Note 2	Page 198, Note 4
Crate structure	24- AMS- 110.AB.XY	7075-T7351	Low risk	Note 2	Page 198, Note 4
XPD board stiffeners	24- AMS- 121.03.XY	6061-T651	Low risk	Note 2	Page 173, Note 4
Links	24- AMS- 130.01.XY	7075-T7351	Low risk	Note 2	Page 198, Note 4
Top bracket plate	24- AMS- 310.02.XY	7075-T7352	Low risk	Note 2	Page 196, Note 4
Mid bracket bar	24- AMS- 320.02.XY	7075-T7351	Low risk	Note 2	Page 196, Note 4
Lower bracket plate	24- AMS- 330-AB.XY	7075-T7351	Low risk	Note 2	Page 196, Note 4
Item	Drawing Number	Material and temper	Fracture Classification	Rationale	Comments
USS to mid Bracket	Joint 1b	NAS1351N4 A 286 0.25-28	fail-safe	Note 3	Joint Separation, Page 325, Note 4
Brackets to Electronic	Joint 2a	EWB-0420-3	fail-safe	Note 3	Combined tension and shear, Page 327,

boxes/upper		A 286 0.190-32			Note 4
Main radiator/ Electronic boxes Joints	Joint 3b	NAS1351N4 A 286 0.250-28	fail-safe	Note 3	Combined tension and shear, Page 330, Note 4
Links to electronic boxes	Joint 4	NAS1351N3 A 286 0.190-32	fail- safe	Note 3	Joint Separation, Page 333, Note 4
Crates/XPD wall joints	Joint 5a	NAS1351N08 A 286 0.164-32	fail-safe	Note 3	Combined tension and shear, page 334, Note 4
TPD wall joints crate	Joint 5b	NAS1351N08 A 286 0.164-32	fail-safe	Note 3	Combined tension and shear, Page 335, Note 4
Upper T Crate wall joints	Joint 5c	A 286 0.190-32 NAS1351N3	fail-safe	Note 3	Joint Separation, Page 336, Note 4

Notes:

1) The components will be classified as per JSC25863A, August 1998 to comply with NASA-STD-5003, October 1996 and SSP 30558 Rev. B, June 1994

2) The component will be classified as low risk as per section 5.1.L.1, 5.1.L.2.A and 5.1.L.2.B.3 of JSC25863A, and will be shown that the component possesses acceptable durability(Possesses acceptable resistance to crack growth)

3) The component will be classified as fail-safe as per section 5.1.c of JSC 25863A

4) Ref. Main Radiators Structural Analysis Report AMS-02-RP-CGS-005, issue 4, April 5, 2007

Fracture Classification for High Voltage (HV) Bricks

Item	Drawing Number	Material and temper	Fracture Classification	Rationale	Comments
Bracket		7075-T7351	Low risk	Note 2	Page 125, Note 4
Frame		7075-T7351	Low risk	Note 2	Page 125, Note 4
Cover		6061-T62	Low risk	Note 2	Page 125, Note 4
Lateral walls		7075-T7351	Low risk	Note 2	Page 125, Note 4
Frame		7075-T7351	Low risk	Note 2	Page 126, Note 4
Cover		6061-T62	Low risk	Note 2	Page126, Note 4
Vertical Stand off		7075-T7351	Low risk	Note 2	Page 126, Note 4
Item	Drawing Number	Material and temper	Fracture Classification	Rationale	Comments
HV Bricks to USS	Joint 1	A 286 0.25-28	fail-safe	Note 3	Combined tension and shear, Note 5
Lateral wall to bracket	Joint 2	A4 70 0.0984 in (2.5 mm)	fail-safe	Note 3	Combined tension and shear, Note 6
Frame and bracket	Joint 3	A 4 70 0.1181 in (3 mm)	fail-safe	Note 3	Combined tension and shear, Note 6
TOF HV bricks to Radiators	Joint 1	A 286 0.25-28	fail- safe	Note 3	Total thread shear ultimate, Note 5
Lateral wall to Frame	Joint 2	A4 70 0.0984 in (2.5 mm)	fail-safe	Note 3	Combined tension and shear, Note 6
Vertical stand off to cover	Joint 3	A4 70 0.1181 (3 mm)	fail-safe	Note 3	Combined tension and shear, Note 6

Notes:

1) The components will be classified as per JSC25863A, August 1998 to comply with NASA-STD-5003, October 1996 and SSP 30558 Rev. B, June 1994

2) The component will be classified as low risk as per section 5.1.L.1, 5.1.L.2.A and 5.1.L.2.B.3 of JSC25863A, and will be shown that the component possesses acceptable durability(Possesses acceptable resistance to crack growth)

3) The component will be classified as fail-safe as per section 5.1.c of JSC 25863A

4) Ref. HV Bricks Structural analysis Report, AMS-02-RP-CGS-007, issue 1, November. 22, 2004

5) Ref. AMS-02 Bolt Analysis_Update_v4.(1), 8/4/2005

6) Ref. AMS-02-DC-CGS-001, issue 1, 8 September 2005

Fracture Classification of Vacuum Case Components

Item	Drawing number	Material and temper	Fracture Classification	Rationale	Comments
Outer Cylinder	SDG39135779	7050-T7452 Forging	Low risk	Note 2	Sect 3.2.1-14, Note 4
Conical Flanges	SDG39135778	2219-T62 Plate	Low risk	Note 2	Sect.3.3.1-14, Note 4
Upper Support rings	SDG39135784	7050-T7452 Forging	Low risk	Note 2	Sect. 3.4-9, Note 4
Lower Support Rings	SEG39135785	7050-T7452 Forging	Low risk	Note 2	Sect. 3.5-10, Note 4
Upper Interface plate Assy	SDG39135788	7050-T7451 plate	Low risk	Note 2	Sect. 3.6-5, Note 4
Lower Interface plate assy	SDG39135789	7050-T7451 plate	Low risk	Note 2	Sect. 3.7-5, Note 4
Item	**Drawing Number**	**Material and temper**	**Fracture Classification**	**Rationale**	**Comments**
Upper I/F plate to Vacuum case	SEG39135776	NAS1956C A 286 0.375-24	Fail-safe	Note 3	Joint separation, sect. 3.10.6-19 Note 4
Lower Support ring to conical flange	SEG39135776	EWB 0.25-28	Fail-safe	Note 3	Combined tension and shear ult, sect. 3.10.2-8 Note 4
Upper Support ring to conical flange	SEG39135776	EWB 0.25-28	Fail-safe	Note 3	Combined tension and shear ult, sect. 3.10.1-8 Note 4
Lower Support ring to outer cylinder	SEG39135776	EWB 0.25-28	Fail-safe	Note 3	Combined tension and shear ult, sect. 3.10.4 1-9Note 4
Upper Support ring to outer cylinder	SEG39135776	EWB 0.25-28	Fail-safe	Note 3	Combined tension and shear ult, sect. 3.10.3-9 ,Note 4
Lower I/F plate to vacuum case	SEG39135776	NAS1958C A 286 ,0.50-20	Fail-safe	Note 3	Total thread shear ult, sect.3.10.7.2-19, Note 4
Lower I/F plate to vacuum case	SEG39135776	NAS1956C A 286 ,0.375-24	Fail-safe	Note 3	Combined tension and shear ultimate, sect.3.10.7.1-19, Note 4
Clevis plate to upper support ring	SEG39135776	A 286 0.50-20	Fail-safe	Note 3	Combined tension and shear ultimate, sect 3.10.5-9, Note 4

Notes:

1) The components will be classified as per JSC25863A, August 1998 to comply with NASA-STD-5003, October 1996 and SSP 30558 Rev. B, June 1994.

2) The component will be classified as low risk as per section 5.1.L.1, 5.1.L.2.A and 5.1.L.2.B.3 of JSC 25863 A and will be shown that the component possesses acceptable durability (Possesses acceptable resistance to crack growth)

3) The component will be classified as fail-safe as per section 5.1.c of JSC 25863A

4) Ref.AMS-02 Strength and stability for Vacuum Case analysis report

5) The component is classified as fracture critical as per sect. 5.2 and will be shown acceptable by compliance with sect. 6.0 of JSC 25863 A

Fracture Classification of USS Components

Item	Drawing number	Material and temper	Fracture Classification	Rationale	Comments
Sill Trunnion	SDG39135732	Custom 455 H1000	Fracture critical	Note 2	Sect. 2.1.5-42, Note 5
Keel Trunnion	SDG39135772	Custom 455 H1000	Fracture critical	Note 2	Sect. 2.3.4-12 Note 5
Upper VC Joint	SDG39135727	7050-T7451 Plate	Low risk	Note 3	Sect. 2.1.1-10 Note 5
Lower VC Joint	SDG39135737	7050-T7451 Plate	Low risk	Note 3	Sect. 2.1.9-13, Note 5
Sill joint primary secondary	SDG39135730	7050-T7451 Plate	Low risk	Note 3	Sect. 2.1.3-10, Note 5
Diagonal strut end fitting	SEG39135743	7075-T73511	Low risk	Note 3	Sect. 2.1.13.2-5,Note 5
Lower center body box joint	SDG39135759 SDG39135760	7050-T7451 Plate	Low risk	Note 3	Sect. 2.2.1-14, Note 5
Sill elbow joint	SDG39135734	7050-T7451 Plate	Low risk	Note 3	Sect. 2.1.7-22, Note 5
Keel block	SEG39135770	7050-T7451 Plate	Fracture critical	Note 2	Sect. 2.3.2-13, Note 5
Diagonal sill bracket	SEG39135740	7050-T7451 Plate	Fracture critical	Note 2	Sect. 2.1.12-2, Note 5
Sill bracket	SEG39135738	7050-T7451 Plate	Low risk	Note 3	Sect. 2.1.10-8, Note 5
Lower USS to Upper USS joint	SDG39135762	7050-T7451 Plate	Low risk	Note 3	Sect. 2.2.4-16, Note 5
Item	**Drawing Number**	**Material and temper**	**Fracture Classification**	**Rationale**	**Comments**
Upper I/F plate to USS-02	SDG39135726	NAS1958C A 286 0.50-20	Fail-safe	Note 4	Combined tension and shear ultimate, sect. 2.4.1.1-19, Note 5
Lower I/F plate to USS-02	SEG39135726	NAS1958C A 286 0.50-20	Fail-safe	Note 4	Combined tension and shear ultimate, Sect.2.4.1.2-19, Note 5
Sill bracket to sill joint	SEG39135726	NAS1958C A 286 0.50-20	Fail-safe	Note 4	Combined tension and shear ultimate, Sect.2.4.1.4-17, Note 5
Lower USS to Upper USS bolts	SEG39135724	NAS1958C A 286 0.50-20	Fail-safe	Note 4	Joint separation, Sect.2.4.2.1-19,Note 5
Lower angle beam to centerbody box joint	SEG39135758	EWB0420 0.50-20	Fail-safe	Note 4	Total thread shear ultimate, Sect.2.4.2.2-17, Note 5
Diagonal sill bracket to sill joint	SEG39135726	EWB0420 0.50-20	Fail-safe	Note 4	Combined tension and shear ultimate, sect. 2.4.1.5-18. Negative M.S. on joint separation is acceptable for fail-safe cases
Keel angle joint to lower USS-02 assy bolts	SEG39135724	EWB0420 0.50-20	Fail-safe	Note 4	Total thread shear ultimate, Sect. 2.4.3.1-17, Note 5
Keel retainer to keel trunnion and keel block	SEG39135768	NAS8103, 0.190-32	Fail-safe	Note 4	Total tension ult., Sect. 2.4.3.2-8, Note 5
Vertex bracket to PAS platform	SEG39135812	A 286 0.375-24	Fail-safe	Note 4	Combined tension and shear ultimate, Note 5
Rear bracket to PAS platform	SEG39135812	EWB 0420	Fail-safe	Note 4	Combined tension and shear ultimate,

		0.375-24			Note 5

Notes:
1) The components will be classified as per JSC25863A, August 1998 to comply with NASA-STD-5003, October 1996 and SSP 30558 Rev. B, June 1994.
2) The component will be classified as fracture critical as per sect 5.2 and will be shown acceptable by compliance with sect. 6.0 of JSC25863A
3) The component will be classified as low risk as per section 5.1.L.1, 5.1.L.2.A and 5.1.L.2.B.3 of JSC 25863A and will be shown that the component possesses acceptable durability (Possesses acceptable resistance to crack growth)
4) The component will be classified as fail-safe as per section 5.1.c of JSC 25863 A
5) Ref. AMS-02, Strength and Stability for USS-02 Stress analysis Report

Fracture Classification of AMS-02 PAS

Item	Drawing number	Material and temper	Fracture Classification	Rationale	Comments
PAS platform	SDG39135817	7050 T7451 plate	Low risk	Note 2	Sect. 4.3-6, Note 5
Capture bar	SDG39135849	A 286 bar	Low risk	Note 2	Sect. 4.11.1-7 Note 5
Bridge beam	SDG39135838	7050-T7451 Plate	Low risk	Note 2	Sect.4.6-9 Note 5
Bearing housing	SDG39135845	15-5PH H1025	Low risk	Note 2	Sect. 4.10-8

Notes:
1) The components will be classified as per JSC25863A, August 1998 to comply with NASA-STD-5003, October 1996 and SSP 30558 Rev. B, June 1994.
2) The component will be classified as fracture critical as per sect 5.2 and will be shown acceptable by compliance with sect. 6.0 of JSC25863A
3) The component will be classified as low risk as per section 5.1.L.1, 5.1.L.2.A and 5.1.L.2.B.3 of JSC 25863A and will be shown that the component possesses acceptable durability (Possesses acceptable resistance to crack growth)
4) The component will be classified as fail-safe as per section 5.1.c of JSC 25863 A
5) Ref. AMS-02, Strength and Stability for USS-02 Stress analysis Report
6) Ref. AMS-02 PAS analysis report

Fracture Classification of AMS-02 E-Crates

Item	Drawing number	Material and temper	Fracture Classification	Rationale	Comments
Bottom plate		7075-T7351	Low risk	Note 2	Page 50, Note 5
Lateral wall		7075-T7351	Low risk	Note 2	Page 50, Note 5
Item	Drawing Number	Material and temper	Fracture Classification	Rationale	Comments
E-Crates to USS-02	Joint 1	A 286 0.190-32 NAS1351N3	Fail-safe	Note 3	Total thread shear ultimate, Note 4
Lateral walls to bottom plate	Joint 2	A 286 0.190-32 NAS1351N3	Fail-safe	Note 3	Combined tension and shear, Note 4
Side wall bolts	Joint 3	A 286 0.164-32 NAS1351N08	Fail-safe	Note 3	Combined tension and shear, Note 4

Notes:
1) The components will be classified as per JSC25863A, August 1998 to comply with NASA-STD-5003, October 1996 and SSP 30558 Rev. B, June 1994.
2) The component will be classified as low risk as per section 5.1.L.1, 5.1.L.2.A and 5.1.L.2.B.3 of JSC 25863 A and will be shown that the component possesses acceptable durability (Possesses acceptable resistance to crack growth)
3) The component will be classified as fail-safe as per section 5.1.c of JSC 25863A
4) Ref. AMS-02 Bolt Analysis_Update_v4.(1), 8/4/2005
5) Ref. AMS02-RP-CGS-003, issue 2, 4 August, 2005, Carlo Gavazzi Space

Fracture Certification for TRD Composite Structures

Components	Materials	Manufacturers Name	Basis for material properties	Quality Control	NDE Techniques	Sample tests	Damage control
Octagon Panels sidewalls	Carbon fiber skin M40JB/EP Honey comb Al. 5056 core	ADCO Gmbh Aachen Gernany	ADCO Data sheets	Note 8	Note 2, 9a	Notes 1,3,4,5,6,7	Note 10
Bulkheads	Carbon fiber skin M40JB/EP Honey comb Al. 5056 core	ADCO Gmbh Aachen Germany	ADCO Data sheets	Note 8	Note 9b		Note 10
Upper plate	Carbon fiber skin M40JB/EP Honey comb Al. 5056 core	ADCO Gmbh Aachen Germany	ADCO Data sheets	Note 8	Note 2, 9b		Note 10
Lower cover	Carbon fiber skin T300/EP Honey comb Al. 5056 core	Euro composites Echternach Luxembourg	Euro Composites Data sheets	Note 8	Note 2, 9b		Note 10
Reinforcement Rings	Carbon fibre T300/EP	Euro composites Echternach Luxembourg	Euro Composites Data sheets	Note 8	Note 9b		Note 10

Notes:
1) TRD Octagon panels Pull Test, RWTH, Aachen, 3/15/2005
2) Venting of parts of TRD detector, RWTH, Aachen,12/13/2004
3) Side Panel skin tension and Bending test samples, ams 2000a
4) Side panel bending test coupons, ams2001a
5) Side Panel Joint test coupon, ams2003_1a
6) Side Panel Corner Junction test coupon, ams2003_2a
7) Panel specimen locations, ams2004a
8) Manufacturer Certificate of Conformance is supplied
9a) NDE includes visual inspection and dimensional verification on 3D measuring device as well as static load test(including acoustic loads) on a sample side panel(RWTH, Aachen/ISAtec, 19/1/2004)
9b) NDE includes visual inspection and dimensional verification on 3D measuring device
10) Damage control will be implemented by careful handling and inspection to assure quality of the hardware

Fracture Certification for TRD Gas System Composite Structures

Components	Material	Manufacturers Name	Basis for material properties	Quality Control	NDE Techniques	Sample tests	Damage Control Plan
Xenon tank	Carbon fiber overwrapped stainless steel	ARDE	ARDE Catalog	Note 4	Note 5	Note1	Note 10
CO2 tank	Carbon fiber overwrapped stainless steel	ARDE	ARDE Catalog	Note 4	Note 5	Note 2	Note 10
Straw tubes	Kapton	Lamina dielectics West Sussex, UK	Manufacturer Catalog	Note 4a,8	Note 6	Note 9	Note 10
Longitudinal stiffeners	Carbon fiber	Secar Murzzusschlag Austria	Manufacturer Catalog	Note 4a,8	Note 7	Note 9	Note 10
Transverse stiffeners	Carbon fiber	Secar Murzzusschlag Austria	Manufacturer Catalog	Note 4a,8	Note 7	Note 9	Note 10

Notes:
1) ARDE Qualification by similarity Report of Xenon Tank PN D4815 to PN D 4636, EG10330, July 6, 2001
2) ARDE Qualification by similarity Report of CO2 Tank PN D4816 to PN D4683, EG10331 July 6, 2001
3) NDE tests on straw tubes by pressure drop measurement at 1.8 bar overpressure
4) Manufacturers Certificate of Compliance will be supplied
4a) Manufacturers Certificate of compliance is supplied
5) ARDE tanks are ultrasonically inspected
6) NDE on Straw tubes is done by pressure drop measurement at 1.8 bar overpressure
7) NDE on Longitudinal and transverse stiffeners include visual inspection, Dimensional and straightness verification
8) Assembly work of straw tubes, Longitudinal and transverse stiffeners are done at the clean room in Aachen, Germany
9) Sample tests include determination of Modulus of elasticity by Eigen frequency on a shaker
10) Damage Control plan will be implemented as per ANSI/AIAA-S081

Fracture Certification for Silicon Tracker Composite Structures							
Component	**Material**	**Manufacturers Name**	**Basis for material properties**	**Quality Control**	**NDE Techniques**	**Sample tests**	**Damage Control plan**
Tracker planes Sandwich facing	Carbon fiber HYE 3454-3J M55 Torayca Fiberite	Contraves AG Zurich	Contraves Catalog	Note 1	Note 4	Notes 2	Note 5
Tracker planes Sandwich core	Al. core 5056	Hexcel	Hexcel Catalog	Note 1	Note 4	Note 3	Note 5
Tracker Shell	Carbon fiber HYE-M55G 954-3 fiberite	ADCO, Aachen Germany	ADCO Catalog	Note 1	Note 4	None	Note 5
Tracker Conical flange	Carbon fiber M55J CE3	ADCO, Aachen Germany	ADCO Catalog	Note 1	Note 4	None	Note 5

Notes:
1) Manufacturers Certificate of Conformity are available
2) Flatwise tensile test on Sandwich facing, traction tests at 90 deg,
3) Insert tests to validate modification of tracker planes, Contraves Report No. W-ET 99.11.15-1, 15 November 1999
4) NDE tests include Electrical continuity tests, Insert proof load test and Interface geometry measurement (Metrology)
5) Damage control will be implemented by careful handling and inspection to assure quality of the hardware

Fracture Certification for Star Tracker Composite Structures							
Component	**Material**	**Manufacturers Name**	**Basis for material properties**	**Quality Control**	**NDE Techniques**	**Sample tests**	**Damage Control Plan**
Upper support bracket	CFRP M55J Fiber ACGLTM110 Cyanate Ester resin	Advanced Composites UK RIBA Composites Italy	Advanced Composites and RIBA Composites catalog	Note 1,2	Note 3	Note 4	Note 7
Lower support bracket	CFRP M55J Fiber ACGLTM110 Cyanate Ester resin	Advanced Composites UK RIBA Composites Italy	Advanced Composites and RIBA Composites catalog	Note 1,2	Note 3	Note 4	Note 7
Attachment between upper bracket and Tracker Conical Flange	Hysol EA 9394	Loctite Aerospace California, USA	Loctite Catalog	Note 1,2	Note 3	Note 4	Note 7

Notes
1) AMICA Star Tracker Support Fracture Control for Composite Parts, AMS-AST-Q1104-i1, 12 July 2005 AMS-AST-Q1104-i1,12 July, 2005
2) Certificate of Conformance for all materials are included in Ref. 1, sect 10.2
3) NDE tests for all materials include Visual, Ultrasonic and 3d inspection
4) Material testing and certification is done. Ref. 2, sect 10
5) AMICA Star Tracker Support Structure handling procedures, Ref 1 sect 11.4, 11.5
6) Star Tracker Support Structure venting, ASTS_Venting_040705, July 4, 2005
7) Damage control will be implemented by careful handling and inspection t0assure quality of the hardware

Fracture Certification for Ring Imaging Chernkov Counter (RICH) Composite Structures							
Component	**Material**	**Manufacturers Name**	**Basis for material properties**	**Quality Control**	**NDE Techniques**	**Sample tests**	**Damage Control Plan**
Aerogel Radito r	Prepreg-1-42%-3KHS-P-193	Plyform Milan, Italy	Plyform Catalog	Note 1,2	Note 1,2	None	Note 5
Reflector	Bryte M46 J/EX-1515 Epibond 1210-AB	Composite Mirror Applications Tucson, Arizona	Technical data sheets	Note 3	Note 3	Note 4	Note 5

Notes:
1) Quality assurance , Plyform document Carlo Gavazzi Space, 16 December 2004
2) Plyform Certification of Conformity, 21 February 2005
3) Certificate of Conformance, CMA document 10025, 8/31/2005, contains Cof C for all materials, Technical data Visual inspection, Material, Quality assurance, process information and handling Procedures and Coordinated Measuring Machine Measurements (CMM).
4) Micro VCM test per ASTM E-595-90
5) Damage control will be implemented by careful handling and inspection to assure quality of the hardware

Fracture Certification for ECAL Composite Structures							
Component	**Material**	**Manufacturers Name**	**Basis for material properties**	**Quality Control**	**NDE Techniques**	**Sample tests**	**Damage Control Plan**
Honey comb Panels	Aluminum core	Capital Aerospace Machinery Corp. Beijing, China	Manufacturer Catalog	Note 1	Note 2	Note 3	Note 4

Notes:
1) Manufacturers Certificate of Conformity will be supplied
2) Standard Honey comb panel NDE tests
3) Sample tests done
4) Damage control will be implemented by careful handling and inspection to assure quality of the hardware

Fracture Certification for Main Radiator Composite Structures

Component	Material	Manufacturers	Basis for material Properties	Quality Control	NDE Techniques	Sample tests	Damage Control Plan
RAM Radiator panel sandwich core	Rohacell 52 PMI foam	AIDC Taiwan	AIDC Brochure	Note 1,6	Note 5	Notes 2,3,4	Note 7
RAM Radiator panel sandwich core	Rohacell 52 PMI foam	AIDC Taiwan	AIDC Brochure	Note 1,6	Note 5	Notes 2,3,4	Note 7

Notes:
1) Manufacturers Certificate of Conformity will be supplied
2) Insert test performed by NASA. Ref report no. 061335, 11 January 2007
3) Insert test samples produced by Plyform, Italy
4) Tension and Shear tests are done by NASA. Ref. report no. 061335, 11 January 2007
5) Fokker Bond test (ultrasonic) on all parts
6) Incoming inspection (FAW, Resin content) as per ASTM Specification
7) Damage control will be implemented by careful handling and inspection to assure quality of the hardware

Fracture Certification for Tracker Radiator Composite Structures

Components	Material	Manufacturers Name	Basis for material properties	Quality Control	NDE Techniques	Sample tests	Damage Control Plan
Ram radiator Panels sandwich core	Rohacell 51 IG PMI foam	AIDC Taiwan	AIDC Brochure	Note 1,4, 5	Note 3	Note 2	Note 7
Wake Radiator Panels sandwich core	Rohacell 51 IG PMI foam	AIDC Taiwan	AIDC Brochure	Note 1,4, 5	Note 3	Note 2	Note 7
Attachment Rods	CFRP Tenax	Plyform Italy	Plyform Catalog	Note 1,4, 5	Note 6	Note 2	Note 7

Notes:
1) Manufacturers Certificate of Conformity will be supplied
2) Mechanical tests on specimens (prepregs, Joints, adhesives). Tests done at NASA, 11 January 2007
3) (A-Scan test for parts produced at AIDC) is done
4) Raw material conformance certificates are collected
5) Incoming inspections (FAW, Resin content) as per ASTM specs.
6) Every piece is tapped and for critical application ultrasonic resistance (Fokker bond test) is done
7) Damage control will be implemented by careful handling and inspection to assure quality of the hardware

Fracture Certification of Upper Time of Flight Composite Structures							
Components	**Material**	**Manufacturers Name**	**Basis for material properties**	**Quality Control**	**NDE Techniques**	**Sample tests**	**Damage Control Plan**
Sensor boxes	Carbon fiber	RAV S.r.l. Italy	S.P. Systems England	Note 1			Note 3
Scintillator cover	Carbon fiber	RAV S.r.l. Italy	S.P. Systems England	Note 1			Note 3
Scintillator core	Polyviniltoluene	Eljen Technology Texas	Eljen Technology Catalog	Note 1			Note 3
Scintillator supports	Carbon fiber	RAV S.r.l. Italy	S.P. Systems England	Note 1			Note 3
PMT boxes	Polycarabonato Makrolon 8325	Meccanica Tecnica Italy	Bayer	Note 1			Note 3
PMT Supports	Polycarabonato Makrolon clear	I.N.F.N. Italy	Bayer				Note 3
PMT Panels support	Carbon fiber sheet Al 5052 core	RAV S.r.l. Italy	S.P. Systems England I.MA.TEC. Catalog				Note 3
Ribs	Carbon fiber	RAV S.r.l. Italy	S.P. Systems England	Note 1			Note 3
Honeycomb Panel	2024-T81 facings Al 5052-Al 3003 core	RAV S.r.l. Italy	I.MA.TEC. Catalog	Note 1			Note 3

Notes:
1) RAV documentation 19 September 2005 contains certification of compliance, process information and manufacturing description
2) NDE techniques
3) Damage control will be implemented by careful handling and inspection to assure quality of the hardware

Fracture Certification for Anti Coincidence Counter							
Components	**Material**	**Manufacturers Name**	**Basis for material properties**	**Quality Control**	**NDE Techniques**	**Sample tests**	**Damage Control Plan**
ACC cylinder	Carbon fiber	IKV (Institut fur Kunststoff verar Beitung, Aachen, Germany	Manufacturer catalog	Note 1, 3	Note 4	None	Note 5

Notes:

1) Certificate of Conformance is available
2) Machining of cylinder at Physikalische Institut RWTH, Aachen, Germany
3) Quality control includes Computer controlled filament winding, curing cycle and mass report
4) Assembly work at RWTH Aachen has been done in restricted area
5) Damage control will be implemented by careful handling and inspection to assure quality of the hardware

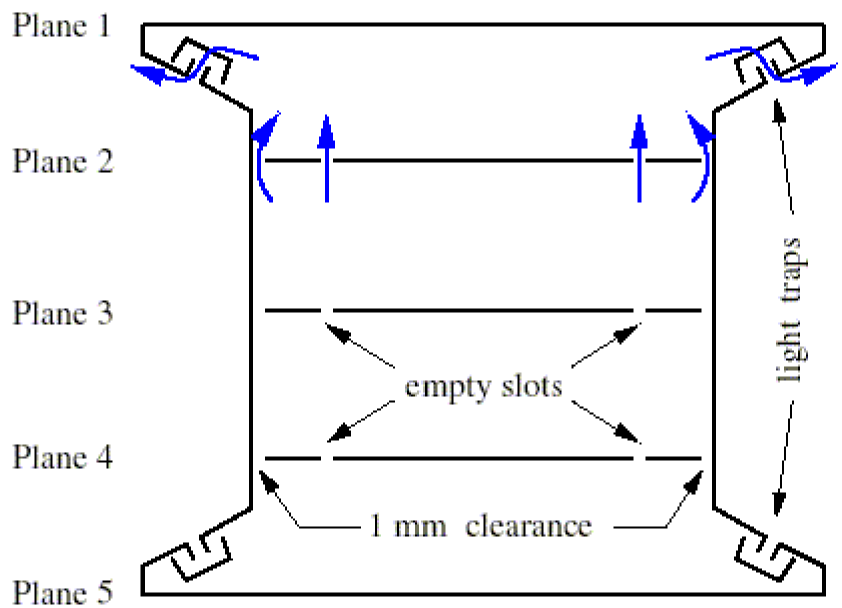
Vented Containers/Structures

System	Item	Function	Control Method	Verification Method
Structures	USS-02	Primary Structural Path. Composed of closed aluminum beams	Vented through assembly joints, but will be analyzed as if closed and with margins to retained atmosphere.	Structural Analysis
Avionics	Avionics Crates	Contain avionics	Vented	Venting Analysis
Avionics	XPD (Power Distribution) Boxes		Vented	Venting Analysis
Avionics	HVB (High Voltage Boxes)	High voltage power sources	Fully Potted No volume to vent	
MLI	MLI/thermal blankets	Thermal protection	MLI/blanket assembly will use standard means of venting layers and will use standoffs to provide venting across MLI/Blanket areas	Review of Design Inspection of as built hardware
TRD	TRD Octagon Structure	Structure to support TRD sensor proportional tubes	VENTED. Structure is heavily perforated to support sensor tubes. Numerous paths for venting exit	Venting Analysis
TRD	TRD Honeycomb Panels	Secondary Structure	VENTED. Panels are perforated (cover and core) and the panels have holes on the outside of the panels 1mm in diameter to enable venting the interior.	Testing/Analysis of Pressure Retention Potential
TRD	Cabling Grid Tubes	Support Cabling runs	VENTED.1 mm holes every 30 cm along length	Inspection of as built hardware
ACC	ACC Connector	Connector for Fiber Optics Connection	VENTED.Filtered (open cell foam) Vents provided	Inspection of as built hardware
ACC	ACC PMT Housing/Box	Covers PMT and Fiber Optics Connections	VENTED.Filtered (open cell foam) Vents provided	Inspection of as built hardware
TOF	TOF paddles	Detector	Carbon fiber enclosure open at	Inspection of as built

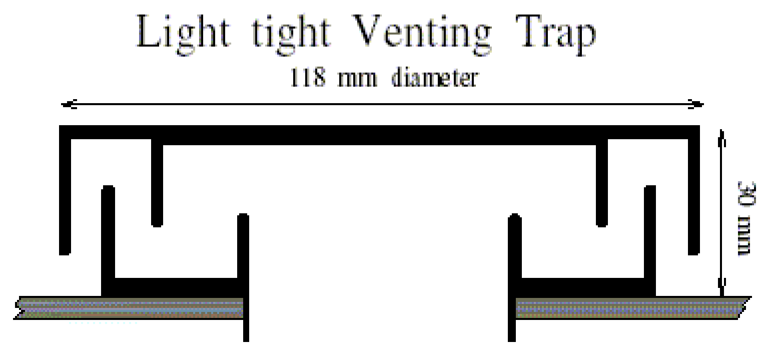
System	Item	Function	Control Method	Verification Method
			the ends and readily releases any gas from the paddles.	hardware
TOF	TOF PMT	Detector	Minimum interior free volume for gas, design is not gas tight	Inspection of as built hardware
Tracker	Tracker Volume	Sensor Volume	Vented through 4 bell shaped labyrinths (light tight traps) with nominal section of 20cm^2 to vent the 1.14m^3 volume	Venting Analysis Inspection of as built hardware
Tracker	Tracker Honeycomb	Secondary Structure	VENTED. Panels are perforated (cover and core) and the panels have holes on the outside of the panels 1mm in diameter to enable venting the interior.	Testing/Analysis of Pressure Retention Potential
Tracker	Tracker Alignment System LFCR Box	Encloses Laser Source and Splitters	Vented through 2 2 mm holes.	Review of Design Inspection of As Built Hardware
Tracker	Plane 1N	Light tight containment, enclosed by composite planes and carbon fiber "C" channel	Venting through light tight labyrinths(light tight traps)	Venting Analysis Inspection of As Built Design
Tracker	Plane 6	Light tight containment, enclosed by composite planes and carbon fiber "C" channel	Venting through light tight labyrinths(light tight traps)	Venting Analysis Inspection of As Built Design
Star Tracker	Star Tracker Enclosure	Enclosure and Support for Star Tracker Electronics and Optics	Volume vented by 14 fastener access holes	Review of Design Inspection of as built hardware
RICH	Aerogel & NAF Container	Contain particle Cherenkov generating materials	Vented. 0.17 m^3 volume vented (out) through 4 1 psi vent valves and 50 μm filter. Vented (in) through 3 1 psi vent valve	Venting Analysis Inspection of as built design
RICH	RICH Detector	Sensor and reflective surface	Vented. 0.7m^3 vented through	Venting Analysis

System	Item	Function	Control Method	Verification Method
		free volume	eight 15 mm holes.	Inspection of as built design
RICH	RICH PMT	Detector	Minimum interior free volume for gas, design is not gas tight	Inspection of as built hardware
ECAL	ECAL PMT	Detector	Minimum interior free volume for gas, design is not gas tight	Inspection of as built hardware
ECAL	Backpanels	Support to PMT	Volume vented through 4 labyrinth groves (1mmx 0.5 mm) to vent volume of 0.03 m^2	Review of Design Inspection of as built hardware
VC	Vacuum Case Volume	Structural support of Permanent Magnet	A minimum of 10 open 4 inch ports distributed about the VC.	Venting Analysis, Inspection of as built hardware.

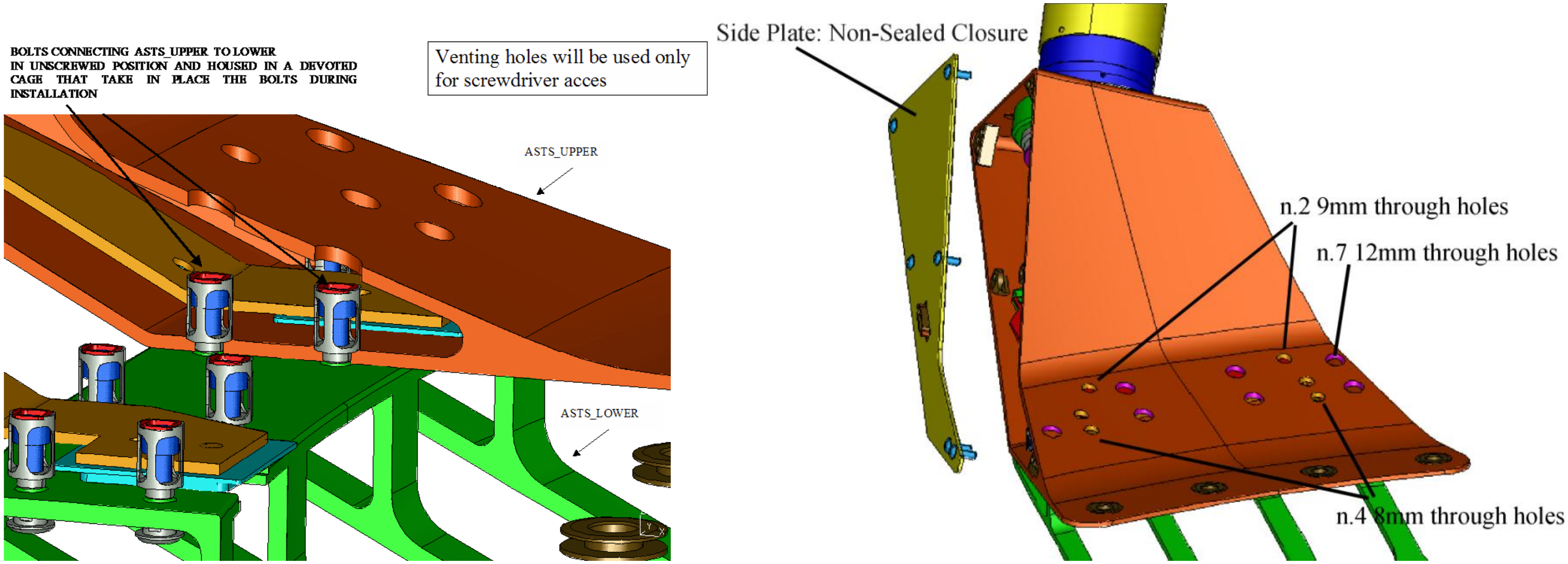
NOTE: All verifications will be tabulated and documented closed in the Chief Engineer's Report on Venting and will be tracked internally within the AMS-02 project, but only single verification will be documented for safety closure, provided by the Chief Engineer.



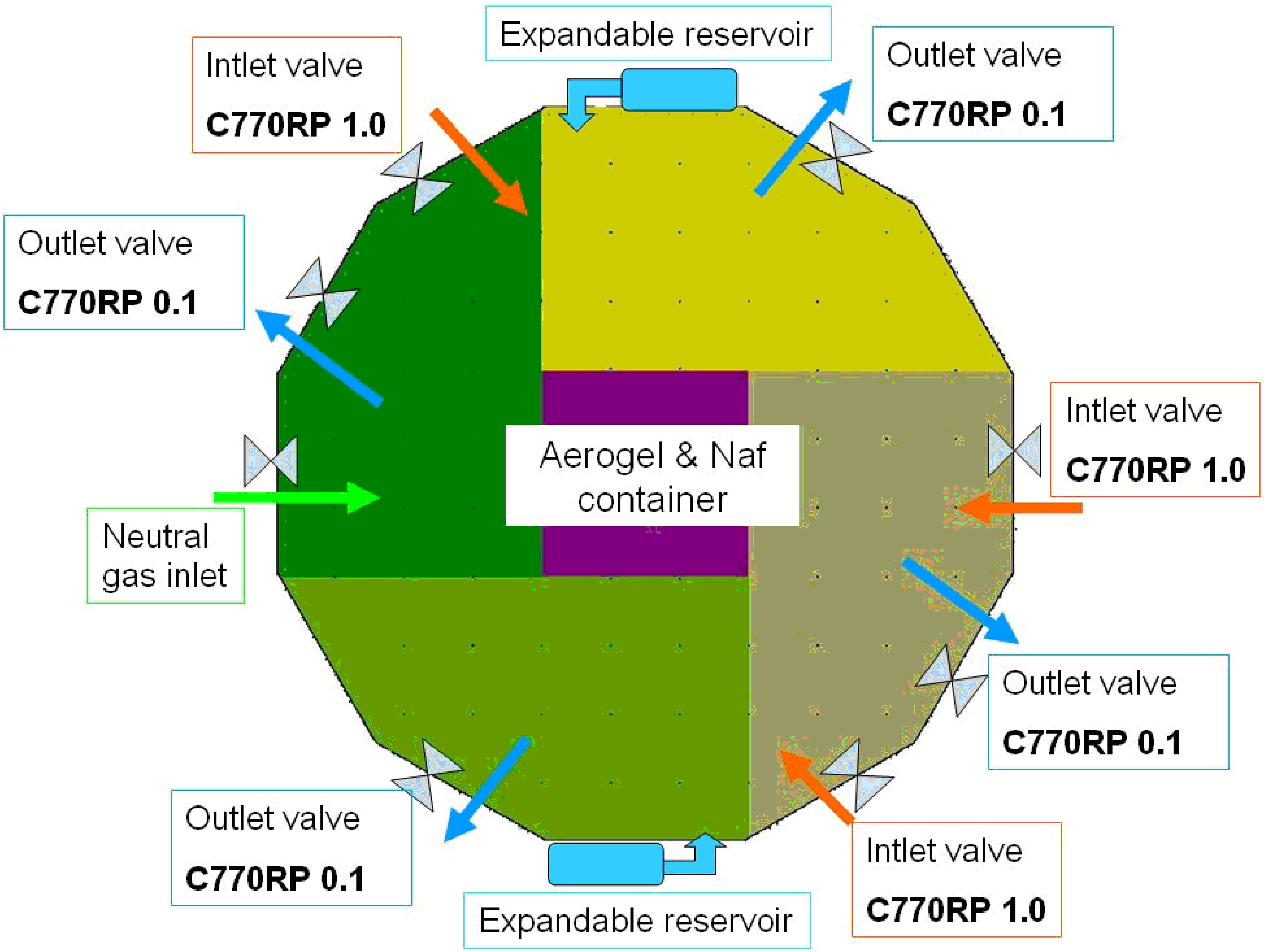
AMS-02 Largest Vented Volume is the Silicon Tracker.



Tracker Vent Design
Implementation similar on Plane 1N and Plane 6 enclosures.



Star Tracker Enclosure Venting



RICH Functional Venting Design

ROTATING EQUIPMENT

System	Rotating Equipment	Rotational Speed	Diameter/ Mass	Control/Fracture Classification	Verification
TRD	Gas pumps (2) KNF NMP830	240 RPM	(15 gram rotating mass, small diameter)	Contained within Box C Vessel, Low Energy	Review of Design Fracture Control Assessment
TTCS	Pumps (4)	9000 RPM Maximum	0.5 inch	Contained, Low Energy	Review of Design Fracture Control Assessment

Note: Individual verifications of the preceding table will be tabulated and documented in unified verification closure

JACOBS SVERDRUP

Engineering and Science Contract Group
2224 Bay Area Boulevard
Houston, Texas 77058
281-461-2300

Memorandum

Date	4 Jul 2005	Memo #: ESCG-4039-05-SP-DO-0003
To	Leland Hill	
From	Chris Tutt	
Subject	Creep in the AMS-02 Composite Straps	

References:
[1] Fax #693, John Ross to Trent Martin, "Creep in Composites," 17 Jul 2001.

[2] Davidson, Roger, "Creep in Polymers and Composites," Crompton Technology Group, 14 Jun 2001.

[3] MIL-HDBK-17F, *Composite Materials Handbook*.

As part of the safety verification process of the AMS-02 payload, I have reviewed all data available on creep of the composite strap systems to see if the cryomagnet support straps will be expected to creep significantly, and thus lose preload, during the duration of the mission. An initial order of magnitude calculation was provided by Space Cryomagnetics Ltd. during the initial design stages, which was based on technical data provided by Crompton Technology Group [2]. At that time, the projected loss of preload after three years was projected to be 1.6 lb. This is a trivial amount and will have no effect on the payload's structural response. In this memo, my goal is to review this calculation based on the matured magnet design and demonstrate that this conclusion still holds.

Creep in composites is primarily a high-temperature phenomenon, affecting materials which are more than 50°C above the material glass temperature [3]. Three of the four bands in the AMS-02 strap system are at cryogenic temperatures and thus need not be considered for creep. The remaining band is the S2-glass bod.

JACOBS SVERDRUP

Test-measurements of glass fiber loaded to 32% of ultimate load at room temperature show a creep rate of 3.9×10^{-4} %ε/hr [2]. To estimate the total load, we need to estimate the maximum sustained load in each of the three configurations of the magnet:

1) Preload + 1g in the –Z direction.
   25 months assembly and testing at SCL, CERN, and KSC. (18,000 hr)
   Maximum sustained load is 2700 lb.

2) Preload +1g in the +X direction.
   One month of assembly time and one month in the canister at KSC. (1440 hr)
   Maximum sustained load is 3198 lb.

3) Preload only, no gravity.
   Three years of on-orbit lifetime. (25,920 hr)
   Maximum sustained load is 1750 lb for C1W1 straps.

For each of these configurations, we can calculate total sustained strain:

$$\varepsilon_1 = 151\ \mu\varepsilon$$
$$\varepsilon_2 = 179\ \mu\varepsilon$$
$$\varepsilon_3 = 98\ \mu\varepsilon.$$

Then using the creep rate listed above, calculate the predicted increase in deformation:

$$\Delta_1 = 7.02\% \text{ of } 151\ \mu\varepsilon = 10.6\ \mu\varepsilon$$
$$\Delta_2 = 0.56\% \text{ of } 179\ \mu\varepsilon = 1.0\ \mu\varepsilon$$
$$\Delta_3 = 10.11\% \text{ of } 98\ \mu\varepsilon = 9.9\ \mu\varepsilon$$

So at the end of assembly, launch, and the primary mission, we can expect to have no more than 21.5 $\mu\varepsilon$ of permanent deformation in the glass bod, or 1.77×10^{-4} inches. This would lead to a loss of preload of 0.5 lb. This, as before is an insignificant amount and will not lead to any change in the structural response of the cryomagnet, nor will it place the straps themselves in jeopardy.

ISS MATERIALS USAGE AGREEMENT	USAGE AGREEMENT NO. AG 577	REV.	PAGE 1 OF 2

TITLE:	CATEGORY:	EFFECTIVITY:
7050-T7451/T7452 Parts in USS, VC, PAS, and ROEU of Alpha Magnetic Spectrometer- 02 (AMS-02)	2	STS-134

TYPE OF DEVIATION:		REQUIREMENT DEVIATED:		
☒ MATERIAL	☐ EQUIPMENT (NO. PER VEHICLE: 1)	☐ FLAMMABILITY ☐ OFFGASSING	☐ TVS ☐ O_2 COMPATIBILITY	☒ SCC ☐ OTHER

EQUIPMENT	PART NUMBER	MANUFACTURER
	See Table I of Attachment 1	

MATERIAL	TRADE NAME	SPECIFICATION	MANUFACTURER
See Table I of Attachment 1		See Table I of Attachment 1	

THICK (in.)	WEIGHT (lbs.)	AREA (in^2)	LOCATION	ENVIRONMENT		
				TEMPERATURE (°F)	PRESS (PSIA)	MEDIA
			☐ HABITABLE ☒ NONHABITABLE	-58 F to +140 F	Space Vacuum	Vacuum

APPLICATION (use second sheet if required)

The AMS-02 is an ISS experiment payload, which will be attached to ISS S3 Zenith Inboard Payload Attachment System (PAS). It uses a large cryogenic superconducting magnet and several high energy particle detector systems to collect cosmic ray data. Its major subsystems include the Unique Support Structure (USS)-02, Vacuum Case (VC), Synchrotron Radiation Dector (SRD), Transition Radiation Detector (TRD), Anti-Coincidence Counter (ACC), Time of Flight (TOF) Detector, Silicon Tracker, Cryogenic Superconducting Magnet, Ring Imaging Cherenkov Counter (RICH), and Electromagnetic Calorimeter (ECAL). The AMS-02 payload configuration for launch, landing, and on-orbit is shown in Figure 1, Attachment 1. The USS-02 is the primary structural element of the AMS-02 payload. The USS-02 consists of five subassemblies- the upper USS-02, VC, lower USS-02, Payload Attach System (PAS), and Keel. An explored view of the USS-02 is shown in Figure 2, Attachment 1. The VC supports the Cryomagnet cold mass by sixteen (Continued on next page)

RATIONALE (use second sheet if required)

The rationale for the use of the Al alloy 7050-T7451 parts in the AMS-02 payload is as follows:
- Aluminum alloy 7050-T7451 is stronger than aluminum alloy 7075-T7351 (Table I material for SCC) and has design allowables for thick plate stocks (greater than 4 inches) in Metallic Materials Properties Development and Standardization (MMPDS) Handbook.
- The sustained tensile stresses of these 7050-T7451 parts are less than the SCC threshold stress for 7050-T7451 Al alloy.
- These 7050-T7451 parts have adequate corrosion protection surface finish and are protected from long exposure to corrosive environments.
- These 7050-T7451 parts are used in benign use environment (space vacuum).

APPROVALS

ORIGINATOR/ORGANIZATION	DATE	JSC MATERIALS AND PROCESSES TECHNOLOGY BRANCH	DATE
[signature]	9/25/09	Julie A. Henkener [signature] 9/25/09	9-25-09
PROJECT MANAGER	**DATE**	**PROGRAM MANAGER**	**DATE**
[signature]	28 Sep 2009		

JSC Form 1466 (Rev June 93) NASA-JSC

Carl Lauritzen 09-28-2009

ISS MATERIALS USAGE AGREEMENT	USAGE AGREEMENT NO. AG577	REV.	PAGE 2 OF 2

TITLE:	CATEGORY:	EFFECTIVITY:
Alpha Magnetic Spectrometer 02 (AMS-02)	2	STS-134

APPLICATION (Cont.)

composite straps and serves as a vacuum jacket for the superfluid helium tank. The VC attaches to the USS-02 via eight interface plates and two clevis plates. The 7050-T7451 Al alloy is used in several structural components of the USS, VC, PAS, and Remotely Operated Electrical Umbilical (ROEU) provided by NASA Johnson Space Center for AMS-02. A list of 7050-T7451 parts provided by NASA JSC is shown in Table I, Attachment 1. The 7050-T7451 (or its equivalent 7050-T73651designation) Al alloy is a Table II material with moderate resistance to SCC per MSFC-STD-3029, Guidelines for the Selection of Metallic Materials for Stress Corrosion Resistance in Sodium Chloride Environments. This MUA provides the acceptance ratioale for the use of these 7050-T7451 parts in the AMS-02 payload.

JSC Form 1466 (Rev June 93) NASA-JSC

Attachment 1

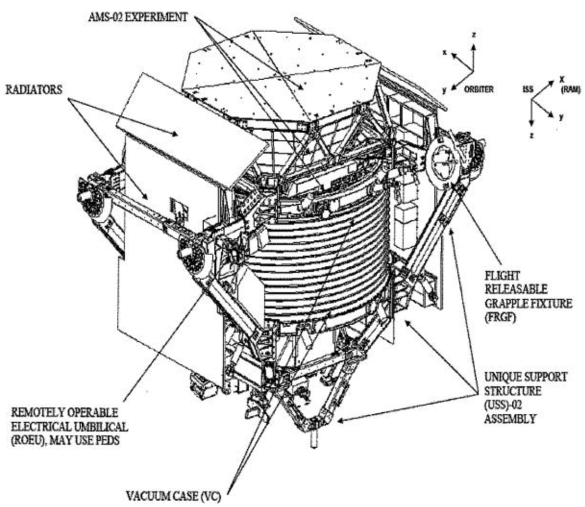


Figure 1 : AMS-02 Payload Configuration- Launch, Landing, and On-Orbit

Attachment 1 (Cont.)

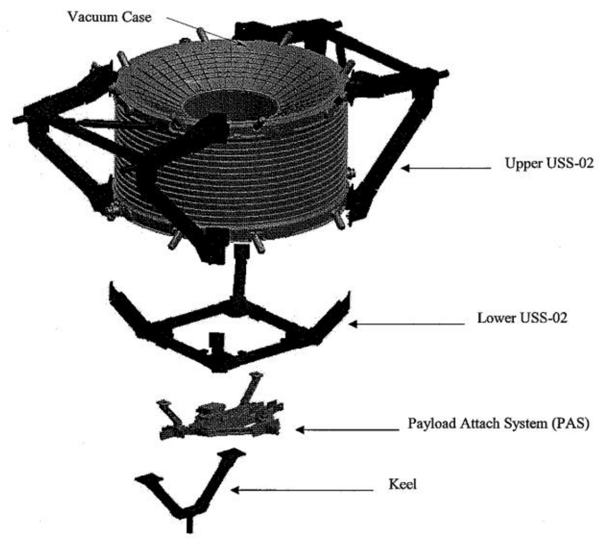


Figure 2: An explored view of USS-02 showing its subassemblies

Attachment 1 (Cont.)

Table I: List of 7050-T7451/T7452 Parts Provided by JSC for AMS-02 Payload

Item No.	Subsystem	Part Name	Part Number	Material	Specification	Dimensions, Inches (LxWxH)	Engineering Drawing	Yield Stress, Fty (ksi)*	SCC Threshold Stress (ksi)**	Sustained Tensile Stress (ksi)
1	VC	Outer Cylinder, Vacuum Case Assy	SDG39135779	AL 7050-T7452 Rolled Ring Forging	AMS 4108	OD= 109", ID=105", L=53"	https://edcc.jsc.nasa.gov/dbase/edrspub/repository/39/SDG39135779__A_0.PDF	S-basis 55 in ST or Radial dir	35 in ST dir	6.9
2	VC	Lower Support Ring, Vacuum Case Assy	SDG39135785	AL 7050-T7452 Rolled Ring Forging	AMS 4108	OD= 110", ID=98", L=6.5"	https://edcc.jsc.nasa.gov/dbase/edrspub/repository/39/SDG39135785_NC_0.PDF	S-basis 52 in ST or Radial dir	35 in ST dir	22.0
3	VC	Upper Support Ring, Vacuum Case Assy	SDG39135784	AL 7050-T7452 Rolled Ring Forging	AMS 4108	OD= 110", ID=98", L=6.5"	https://edcc.jsc.nasa.gov/dbase/edrspub/repository/39/SDG39135784_NC_0.PDF	S-basis 52 in ST or Radial dir	35 in ST dir	20.6
4	VC	Interface Plate Assy, Upper, VCA	SDG39135788	AL 7050-T7451	AMS 4050	10.5 x 8.0 x 2.8	https://edcc.jsc.nasa.gov/dbase/edrspub/repository/39/SDG39135788__A_0.PDF	A-basis 59 in ST dir	35 in ST dir	19.7
5	VC	Interface Plate Assy, Lower, VCA	SDG39135789	AL 7050-T7451	AMS 4050	11.0 x 8.0 x 2.8	https://edcc.jsc.nasa.gov/dbase/edrspub/repository/39/SDG39135789__A_0.PDF	A-basis 59 in ST dir	35 in ST dir	13.3
6	USS	Interface Joint Assy, Upper VC, Upper USS-02 Assy	SDG39135727	AL 7050-T7451	BMS 7-323C	21.1 x 15.7 x 6.9	https://edcc.jsc.nasa.gov/dbase/edrspub/repository/39/SDG39135727__C_0.PDF	Min. 56 in ST dir	35 in ST dir	5.6
7	USS	Sill Joint Assy, Upper USS-02 Assy	SDG39135730	AL 7050-T7451	BMS 7-323C	16.5 x 15.5 x 6.5	https://edcc.jsc.nasa.gov/dbase/edrspub/repository/39/SDG39135730__C_0.PDF	Min. 56 in ST dir	35 in ST dir	26.7
8	USS	Bridge Beam Elbow, Lower Trunnion	SDG39135734	AL 7050-T7451	BMS 7-323C	14.2 x 10.0 x 6.0	https://edcc.jsc.nasa.gov/dbase/edrspub/repository/39/SDG39135734__C_0.PDF	Min. 56 in ST dir	35 in ST dir	5.9
9	USS	Interface Joint Assy, Lower VC, Lower USS-02 Assy	SDG39135737	AL 7050-T7451	BMS 7-323C	18.4 x 17.9 x 7.6	https://edcc.jsc.nasa.gov/dbase/edrspub/repository/39/SDG39135737__A_0.PDF	Min. 55 in ST dir	35 in ST dir	7.9
10	USS	Bracket, Sill, Upper USS-02 Assy	SDG39135738	AL 7050-T7451	BMS 7-323C	9.0 x 5.8 x 5.8	https://edcc.jsc.nasa.gov/dbase/edrspub/repository/39/SDG39135738__B_0.PDF	Min. 56 in ST dir	35 in ST dir	31.0
11	USS	Diagonal Bracket, Sill, Upper USS-02 Assy	SDG39135740	AL 7050-T7451	BMS 7-323C	23.1 x 10.0 x 5.8	https://edcc.jsc.nasa.gov/dbase/edrspub/repository/39/SDG39135740__B_0.PDF	Min. 56 in ST dir	35 in ST dir	25.0
12	USS	Centerbody Box Joint Keel Interface Assy, Lower USS-02 Assy	SDG39135759	AL 7050-T7451	BMS 7-323C	14.9 x 14.9 x 6.0	https://edcc.jsc.nasa.gov/dbase/edrspub/repository/39/SDG39135759__D_0.PDF	Min. 56 in ST dir	35 in ST dir	8.8
13	USS	Centerbody Box Joint Assy, Lower USS-02 Assy	SDG39135760	AL 7050-T7451	BMS 7-323C	14.9 x 14.9 x 6.0	https://edcc.jsc.nasa.gov/dbase/edrspub/repository/39/SDG39135760__B_0.PDF	Min. 56 in ST dir	35 in ST dir	8.8
14	USS	Joint Assy, Lower USS to Upper USS, Lower USS-02 Assy	SDG39135762	AL 7050-T7451	BMS 7-323C	11.9 x 7.5 x 7.2	https://edcc.jsc.nasa.gov/dbase/edrspub/repository/39/SDG39135762__A_0.PDF	Min. 55 in ST dir	35 in ST dir	10.9
15	USS	RICH Mounting Bracket, Lower USS-02 Assy	SDG39135763	AL 7050-T7451	BMS 7-323C	6.4 x 4.1 x 4.0	https://edcc.jsc.nasa.gov/dbase/edrspub/repository/39/SDG39135763_NC_0.PDF	Min. 57 in ST dir	35 in ST dir	21.4
16	USS	PAS RICH Bracket Assy, Lower USS-02 Assy	SDG39135766	AL 7050-T7451	BMS 7-323C	7.5 x 6.9 x 5.3	https://edcc.jsc.nasa.gov/dbase/edrspub/repository/39/SDG39135766__B_0.PDF	Min. 57 in ST dir	35 in ST dir	27.5
17	USS	Lower Angle Beam Flange, Lower USS-02 Assy	SDG39135767	AL 7050-T7451	BMS 7-323C	7.5 x 7.4 x 6.4	https://edcc.jsc.nasa.gov/dbase/edrspub/repository/39/SDG39135767__A_0.PDF	Min. 56 in ST dir	35 in ST dir	18.4
18	USS	Keel Angle Joint, Keel Assy	SDG39135769	AL 7050-T7451	BMS 7-323C	11.6 x 8.8 x 5.8	https://edcc.jsc.nasa.gov/dbase/edrspub/repository/39/SDG39135769__B_0.PDF	Min. 56 in ST dir	35 in ST dir	1.8
19	USS	Keel Block Assy, Keel Assy	SDG39135770	AL 7050-T7451	BMS 7-323C	20.7 x 7.0 x 5.0	https://edcc.jsc.nasa.gov/dbase/edrspub/repository/39/SDG39135770__A_0.PDF	Min. 57 in ST dir	35 in ST dir	0.6
20	PAS	PAS Platform Assy, PAS Base Assy	SDG39135817	AL 7050-T7451	BMS 7-323C	44.8 x 45.4 x 2.8	https://edcc.jsc.nasa.gov/dbase/edrspub/repository/39/SDG39135817__A_0.PDF	Min. 56 in ST dir	35 in ST dir	21.3
21	PAS	Bridge Assy, PAS Bridge Assy	SDG39135837	AL 7050-T7451	BMS 7-323C	37.6 x 3.6 x 2.1	https://edcc.jsc.nasa.gov/dbase/edrspub/repository/39/SDG39135837__B_0.PDF	Min. 59 in ST dir	35 in ST dir	28.2
22	PAS	PAS Vertex Bracket	SDG39135813	AL 7050-T7451	BMS 7-323C	16.5 x 10.7 x 7.9	https://edcc.jsc.nasa.gov/dbase/edrspub/repository/39/SDG39135813_NC_0.PDF	Min. 55 in ST dir	35 in ST dir	23.0
23	PAS	PAS Aft Bracket	SDG39135814	AL 7050-T7451	BMS 7-323C	14.6 x 12.0 x7.5	https://edcc.jsc.nasa.gov/dbase/edrspub/repository/39/SDG39135814_NC_0.PDF	Min. 55 in ST dir	35 in ST dir	26.8
24	PAS	PAS Guide Pins	SDG39135818	AL 7050-T7451	BMS 7-323C	14.0 x 3.8 x 3.0	https://edcc.jsc.nasa.gov/dbase/edrspub/repository/39/SDG39135818_NC_0.PDF	Min. 58 in ST dir	35 in ST dir	1.7

Attachment 1 (Cont.)

Table I: List of 7050-T7451/T7452 Parts Provided by JSC for AMS-02 Payload

25	ROEU	Clevis, ROEU Assembly	SDG39137676	AL 7050-T7451	BMS 7-323C	12.0 x 8.6 x 4.6	https://edcc.jsc.nasa.gov/dbase/edrspub/repository/39/SDG39137676__A_0.PDF	Min. 57 in ST dir	35 in ST dir	4.4
26	ROEU	PDA Mounting Bracket, ROEU Assembly	SEG39137678	AL 7050-T7451	BMS 7-323C	25.8 x 7.8 x 4.6	https://edcc.jsc.nasa.gov/dbase/edrspub/repository/39/SDG39137678__A_0.PDF	Min. 57 in ST dir	35 in ST dir	negligible
27	ROEU	PDA Harness Bracket, ROEU Assembly	SEG39135865	AL 7050-T7451	BMS 7-323C	8.8 x 7.5 x 3.0	https://edcc.jsc.nasa.gov/dbase/edrspub/repository/39/SDG39135865_NC_0.PDF	Min. 58 in ST dir	35 in ST dir	5.5
28	USS	FRGF Bracket	SDG39135861	AL 7050-T7451	BMS 7-323C	12.0 x 10.7 x 5.5	https://edcc.jsc.nasa.gov/dbase/edrspub/repository/39/SDG39135861__A_0.PDF	Min. 57 in ST dir	35 in ST dir	17.2
29	USS	Scuff Plate	SDG39135867	AL 7050-T7451	BMS 7-323C	26.0 x 18.8 x 3.8	https://edcc.jsc.nasa.gov/dbase/edrspub/repository/39/SDG39135867__A_0.PDF	Min. 57 in ST dir	35 in ST dir	21.4

NOTES:

* - The tensile yield stress values were obtained from Table 3.7.4.0 (b) in MMPDS-03 for 7050-T7451plates and Table 3.7.4.0 (d) in MMPDS-03 for 7050-T7452 rolled ring forging.

** - The SCC threshold stress values were obtained from Table 3.1.2.3.1(b) in MMPDS-03 for 7050-T7451 plates per AMS4050 and Table 3.1.2.3.1 (e) in MPDS-03 for 7050-T7452 rolled ring forging per AMS 4108.

ST- Short Transverse, dir- direction

(1) Boeing material specification BMS 7-323C, High Strength Fatigue Tolerant, Stress Corrosion Resistant 7050 Aluminum Alloy Plate, meets the technical requirements of AMS4050.

(2) The manufacturing processes used for these parts were not susceptible to generating residual stresses.

(3) These parts have all been checked by quality personnel to ensure that the part meets the tolerances on the drawings, thus, minimizing stress due to misalignments during assembly. During assembly, the procedures ensure that the parts are not forced to fit and fasteners are not over-torqued.

PAYLOAD FLIGHT HAZARD REPORT				a. NO: AMS-02-F02
b. PAYLOAD	Alpha Magnetic Spectrometer-02 (AMS-02)			c. PHASE: III
d. SUBSYSTEM:	Materials, AMS-02 DDRS-02	e. HAZARD GROUP:	Injury/Illness	f. DATE: August 4, 2010
g. HAZARD TITLE:	Toxic Material Offgassing			i. HAZARD CATEGORY: CATASTROPHIC CRITICAL X
h. APPLICABLE SAFETY REQUIREMENTS:	NSTS 1700.7B 209.3			

j. DESCRIPTION OF HAZARD:

Offgas evolution of toxic vapors from materials of construction of hardware used within the Orbiter crew habitable volume can result in injury/illness.

This hazard report covers the AMS-02 provided hardware to be used within the Shuttle Orbiter crew habitable volume during AMS-02 systems check out prior to deployment to the ISS. This hardware consists of interface cables and a RS 422 interface card to be Interfaced with the standard PGSC/NGLS through a USB port.

k. CAUSES

(list)

1. Use of hardware/materials of construction which offgas excessive levels of toxic products.

o. APPROVAL	PAYLOAD ORGANIZATION	SSP/ISS
PHASE I		
PHASE II		
PHASE III		

l. HAZARD CONTROL (CONTROL), m. SAFETY VERIFICATION METHODS (SVM), n. STATUS OF VERIFICATIONS (STATUS)	OPS CONTROL

PAYLOAD FLIGHT HAZARD REPORT	a. NO: AMS-02-F02
b. PAYLOAD Alpha Magnetic Spectrometer-02 (AMS-02)	c. PHASE: III

1. CAUSE: Use of hardware/materials of construction which offgas excessive levels of toxic products.

1.1 CONTROL: Materials of construction of the AMS-02 Interior cabling have been selected based on material ratings and past flight experience for cable construction to minimize offgassing potential.

1.1.1 SVM: Material Selection Assessment for Offgas Rating.

1.1.2 SVM: JSC ES4 approval of material certification.

1.1.3 SVM: QA certification of as built hardware.

1.1.1 STATUS: Closed. ESCG Memorandum ESCG-4390-08-SP-MEMO-0021_RevA, "IVA Offgassing and Flammability," dated February 17, 2009

1.1.2 STATUS: Closed. JSC Materials and Fracture Control Certification MATL-09-036, "Alpha Magnetic Spectrometer (AMS-02) Data Interface Hardware," Approved 3/25/2009

1.1.3 STATUS: Closed. DDRS-02 TPS providing QA approval: DDRS-02 Assembly p/n SED39136116-301 (s/n 1001 = 2A0920129, s/n 1002 = 2A0920130), USB422 Assembly p/n SED39137921-301 (s/n 1013 = 2A0920093, s/n 1014 = 2A0920094, s/n 1015 = 2A0920095, s/n 1016 = 2A0920096), USB-422/PDIP Cable Assy p/n SED39136111-301 (s/n 1001 = 2A0720285, s/n 1002 = 2A0720285), USB A/B Cable Assy p/n SED39136130-801 (s/n 1001 = 2A0920015, s/n 1002 = 2A0920100). Review and Summary Date January 21, 2010

1.2 CONTROL: The DDRS2 USB interface hardware will be conformally coated and constructed of materials selected for IVA offgassing compatibility.

1.2.1 SVM: Review of Design.

1.2.2 SVM: QA inspection of flight hardware.

1.2.3 SVM: Material Selection Assessment for Offgas Rating.

1.2.4 SVM: JSC ES4 approval of material certification.

1.2.1 STATUS: Closed. ESCG Memorandum ESCG-4390-08-SP-MEMO-0021_RevA, "IVA Offgassing and Flammability," dated February 17, 2009

1.2.2 STATUS: Closed. DDRS-02 TPS providing QA approval: DDRS-02 Assembly p/n SED39136116-301 (s/n 1001 = 2A0920129, s/n 1002 = 2A0920130), USB422 Assembly p/n SED39137921-301 (s/n 1013 = 2A0920093, s/n 1014 = 2A0920094, s/n 1015 = 2A0920095, s/n 1016 = 2A0920096), USB-422/PDIP Cable Assy p/n SED39136111-301 (s/n 1001 = 2A0720285, s/n 1002 = 2A0720285), USB A/B Cable Assy p/n SED39136130-801 (s/n 1001 = 2A0920015, s/n 1002 = 2A0920100). Review and Summary Date January 21, 2010

PAYLOAD FLIGHT HAZARD REPORT	a. NO: AMS-02-F02
b. PAYLOAD Alpha Magnetic Spectrometer-02 (AMS-02)	c. PHASE: III

1.2.3 STATUS: Closed. Material Assessment documented in attachment to JSC Materials and Fracture Control Certification MATL-09-036, "Alpha Magnetic Spectrometer (AMS-02) Data Interface Hardware," Approved 3/25/2009 1.2.4 STATUS: Closed. JSC Materials and Fracture Control Certification MATL-09-036, "Alpha Magnetic Spectrometer (AMS-02) Data Interface Hardware," Approved 3/25/2009	
1.3 CONTROL: DDRS-02 COTS USB A-B connector will be tested for offgassing if material analysis and acceptance is not possible. 1.3.1 SVM: JSC ES4 Approval of materials analysis or offgas testing results (Note: If analysis is deemed sufficient the analysis will be tracked under SVM 1.1.1) 1.3.1 STATUS: Closed. JSC Materials and Fracture Control Certification MATL-09-036, "Alpha Magnetic Spectrometer (AMS-02) Data Interface Hardware," Approved 3/25/2009	
Notes:	

ACRONYMS	
AMS-02 – Alpha Magnetic Spectrometer 02	Ops – Operations
COTS – Commercial Off the Shelf	QA – Quality Assuranec
DDRS2 – Digital Data Recording System 2	SVM – Safety Verification Method
PGSC – Payload General Support Computer	

JSC MATERIALS AND FRACTURE CONTROL CERTIFICATION

PROJECT/SUBSYSTEM MANAGER: **T. Martin/EA321**	REF: MATL – 09 – 036 p.1 of 4
HARDWARE NAME: **Alpha Magnetic Spectrometer (AMS-02) Data Interface Hardware**	PART NUMBER: **See Attachment 2**

APPLICABLE REQUIREMENTS:

Materials Requirements:

- ☒ NSTS 1700.7B, Safety Policy and Requirements for Payloads Using the Space Transportation System
- ☒ SE-R-0006D, Space Shuttle System Requirements for Materials and Processes
- ☒ SSP 30233G, Space Station Requirements for Materials and Processes
- ☒ JSC 27301E, Materials Control Plan for JSC Flight Hardware
- ☒ JSC 49774A, Standard Manned Spacecraft Requirements for Materials and Processes
- ☐ Other:

Fracture Control Requirements:

- ☐ NASA-STD-5003, Fracture Control Requirements for Payloads Using the Space Shuttle
- ☐ SSP 30558C, Fracture Control Requirements for Space Station
- ☐ SSP 52005B, ISS Payload Flight Equipment Requirements and Guidelines for Safety-Critical Structures

SPECIFIC ASSESSMENTS:

- ☒ Flammability
- ☒ Toxicity
- ☒ Stress Corrosion Cracking
- ☒ General Corrosion
- ☐ Fracture Control (☒ Not Applicable; Concurrence: **M.S.**)
- ☒ Age Life ☐ Other:
- ☐ Atomic Oxygen/Ultraviolet
- ☐ Thermal Vacuum Stability
- ☐ Fluid Compatibility:
- ☒ Microbiological Resistance

LOCATION:

- ☒ Orbiter Crew Cabin
- ☐ Orbiter Payload Bay
- ☒ Progress
- ☒ Spacehab
- ☒ MPLM
- ☒ Soyuz
- ☒ ATV ☒ HTV
- ☒ Space Station: ☒ Internal ☐ External
- ☐ Other:

MATERIALS USAGE AGREEMENTS (MUAs):

- ☒ No MUAs
- ☐ MUA Number(s):

Deviation:

LIMITATIONS: ☒ No Limitations

- ☐ Materials:
- ☐ Fracture Control:

This JSC Materials and Fracture Control Certification is consistent with existing Materials or Fracture Control Reciprocal Agreements.

APPROVALS

M.D. Pedley	3/25/09	M.D. Pedley	3/25/09
Fracture Control Manager, S. Forth	Date	GFE Materials Control Manager, M. Pedley	Date

ATTACHMENT 1

Hardware Acceptance Summary Report for Materials

The following data interface hardware will be used in the crew compartment during various stages of data transmission from the AMS-02 payload in the Shuttle Cargo Bay to the T0 umbilical and theNext Generation Laptop System (NGLS):

1. AMS-02 RS422 T-0/PDIP Cable Assembly (SED39136112-302)
2. DDRS-02 Assembly (SED39136116-301)
3. USB 422 Assembly (SED39137921-301)
4. AMS-02 USB-422/PDIP Cable Assembly (SED39136111-301)
5. USB A/B Cable Assembly (SED39136130-801)

The AMS-02 RS422 T-0/PDIP cable will be used to patch RS422 signal from the payload to the Shuttle T0 umbilical for GSE monitoring and control prior to launch. The cable is connected between the Payload Data Interface Panel (PDIP) connectors J103 and J105. The cable is made of flight approved materials including nonflammable HR Plus Expando sleeving, Teflon-coated lacing cord, Scotch Weld 2216, P213 glass cloth tape, FEP Type C tape, Velcro fastener straps, Vibratite Formula 3, Teflon-insulated data bus cable, Twinax plug connector, and NLS plug connector. The use of Vibratite Formula 3 on non-structural, non-critical fasteners on soft-stowed hardware is acceptable.

The DDRS-02 Assembly will be used to patch RS422 signal from the payload to the NGLS A31P hard drive for data storage during on-orbit operations. It consists of one USB 422 unit connected to the USB A/B cable at one end and the USB-422/PDIP cable at the other end.

The USB 422 Assembly provides in-line conversion of RS422 synchronous serial signals to a USB 2.0 interface. The USB 422 unit consists of a single PCB housed in an anodized 6063-T6 enclosure with Twinax and USB type B connectors. The unit draws less than 0.5 amps and is powered by the NGLS USB 5.0 VDC source. The materials used in the USB 422 unit include RTV 3145 adhesive, RTV 3140 conformal coating, Kynar shrink tubing, Velcro fasteners, and Loctite 21463. The use of Loctite 21463 on non-critical fasteners of soft-stowed hardware is acceptable.

The USB-422/PDIP Cable Assembly is connected between the PDIP connector J105 and the USB 422 Assembly. The cable is made of flight approved materials including Teflon-insulated cable (M27500-22RE2S06), HR plus Expando sleeve, FEP Type C tape, P213 glass cloth tape, Vibratite Formula 3, and NLS plug connectors. The use of Vibratite Formula 3 on non-critical fasteners of soft-stowed hardware is acceptable.

The USB A/B Cable Assembly is connected between the USB 422 Assembly and NGLS. The cable is made of flight approved materials including the USB 2.0 cable wrapped with FEP Type C tape, P213 glass cloth tape, and Velcro fastener straps. No thread locking compound or adhesive is used in the USB A/B cable Assembly.

The AMS-02 data interface hardware will be soft stowed in crew cabin for launch and landing.

Stress Corrosion Cracking:
All metallic materials were evaluated for SCC and found acceptable.

General Corrosion:
All metallic materials were evaluated for corrosion and found acceptable.

Flammability:
All non-metallic materials are "A" rated for flammability or used in non-flammable configuration by analysis.

Toxicity:
All non-metallic materials are "A' rated or better for toxicity, or used in quantities below their maximum allowable limits for Shuttle and ISS per MAPTIS>

Aging:
The AMS-02 data interface hardware was evaluated for aging and found acceptable. It is replaceable as needed.

Microbiological Resistance:
The AMS-02 data interface hardware was evaluated for microbiological resistance and found acceptable based on its accessibility for cleaning.

Conclusion:
There are no limitations on the use of the AMS-02 data interface hardware in Orbiter and ISS habitable areas.

MPE - C. Chang

ATTACHMENT 2

Attachment to MATL – **09-036**

AMS-02 RS422 T-0/PDIP Cable Assembly	SED39136112-302
DDRS-02 Assembly	SED39136116-301
USB422 Assembly	SED39137921-301
AMS-02 USB-422/PDIP Cable Assembly	SED39136111-301
USB A/B Cable Assembly	SED39136130-801

PAYLOAD FLIGHT HAZARD REPORT				a. NO: AMS-02-F04
b. PAYLOAD	Alpha Magnetic Spectrometer-02 (AMS-02)			c. PHASE: III
d. SUBSYSTEM:	Pressure Systems	e. HAZARD GROUP:	Structural	f. DATE: August 4, 2010
g. HAZARD TITLE:	Overpressurization of Orbiter Payload Bay			i. HAZARD CATEGORY: CATASTROPHIC X / CRITICAL
h. APPLICABLE SAFETY REQUIREMENTS:	NSTS 1700.7B, 200.1, 200.2, 200.3, 200.4a, 201.3, 202.6, 205, 206, 208.4, 208.4a, 208.4b, 208.4c, 208.4e			
j. DESCRIPTION OF HAZARD:	Nominal or fault venting/release of stored gases (TRD Gas Supply (CO_2, Xe) and the Thermal Control System (Ammonia, CO_2) generates excessive volume/pressure within the Orbiter payload bay during ascent or entry (doors closed) damaging the payload bay doors or aft bulkhead. Damage of these critical structures can result in the loss of Orbiter safe entry capability.			

k. CAUSES

(list)

1. Nominal boil off of cryogenic helium <Deleted>
2. Loss of Vacuum Case thermal isolation <Deleted>
3. Leakage of Warm Helium Gas Supply <Deleted>
4. Leakage of TRD Gas System
5. Leakage of Thermal Control Systems
6. Blockage of Payload Bay Vents with MLI

o. APPROVAL	PAYLOAD ORGANIZATION	SSP/ISS
PHASE I		
PHASE II		
PHASE III		

PAYLOAD FLIGHT HAZARD REPORT	a. NO: AMS-02-F04
b. PAYLOAD Alpha Magnetic Spectrometer-02 (AMS-02)	c. PHASE: III

l. HAZARD CONTROL (CONTROL), m. SAFETY VERIFICATION METHODS (SVM), n. STATUS OF VERIFICATIONS (STATUS)	OPS CONTROL
1. CAUSE: <Deleted. Cryomagnet System Removed from AMS-02>	
2. CAUSE: <Deleted. Cryomagnet System Removed from AMS-02>	
3. CAUSE: <Deleted. Warm Helium Gas Supply Removed from AMS-02>	
4. CAUSE: Leakage of TRD Gas System	
4.1 CONTROL: During ascent and landing phases, each of the TRD Xenon and Carbon Dioxide gas tanks are isolated by three valves and flow limiting orifices. Valves are normally closed and close when power is removed. During Ascent the AMS-02 is depowered and no power is available for operations. If these valves are open, by three fault conditions in the valve mechanisms, and the gas pressure released through a flow restricting orifice to the vent line, protected by burst disk and pressure relief valves (will open under direct pressure of tanks), Xenon and Carbon Dioxide gas will be released into the payload bay. Xenon will have the highest continuous mass flow rate potential through a single burst disc with a value of 5 g/sec (0.0017 ft^3/s). Carbon dioxide will have the flow rate of 0.3 g/s (0.005 ft^3/s). These continuous rate values are achieved after a release of stored pressure within the mixing tank of 10 grams for the Xenon or 3 grams for the Carbon Dioxide. Operation of valves would require powering of AMS control systems that are unpowered during ascent. Under nominal operations (installed on ISS) the worst case leakage through the sensor straws has been established by testing to be 3.1 x 10^{-6} l/sec. During operations on the ISS, a mixed gas purge may be used to assure a known mix of gases within Box C. 4.1.1 SVM: Review of design to confirm implementation of valves and orifices to isolate gas supply tanks. 4.1.2 SVM: Inspection of as built hardware to confirm implementation of valves to isolate gas supply tanks. 4.1.3 SVM: Functional testing of TRD confirms operation of valves to close with power removal. 4.1.4 SVM: Environmental/vibration testing to confirm valves remain closed during ascent/descent conditions. 4.1.5 SVM: Xenon and Carbon Dioxide Tanks will be filled with the appropriate gases per ground filling procedures. 4.1.6 SVM: Vent Rate Analysis 4.1.7 SVM: Approval of Venting Analysis 4.1.1 STATUS: Closed. ESCG Memorandum ESCG-4175-09-REENTES-MEMO-0011, “Review of TRD Gas Supply Design,” dated March 20, 2009	

4.1.2 STATUS: Closed. ESCG Memorandum ESCG-4295-09-CPAS-MEMO-0019, "Review of the AMS-02 TRD Gas Supply Acceptance Data Package," dated December 22, 2009.

4.1.3 STATUS: Closed. “UG and UGPD test report,” A. Bartoloni, B. Borgia, T. Siedenburg, F. R. Spada, CERN, 6/17/2009

4.1.4 STATUS: Closed. ESCG Memorandum ESCG-4295-09-CPAS-MEMO-0019, "Review of the AMS-02 TRD Gas Supply Acceptance Data Package," dated December 22, 2009.

4.1.5 STATUS: Closed. AMS-02 Task Sheet (ATS) TRD 090131-1, “TRD_GAS_SUPPLY_SYSTEM_CO2_VESSEL_FILLING_FOR_FLIGHT,” and TRD 090522-1, “TRD_GAS_SUPPLY_SYSTEM_XENON_VESSEL_FILLING_FOR_FLIGHT,” establish filling procedures.

4.1.6 STATUS: Closed. “Determination of venting flow rate for AMS TRD Gas System,” 23 June 2004, Ulrich Becker, Peter Fisher.

4.1.7 STATUS: Closed. Contractor Shuttle Integration Office has assessed all possible gas release scenarios and provided acceptance of them. This is documented in Boeing technical memorandums TS-TM02-064 dated December 12, 2002, additionally gas release from associated sources were reviewed and found acceptable in Boeing Technical Memorandums TS-TM-05-37, dated December 9, 2005 and TS-TM-07-035 dated August 8, 2007. All have been concurred to by Shuttle Integration Representative to PSRP.

4.2 CONTROL: The construction of the TRD high pressure gas supply utilizes stainless steel lines, (orbital) welded joints and fittings. Rupture of these DFMR lines would be required to release the pressure tank supply of gas. Reference DFMR compliance in AMS-02-F05.

4.2.1 SVM: Review of Design

4.2.2 SVM: Inspection of As Built Design.

4.2.1 STATUS: Closed. ESCG Memorandum ESCG-4175-09-REENTES-MEMO-0011, “Review of TRD Gas Supply Design,” dated March 20, 2009

4.2.2 STATUS: Closed. ESCG Memorandum ESCG-4295-09-CPAS-MEMO-0019, "Review of the AMS-02 TRD Gas Supply Acceptance Data Package," dated December 22, 2009. TRD Leak Repair, CERN weld inspection report EDMS No: 1078985 dated May 26, 2010

4.3 CONTROL: Fill and drain ports for the TRD tanks (Box S) utilize check valves and dual sealed caps to preclude gas release.

4.3.1 SVM: Review of design

4.3.2 SVM: Inspection of as built hardware.

4.3.3 SVM: Post filling inspection of cap installation

4.3.1 STATUS: Closed. ESCG Memorandum ESCG-4175-09-REENTES-MEMO-0011, "Review of TRD Gas Supply Design," dated March 20, 2009

4.3.2 STATUS: Closed. ESCG Memorandum ESCG-4295-09-CPAS-MEMO-0019, "Review of the AMS-02 TRD Gas Supply Acceptance Data Package," dated December 22, 2009.

4.3.3 STATUS: Closed to SVTL.

4.4 CONTROL: The amount of gas that can be released from the TRD Box C, including the mixing tank is limited by the volumes and pressure of mixed gases present and will not present a danger of over pressurization of the Orbiter Payload Bay during ascent and entry as the system is unpowered and the supply of gas is isolated though unpowered closed valves (7). The entire box operates at pressures lower than 17.4 psia and the total gas volume is $0.0028m^3$ ($0.1 ft^3$). The "straw" volume is divided into 41 segments, each is isolatable by redundant valves (provided for mission success reasons). A leak in any segment would release at most $0.007 m^3$ ($0.25 ft^3$) of mixed gas. If the volume of the entire straw system is released $0.23 m^3$ ($8 ft^3$) of mixed gas could be released. Mixed gas is nominally a 4 to 1 ratio of xenon to carbon dioxide. The TRD sensor straws have been tested for leakage, which easily enveloped by the fault condition, with an established leak rate for an <u>operational</u> TRD of 3.1×10^{-6} l/sec.

4.4.1 SVM: Review of design

4.4.2 SVM: Inspection of as built hardware.

4.4.1 STATUS: Closed. ESCG Memorandum ESCG-4175-09-REENTES-MEMO-0011, "Review of TRD Gas Supply Design," dated March 20, 2009

4.4.2 STATUS: Closed. ESCG Memorandum ESCG-4295-09-CPAS-MEMO-0019, "Review of the AMS-02 TRD Gas Supply Acceptance Data Package," dated December 22, 2009.

5. CAUSE: Leakage of Thermal Control Systems

5.1 CONTROL: The Tracker TCS (TTCS) utilizes two actively pumped carbon dioxide loops that contain approximately 842 grams of CO_2 in the largest of the two loops (approx $15.05 ft^3$ ($0.426 m^3$) @ STP). Loops operate in a sealed mode qualified under DFMR without nominal or fault venting, reference AMS-02-F05.

5.1.1 SVM: Review of Design

5.1.2 SVM: Approval of AMS-02 Potential Gas Release

PAYLOAD FLIGHT HAZARD REPORT	a. NO: AMS-02-F04
b. PAYLOAD Alpha Magnetic Spectrometer-02 (AMS-02)	c. PHASE: III

5.1.1 STATUS: Closed. Email from NLR/J. Van Es, "TTCS Pressure Tables," on May 29, 2010 with fill volumes of Primary 816 g and Secondary 842 g quantities. TTCS Fill report, transmitted by NLR/Johannes Van Es for Primary (819 grams CO_2) and Secondary (850 grams CO_2) Loops, dated 7/26/2010. Fill quantities make mass per liter of internal volume under the maximum allowed for establishing MDP.

5.1.2 STATUS: Closed. Contractor Shuttle Integration Office has assessed all possible gas release scenarios and provided acceptance of them. This is documented in Boeing technical memorandums TS-TM02-064 dated December 12, 2002, additionally gas release from associated sources were reviewed and found acceptable in Boeing Technical Memorandums TS-TM-05-37, dated December 9, 2005 and TS-TM-07-035 dated August 8, 2007. All have been concurred to by Shuttle Integration Representative to PSRP.

5.2 CONTROL: <Deleted. Cryocooler Loop Heat Pipe Removed from the AMS-02>

5.3 CONTROL: Radiator panels contain isolated heat pipe (and USS-02) elements with ammonia as a working fluid. Largest single heat pipe quantity of ammonia is less than 41 grams (32.7 grams maximum final fill of a single heat pipe). Heat pipes operate as closed systems qualified under DFMR and have no nominal or fault venting conditions, reference AMS-02-F05.

5.3.1 SVM: Review of Design

5.3.2 SVM: Approval of AMS-02 Potential Gas Release

5.3.1 STATUS: Closed. ESCG-4470-09-TEAN-DOC-0121, "AMS-02 Heat Pipes and Loop Heat Pipes Fluid Fill Quantities," dated September 1, 2009

5.3.2 STATUS: Closed. Contractor Shuttle Integration Office has assessed all possible gas release scenarios and provided acceptance of them. This is documented in Boeing technical memorandums TS-TM02-064 dated December 12, 2002, additionally gas release from associated sources were reviewed and found acceptable in Boeing Technical Memorandums TS-TM-05-37, dated December 9, 2005 and TS-TM-07-035 dated August 8, 2007. All have been concurred to by Shuttle Integration Representative to PSRP.

5.4 CONTROL: <Deleted. OHP Removed from AMS-02>

5.5 CONTROL: <Deleted. The CAB Loop Heat Pipes Removed from AMS-02>

5.6 CONTROL: <Deleted. The Cryocooler Removed from AMS-02>

5.7 CONTROL: TTCS Accumulator Heat Pipes contains 3.6 grams (max) of ammonia. The TTCS Accumulator Heat Pipe is a closed system qualified under DFMR and has no nominal or fault venting conditions, reference AMS-02-F05.

5.7.1 SVM: Review of the Design

5.7.2 SVM: Approval of AMS-02 Potential Gas Release

5.7.1 STATUS: Closed. ESCG-4470-09-TEAN-DOC-0121, "AMS-02 Heat Pipes and Loop Heat Pipes Fluid Fill Quantities," dated September 1, 2009

5.7.2 STATUS: STATUS: Closed. Contractor Shuttle Integration Office has assessed all possible gas release scenarios and provided acceptance of them. This is documented in Boeing technical memorandums TS-TM02-064 dated December 12, 2002, additionally gas release from associated sources were reviewed and found acceptable in Boeing Technical Memorandums TS-TM-05-37, dated December 9, 2005 and TS-TM-07-035 dated August 8, 2007. All have been concurred with by Shuttle Integration Representative to PSRP.

6. CAUSE: Blockage of Payload Bay Vents with MLI

6.1 CONTROL: All MLI and thermal blankets used on the AMS-02 will be secured to AMS using positive mechanical means. "Soft": techniques such as hook and loop fasteners (Velcro ®) will not be used as a primary means of retaining the AMS-02 MLI and thermal blankets. Note GFE provided by Shuttle/ISS Programs are independently certified and used by tha AMS-02 in accordance with their certifications, may exclusively use hook and loop fasteners for retaining thermal blankets.

6.1.1 SVM: Review of design

6.1.2 SVM: Inspection of as built hardware.

6.1.1 STATUS: Closed. ESCG Memorandum ESCG-4470-09-TEAN-DOC-0025, "Attachment of AMS-02 Thermal Blankets". Dated February 27, 2009

6.1.2 STATUS: Closed to SVTL.

Notes:

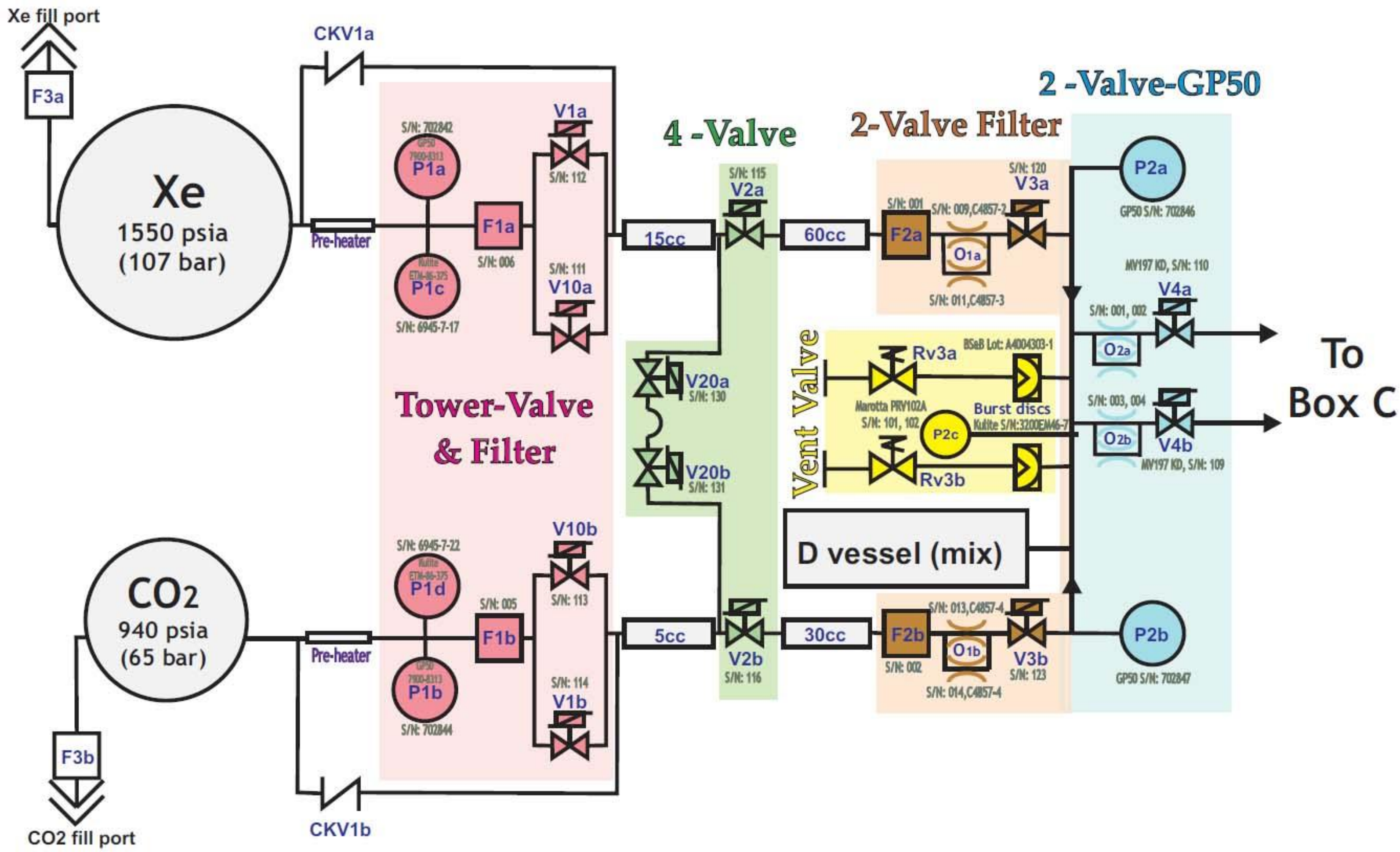
Fluid/Gas (at STP)	g/l	lb/ft^3
Ammonia	0.7710	0.11135
Carbon Dioxide	1.9769	0.12341
Xenon	5.85	0.365

ACRONYMS	
°C – Degrees Centigrade (Celsius)	MDP – Maximum Design Pressure
°F – Degrees Fahrenheit	mg/sec – milligrams per second
AMS-02 – Alpha Magnetic Spectrometer 02	min – Minutes
atm – atmospheres	MLI – Multilayer Insulation
C of C – Certificate of Compliance	MUA – Material Usage Agreements
CAB – Cryomagnet Avionics Box	Ops – Operations
CDC – Cool Down Circuit	PGSC – Payload General Support Computer
CHX – Cold Heat Exchanger	psia – pounds per square inch absolute
CO_2 – Carbon Dioxide	psid – pounds per square inch differential
COTS – Commercial Off the Shelf	PSRP – Payload Safety Review Panel
DDRS2 – Digital Data Recording System 2	QA – Quality Assurance
DFMR – Design for Minimum Risk	SCL – Space Cryomagnetics Limited
ft^3 – Cubic Feet	SCL – Superfluid Cooling Loop
ft^3/s – Cubic feet per second	SFHe – Superfluid Helium
g/l – Grams per liter	STA – Structural Test Article
He – Helium	STA – Structural Test Article
K – Kelvin	STP – Standard Temperature and Pressure
K – Kelvin	SVM – Safety Verification Method
kg/sec – kilograms per second	SVP – Safety Verification Plan
ksi – kilo pounds per square inch	TCS – Thermal Control System
lb/ft^3 – Pound per cubic foot	TIM – Technical Interchange Meeting
lb/sec – Pounds (mass) per second	TRD – Transition Radiation Detector

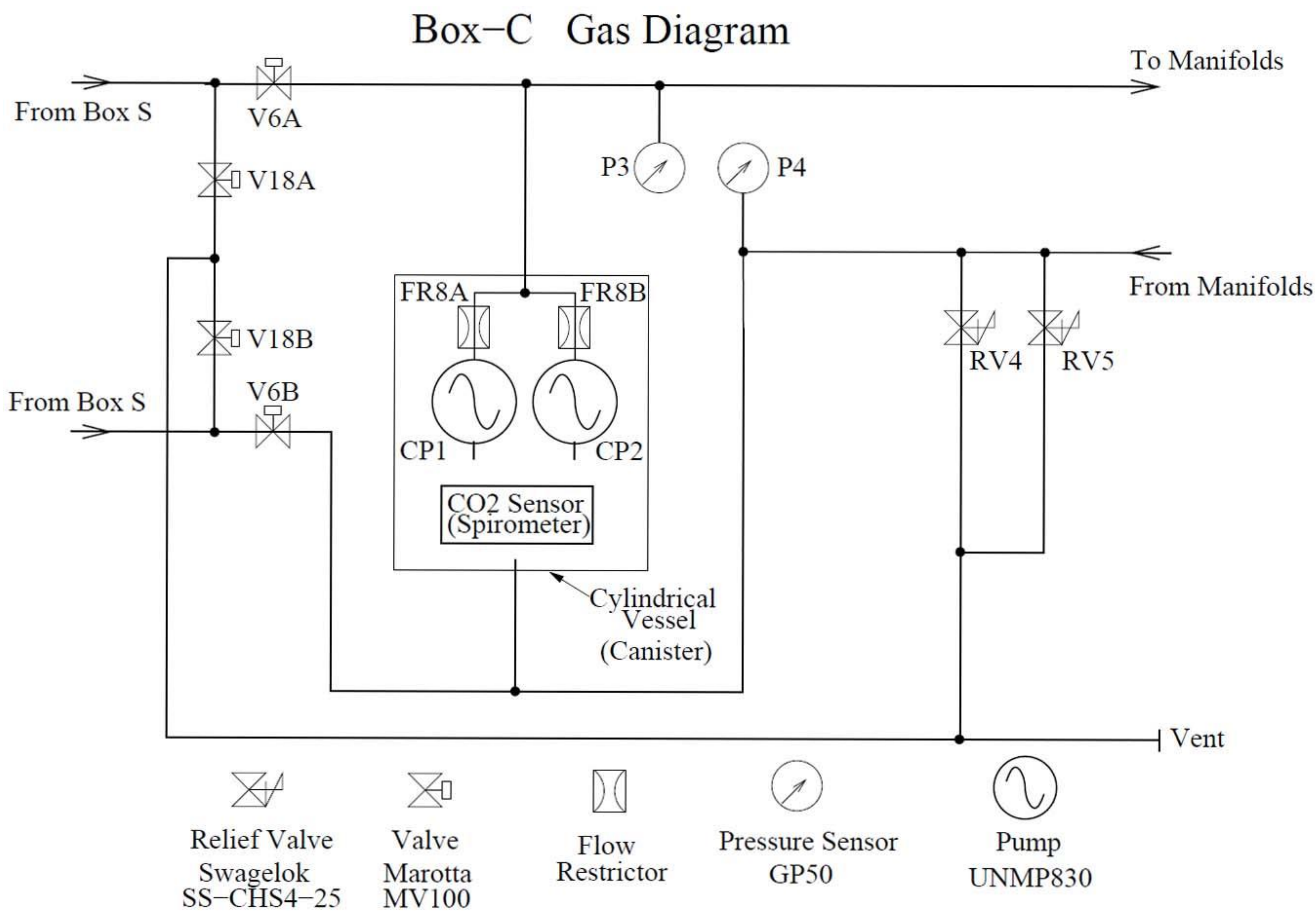
ACRONYMS	
lbf – pound force	TTCS – Tracker Thermal Control System
M/OD – Meteoroid/Orbital Debris	ult – Ultimate
m^3 – Cubic Meters	USS-02 – Unique Support Structure 02
m^3/sec – Cubic meters per second	VC – Vacuum Case
mbar – millibar	Xe – Xenon
MUA – Material Usage Agreements	OHP – Oscillating Heat Pipe (Deleted from Design)

Stored Gas Reservoirs				
System	Working Fluid	Quantity	Gas Volume (at STP)	Notes:
TRD Xenon Gas Supply	Xenon (Xe)	109 lbs (49.4 kg)	299 ft^3 (8.46 m^3)	Three failures to open valves during ascent/descent, worst case sustained flow is 0.03 ft^3/s (Single burst disc open).
TRD Carbon Dioxide Gas Supply	Carbon dioxide (CO_2)	12 lbs (5.5 kg)	98.2 ft^3 (2.78 m^3)	Three failures to open valves during ascent/descent, worst case sustained flow is 0.005 ft^3/s (Single burst dic open).
TRD Mixing Vessel/Box C	4:1 Xenon: CO_2 mix	Quantity supplied from TRD Box S ⇒ 0.04 lbs (0.03 kg)	0.012 m^3	During ascent/descent this is a non-operational system that requires the Box S to charge Box C with gas pressure and a failure of a relief valve.
TRD proportional counters "Straws", manifold & delivery from Box C	4:1 Xenon: CO_2 mix	Quantity supplied from TRD Box C ⇒ 2.58 lbs (1.17 kg)	0.23 m^3 total with 0.0056 m^3 per straw segment with interconnecting tubing and connection to Box C	Straw Modules are approximately 500 m in length with sixteen straws per module (dia. of 6 mm). Interconnecting tubing and connection to the Box C account for less than 0.001 m^3 each. This value is rounded up to 0.23 m^3.
Tracker TCS	Carbon dioxide	816g/842g grams (two loops)	15.05 ft^3 (0.426 m^3) max per loop	Closed system design qualified under Design for Minimum Risk (DFMR) Criteria
Heat Pipes (various)	Ammonia	Largest Quantity in single heat pipe is 32.7 grams	2.01 ft^3 (0.057 m^3)	Closed heat pipe systems qualified under DFMR criteria
USS-02 Heat Pipes	Ammonia	3 pipes with 7.6 grams each	0.35ft^3 (0.01m^3)	Closed heat pipe qualified under DFMR criteria
TTCS Accumulator Heat Pipe	Ammonia	2 pipes, 3.6, 3.3 grams	0.16ft^3 (0.0046m^3)	Closed heat pipe qualified under DFMR.

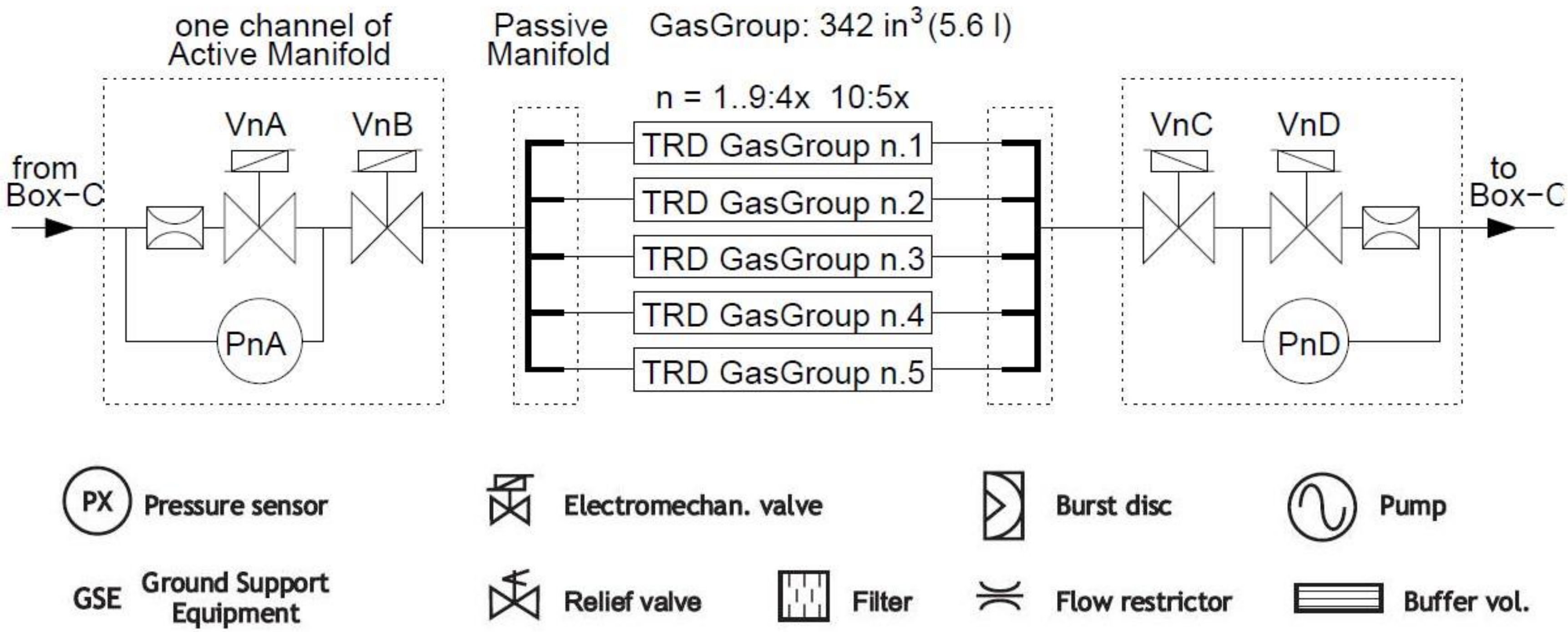
Box S Schematic



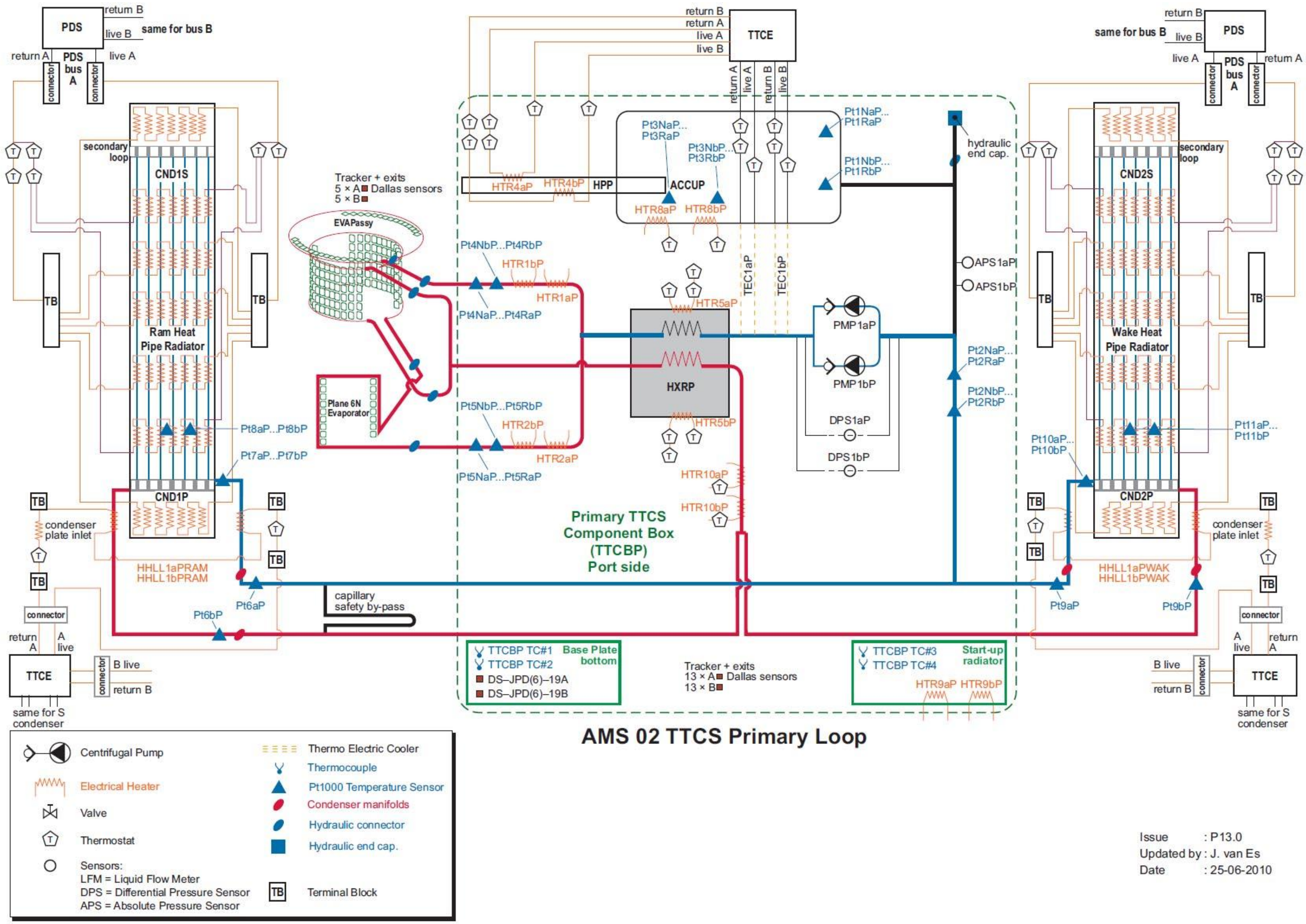
TRD Box S (Pressures are nominal operating pressure)


Box−C Gas Diagram
To Manifolds
From Box S
V6A
V18A
P3
P4
From Manifolds
FR8A
FR8B
V18B
RV4
RV5
From Box S
V6B
CP1
CP2
CO2 Sensor
(Spirometer)
Cylindrical
Vessel
(Canister)
Vent
Relief Valve
Swagelok
SS−CHS4−25
Valve
Marotta
MV100
Flow
Restrictor
Pressure Sensor
GP50
Pump
UNMP830

TRD Box C

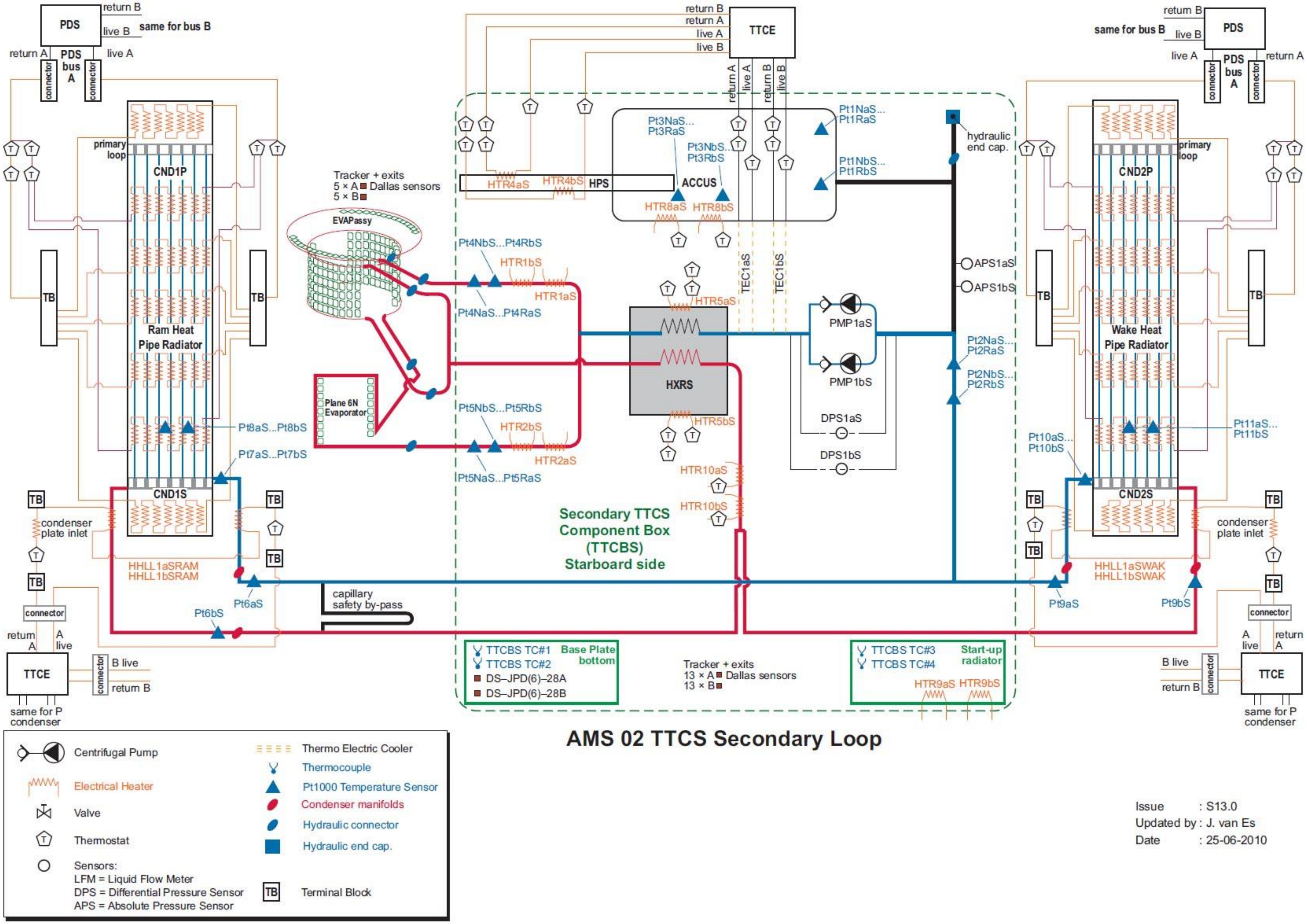


TRD Manifold-Straw Representation



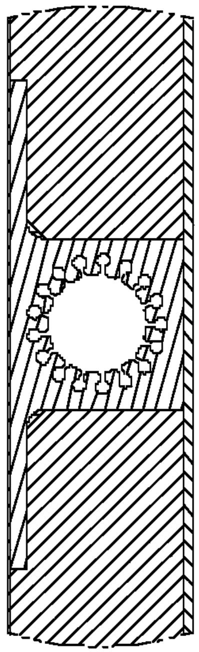
AMS 02 TTCS Primary Loop

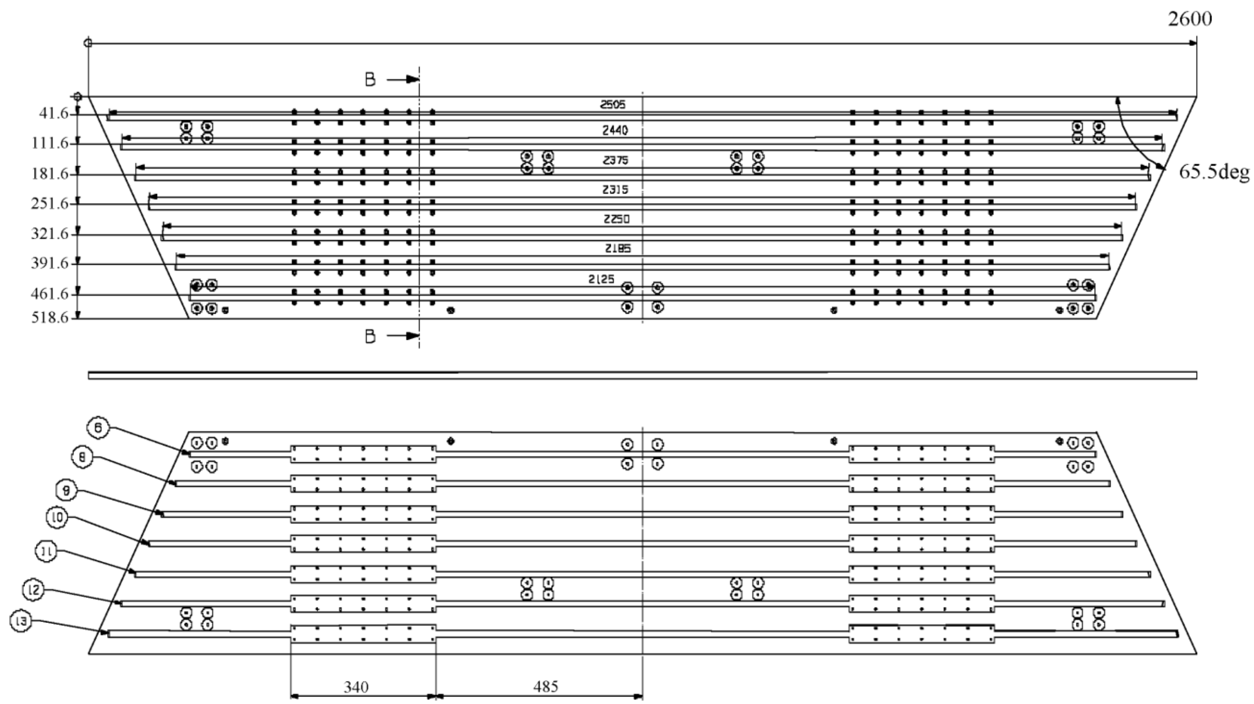
Issue : P13.0
Updated by : J. van Es
Date : 25-06-2010



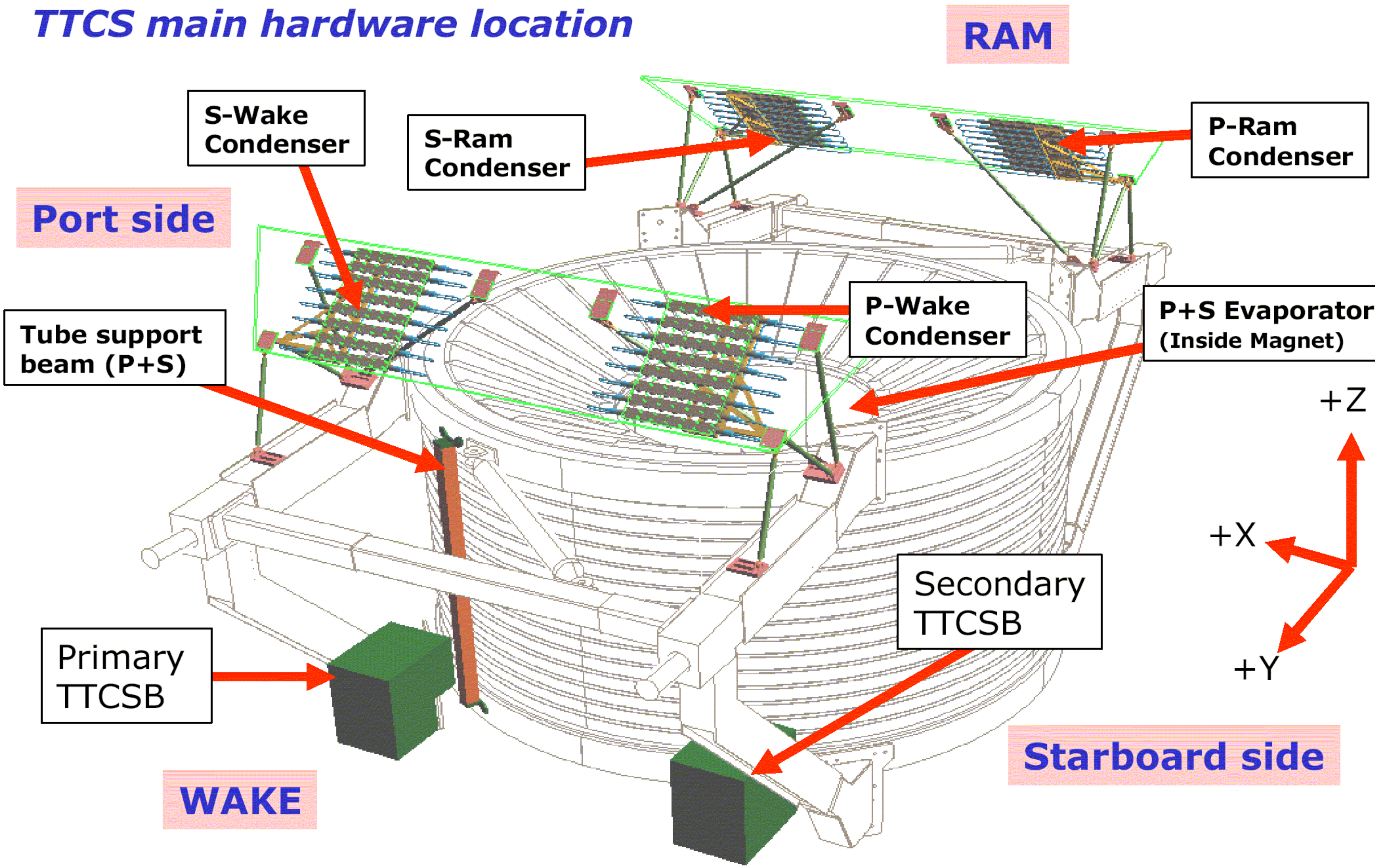
AMS 02 TTCS Secondary Loop

Tracker
Heat
Pipe

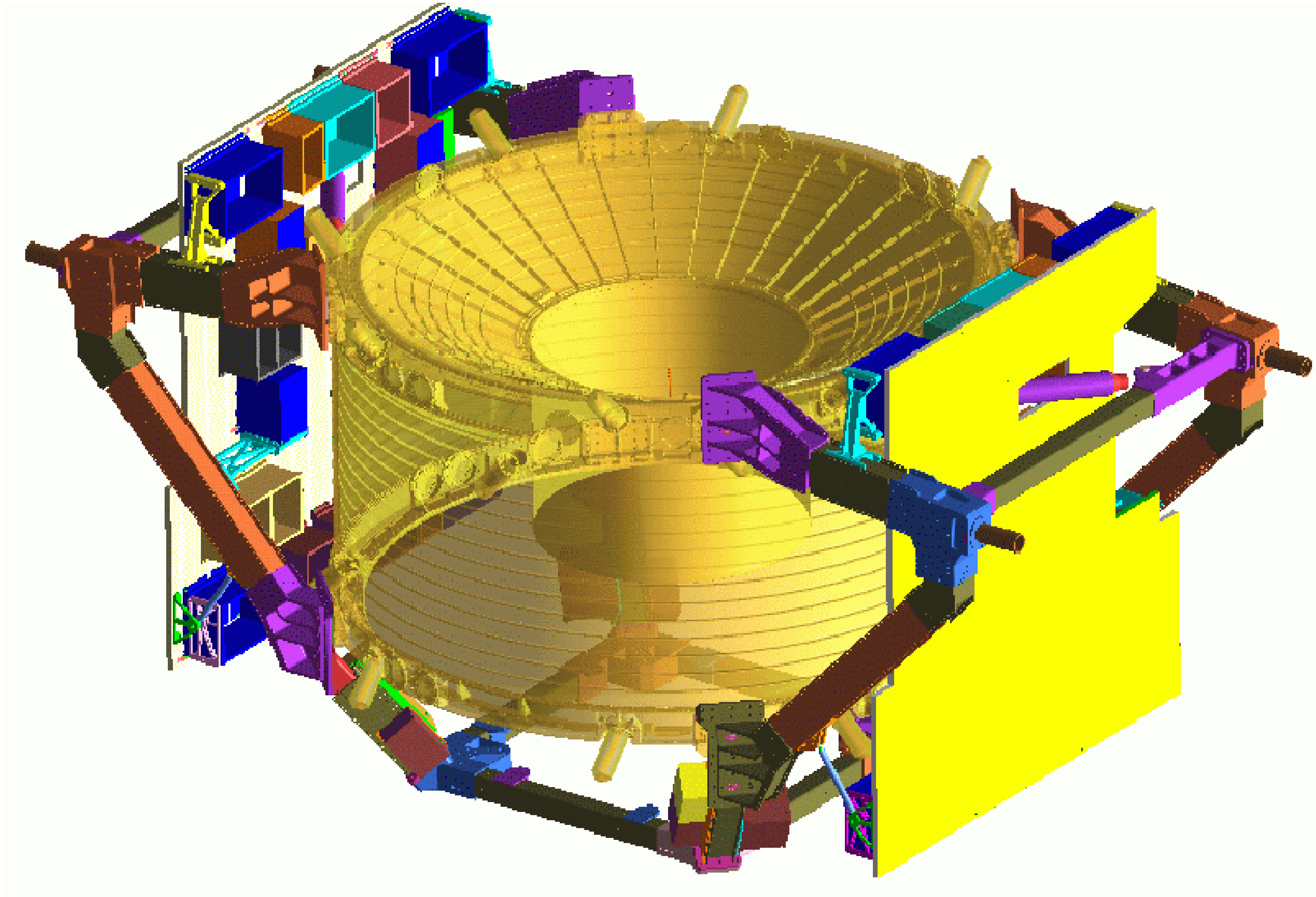




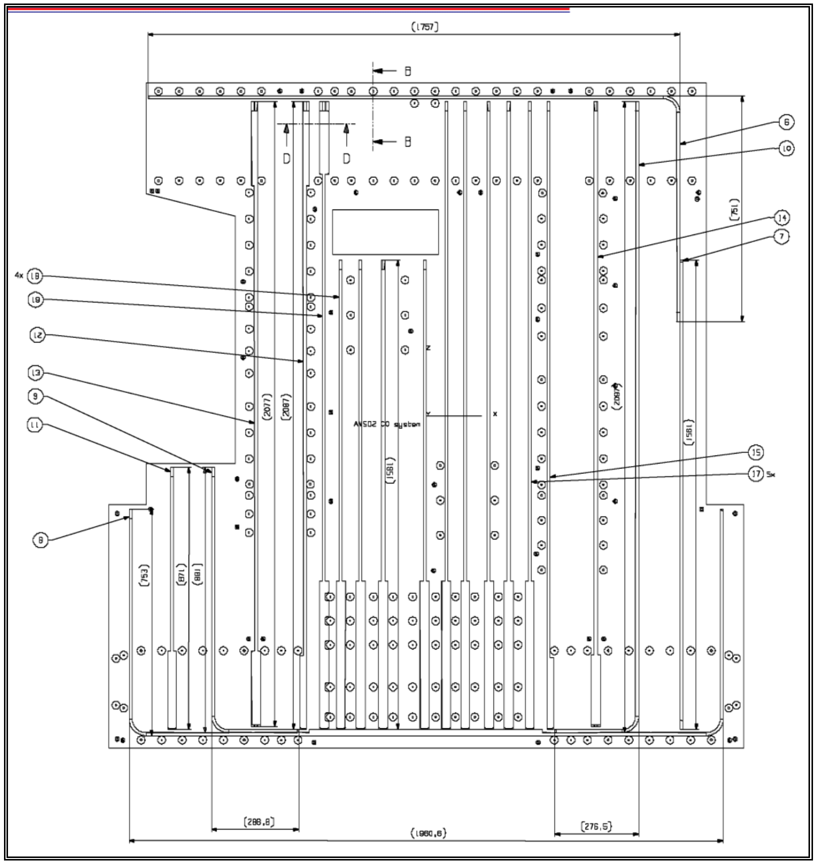
Tracker TCS Heat Pipe Layout



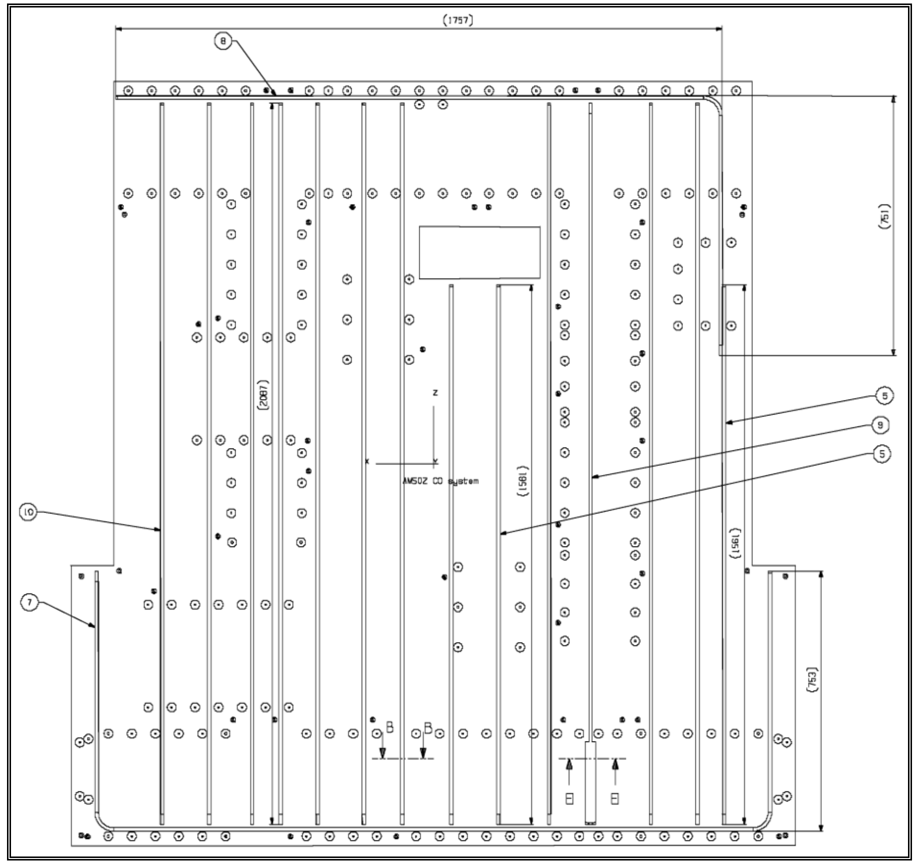
Components of the Tracker Thermal Control System



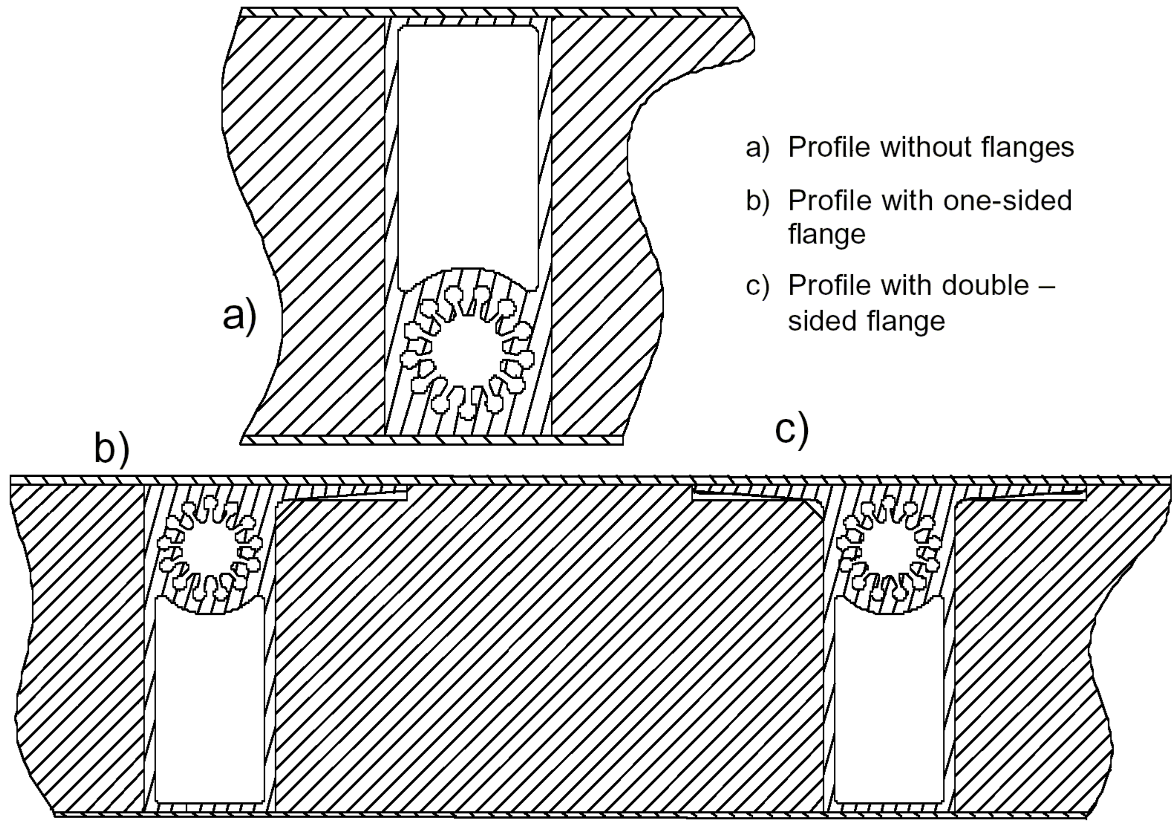
AMS-02 Wake and Ram Radiators



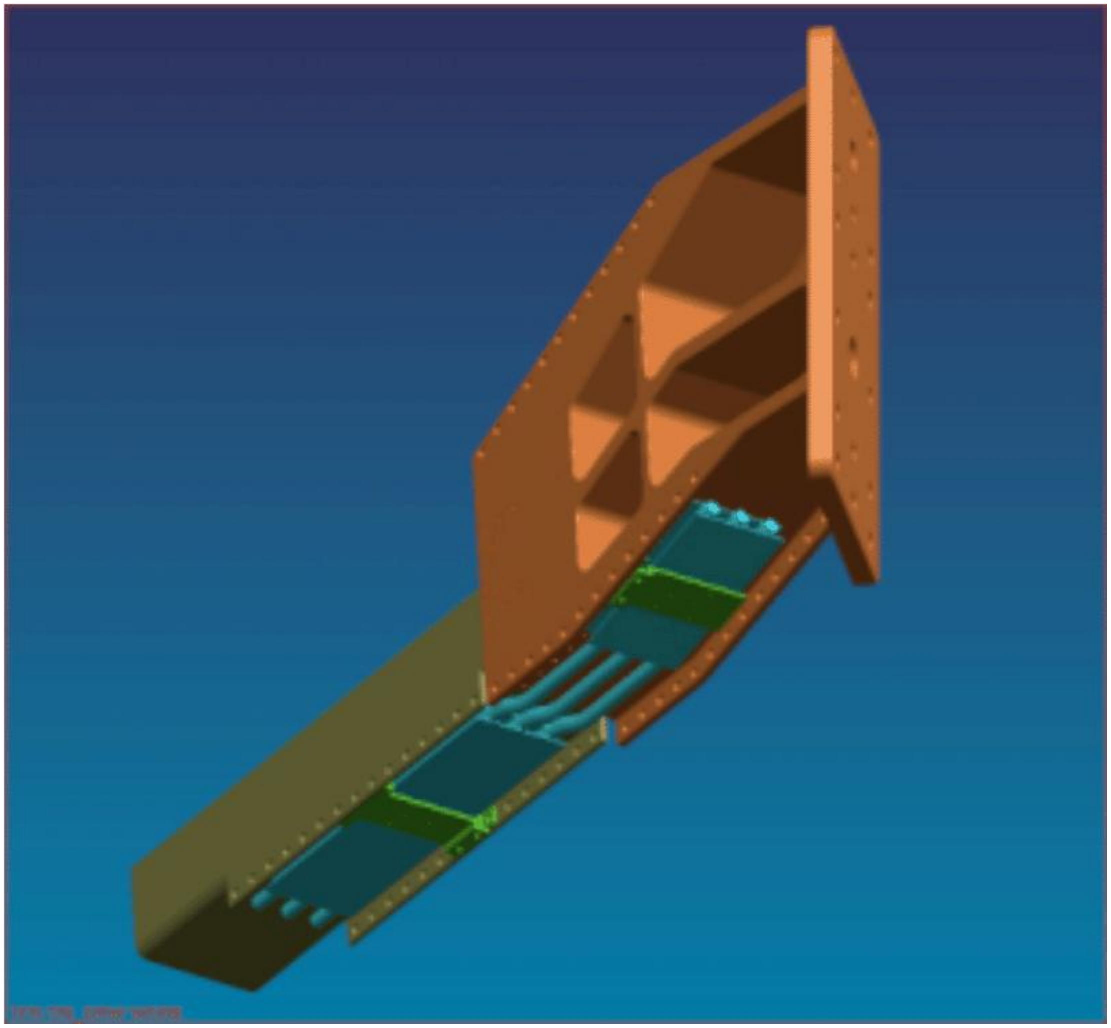
TCS – Wake Side Radiator for Avionics Crates



TCS – Ram Side Radiator for Avionics Crates



TCS Wake and Ram Radiators Heat Pipe Methods of Mounting



CAB USS Heat Pipes – Enveloped in Heat Pipe Analyses

BOEING ***Technical Memorandum***

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Date	December 19, 2002	No.	TS-TM-02-064
To:	Darryl L. Archer IDS – NASA Systems D/J387, HS3-30	From:	Mark E. Fields IDS – NASA Systems D/J351, HS3-30 281-226-5814

Subject: Alpha Magnetic Spectrometer II During Ascent and Descent Orbiter Operations

Contract:	NAS9-20000
Purchase Order:	1970483303
PDRD No.:	N/A
WBS No.:	1.7.1.1
Task No.:	70004
Artemis No:	N/A

References:

1. Request for Assessment, B. Harris, USA, Tracking # TH-GEN-010, December 16, 2002.
2. Fields, M. E., “Superfluid Helium Venting into the Payload Bay from the Alpha Magnetic Spectrometer II During Ascent and Descent Mission Phases”, TM-TS-00-048, December 15, 2000.
3. Harrison, S. M., “Loss of Vacuum and Venting from the AMS-02 Cryostat”, Lockheed Martin Technical Report, December 11, 2002

1.0 Summary

The Alpha Magnetic Spectrometer II (AMS-2) is an experiment proposed for flight to the International Space Station. The AMS-2 is comprised of a large superfluid helium dewar insulated by a vacuum jacket. The large volume of the superfluid helium if vented into the payload bay during ascent or descent phases would cause pressure increases on structures above Orbiter certification. Current failure venting scenarios of the AMS-2 specify that any release of helium into the payload bay would be after the critical portion of the ascent phase or would happen after landing of the descent phase (Ref 1).

2.0 Background

The AMS-2 contains 2460 liters (86.87 ft^3) of superfluid helium cooled to a temperature of 1.8°K (-456.4°F). The helium, if released, would vaporize to a volume of approximately 76000 ft^3. The payload bay and lower mid-fuselage volume is 18400 ft^3. Previous venting analysis of the AMS-2 (Ref 2) has demonstrated that the increase in the pressure due to the release of the helium would exceed Orbiter certification of existing structures. That study analyzed the helium leaking into the payload bay during the first 3 minutes of the ascent mission phase and during the open vent door portion of the descent mission phase. The leak rate was a blow-down curve that had a duration of 700+ seconds. The failure scenario involved a large hole in the vacuum jacket with an approximate area of 3.29 in^2 that allowed external air to compromise the AMS-2.

The current failure scenario of the AMS-2 involves the O-rings that seal the vacuum jacket. The equivalent hole size in the vacuum jacket is 0.0095 in^2 (Ref 3) due to the O-ring failure. This smaller hole along with factors associated with the size, allow for a longer time between vacuum jacket failure and the release of the helium. This extension prohibits the accumulation of external gasses due to the attainment of a near vacuum in the payload bay after 3 minutes of the ascent flight. During descent, the 23 minutes specified in Reference 2 would place the time of helium release after Orbiter landing.

3.0 Conclusion

The release of the superfluid helium from the AMS-2 cryostat into the payload bay would exceed the certification levels of many Orbiter structures if it occurred during the critical ascent and descent mission phases. The specified failure scenario of the protective O-rings sealing the vacuum jacket of the AMS-2 helium cryostat does not allow the release of helium during any of these critical mission phases.

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BOEING

Technical Memorandum

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Date: December 9, 2005 No.: TS-TM-05-037

To: W.K. Smith
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From: William R. Griebel
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281-226-8818

Subject: Venting Case s70: Overpressurization Assessment of AMS-02 Warm Helium System

Contract:	NAS9-20000
Purchase Order:	1970483303
PDRD No.:	N/A
WBS No.:	1.7.1.1
Task No.:	70004
Atremis No.:	N/A

References:

1. Email from L. Hill/Hernandez Engineering to Brad Harris, November 10, 2005. Subject was overpressurization of payload bay.
2. Nieder, R. L., "Venting Analysis Digital Computer Program (VADIC)", JSC-20779, September 1985.
3. Request for Assessment, TH-GEN-014, B. Harris, USA, November 17, 2005.

An analysis was performed to determine the effects of a helium leak into the orbiter payload bay. The leak is a failure scenario associated with the Alpha Magnetic Spectrometer II (AMS-02) payload Warm Helium System. The failure condition is a rupture of the helium container resulting in total release of the helium (Reference 3). The only hazardous gas problem analyzed in this study is possible overpressurization of the orbiter. The analysis was performed with the VADIC vent program (Reference 2) and the flight correlated models of the STS-63 ascent and descent.

The burst point of the helium vessel is 320 bars (668,334 pound/ft^2) at a temperature of 295 K. The total initial mass of the helium is 0.43349 kg. The vessel volume is 8.3 liters. The payload bay volume was set at 15000 cubic feet. The leak rate was modeled from a blowdown curve provided by Leland Hill at Hernandez Engineering Inc (Reference 1). The curve assumed a 3.2mm diameter hole venting to vacuum.

The ascent analysis investigated a helium leak beginning at liftoff (T+0) and near the peak payload bay to ambient pressure differential (T+35). The timeline ran for 180 seconds after launch, and the blowdown curve extended for approximately 22 seconds. The rate of helium mass flow would decrease to zero, but for simplicity the final value from the curve was assumed to continue for the remaining 158 seconds. This assumption is conservative because it models a higher mass flow into the payload bay than would actually occur.

The descent analyses investigated a leak beginning at entry interface (EI) and near the peak payload bay to ambient pressure differential (EI+930). The descent analyses looked only at the closed door phase of the descent. The open door phase was not included based on the results of the ascent analysis and because during descent the compartments are repressurizing rather than depressurizing. The descent timeline extends for 1937 seconds. The blowdown curve extends for 22 seconds. The helium mass flow was assumed to go to zero 40 seconds after the leak began. This was based on the mass flow rate at the end of the blowdown curve; if that rate were held constant the remaining helium would be gone 9 seconds later. The 9 seconds was doubled to account for the linear interpolation between data points.

An assessment of the predicted pressure increments resulting from the inadvertent/planned payload venting has been performed. The results have been determined to be acceptable and both the Orbiter PV&D and Orbiter Stress SSMs concur.

Payload venting was not considered in the Orbiter structural certification analysis. Although this failure case results in a pressure increment that is outside of Orbiter Certification, it was determined that the Orbiter has the capability to sustain this loading without structural damage or loss of mission. This contingency case assessment is valid for the AMS-02 payload on flight UF-4, and includes no other venting or leaking payloads.

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Table 1: Case Description Matrix

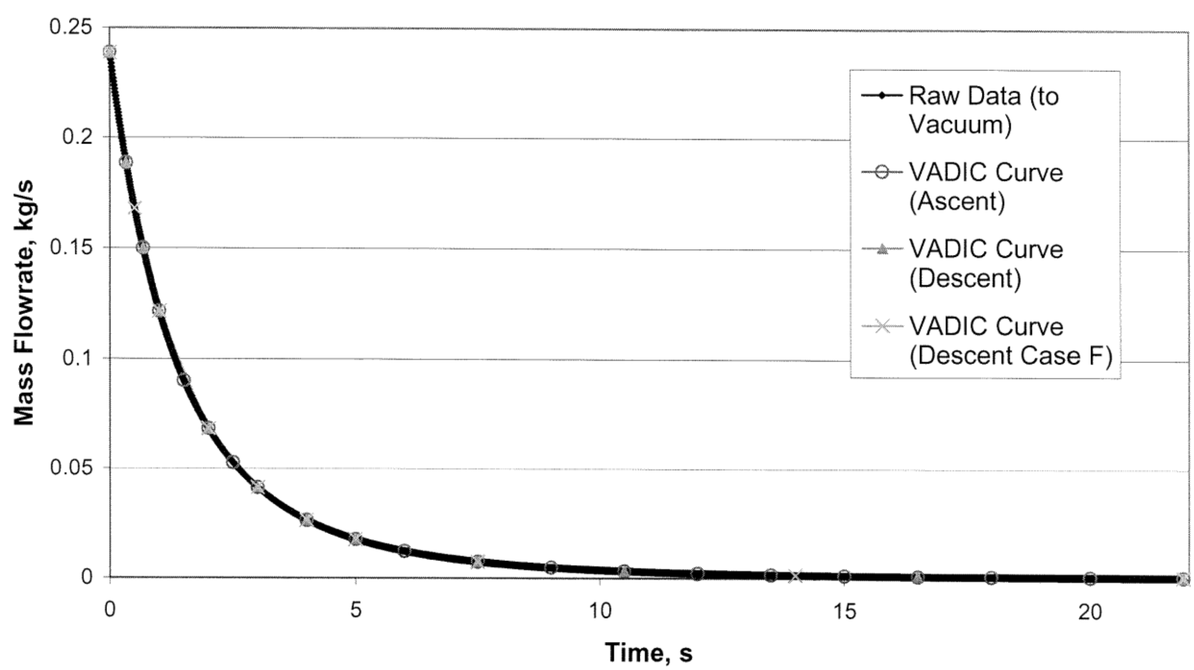
Case #	Model	Trajectory	Leak Time (sec)	Description
S70A	103FC	STS63 ASC BET	-	Baseline OV-103 Ascent Common Vent Model
S70B	103FC	STS63 ASC BET	T+0	Helium Disk Fails at Launch
S70C	103FC	STS63 ASC BET	T+35	Helium Disk Fails at T+35 (Max Baseline dP)
S70D	103FC	STS63 DSC BET	-	Baseline OV-103 Descent Common Vent Model
S70E	103FC	STS63 DSC BET	EI+0	Helium Disk Fails at Entry Interface
S70F	103FC	STS63 DSC BET	EI+930	Helium Disk Fails at EI + 930 (Max Baseline dP)

C 49978D

Table 2: Case s70 Timelines

	Ascent						Descent					
	Case B (Leak at Launch)			Case C (Leak at L+35)			Case E (Leak at EI)			Case F (Leak at EI+930)		
	Time	Event	Mass Flow	Time	Event	Mass Flow	Time	Event	Mass Flow	Time	Event	Mass Flow
	(seconds)		(slug/s)	(seconds)		(slug/s)	(seconds)		(slug/s)	(seconds)		(slug/s)
1	-60.00		0.000000	-60.00		0.000000	0.00	EI	0.016360	0.00	EI	0.000000
2	-0.10		0.000000	-0.10		0.000000	0.33		0.012930	1.00	EI+1	0.000000
3	0.00	Launch	0.016360	0.00	Launch	0.000000	0.67		0.010286	929.00	Leak -1	0.000000
4	0.33		0.012930	34.90	Leak -0.1	0.000000	1.00	EI+1	0.008336	930.00	Leak Starts	0.016360
5	0.67		0.010286	35.00	Leak	0.016360	2.00		0.004683	930.50		0.011514
6	1.00		0.008336	35.33		0.012930	3.00		0.002829	931.00		0.008336
7	1.50		0.006183	35.67		0.010286	4.00		0.001808	932.00		0.004683
8	2.00		0.004683	36.00		0.008336	5.00		0.001209	933.00		0.002829
9	2.50		0.003610	36.50		0.006183	7.50		0.000513	934.00		0.001808
10	3.00		0.002829	37.00		0.004683	10.50		0.000223	935.00		0.001209
11	4.00		0.001808	37.50		0.003610	16.50		0.000062	937.50		0.000513
12	5.00		0.001209	38.00		0.002829	21.89		0.000026	944.00		0.000101
13	6.00		0.000839	39.00		0.001808	40.00	Est. He gone	0.000000	951.89		0.000026
14	7.50		0.000513	40.00		0.001209	1337.00	V=5300	0.000000	970.00	Est. He gone	0.000000
15	9.00		0.000330	41.00		0.000839	1338.00	FULL UP PRG	0.000000	1337.00	V=5300	0.000000
16	10.50		0.000223	42.50		0.000513	1387.00	PRG+50	0.000000	1338.00	FULL UP PRG	0.000000
17	12.00		0.000156	44.00		0.000330	1457.00	PRG+120	0.000000	1387.00	PRG+50	0.000000
18	13.50		0.000112	45.50		0.000223	1487.00	PRG+150	0.000000	1457.00	PRG+120	0.000000
19	15.00		0.000082	47.00		0.000156	1497.00	VENT TO OPEN	0.000000	1487.00	PRG+150	0.000000
20	16.50		0.000062	48.50		0.000112	1501.00	FULL OPEN	0.000000	1497.00	VENT TO OPEN	0.000000
21	18.00		0.000047	50.00		0.000082	1887.00	PRG+550	0.000000	1501.00	FULL OPEN	0.000000
22	20.00		0.000034	51.50		0.000062	1936.00	TRAJ END-1	0.000000	1887.00	PRG+550	0.000000
23	21.89		0.000026	53.00		0.000047	1937.00	TRAJ END	0.000000	1936.00	TRAJ END-1	0.000000
24	179.90		0.000026	56.89		0.000026				1937.00	TRAJ END	0.000000
25	180.00		0.000026	180.00		0.000026				1937.00	PRG+600	

Figure 1: VADIC Approximation of Blowdown Curve
AMS-02 Helium Vessel



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Technical Memorandum

Date:	August 9, 2007	No.:	TS-TM-07-035
To:	W.K. Smith IDS-NASA Systems HB2-30 281-226-5760	From:	William R. Griebel IDS – NASA Systems HB2-30 281-226-8818

Subject: Venting Case s73: Venting of Miscellaneous Pressure Vessels On the AMS-02 Payload

Contract:	NNJ06VA01C
Subcontract:	6000132079
PDRD No.:	N/A
WBS No.:	2.2.1.4
Task No.:	60015

References:

1. Email from Brad Harris to Guadalupe Gonzales, July 12, 2007. Subject AMS Venting
2. Nieder, R. L., “Venting Analysis Digital Computer Program (VADIC)”, JSC-20779, September 1985
3. “Space Station Payload Xenon Leak in Payload Bay During Ascent, On-Orbit and Descent”, Rockwell No. 096-P&E-045, June 19, 1996
4. “Ammonia Venting into Payload Bay from ISS PVR/FSE Failed FQDC During Ascent and Descent Mission Phases”, Boeing TM TS-TM-02-048, October 25, 2002
5. “Venting Case s70: Overpressurization Assessment of AMS-02 Warm Helium System”, Boeing TM TS-TM-05-037, December 9, 2005

The Alpha Magnetic Spectrometer II (AMS-02) payload, currently scheduled for ISS flight ULF-4, contains several pressurized vessels that could leak under certain failure conditions. A summary of these leak scenarios (Reference 1) was delivered to Boeing with a request to evaluate them for overpressurization concerns during ascent and entry. A short description and numbering of the leak cases can be found in Table 1 of this document.

A total of 11 cases were evaluated. When possible, cases were evaluated by comparison to previous analyses of the same gas.

Case 1, a leak of 109 pounds of Xenon from the TRD Xenon gas supply, was compared to analysis “Space Station Payload Xenon Leak in Payload Bay During Ascent, On-Orbit and Descent” (Reference 3), which analyzed Xenon leaks at much higher leak rates. The analysis indicated a marginal violation for the ascent failure at T+0 case for a leak rate of 1 lbm/s. Because the leak rate for the AMS-02 payload is approximately 0.01 lbm/s (0.03 ft^3/s), case 1 was determined to be acceptable.

Cases 7, 8, 9, and 10 are ammonia (NH_3) leaks, the largest of which is 55 grams. These were compared to the analysis “Ammonia Venting into Payload Bay from ISS PVR/FSE Failed FQDC During Ascent and Descent Mission Phases” (Reference 4), which analyzed a leak of 62.2 lbm of ammonia at a constant leak rate of 0.73 lbm/s. Because the higher leak rate and mass of the previous analysis did not violate the pressurization limits, cases 7 through 10 were cleared.

Case 11 is a helium leak of 0.72 grams. This was compared to the venting analysis case number s70 (Reference 5), which analyzed a mass of 0.43349 kg leaking at an initial rate of over 0.2 kg/s. Because there was no violation for the higher mass and leak rate, case 11 was cleared.

Cases 2 and 5 involve leaks of carbon dioxide. Case 2 is a leak of 12 lbs of CO_2 gas from the TRD CO_2 gas supply. This amount is higher than that of previous CO_2 leaks analyzed; however the leak rate is extremely low, with a worst case leakage of 0.005 ft^3/s. Because of the low leak rate, combined with the relatively small volume of the gas (98.2 ft^3), case 2 was cleared. Case 5 is a leak of 743 grams of CO_2 from one of two Tracker TCS loops. This is equivalent to 13.27 ft^3 of the gas. Case 5 has been cleared because of the small amount of gas that could leak.

Cases 3 and 4 are leaks of a mixture of Xenon and CO_2 gas, at a ratio of 4:1. Case 3 is a leak of 0.04 lbs, and case 4 is a leak of 2.58 lbs. In case 4, however, the mass is divided into several small ‘straws’ containing approximately 0.063 lbm each. Because of the small amounts of gas that would result from each leak, cases 3 and 4 were cleared.

Case 6 is a propylene (C_3H_6) leak from one of eight Cryocooler Loop Heat Pipes. Each pipe contains 42 grams of gas (0.83 ft^3). Because of the small amount of gas in each pipe, case 6 was cleared.

Of the 11 cases, 6 were cleared through comparison to previous analyses of an increased amount of the same gas leaking at a faster rate. The remaining 5 cases were cleared based on the small amount of gas available to be leaked or a restricted leak rate. No new VADIC (Reference 2) runs were performed for any of these cases; however the previous analyses referenced in this document were preformed with VADIC. This review only relates to overpressurization concerns, no flammability or other limits were included.

An assessment of the predicted leak rates and masses has been performed. The leak scenarios have been determined to be acceptable based on previous analysis experience and both the Orbiter PV&D and Orbiter Stress SSMs concur.

Payload venting was not considered in the Orbiter structural certification analysis. Although these failure cases result in pressure increments that are outside of Orbiter Certification, it was determined that the Orbiter has the capability to sustain this loading without structural damage or loss of mission. This assessment is valid for the defined payload (AMS-2) manifest for ULF-4 which assumes no other venting or leaking payloads.

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Table 1: Leak Description Matrix

#	Gas	Mass	Volume	Description
1	Xe	109 lbm	299 ft^3	TRD Xenon Gas Supply. Worst case sustained flow of 0.03 ft^3/s
2	CO_2	12 lbm	98.2 ft^3	TRD CO_2 Gas Supply. Worst case sustained flow of 0.005 ft^3/s
3	4:1 Xe:CO_2	0.04 lbm	0.012 m^3	TRD Mixing Vessel/Box C. Non-op during Ascent/Descent
4	4:1 Xe:CO_2	2.58 lbm	0.23 m^3 total, 0.0056 m^3 per straw	TRD Proportional Counters, Straws, Manifold, and Delivery from Box C. Straw modules approx. 500m long, 16 straws per module, 6mm diameter
5	CO_2	743g (x2)	13.27 ft^3 (x2)	Tracker TCS
6	C_3H_6	42g (x8)	0.83 ft^3	Cryocooler Loop Heat Pipe (Propylene)
7	NH_3	Largest 41g	1.88 ft^3	Heat Pipes, Various sizes. (Ammonia)
8	NH_3	55g (x2)	2.52 ft^3	CAB Loop Heat Pipe
9	NH_3	7g (x3)	0.19 ft^3	USS-02 Heat Pipes
10	NH_3	3g	0.8 ft^3	TTCS Accumulator Heat Pipe
11	He	0.72g	0.15 ft^3	Cryocooler

Appendix A:
Stored Gas Reservoirs Table from USA

AMS-02 Stored Gas Reservoirs

System	Working Fluid	Broken Line Diameter	MDP (psi)	Quantity	Gas Volume (at STP)	Notes:
~~Superfluid Helium Tank~~	~~Superfluid Helium~~	~~N/A~~	~~N/A~~	~~800 lbs (362.8 kg) ~2500 liters@ 145 g/l @ 1.8 K~~	~~Thermal design limits release rate with worst case failure, heat must be introduced to phase change the superfluid helium.~~	
~~Superfluid Helium Tank~~	~~Superfluid Helium~~	~~N/A~~	~~N/A~~		~~Given worst case credible leak of VC, requires 23 minutes to warm up the cryogenic helium sufficiently to open burst disks and allow venting to begin. (Extremely conservative analysis, reference SCL Report on Loss of Vacuum.) This conditioned is monitored to L-9 minutes or less with a LCC in place if leak is detected.~~	
~~Superfluid Helium Tank~~	~~Helium~~	~~N/A~~	~~N/A~~		~~At baroswitch operation at external pressure of approximately 5 mbar, the nominal vent rate of 0.11 ft3/min begins.~~	
~~Warm Helium Gas Supply~~	~~Helium~~	~~0.5"~~	~~3538~~	~~241 grams~~	~~47.68 ft3 (1.35 m^3)~~	~~Worst case flow rate after failure two valve seats, through 6 bar regulator and out 8 bar pressure relief devices.~~
TRD Xenon Gas Supply	Xenon (Xe)	0.25"	3000	109 lbs (49.4 kg)	299 ft3 (8.46 m^3)	Three failures to open valves during ascent/descent, worst case sustained flow is 0.03 ft3/s (Single burst disc

AMS-02 Stored Gas Reservoirs

System	Working Fluid	Broken Line Diameter	MDP (psi)	Quantity	Gas Volume (at STP)	Notes:
						open).
TRD Carbon Dioxide Gas Supply	Carbon dioxide (CO_2)	0.25"	3000	12 lbs (5.5 kg)	98.2 ft3 (2.78 m^3)	Three failures to open valves during ascent/descent, worst case sustained flow is 0.005 ft3/s (Single burst dic open).
TRD Mixing Vessel/Box C	4:1 Xenon: CO_2 mix	0.25"	300	Quantity supplied from TRD Box S ⇒ 0.04 lbs (0.03 kg)	0.012 m^3	During ascent/descent this is a non-operational system that requires the Box S to charge Box C with gas pressure and a failure of a relief valve.
TRD proportional counters "Straws", manifold & delivery from Box C	4:1 Xenon: (CO_2) mix	.125"	17.4	Quantity supplied from TRD Box C ⇒ 2.58 lbs (1.17 kg)	0.23 m^3 total with 0.0056 m^3 per straw segment with interconnecting tubing and connection to Box C	Straw Modules are approximately 500 m in length with sixteen straws per module (dia. of 6 mm). Interconnecting tubing and connection to the Box C account for less than 0.001 m^3 each. This value is rounded up to 0.23 m^3.

AMS-02 Stored Gas Reservoirs

System	Working Fluid	Broken Line Diameter	MDP (psi)	Quantity	Gas Volume (at STP)	Notes:
Tracker TCS	Carbon dioxide	~0.236"	2320	743 grams (Repeated in two loops)	13.27 ft3 (0.376 m^3) @ STP per loop	Closed system design qualified under Design for Minimum Risk (DFMR) Criteria
Cryocooler Loop Heat Pipe (x8)	Propylene	~0.12"	261	42 grams each	0.83 ft3 (0.024m^3)	Closed heat pipe qualified under DFMR Criteria
Heat Pipes (various)	Ammonia	~0.31"	~300	Largest Quantity in single heat pipe is 41 grams	1.88 ft3 (0.053 m^3)	Closed heat pipe systems qualified under DFMR criteria
CAB Loop Heat Pipe (x2)	Ammonia	~0.12"	261	55 grams each	2.52ft3 (0.07 m^3)	CAB Loop Heat Pipe system qualified under DFMR Criteria
USS-02 Heat Pipes	Ammonia	*	*	3 pipes with 7 grams each	0.19ft3 (0.005m^3)	Closed heat pipe qualified under DFMR criteria
TTCS Accumulator Heat Pipe	Ammonia	*	*	3 grams	0.8ft3 (0.0023m^3)	Closed heat pipe qualified under DFMR.
Cryocooler	Helium	*	*	0.72 grams	0.15ft3 (0.004 m^3)	Closed Stirling Cycle Heat Pump under DFMR.
Note: Bypass valves used in the Cryocooler Loop Heat Pipe and the CAB Loop Heat Pipe have a small argon volume required for operations. The volume of argon has been calculated to be approximately 0.2 grams.						

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b. PAYLOAD	Alpha Magnetic Spectrometer-02 (AMS-02)			c. PHASE: III
d. SUBSYSTEM:	Pressurized Systems	e. HAZARD GROUP:	Explosion, Contamination	f. DATE: January 20, 2011
g. HAZARD TITLE:	Rupture of AMS-02 Pressurized Systems: TRD Gas System (Xe & CO_2), Tracker Thermal Control System, Thermal Control Systems			i. HAZARD CATEGORY: CATASTROPHIC X; CRITICAL
h. APPLICABLE SAFETY REQUIREMENTS:	NSTS 1700.7B and ISS Addendum: 200.1, 200.1b, 200.2, 200.3, 200.4a, 201.3, 205, 206, 208.1, 208.2, 208.3, 208.4, 208.4a, 208.4b, 208.4c & 208.4e			
j. DESCRIPTION OF HAZARD:	Rupture/Explosion of the pressurized systems results in significant damage to or loss of the STS, ISS, crewmembers and/or other payloads.			

k. CAUSES *(list)*

1. Inadequate design strength for pressure and other loading environments.
2. Improper material selections and processing.
3. Improper workmanship and/or assembly.
4. Propagation of crack-like defects.
5. Liquefaction/freezing/thawing in lines.
6. Improper filling/over filling of vessel/system.
7. Incorrect commanding of valves.
8. Heater Failure
9. Meteoroid and Orbital Debris (M/OD) impact.
10. Damage to Composite Overwrapped Pressure Vessel

o. APPROVAL	PAYLOAD ORGANIZATION	SSP/ISS
PHASE I		
PHASE II		
PHASE III		

PAYLOAD FLIGHT HAZARD REPORT	a. NO: AMS-02-F05
b. PAYLOAD Alpha Magnetic Spectrometer-02 (AMS-02)	c. PHASE: III

l. HAZARD CONTROL (CONTROL), m. SAFETY VERIFICATION METHODS (SVM), n. STATUS OF VERIFICATIONS (STATUS)	OPS CONTROL
1. CAUSE: Inadequate design strength for pressure and other loading environments.	
1.1 CONTROL: The AMS-02 hardware is being designed to provide positive margins using appropriate factors of safety. The attached tables provide the MDP, factors of safety and associated margins per NSTS 1700.7B ISS Addendum paragraph 208.4 for the pressurized systems addressed in this hazard report. The loading factors and conditions, mechanical, pressure and thermal have been considered in establishing a positive margin of safety of the pressure systems associated with the pressurized systems. 1.1.1 SVM: AMS-02 Pressure Systems Structural/Stress Analysis and Tests as defined in AMS-02 SVP (JSC 28792). 1.1.1 STATUS: Closed. ESCG Memorandum ESCG-4295-10-ADV SY-MEMO-027, "Review of AMS-02 Pressure System Analysis Results, Dated July 21, 2010	
1.2 CONTROL: TRD SYSTEM. The TRD consists of three zones of pressure control by design. The first zone, referred to as Box S, contains two pressure zones within it. The high pressure supply and the low pressure supply to Box C. The high pressure side pressure is driven by the pressure vessels that provide the Xenon (at 1550 psia, nominal) and carbon dioxide (at 940 psia). Within these high pressure tanks the MDP has been established to be 2960 and 2040 psia respectively in isolation. These values are based on worst case thermal environments and quantities loaded. As there is a conceivable failure mode that can cross-link the two high pressure tanks, the mixing of the two gas supplies yields an approximate **MDP of 3000 psi** (2980 psi calculated), which is the value used for the Box S high pressure side tanks and lines (3000 psi = 206.8 bar). Within Box S these high pressure sources are fed through valves and orifices to fill a mixing tank which has an **MDP of 300 psia (20.68 bar)**. Pressure monitors are provided in the system to allow for computer control of the valves to regulate pressure/gas management by opening and closing a series of valves in each supply line. This MDP is kept from being exceeded by the computer-controlled valves and orifice delivery system (level 1) and two parallel, series coupled pressure relief devices set to 300 psia (260 ± 25psi). Either branch of the pressure relief devices (Burst disk and pressure relief valve) is capable of handling the full flow of the gas supplies if all the valves were to open. The burst discs are provided up-stream of the pressure relief devices for isolation of the pressure relief valves from the operating loops (Rated 295 psig by BS&B Safety Systems). The pressure relief devices have been shown to be insensitive to any debris that the burst disc may generate in providing MDP protection.	

The next zone of the TRD is fed from the mixing tank into Box C, which provides pumping of the gas to the manifold and TRD sensor segments (straws). Pressure is regulated to a **maximum of 300 psi** from Box S through valves and orifices, and computer controlled valves can vent the gas in addition to two pressure relief valves, these three levels of control (computer controlled valves, two pressure relief valves) regulate the pressure to **29.4 psia (2.02 bar) MDP**. TRD pump design can provide gas flow but is designed not to add to the overall pressure head within the system.

The third zone is the manifold and sensor "straws" the pressure of which is controlled by **Box C to 29.4 psia (2.02 bar) MDP**. Gas flow is supplied through the Box C pumps with an inconsequential pressure head.

- HIGH PRESSURE SECTION (Box S, 3000 psi) – MDP Set by Fill Quantity and Worst Case Thermal Environment when tanks mixed. (1.2.5, 1.2.8)
  - High Pressure Tanks are COPV
- MEDIUM PRESSURE SECTION (Box S, 300 psi) – MDP set by valve-metering and orifice and two independent pressure relief set at 260 ± 25psi (1.2.1, 1.2.2, 1.2.3, 1.2.5)
  - Burst disks used to Keep Medium Pressure Section (Box S) from leaking through pressure reliefs will not generate debris that will keep pressure reliefs from working. (1.2.3, 1.2.6,1.2.7)
- LOW PRESSURE (Box C, 29.4 psi) – MDP set by valve metering through orifice and two independent pressure relief valves. (1.2.1, 1.2.2, 1.2.3, 1.2.5)
  - Box C Low Pressure Pumps operate in an open system creating flow without the ability to generate a significant pressure. (1.2.4)
- All Pressure Reliefs sized for maximum flow rate and not experience Pressure Rise. (1.2.9)

1.2.1 SVM: Manufacturer's Certification/Testing of relief valves to verify opening pressure and flow capacity.

1.2.2 SVM: Functional testing of computer controlled valves.

1.2.3 SVM: Flow rate analyses (orifice, valve, relief valve flow)

1.2.4 SVM: Functional testing of gas flow pumps

1.2.5 SVM: Pressure system thermal analyses (included in stress analysis)

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b. PAYLOAD Alpha Magnetic Spectrometer-02 (AMS-02)	c. PHASE: III

1.2.6 SVM: Manufacturer's qualification/certification of burst disk.

1.2.7 SVM: Acceptance Testing of Burst disc

1.2.8 SVM: Ground loading procedures to provide proper filling conditions, quality and quantities.

1.2.9 SVM: COPV Stress Analysis Per ANSI/AIAA S-081

1.2.1 STATUS: Closed. Marotta Relief Valve Acceptance Test Certification for PRV102A Pressure Relief Valves, P/N 284906-0001, S/N 101-103, dated April 23, 2005.

1.2.2 STATUS: Closed. "UG and UGPD test report," A. Bartoloni, B. Borgia, T. Siedenburg, F. R. Spada, CERN, 6/17/2009

1.2.3 STATUS: Closed. ESCG Memorandum ESCG-4175-09-REENTES-MEMO-0011, "Review of TRD Gas Supply Design," dated March 20, 2009

1.2.4 STATUS: Closed. "UG and UGPD test report," A. Bartoloni, B. Borgia, T. Siedenburg, F. R. Spada, CERN, 6/17/2009

1.2.5 STATUS: Closed. Main TRD gas tank stress analysis documented thermal analysis results in EG 10348, Fracture and Stress Report of CO_2/Xenon Tank Assembly PN C4810/D4852 for TRD Gas Supply System, Nov 6, 2001. Tanks are identical to Arde tanks previously flown on ISS.

1.2.6 STATUS: Closed. BS&B Safety Systems LLC Burst Test Certificate and Certificate of Conformance, BS&B Lot Number A4004303-1, dated 10/20/2004.

1.2.7 STATUS: Closed. BS&B Safety Systems LLC Burst Test Certificate and Certificate of Conformance, BS&B Lot Number A4004303-1, dated 10/20/2004, confirmation with BS&B Test Engineer that test was performed to 175 psi for 60 minutes with no leakage.

1.2.8 STATUS: Closed. AMS-02 Task Sheet (ATS) TRD 090131-1, "TRD_GAS_SUPPLY_SYSTEM_CO2_VESSEL_FILLING_FOR_FLIGHT," and TRD 090522-1, "TRD_GAS_SUPPLY_SYSTEM_XENON_VESSEL_FILLING_FOR_FLIGHT," establish filling procedures.

1.2.9 STATUS: Closed. Email confirmation of acceptability of COPV to ES4-08-043 and ES4-09-031 from JSC-ES4/S.C. Forth, "AMS COPVs," dated July 26, 2010

1.3 CONTROL: <Deleted with the Removal of the Warm Helium Gas Supply>

1.4 CONTROL: TTCS TWO PHASE LOOP. The nominal TTCS MDP has been established by TTCS fill and the worst case thermal profile of the TTCS. Heater failure for this system is addressed under Cause 8 of this hazard report. This value is **160 bar (2320 psi)** and encompasses the extremely small pressure differential across the circulation pump. All other components and lines are designed to maintain a safety factor of 4.0 per NSTS 1700.7B and ISS Addendum. NOTE: *The TTCS has a special consideration addressed in Control 5.4 where segments of the TTCS are susceptible to freezing of the carbon dioxide working fluid, these components have a specific MDP established based on the stress of the freeze/thaw cycle.*

- MDP established to be 160 bar (2320 psi) considers fill, and thermal environments. Heater failures have been protected by thermostatic control to maintain this MDP. (1.4.1, 1.4.2)

1.4.1 SVM: Thermal Analysis

1.4.2 SVM: Manufacturer's Certification of TTCS Filling.

1.4.1 STATUS: Closed. NLR document AMSTR-NLR-TN044 Issue 2.0 March 2010, "AMS Tracker Thermal Control Subsystem TTCS Safety Approach" and Sun Yet-Sen Univeristy document TTCS SYSU-AN-001-6.0 "TTCS-Accumulator Thermal Safety Analysis" dated November 18, 2009

1.4.2 STATUS: Closed. TTCS Fill report, transmitted by NLR/Johannes Van Es for Primary (819 grams CO_2) and Secondary (850 grams CO_2) Loops, dated 7/26/2010. Fill quantities make mass per liter of internal volume under the maximum allowed for establishing MDP.

1.5 CONTROL: TTCS RADIATOR HEAT PIPES. The AMS-02 TTCS utilizes a seven sealed heat pipes in each of the two Tracker Radiators that are situated atop the AMS-02. These heat pipes are of identical design throughout but with varying length, constructed of Al 6063 and filled with ammonia with pipe quantities varying with length (44.6 – 52.6 grams), 14 mm diameter with a minimum thickness of 1.25 mm. This heat pipe is manufactured with a 40 mm flange that is used to interface with the TTCS condensers. These flanges are milled down for the rest of the heat pipe's length along the Tracker Radiator. The MDP of the heat pipes are based on the worst case thermal profile while on-orbit for the ammonia filled tubes, considering the worst case heater failures, with a final temperature of the systems as being 50°C. This MDP is **290 psi (20 bar)** and is inclusive of all heat pipes although not all heat pipes could possibly see this particular temperature and pressure. The heat pipes meet a 4.0 factor of safety satisfying the required 2.5 factor of safety per NSTS 1700.7B and ISS Addendum. Heater Failure Tolerance is discussed under Cause 8.

- Highest possible MDP of any TTCS radiator heat pipe is 20 bar (290 psi). This is based on worst case thermal pressure and possible heater failures. Not all heat pipes could possibly see this worst case pressure, but the highest was selected to apply to all heat pipes. (1.5.1, 1.5.2)

1.5.1 SVM: Thermal Analysis of AMS-02 for worst case thermal condition of heat pipes

1.5.2 SVM: Manufacturer's Certification of heat pipe filling.

1.5.1 STATUS: Closed. OPMT Action 09-033 Closure Response from Christian Vettore, September 23, 2009, "AMS TCS OPMT Action 09-033." Email from Johannes Van Es documents that under the PM design, the heat load that much be rejected by the TTCS is less than the original Cryomagnet heat load, sent June 24, 2010.

1.5.2 STATUS: Closed. ESCG-4470-09-TEAN-DOC-0121, "AMS-02 Heat Pipes and Loop Heat Pipes Fluid Fill Quantities," dated September 1, 2009

1.6 CONTROL: <Deleted with the removal of the OHP from AMS-02 >

1.7 CONTROL: TTCS Accumulator Heat Pipe. The TTCS accumulator heat pipe (one on primary and one on secondary TTCS systems) is unique in that it is integrated into the TTCS carbon dioxide accumulator structure, a portion of the heat pipe experiences external pressure as defined by the TTCS system (160 bar) and the rest (100mm extending outside of the TTCS Accumulator) it's own internal pressure under worst case thermal loading conditions of the ammonia working fluid. The construction of the TTCS Accumulator heat pipe also differs from other heat pipes as it has a smooth bore with an inserted artery wick structure along the periphery of the tube and bridging singularly across the heat pipe to supply wicking effects. The MDP established by the thermal condition of the heat load applied by the dedicated heaters in the worst case environment has been established to be **50.2 bar (728.1 psi)** relative to vacuum and the MDP of the portion interior to the accumulator has been set to the MDP of the accumulator **(160 bar, 2320.6 psi).** This "interior" MDP could be set to 160 bar minus the lowest pressure of the heat pipe, but for simplicity the worst case is assumed. The heat pipes meet a 2.5 factor of safety per NSTS 1700.7B and ISS Addendum (they are self imposed against a 4.0 FOS for exterior exposure). Heater Failure Tolerance is discussed under Cause 8.

- TTCS Heat Pipe has multiple MDPs.
    - 50.2 bar (728.1 psi) expansive pressure (pressure from inside) based on worst case heat pipe fill, thermal conditions and maximum heater influx (1.7.1, 1.7.2)
    - 160 bar (2320.6 psi) compressive pressure (pressure from outside) based on highest TTCS pressure that can

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be present in accumulator.(1.7.1)

1.7.1 SVM: Thermal Analysis of TTCS and TTCS Accumulator Heat Pipe Operations including failure conditions.

1.7.2 SVM: Manufacturer's certification on filling the TTCS Accumulator Heat Pipe

1.7.1 STATUS: Closed. NLR document AMSTR-NLR-TN044 Issue 2.0 March 2010, "AMS Tracker Thermal Control Subsystem TTCS Safety Approach" and Sun Yet-Sen Univeristy document TTCS SYSU-AN-001-6.0 "TTCS-Accumulator Thermal Safety Analysis" dated November 18, 2009

1.7.2 STATUS: Closed. ESCG-4470-09-TEAN-DOC-0121, "AMS-02 Heat Pipes and Loop Heat Pipes Fluid Fill Quantities," dated September 1, 2009

1.8 CONTROL: HEAT PIPES. The AMS-02 utilizes a number of sealed heat pipes throughout its TCS design. These heat pipes are of axial grove design, constructed of Al 6063. The MDP of the heat pipes are based on the worst case thermal profile while on-orbit for the ammonia filled tubes, considering the worst case heater failures. This MDP for the Wake and Ram Radiator Heat Pipes are **1183 psi (81.6 bar)** and is inclusive of all heat pipes although not all heat pipes could possibly see this particular temperature and hence this pressure. The USS-02 heat pipes have an MDP of **26 bar (377.2 psi)**. The heat pipes meet a 4.0 factor of safety satisfying the required 2.5 factor of safety per NSTS 1700.7B and ISS Addendum. Heater Failure Tolerance is discussed under Cause 8.

- Wake and Ram Heat Pipes MDP = 81.6 bar (1183 psi)
- USS-02 Heat Pipes MDP = 26 bar (377.2)

1.8.1 SVM: Thermal Analysis of AMS-02 for worst case thermal condition of heat pipes

1.8.2 SVM: Manufacturer's Certification of heat pipes for proper filling.

1.8.1 STATUS: Closed. OPMT Action 09-035 Closure Response from Christian Vettore, January 21, 2010, "CAB-USS HP MDT", AMSTCS-TN-CGS-001, "Safety Thermostats for the Main Radiators: Thermal Assessment," dated December 5, 2007

1.8.2 STATUS: Closed. ESCG-4470-09-TEAN-DOC-0121, "AMS-02 Heat Pipes and Loop Heat Pipes Fluid Fill Quantities," dated September 1, 2009

1.9 CONTROL: <Deleted with the Removal of the CAB Loop Heat Pipe>

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1.10 CONTROL: <Deleted with the Removal of the Cryocooler Loop Heat Pipe/Zenith Radiators>	
1.11 CONTROL: <Deleted with Removal of Cryocoolers>	
1.12 CONTROL: <Deleted with the Removal of Cryosystem>	
1.13 CONTROL: <Deleted>	
2. CAUSE: Improper material selections and processing.	
2.1 CONTROL: All AMS-02 pressure system materials will be selected to meet the requirements of MSFC-STD-3029 for stress corrosion cracking. Materials with high resistance to stress corrosion cracking will be used where possible. Where materials with moderate to low resistance to stress corrosion cracking are utilized, MUAs have been prepared and will be submitted for approval. 2.1.1 SVM: Stress Corrosion Evaluation of materials list and drawings. 2.1.2 SVM: ES4/Material and Processes Branch Certification for materials usage. 2.1.1 STATUS: Closed. AMS Approved MUAS for SCC. 7050-T7451/T7452 Parts in USS, VC, PAS, and ROEU of Alpha Magnetic Spectrometer- 02 (AMS-02), Usage Agreement AG 577. Al 5083-H111 and 5083-H321 Parts Used in Helium Tank of Alpha Magnetic Spectrometer- 02 (AMS-02), Usage Agreement AG 594. JSC Materials and Fracture Control Certification, REF: MATL-09-036, Alpha Magnetic Spectrometer (AMS-02) Data Interface hardware. Utilization of Aluminum Alloy 7175 T 7351, MUA PI-217. Electromagnetic Calorimeter (ECAL), Alpha Magnetic Spectrometer-02 (AMS-02), MUA ESCG/ISS-256. Al 7050-T7451 Parts in Transition Radiation Detector (TRD) Gas Supply System, AMS-02, MUA ESCG/ISS-257. (See Appendix C) 2.1.2 STATUS: Closed. MUA AG577, "7050-T7451/T7452 Parts in USS, VC, PAS and ROEU of Alpha Magnetic Spectrometer- 02 (AMS-02), Approved 9/28/2009.	
2.2 CONTROL: Working fluids/gasses are inert and will be non-reactive, with the exception of ammonia. All working fluids are compatible with all materials of construction. Materials of construction are principally stainless steel and aluminum. The TRD (working fluids carbon dioxide and xenon) (Arde) are stainless steel lined, composite overwrapped tanks. The TRD also has composite-wound sensors through which gas is pumped at low pressure. 2.2.1 SVM: Materials Compatibility Assessment 2.2.2 SVM: Approval of material use and MUAs by JSC ES4/Materials and Processes Branch	

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2.2.1 STATUS: Closed. JSC Materials and Fracture Control Certification MATL-11-009, "Alpha Magnetic Spectrometer -02 (AMS-02) Payload Assembly," Approved December 10, 2010 2.2.2 STATUS: Closed. JSC Materials and Fracture Control Certification MATL-11-009, "Alpha Magnetic Spectrometer -02 (AMS-02) Payload Assembly," Approved December 10, 2010	
2.3 CONTROLS: Cleaning materials will be compatible with working fluid and materials of construction. 2.3.1 SVM: Materials Compatibility Assessment/Review 2.3.1 STATUS: Closed. Cleaning Procedures for Iberespacio Document CG022-PA-001, Scientific Magnetics Work Instruction WI 125, Arde End Item Specification Packages for TRD and NLR Procedure Sheets have been reviewed for appropriate cleaning materials and processes, review closed April 7, 2009	
2.4 CONTROL: Metallic materials that touch in the pressure system will be assessed for potential galvanic reactions that could degrade welds and other joints. 2.4.1 SVM: Material Compatibility Assessment 2.4.2 SVM: Approval of material use and MUAs by JSC ES4/Materials and Processes Branch 2.4.1 STATUS: Closed. JSC Materials and Fracture Control Certification MATL-11-009, "Alpha Magnetic Spectrometer -02 (AMS-02) Payload Assembly," Approved December 10, 2010 2.4.2 STATUS: Closed. JSC Materials and Fracture Control Certification MATL-11-009, "Alpha Magnetic Spectrometer -02 (AMS-02) Payload Assembly," Approved December 10, 2010	
3. CAUSE: Improper workmanship and/or assembly.	
3.1 CONTROL: Manufacturing and Assembly AMS-02 pressurized systems will be done in accordance with approved drawings and procedures. Manufacturing and Assembly processes have certification processes in place to document compliance with approved drawings and procedures. 3.1.1 SVM: All discrepancies and deviations from approved drawings/procedures are reconciled through a MRB process to assure compliance with requirements. 3.1.1 STATUS: Closed. ESCG Memorandum ESCG-4295-09-CPAS-MEMO-0020, "Manufacturing of AMS-02 Pressure Vessels," dated December 22, 2009	
3.2 CONTROL: All welds will be compliant to the standards of the AMS-02 weld policy (compliant with JSC standards for	

welding).

3.2.1 SVM: Review of weld plans, processes and certification of welds of the AMS-02 systems. ES4 approval.

3.2.2 SVM: Proof Pressure Testing, Dye Penetrant inspection, Radiological (or ultrasound) inspection of welds.

3.2.1 STATUS: Closed. Confirmation of ES4 acceptance of Weld Plan Review by ESCG/D. Rybiki and ES4/G. Ecord transmitted by email from ES4/B. S. Files on November 20, 2006 to AMS-02 Chief Engineer Chris Tutt.

3.2.2 STATUS: Closed. TRD documentation in TRD GAS ADP Rev 1.0 for pressurized components, lines and fittings, on file AMS-02 Project Office. TTCS documents in ADP record Weld inspections, helium leak checks and proof tests for the accumulator, condensers and the entire TTCS loop. Review and Closure Date August 20, 2010, TRD leak Repair radiological examination report EDMS No: 1078985 dated 5/25/2010.

4. CAUSE: Propagation of crack-like defects.

4.1 CONTROL: The AMS-02 pressurized systems uses JSC 25863A to implement the fracture control requirements of NASA-STD-5003 and SSP 30558C.

4.1.1 SVM: Compliance with the fracture control requirements of NASA-STD-5003 and SSP-30558C will be verified by approval of fracture control summary by JSC ES4/Materials and Processes Branch.

4.1.2 SVM: Compliance with COPV Letters ES4-08-043, “Composite Overwrapped Pressure Vessel Risks,” dated September 30, 2008 and ES4-09-031, “NASA Carbon Overwrapped Pressure Vessel (COPV) Pressure Restrictions,” dated September 8, 2009

4.1.1 STATUS: Closed. JSC Materials and Fracture Control Certification MATL-11-009, "Alpha Magnetic Spectrometer -02 (AMS-02) Payload Assembly," Approved December 10, 2010

4.1.2 STATUS: Closed. Email confirmation of acceptability of COPV to ES4-08-043 and ES4-09-031 from JSC-ES4/S.C. Forth, "AMS COPVs," dated July 26, 2010

5. CAUSE: Liquefaction/freezing/thawing in lines

5.1 CONTROL: TRD GAS SUPPLY. The TRD Gas Supply system (CO_2 & Xenon) will not freeze under the worst case thermal conditions that the system will experience on-orbit. The high pressure TRD system is mounted on a common thermal plate to keep the entire high pressure side thermally uniform. The lowest temperature that has been assessed for the TRD system, using an indefinite period at the worst possible cold attitude with no other attitudes occurring (extremely conservative), to be -50°C (-43°C at 200 hours of exposure with asymptotic approach to approximately -50°C). Even with

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TRD heaters failed on for the tank only (more than two failures), driving the pressure up, and heaters off for the lines and components, the pressure-temperature curve for CO_2 will not transition to solid phase. Xenon's physical properties make it more difficult to freeze than CO_2. The low pressure side does not have a constant supply of carbon dioxide sufficient to fill a potentially frozen segment with CO_2. Liquid CO_2 is prevented from going from the CO_2 tank to the lines by a dual heater system (Side A and B) that will keep the CO_2 gaseous before entering the high pressure lines. If power is lost for the heaters, power is also lost for operating the valves (normally close) that would allow for the introduction of liquid CO_2 into potentially isolated segments. Heater operations on these isolated segments are controlled in a 2 fault tolerant manner, reference Control 8.1.

5.1.1 SVM: AMS-02 Thermal Assessment

5.1.2 SVM: TRD Thermal Assessment for Freezing of CO_2 and Xenon

5.1.3 SVM: Review of TRD Heater Design for fault tolerant design.

5.1.1 STATUS: Closed. ESCG Memo, "Thermal Analysis of Transition Radiation Detector (TRD) Gas System for the Alpha Magnetic Spectrometer", ESCG-4470-06-TEAN-DOC-0086, dated July 7, 2006

5.1.2 STATUS: Closed. ESCG Memo, "Thermal Analysis of Transition Radiation Detector (TRD) Gas System for the Alpha Magnetic Spectrometer", ESCG-4470-06-TEAN-DOC-0086, dated July 7, 2006

5.1.3 STATUS: Closed. ESCG Memo, "Thermal Analysis of Transition Radiation Detector (TRD) Gas System for the Alpha Magnetic Spectrometer", ESCG-4470-06-TEAN-DOC-0086, dated July 7, 2006

5.2 CONTROL: <Deleted. Warm Helium Gas Supply has been Removed from the AMS-02>

5.3 CONTROL: TTCS TWO PHASE LOOP. The Tracker Thermal Control System (TTCS) will freeze under a loss of power from the ISS under worst case thermal conditions at the condensers, located on the Tracker Radiators. The TTCS components subject to freezing have had their MDPs established based on a freezing event and subsequent heating/thawing that results in a trapped volume of carbon dioxide. The condenser tubes of the TTCS could freeze and thaw and the resulting MDP has been established to be 3009 bar (43641.9 psi). Special proof testing and NDE will be conducted on the sample lot of the tubing used in the construction of the condensers to allow for a reduction in the acceptable factor of safety (per ES4). Using standard techniques of analysis, the tubing indicates a burst proof factor of safety of 2.14, but if the material's strain hardening is taken into account this value rises to 4.6. Thermal Analysis indicates that all other TTCS system components and lines are not subjected to freezing potential.

5.3.1 SVM: Testing of carbon dioxide freezing/heating cycles

5.3.2 SVM: Thermal Analysis

5.3.3 SVM: MDP Analysis based on worst case thermal profiles and two failures (if applicable)

5.3.4 SVM: Review and approval of testing plan for freezing/thawing lines by JSC/ES4.

5.3.5 SVM: Testing/analysis of flight hardware per testing plan of 5.3.4.

5.3.6 SVM: Thermal Analysis of TTCS System to establish freezing/non-freezing elements.

5.3.1 STATUS: Closed AMSTR-NLR-TN-039, Issue 3.0, "TTCS Condenser Freezing Test Report", 8/23/2005 from Nationaal Luchten Ruimtevaartlaboratorium (NLR)

5.3.2 STATUS: Closed. TTCS freezing potential documented in ESCG Memorandum ESCG-4470-06-TEAN-DOC-0032, "Alpha Magnetic Spectrometer (AMS-02) Tracker Thermal Control System (TTCS) Cold Environment Temperatures", dated March 22, 2006. ESCG Memorandum ESCG-4470-10-TEAN-DOC-0098, "Re-evaluation of Potential Freezing of CO2 in AMS-02 TTCS," dated July 19, 2010

5.3.3 STATUS: Closed. AMSTR-NLR-TN-039, Issue 3.0, "TTCS Condenser Freezing Test Report", 8/23/2005 from Nationaal Luchten Ruimtevaartlaboratorium (NLR). ESCG Memorandum ESCG-4470-10-TEAN-DOC-0098, "Re-evaluation of Potential Freezing of CO2 in AMS-02 TTCS," dated July 19, 2010.

5.3.4 STATUS: Closed. Review cycle with ES4 representative ESCG/W. Manha, (Including Glenn Ecord, and Adrian Martinez) culminating in acceptance email of Testing Plan and Results on March 5, 2008, "Summary of AMS-02 Tracker Thermal Control System (TTCS) Condenser Freezing - Manha (EP4) agrees with finding," to ESCG/L. Hill.

5.3.5 STATUS: Closed. AMSTR-NLR-TR-007, Issue 1,"TTCS Condenser High Pressure Test Report," December 2007, from Nationaal Luchten Ruimtevaartlaboratorium (NLR)

5.3.6 STATUS: Closed. ESCG-4470-06-TEAN-DOC-0032, "Alpha Magnetic Spectrometer (AMS-02) Tracker Thermal Control System (TTCS) Cold Environment Temperatures), Dated March 22, 2006, from ESCG/E. L. Yagoda indicates no other system elements will freeze. ESCG Memorandum ESCG-4470-10-TEAN-DOC-0098, "Re-evaluation of Potential Freezing of CO2 in AMS-02 TTCS," dated July 19, 2010.

5.4 CONTROL: TTCS ACCUMULATOR HEAT PIPE. The TTCS Accumulator Heat Pipe is filled with 3 grams of ammonia and will not reach temperatures that can freeze the ammonia. NOTE: Even if the ammonia were capable of freezing, the straight pipe construction with interior mesh and fill quantity of the heat pipe would preclude an accumulation of a solid block of ammonia.

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5.4.1 SVM: Thermal Analysis 5.4.1 STATUS: Closed. TTCS-SYSU-AN-001-2.0_"TTCS-Accumulator Thermal Safety Analysis," October 18, 2006, Sun Yat-Sen University	
5.5 CONTROL: HEAT PIPES. The design of the ammonia heat pipes allows for the ammonia to condense and freeze without damage to the heat pipes. The low quantity of ammonia, interior shape of heat pipes and the melting/vaporization of the ammonia cannot create trapped volumes that can generate elevated pressures. 5.5.1 SVM: Review of design 5.5.2 SVM: Vendor Certification/Testing 5.5.1 STATUS: Closed. ESCG Memorandum ESCG-4470-TEAN-DOC-0179, "Design of AMS-02 Heat Pipes," dated October 23, 2009 5.5.2 STATUS: Closed. Acceptance Data Packages CG020 ADP-001, CG020 ADP-002, CG020 ADP-003, CG025 ADP-002 confirm design and fill of heat pipes.	
5.6 CONTROL: <Deleted. OHP has been removed from AMS-02 >.	
5.7 CONTROL: <Deleted. CAB Loop Heat Pipe has been removed from the AMS-02>	
5.8 CONTROL: <Deleted. Cryocooler Loop Heat Pipe/Zenith Radiator have been removed from the AMS-02>	
5.9 CONTROL: <Deleted. Cryocoolers have been removed from the AMS-02>	
6. CAUSE: Improper filling/over filling of vessel/system.	
6.1 CONTROL: All pressurized systems will be filled with high purity gases and appropriate quantities. 6.1.1 SVM: Review of TRD Ground Filling Procedures. 6.1.2 SVM: <Deleted with removal of Warm Helium Gas Supply> 6.1.3 SVM: Review of Tracker Thermal Control System Filling Procedures. 6.1.4 SVM: Manufacturers' Certifications on filling of Ammonia Heat Pipes. 6.1.5 SVM: <Deleted OHP Removed from AMS-02> 6.1.6 SVM: <Deleted with Removal of the CAB Loop Heat Pipe>	

6.1.7 SVM: <Deleted with the Removal of the Cryocooler Loop Heat Pipe/Zenith Radiator>

6.1.8 SVM: <Deleted with the Removal of the Cryocoolers>

6.1.1 STATUS: Closed. AMS-02 Task Sheet (ATS) TRD 090131-1, "TRD_GAS_SUPPLY_SYSTEM_CO2_VESSEL_FILLING_FOR_FLIGHT," and TRD 090522-1, "TRD_GAS_SUPPLY_SYSTEM_XENON_VESSEL_FILLING_FOR_FLIGHT," establish filling procedures.

6.1.2 STATUS: <Deleted>

6.1.3 STATUS: Closed. Sun Yat Sen University Document AMSTR-SYSU-PR-024, "FM TTCB Filling and Venting Procedure," dated10/8/2009

6.1.4 STATUS: Closed. ESCG-4470-09-TEAN-DOC-0121, "AMS-02 Heat Pipes and Loop Heat Pipes Fluid Fill Quantities," dated September 1, 2009

6.1.5 STATUS: <Deleted>

6.1.6 STATUS: <Deleted>

6.1.7 STATUS: <Deleted>

6.1.8 STATUS: <Deleted>

7. CAUSE: Incorrect commanding of valves.

7.1 CONTROL: TRD SYSTEM. The TRD system has a potential for entrapping gas and liquid between controlling valves. Nominally redundant line heaters on the gas feed lines from the tanks will prevent liquid from being present in the lines and thus taken into the entrapped volume. Heater operations may individually fail, but a total power loss for the system would preclude opening the valves as the valves are normally closed. Computer operations will not allow the valves to cycle if the temperature of the line is not at a level to prevent the introduction of liquid into the lines. A pressure relief device set to leak back starting at a 25 psi differential and full flow capability at a 100 psi differential is provided in the first entrapped volume to allow any liquid in the line to be relieved back into the tank (which can not be at or near MDP to have liquid present to cause this condition). *NOTE: In addition to these three levels of control, the TRD valves (Marotta MV 197) will relieve under a back pressure differential of 1535 psid (Manufacturer's Data). Assuming that the highest pressure upstream is the MDP of the system (which cannot be the case and have liquid to ingest into the lines to cause it to occur) the maximum pressure of this segment considering two failures would be 4535 psia. In this extreme unrealistic case of compounded failures, after* ***three*** *failures, the factor of safety of the lines, and fittings are 2.8 not the required 4.0 (after two* *failures).*

7.1.1 SVM: Review of TRD Design

7.1.2 SVM: Inspection of TRD Flight hardware

7.1.3 SVM: Functional testing of thermal interlock of valve operations

7.1.4 SVM: Testing of Pressure Relief Valves

7.1.5 SVM: Thermal Analysis

7.1.1 STATUS: Closed. ESCG Memorandum ESCG-4175-09-REENTES-MEMO-0011, “Review of TRD Gas Supply Design,” dated March 20, 2009

7.1.2 STATUS: Closed. ESCG Memorandum ESCG-4295-09-CPAS-MEMO-0019, "Review of the AMS-02 TRD Gas Supply Acceptance Data Package," dated December 22, 2009.

7.1.3 STATUS: Closed. Testing of thermal interlock reported by email from Francesca Spada, “Re: updated UGSCM LeCroy Command thermal interlock,” dated October 14, 2009 details functional testing success.

7.1.4 STATUS: Closed. ESCG Memorandum ESCG-4295-09-CPAS-MEMO-0019, "Review of the AMS-02 TRD Gas Supply Acceptance Data Package," dated December 22, 2009.

7.1.5 STATUS: Closed. ESCG Memo, “Thermal Analysis of Transition Radiation Detector (TRD) Gas System for the Alpha Magnetic Spectrometer”, ESCG-4470-06-TEAN-DOC-0086, dated July 7, 2006

7.2 CONTROL: <Deleted. VALVES HAVE BEEN DELETED FROM DESIGN>

7.3 CONTROL: <Deleted. Warm Helium Gas Supply has been Removed from the AMS-02>

8. CAUSE: Heater Failure

8.1 CONTROL: TRD GAS SUPPLY. The TRD utilizes heaters strings to allow for pressure sensing within the TRD tanks (unable to measure liquid state). These heaters are capable of causing a condition where the MDP would be exceeded if the heaters are failed on and the system is exposed to the worst case thermal environment. To preclude these heaters from failing on, there are four thermostatic control devices controlling the operation of the heaters (two in return leg of heaters) in addition to a computer control of the heater’s operations through heater power application and thermal feedback from temperature sensors. Four are used to assure that there are no proximity failures (of heaters) that would make a thermostatic control less responsive assuring two fault tolerance. Each of the TRD tanks utilizes two strings of heaters, and each string has independent controls (computer is not tallied as a safety control). Thermal set points for the TRD system are attached to this hazard report. TRD Gas Supply isolated segments from the xenon and carbon dioxide tanks, used to control the mass of gas introduced into the system, are protected from thermal extremes generated by the valve block heater runaway by the use of two fault tolerance thermostatic control on each heater, with one of the thermostatic devices in the return leg of the heater circuit.

8.1.1 SVM: Review of Design

8.1.2 SVM: Thermal Analysis (establishing maximum temperature settings and thermal sensitivity of thermostatic control locations.

8.1.3 SVM: Functional testing/Acceptance testing of thermostatic switches.

8.1.4 SVM: Inspection of flight hardware for proper installation of thermostatic switches.

8.1.1 STATUS: Closed. ESCG Memorandum ESCG-4175-09-REENTES-MEMO-0011, “Review of TRD Gas Supply Design,” dated March 20, 2009

8.1.2 STATUS: Closed. ESCG Memo, “Thermal Analysis of Transition Radiation Detector (TRD) Gas System for the Alpha Magnetic Spectrometer”, ESCG-4470-06-TEAN-DOC-0086, dated July 7, 2006

8.1.3 STATUS: Closed. ESCG Memorandum ESCG-4295-09-CPAS-MEMO-0019, "Review of the AMS-02 TRD Gas Supply Acceptance Data Package," dated December 22, 2009.

8.1.4 STATUS: Closed. TRD Gas Box Traveler Wiring #1.4, 2/17/07 and TRD Gas Box Traveler Wiring #1.5 CO2 Vessel, 3/12/07 documents inspection of installed thermostats.

8.2 CONTROL: <Deleted. Warm Helium Gas Supply has been Removed from the AMS-02>

8.3 CONTROL: TRACKER RADIATOR HEAT PIPES. The heaters on the Tracker radiator heat pipes will utilize two fault tolerance in the implementation of thermostatic control of the heaters. To preclude these heaters from failing on, there are three thermostatic control devices controlling the operation of the heaters (one in return leg of heaters) in addition to a computer control of the heater’s operations through heater power application and thermal feedback from temperature sensors. Each string of the heaters on the radiators is controlled in this two fault tolerance manner. The thermostatic threshold for the heaters is set to -35ºC to -25 ºC.

8.3.1 SVM: Review of Design for inclusion of heater thermostatic control and thermal threshold values

8.3.2 SVM: Thermal Analysis to Establish MDP

8.3.3 SVM: Functional testing/Acceptance Testing of thermostatic switches.

8.3.4 SVM: Inspection of flight hardware for proper installation of thermostatic switches.

8.3.1 STATUS: Closed. ESCG Memorandum ESCG-4470-09-TEAN-DOC-0161, "AMS-02 Tracker Thermal Control System Heaters," dated September 24, 2009 documents review of AMSTR-NLR-TN-043, Issue 4, "AMS Tracker Thermal Control Subsystem TTCS Heater Specification," August 2009.

8.3.2 STATUS: Closed. OPMT Action 09-033 Closure Response from Christian Vettore, September 23, 2009, "AMS TCS OPMT Action 09-033."

8.3.3 STATUS: Closed. Thermal Vacuum Testing Report DEL037-UNIPC-20100603-is2.doc, "DEL037 TV TB Test Report," June 3, 2010. AMSTR-AIDC-PR-019, "TTCS-Thermal Switch Incoming Inspection Procedure, Testing Results,"April 22, 2008, AMSTR-NLR-TR-080, "TTCS Condenser Heater Wire Test Report," February 2, 2010.

8.3.4 STATUS: Closed. AMS-02 ATS TTCS-090716.01-A, "TTCS Condenser Installation Ram Side," dated 11/29/2009, AMS-02 ATS TTCS-090716-01-B, "TTCS Condenser Installation Wake Side," dated 11/25/2009, Carlo Gavazzi Drawing 47-AMS02TCS-200.10.00, "AMS TCS Condenser RAM Heaters and Thermostats Cabling," 9/16/2009, Carlo Gavazzi Drawing 47-AMS02TCS-300.10.00, "AMS TCS Condenser WAKE Heaters and Thermostats Cabling," 9/16/2009,

8.4 CONTROL: TTCS TWO PHASE LOOP. The Tracker Thermal Controls System utilizes heaters on the two phase loop that are not controlled in a two-fault tolerant means to prevent continuous heater operation. Thermal analysis of the two phase loop indicates that only the temperature of the accumulator is capable of driving the pressure of the system to MDP. Failed on heaters on the "loop" will only force the liquid phase of the working fluid to an alternate location. Only single thermostatic control is implemented at these line heaters. The accumulator heater system implements a two-fault tolerant heater control circuitry as described in Control 8.5. Note: Controls 8.5 and 8.11 document heater elements that are capable of driving the pressure of the TTCS Two Phase Loop.

8.4.1 SVM: Analysis of TTCS Two Phase Loop thermal response to failed heater operations.

8.4.1 STATUS: Closed. NLR document AMSTR-NLR-TN044 Issue 2.0 March 2010, "AMS Tracker Thermal Control Subsystem TTCS Safety Approach" and Sun Yet-Sen University document TTCS SYSU-AN-001-6.0 "TTCS-Accumulator Thermal Safety Analysis" dated November 18, 2009

8.5 CONTROL: TTCS ACCUMULATOR HEAT PIPE/TTCS ACCUMULATOR. The TTCS Accumulator is heated by the TTCS accumulator heat pipe that is situated down the center of the accumulator and possibly by Peltier Devices attached to the Accumulator shell. The accumulator heat pipe extends out of the accumulator and is fitted with heaters and thermostatic switches. These heaters/Peltier devices will be controlled by thermostatic control devices that are attached to the heat pipe and accumulator by way of thermally conductive fixtures. The thermostatic control for the heaters/Peltier devices is two fault tolerant, with one thermostatic control device implemented in the return leg of the heaters. NOTE: In addition to heater control by thermostatic devices, the pressure of the TTCS is monitored and a computer system is capable of shutting down the heater sources if the pressure is too high for efficient operations, this value is lower than the MDP.

8.5.1 SVM: Review of Design for inclusion of heater thermostatic control and thermal threshold values.

8.5.2 SVM: Thermal Analysis to Establish MDP.

8.5.3 SVM: Functional testing/Acceptance Testing of thermostatic switches.

8.5.4 SVM: Inspection of flight hardware for proper installation of thermostatic switches.

8.5.1 STATUS: Closed. NLR document AMSTR-NLR-TN044 Issue 1.0 October 2006, "AMS Tracker Thermal Control Subsystem TTCS Safety Approach" and Sun Yet-Sen University document TTCS SYSU-AN-001-2.0 "TTCS-Accumulator Thermal Safety Analysis" dated August 10, 2006 and ESCG Memorandum ESCG-4470-09-TEAN-DOC-0161, “AMS-02 Trackert Thermal Control System Heaters,” dated September 24, 2009 documents review of AMSTR-NLR-TN-043, Issue 4, “AMS Tracker Thermal Control Subsystem TTCS Heater Specification,” August 2009.

8.5.2 STATUS: Closed. NLR document AMSTR-NLR-TN044 Issue 1.0 October 2006, "AMS Tracker Thermal Control Subsystem TTCS Safety Approach" and Sun Yet-Sen University document TTCS SYSU-AN-001-2.0 "TTCS-Accumulator Thermal Safety Analysis" dated August 10, 2006

8.5.3 STATUS: Closed. AIDC document AMSTR-AIDC-PR-019, “AMS Tracker Thermal Control Subsystem Thermal Switch Incoming Inspection Procedure,” dated 4/22/2008, Inspection Log dated 12/3/2008 and Sun Yat-Sen University document TTCS-SYSU-TEST-TRP-016, “TTCBQM Test Report for 2nd Micro-G Loop Performance Test,”10/7/2009

8.5.4 STATUS: Closed. AIDC document AMSTR-AIDC-PR-037, “AMS Tracker Thermal Control Subsystem Thermal Switch and Sensor Gluing Integration Procedure,” dated January 2008 and Sun Yat-Sen University document TTCS-SYSU-TEST-TRP-016, “TTCBQM Test Report for 2nd Micro-G Loop Performance Test,”10/7/2009

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8.6 CONTROL: HEAT PIPES. The worst case thermal conditioning for heat pipes consider the heaters that have been provided on the Tracker Radiator – RAM, Main Radiator – RAM, Tracker Radiator – Wake, Main Radiator – Wake, and the PDS heat pipes. Each of these heater systems has implemented a two fault tolerant system for inhibiting heater operations over the thermal threshold that could induce pressures over the MDP. (Set points for some thermostats are lower than the thermal environments that actually drive the MDP.) All heater systems utilize one thermostatic switch in the power leg, one in the return leg that are set to lower, health maintenance temperatures below the safety limit and a third "safety" thermostat that is dedicated to precluding exceeding the safety threshold for temperature (60°C, main radiators) under worst case conditions and faults. Note: Independent of the safety controls there is a computer based, thermal sensor driven control of the entire heater circuitry power supply that will activate if temperature gets too high to protect the electronics. PHASE III REVISION: The Main Ram and Wake heaters utilize only two thermostatic controls, one on source, one on ground legs. Analysis shows that multiple heater failures are required to drive the heat pipes above the rated MDPs that are based on environmental extremes. This system remains 2-fault tolerant to exceeding MDP by heater failure.

8.6.1 SVM: Heater Fault Tolerance Thermal Analysis

8.6.2 SVM: Review of design for inclusion of heater thermostatic control and thermal threshold values

8.6.3 SVM: Inspection of Flight Hardware to assure proper thermostatic control placement and parts used.

8.6.4 SVM: Functional testing of thermostatic switches/Acceptance testing.

8.6.5 SVM: Ram and Wake Main Radiator Heater Fault Analysis for use of two thermostats.

8.6.1 STATUS: Closed. OPMT Action 09-033 Closure Response from Christian Vettore, September 23, 2009, "AMS TCS OPMT Action 09-033." OPMT Action 09-035 Closure Response from Christian Vettore, January 21, 2010, "CAB-USS HP MDT", AMSTCS-TN-CGS-001, "Safety Thermostats for the Main Radiators: Thermal Assessment," dated December 5, 2007

8.6.2 STATUS: Closed. ESCG Memorandum ESCG-4470-09-TEAN-DOC-0161, "AMS-02 Tracker Thermal Control System Heaters," dated September 24, 2009 documents review of AMSTR-NLR-TN-043, Issue 4, "AMS Tracker Thermal Control Subsystem TTCS Heater Specification," August 2009. ESCG Memorandum ESCG-4470-10-TEAN-DOC-0010, "AMS-02 Main Radiator Heat Pipe Safety Assessment," dated February 5, 2010

8.6.3 STATUS: Closed. Carlo Gavazzi Space SpA Inspection Report, AMSTCS-RP-CGS-017, "RAM Radiator Cabling Checkout Report," dated November 2, 2009, Carlo Gavazzi Space SpA Inspection Report, AMSTCS-RP-CGS-018, "WAKE Radiator Cabling Checkout Report," dated November 2, 2009, AMS-02 ATS TTCS-090716.01-

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A, “TTCS Condenser Installation Ram Side,” dated 11/29/2009, AMS-02 ATS TTCS-090716-01-B, “TTCS Condenser Installation Wake Side,” dated 11/25/2009, Carlo Gavazzi Drawing 47-AMS02TCS-200.10.00, “AMS TCS Condenser RAM Heaters and Thermostats Cabling,” 9/16/2009, Carlo Gavazzi Drawing 47-AMS02TCS-300.10.00, “AMS TCS Condenser WAKE Heaters and Thermostats Cabling,” 9/16/2009,

8.6.4 STATUS: Closed. Thermal Vacuum Testing Report DEL037-UNIPC-20100603-is2.doc, “DEL037 TV TB Test Report,” June 3, 2010.

8.6.5 STATUS: Closed. Carlo Gavazzi Space SpA Technical Note, “AMSTCS-TN-CGS-001, “Safety Thermostats for the Main Radiators: Thermal Assessment,” dated December 5, 2007

8.7 CONTROL: <Deleted. CAB Loop Heat Pipe has been removed from the AMS-02>

8.8 CONTROL: <Deleted. Cryocooler Loop Heat Pipes/Zenith Radiators have been removed from the AMS-02>

8.9 CONTROL: <Deleted. Cryocoolers have been removed from AMS-02>

8.10 CONTROL: <Deleted. OHP removed from AMS-02 >

8.11 CONTROL: TTCS Start Up Heaters. The TTCS Start Up Heaters have been assessed as being capable of driving the pressure of the TTCS CO2 loops sufficiently to warrant two fault tolerant thermostatic control devices to be implemented on each of the TTCS Start Up Heater loops. These thermostatic switches have been set to thermal threshold values that will preclude the TTCS Start Up Heaters from driving the pressure of the TTCS two phase loop beyond the established MDP. Two thermostatic control devices are in the source (power) to the heater elements and a single thermostatic control device in the return leg from the heater elements.

8.11.1 SVM: Review of Design for inclusion of heater thermostatic control and thermal threshold values.

8.11.2 SVM: Thermal Analysis to Establish MDP

8.11.3 SVM: Functional testing/Acceptance Testing of thermostatic switches.

8.11.4 SVM: Inspection of flight hardware for proper installation of thermostatic switches.

8.11.1 STATUS: Closed. NLR document AMSTR-NLR-TN044 Issue 1.0 October 2006, "AMS Tracker Thermal Control Subsystem TTCS Safety Approach" and ESCG Memorandum ESCG-4470-09-TEAN-DOC-0161, “AMS-02 Trackert Thermal Control System Heaters,” dated September 24, 2009 documents review of AMSTR-NLR-TN-043, Issue 4, “AMS Tracker Thermal Control Subsystem TTCS Heater Specification,” August 2009.

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8.11.2 STATUS: Closed. NLR document AMSTR-NLR-TN044 Issue 2.0 March 2010, "AMS Tracker Thermal Control Subsystem TTCS Safety Approach" and Sun Yet-Sen Univeristy document TTCS SYSU-AN-001-6.0 "TTCS-Accumulator Thermal Safety Analysis" dated November 18, 2009 8.11.3 STATUS: Closed. AIDC document AMSTR-AIDC-PR-019, “AMS Tracker Thermal Control Subsystem Thermal Switch Incoming Inspection Procedure,” dated 4/22/2008, Inspection Log dated 12/3/2008 and Sun Yat-Sen University document TTCS-SYSU-TEST-TRP-016, “TTCBQM Test Report for 2nd Micro-G Loop Performance Test,”10/7/2009 8.11.4 STATUS: Closed. AIDC document AMSTR-AIDC-PR-037, “AMS Tracker Thermal Control Subsystem Thermal Switch and Sensor Gluing Integration Procedure,” dated January 2008 and Sun Yat-Sen University document TTCS-SYSU-TEST-TRP-016, “TTCBQM Test Report for 2nd Micro-G Loop Performance Test,”10/7/2009	
9. CAUSE: Meteoroid and Orbital Debris (M/OD) impact.	
9.1 CONTROL: All pressurized tanks will be protected by M/OD shields. The shields are designed to meet the Probability of Non-Penetration (PNP) requirement of SSP 52005. While the AMS-02 will have an extended on-orbit life, the pressurized tanks will only represent a hazardous condition for a limited period of time before the pressure reserves are spent. Each tank will be assessed for PNP for the duration of operational life. 9.1.1 SVM: AMS-02 M/OD Risk Analysis 9.1.2 SVM: Analysis of AMS-02 pressurized system utilization to establish on-orbit penetration threat life duration (period during which M/OD represents a hazard to the pressure vessel.) 9.1.1 STATUS: Closed. ESCG Memo ESCG-4175-09-REENTES-MEMO-0002, “Review of AMS-02 Micrometeoroid and Orbital Debris Analysis,” daed February 12, 2009 9.1.2 STATUS: Closed. ESCG Memo SSCG-4390-07-SP-MEMO-0023, “AMS-02 Pressurized Systems”, December 6, 2007	
9.2 CONTROL: <Deleted with the Removal of the Warm Helium Gas Supply>	
9.3 CONTROL: Upon depletion of one gas source of the TRD Gas Supply, the other gas source will be slowly released by AMS-02 ground controller commands (multi-step process) through the TRD purging system until the tank is also depleted. Procedure implementation will be coordinated with the ISS for appropriate timing of gaseous release. Note: This control is	I(A)

PAYLOAD FLIGHT HAZARD REPORT	a. NO: AMS-02-F05
b. PAYLOAD Alpha Magnetic Spectrometer-02 (AMS-02)	c. PHASE: III

a foundation of the MMOD Analysis.

9.3.1 SVM: Review of design/Analysis to confirm ability to empty residual gas from TRD Pressurized Tanks.

9.3.2 SVM: Review of Procedures for inclusion of TRD Pressurized Tank Residual Release (AMS Project Procedure)

9.3.3 SVM: Acceptance by POIC of Flight Regulations.

9.3.1 STATUS: Closed. ESCG Memo SSCG-4390-07-SP-MEMO-0023, "AMS-02 Pressurized Systems", December 6, 2007

9.3.2 STATUS: Closed. Procedure documented in AMS-02 Task Sheet (ATS) TRD 123115-1, dated April 24, 2009.

9.3.3 STATUS: Closed. Email from MSFC-EO03/Payload Operations Director/R. S. Grimaldi, "AMS-02-F05 Hazard Report – FR Acceptance," dated October 15, 2010

10.0 CAUSE: Damage to Composite Overwrapped Pressure Vessel

10.1 CONTROL: All Composite Overwrapped Pressure Vessels will implement the ground handling damage control requirements of ANSI/AIAA S-081 for the protection and inspection of COPV.

10.1.1 SVM: Review of TRD COPV Protection Protocols

10.1.2 SVM: <Deleted>

10.1.3 SVM: Inspection of TRD COPVs (at late in process as possible prior to flight)

10.1.4 SVM: <Deleted>

10.1.1 STATUS: Closed. ESCG Memorandum, ESCG-4390-09-SP-MEMO-0002, "AMS-02 COPV Damage Control Plan," Dated January 26, 2009

10.1.2 STATUS: <Deleted>

10.1.3 STATUS: Closed. WSTF-IR-1144-001-09, "Visual Inspection Report for the Alpha Magnetic Spectrometer (AMS-02) Payload," August 19, 2009

10.1.4 STATUS: <Deleted>

10.2 CONTROL: Thermostatic control of the heaters mounted to the exterior of the TRD Composite Overwrapped Pressure Vessels have four thermostatic control devices that are set to a thermal limit below the temperature that could

PAYLOAD FLIGHT HAZARD REPORT	a. NO: AMS-02-F05
b. PAYLOAD Alpha Magnetic Spectrometer-02 (AMS-02)	c. PHASE: III

possibly induce delaminations. 10.2.1 SVM: Arde Certification of thermostatic control acceptability. 10.2.2 SVM: Inspection of as built hardware for proper thermostat installation. 10.2.1 STATUS: Closed. TRD Gas Box Traveler Wiring #1.4, 2/17/07 and TRD Gas Box Traveler Wiring #1.5 CO2 Vessel, 3/12/07 document Arde sign off on installation. 10.2.2 STATUS: Closed. TRD Gas Box Traveler Wiring #1.4, 2/17/07 and TRD Gas Box Traveler Wiring #1.5 CO2 Vessel, 3/12/07 documents inspection of installed thermostats.	
NOTES:	

ACRONYMS	
°C – degrees Centigrade (Celsius)	mm – millimeter
AIAA – American Institute Aeronautics and Astronautics	MUAs – Material Usage Agreements
AMS-02 – Alpha Magnetic Spectrometer - 02	OHP – Oscillating Heat Pipe (experiment)
ANSI – American National Standards Institute	PNP – Probability of No Penetration
CAB – Cryomagnet Avionics Box	psi – Pounds per square inch
CO_2 – Carbon Dioxide	psia – Pounds per square inch absolute
COPV – Composite Overwrapped Pressure Vessel	SVM – Safety Verification Method
He – Helium	SVP – Structural Verification Plan
HP – Heat Pipe	TRD – Transition Radiation Detector
M/OD – Meteoroid/Orbital Debris	TTCS – Tracker Thermal Control System
MDP – Maximum Design Pressure	USS-02 – Unique Support Structure 02
MLI – Multilayer insulation	Xe – Xenon
C of C – Certificate of Compliance	ksi – kilo pounds per square inch
lbf – pound force	mbar – millibar
MUA – Material Usage Agreements	Ops – Operations
QA – Quality Assurance	Ult - Ultimate

A. TRD Gas Supply

TRD Pressure System Components

Description	Material Of Construction	Mass Of Fluid		Operating Pressure (max)		MDP[1]		Burst Pressure		Burst SF		Proof Pressure		Proof SF	Analysis Test or Similarity	Reference Document
		kg	lbm	bar	psid	bar	psid	bar	psid	Req	Actual	bar	psid			
Xe Storage Vessel, ARDE D4815 (similarity: D4636) [2]	Carbon Fiber Overwrapped Stainless Steel Liner	49.4	109	173	2500	206.8	3,000	641.2	9,300	2	3.1	310.3	4500	1.5	Similarity & Test	MIL-STD-1522A SSP 30559C
CO_2 Storage Vessel, ARDE D4816 (similarity: D4683) [2]	Carbon Fiber Overwrapped Stainless Steel Liner	5.0	11.0	100	1440	206.8	3,000	441.3	6,400	2	2.1	330.9	4800	1.6	Similarity & Test	SSP 30559C
Mixing Vessel, ARDE C4810 [2]	Stainless Steel	0.1	0.22	13.8	200	20.7	300	82.7	1,200	2	4.0	41.4	600	2	Test	SSP 30559C
TRD "Straw" Tubes	Wrapped Carbon-Kapton-Aluminum Composite	1.17	2.58	1.2	17..4	2.0	29.4	>5	>72.5	2.5	2.5	3.0	44.1	1.5	Test	NSTS 1700.7B SSP 30559C
Plumbing Line 1/8"	Stainless Steel	0.003	0.01	120.0	1,740	206.8	3,000	882.5	12,800	4	4.3	413.7	6,000	2	Test	
Plumbing Line 1/4"	Stainless Steel	0.005	0.01	120.0	1,740	206.8	3,000	882.5	12,800	4	4.3	413.7	6,000	2	Test	NSTS 17007B SSP 30559C
Plumbing Line 1/16"	Stainless Steel	<0.001	<0.002	1.2	17.4	2.0	29.4	>11.0	160	4	5.44	3	44.1	1.5	Test	NSTA 17007B SSP 30559 C
Swagelok ¼" T-Fitting with Swagelok VCR ¼" cap.	Stainless Steel	<0.001	<0.002	1.2	17.4	2.0	29.4	>11.0	160	4	5.44	3	44.1	1.5	Test	NSTA 17007B SSP 30559 C
TRD segment metal fitting	Stainless steel aluminum Viton	<0.001	<0.002	1.2	17.4	2.0	29.4	>11.0	160	4	5.44	3	44.1	1.5	Test	NSTA 17007B SSP 30559 C
Marotta MV 100 Valves [2]	See Data Sheet	<0.002	0.004	2.0	29.4	20.7	300	517.1	7,500	2.5	25	310.3	4,500	15	Similarity & Test	NSTS 1700.7B Marotta Spec SP 1200
Marotta MV 197 Valves [2]	See Data Sheet	<0.002	0.004	106.9	1,550	206.8	3,000	1,723.7	25,000	2.5	8.3	868.7	12,600	4.2	Similarity & Test	NSTS 1700.7B Marotta Spec SP 1200
Bürkert Type 6124 Flipper	See Data Sheet	N/A	N/A	1.2	17.4	2.0	29.4	8.6	125	2.5	4.3	3.0	44.1	1.5	Similarity & Test	

TRD Pressure System Components

Description	Material Of Construction	Mass Of Fluid		Operating Pressure (max)		MDP[1]		Burst Pressure		Burst SF		Proof Pressure		Proof SF	Analysis Test or Similarity	Reference Document
		kg	lbm	bar	psid	bar	psid	bar	psid	Req	Actual	bar	psid			
Valves Manifold: VA, B, C, D)[9]																
GP-50 Pressure Sensors [3]	See Data Sheet	<0.002	0.004	1.4	20.4	2.0	29.4	41.4	600	2.5	20.4	13.8	200.0	6.8	Similarity & Test	NSTS 1700.7B SSP 30559C
GP-50 Pressure Sensors [3]	See Data Sheet	<0.002	<0.004	13.8	200	20.7	300	62.1	900	2.5	3.0	41.4	600	2	Similarity & Test	NSTS 1700.7B SSP 30559C
GP-50 Pressure Sensors [3]	See Data Sheet	<0.002	<0.004	106.9	1,550	206.8	3,000	620.5	9,000	2.5	3.0	413.7	6,000	2	Similarity & Test	NSTS 1700.7B SSP 30559C
Kulite Pressure Sensors [3]	Stainless Steel	<0.002	<0.004	13.8	200	20.7	300	62.1	900	2.5	3.0	41.4	600	2	Similarity & Test	NSTS 1700.7B SSP 30559C
Kulite Pressure Sensors [3]	Stainless Steel	<0.002	<0.004	106.9	1,550	206.8	3,000	620.5	9,000	2.5	3.0	310.3	4,500	1.5	Similarity & Test	NSTS 1700.7B SSP 30559C
TheLeeCo restictor housing	Stainless Steel, 304L	N/A	N/A	20.7	300	206.8	3,000	413.7	>12000	2.5	>4.0	310.3[10]	4500[10]	1.5	Similarity & Test	
TheLeeCo Inline Check Valve CKV1a,b	See Data Sheet	N/A	N/A	106.9	1,550	206.8	3,000	827.4	12,000	2.5	4.0	310.3[10]	4500[10]	1.5	Similarity & Test	
7 micron Inline Filters	See Data Sheet	N/A	N/A	106.9	1,550	206.8	3,000	827.4	12,000	2.5	4.0	310.3[10]	4500[10]	1.5	Similarity & Test	
Pressure Container for CO_2 sensor, Box C [4, 5]	Stainless Steel	<0.01	<0.02	1.2	17.4	2.0	29.4	4.1	58.8	2	2.0	3.0	44.1	1.5	Test	MIL-STD-1522A SSP 30559C
Pumps	See Data Sheet	<0.002	<0.004	1.2	17.4	1.7	25.0	2.4	35.0	N/A	N/A	N/A	N/A	N/A	Test	NSTS 1700.7B SSP 30559C
Marotta Pressure Relief Valves [2]	See Data Sheet	<.002	<0.004	13.8	200	20.7	300	61.0	885	2.5	3.0	32.8	475	1.6	Similarity & Test	NSTS 1700.7B SSP 30559C
Pressure Relief Valve Box C	See Data Sheet	<.002	<0.004	1.2	17.4	2.0	29.4	20.7	300.0	2.5	10.2	3.0	44.1	1.5	Test	MIL-STD-1522A SSP 30559C
Burst Disks Box S [2,6]	Stainless Steel	<.002	<0.004	13.8	200	20.3	295	20.3	295	N/A	N/A	N/A	N/A	N/A	Similarity & Test	BS & B, M.S. 18
Xe Fill Port Valves	Stainless Steel	N/A	N/A	106.9	1550	206.8	3,000	>520	>7541	2.5	>2.5	520	7541	2.5	Test	
CO_2 Fill Port Valves [4]	Stainless Steel	N/A	N/A	64.8	940	206.8	3,000	>520	>7541	2.5	>2.5	520	7541	2.5	Test	
Xe Fill Port Caps [4]	Stainless Steel	N/A	N/A	106.9	1550	206.8	3,000	>689	>10000	2.5	>3.3	520	7541	2.5	Similarity & Test	
CO_2 Fill Port Caps [4]	Stainless Steel	N/A	N/A	64.8	940	206.8	3,000	>689	>10000	2.5	>10.6	520	7541	2.5	Similarity & Test	

TRD Pressure System Components

Description	Material Of Construction	Mass Of Fluid		Operating Pressure (max)		MDP[1]		Burst Pressure		Burst SF		Proof Pressure		Proof SF	Analysis Test or Similarity	Reference Document
		kg	lbm	bar	psid	bar	psid	bar	psid	Req	Actual	bar	psid			

Notes:

[1] MDP has been established based on worst case thermal profile and where applicable (with mechanisms to fail) worst case two fault condition.

[2] Pressure is in psig.

[3] Pressure is in psia

[4] Manufactured at CERN and pressure is in psia

[5] As per data approved by Peter Fisher, file: TRD_gas-press.doc, 06/23/2004

[6] Burst pressure equals 5% to the stamped burst pressure of 295 psig; proof SF is 80% of stamped burst pressure.

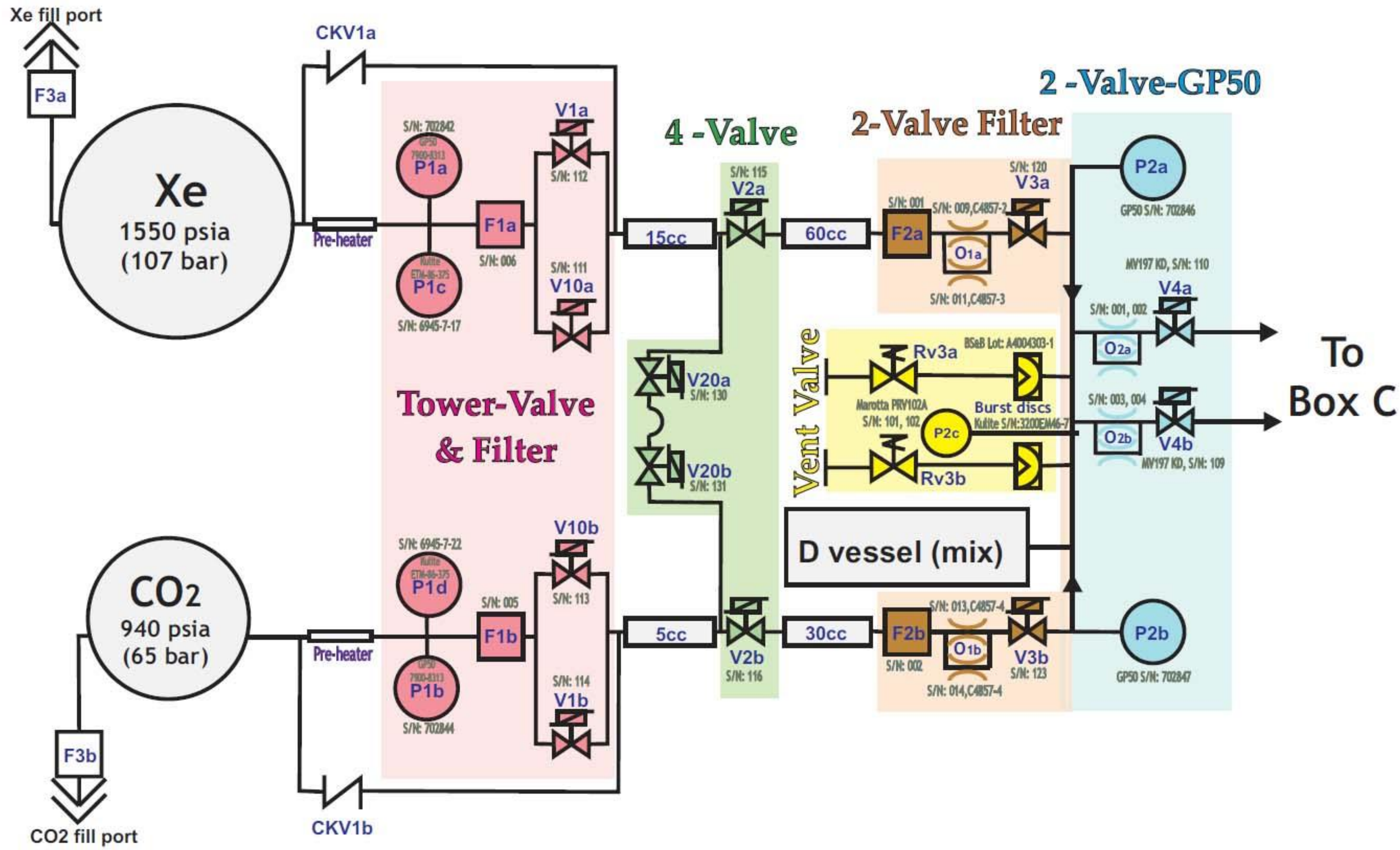
7) All 328 Straw modules have been tested to 1.8 bar (26.1 psid)

8) Maximum applied test pressure

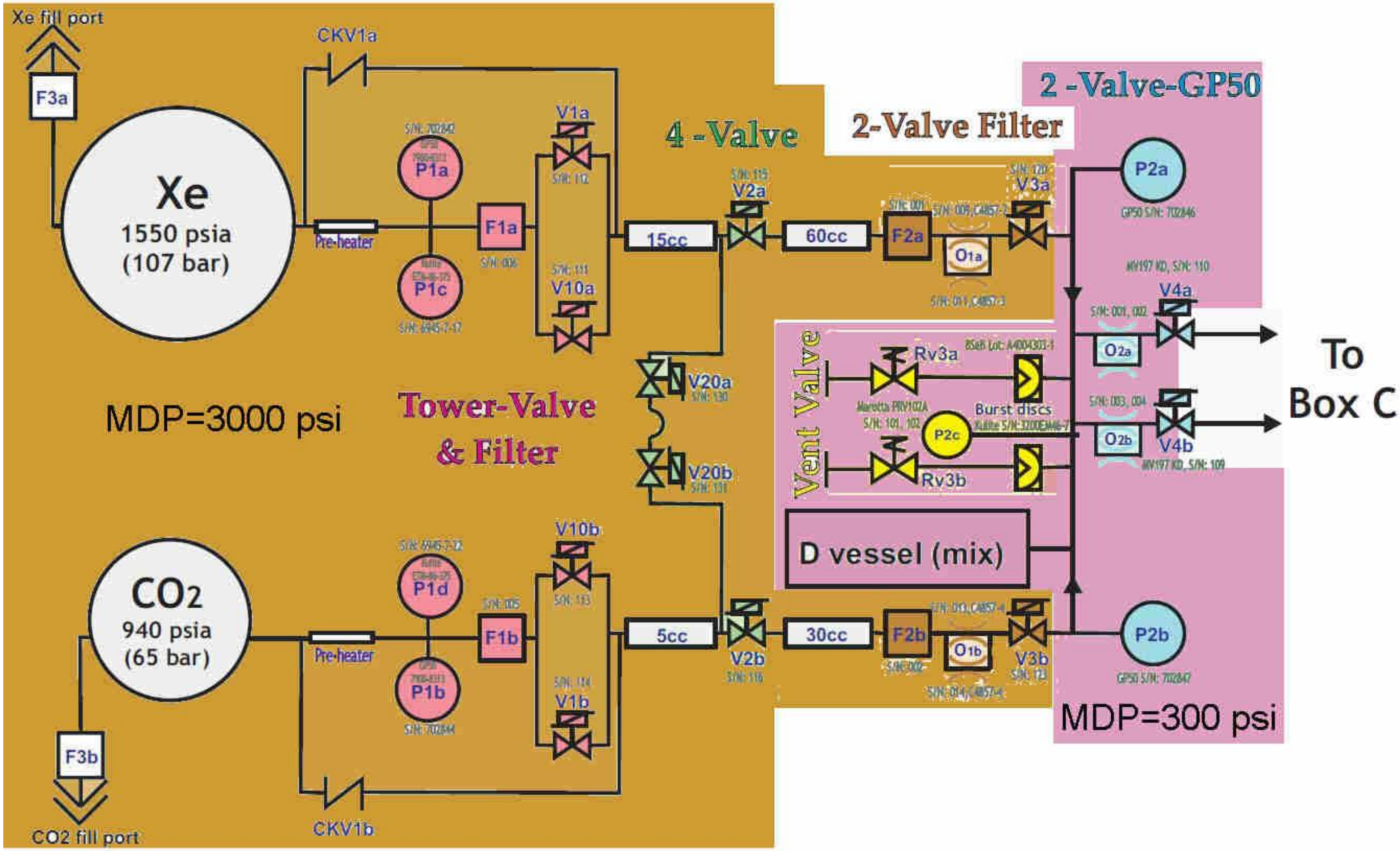
9) The valves are completely contained inside potted magnetic shielding

10) Flow Restrictor and filters are installed within housings that have been proof tested at Arde

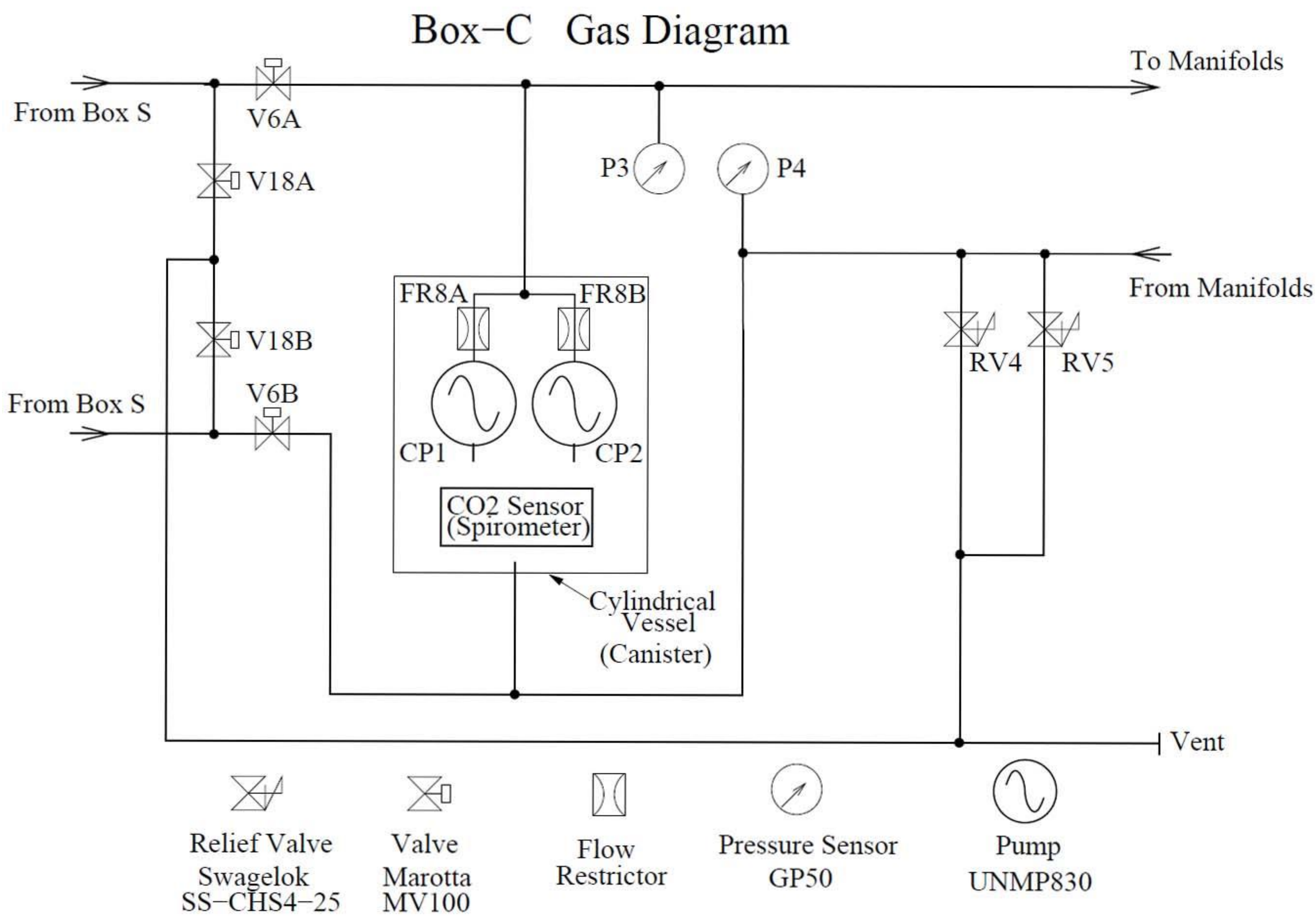
Box S Schematic



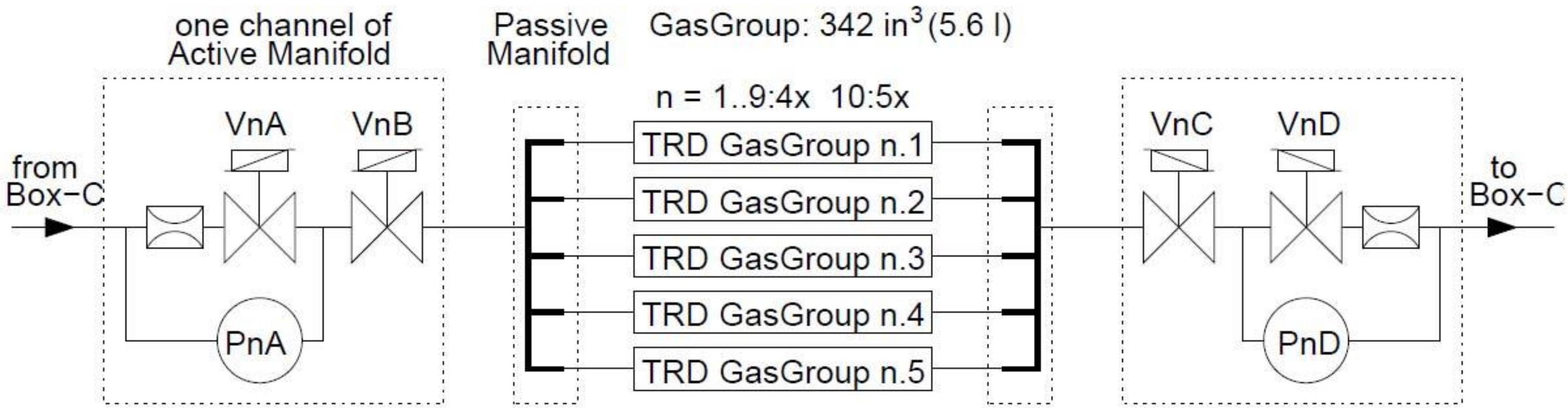
TRD Box S



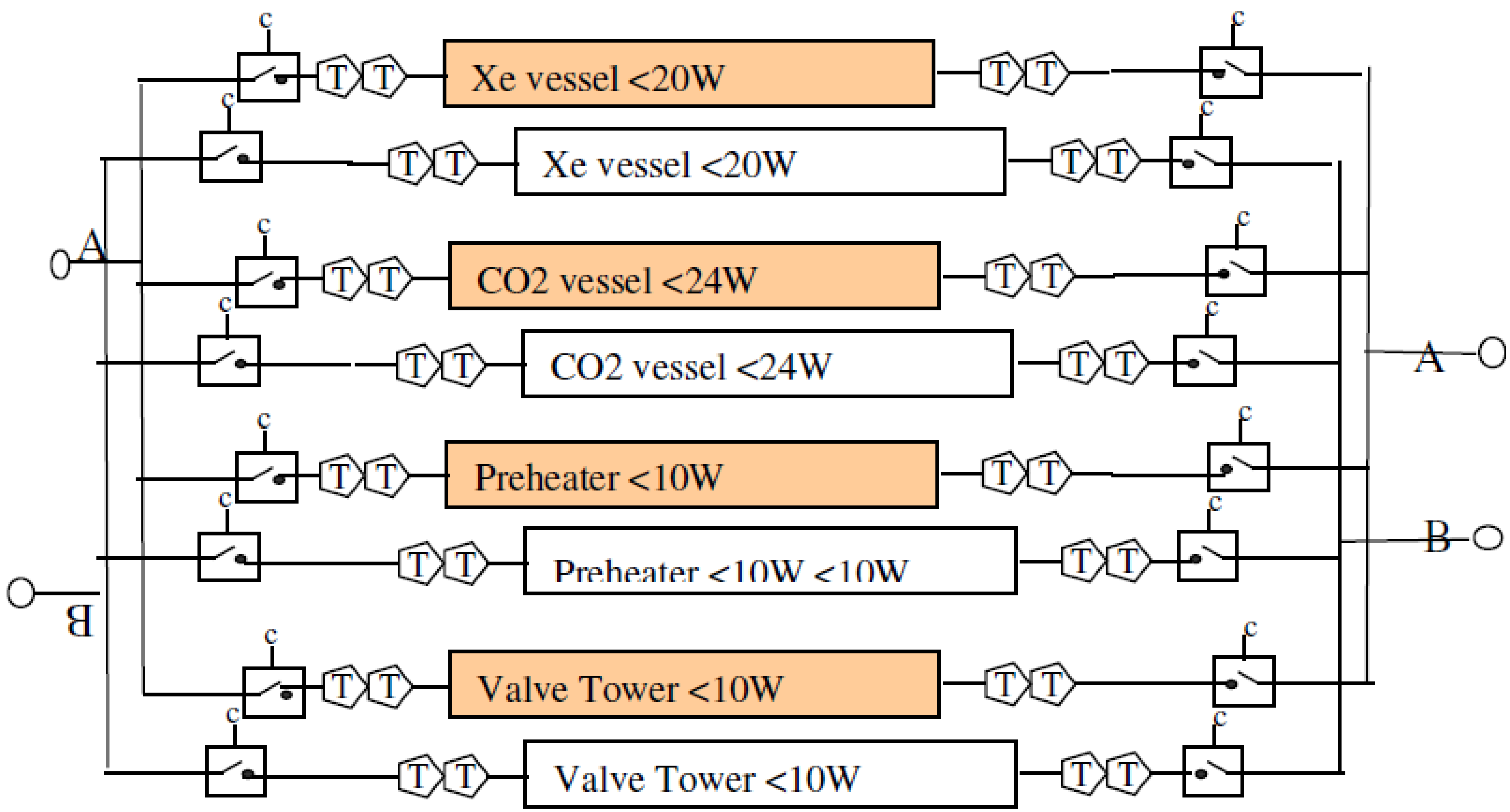
TRD Box S MDP Zones



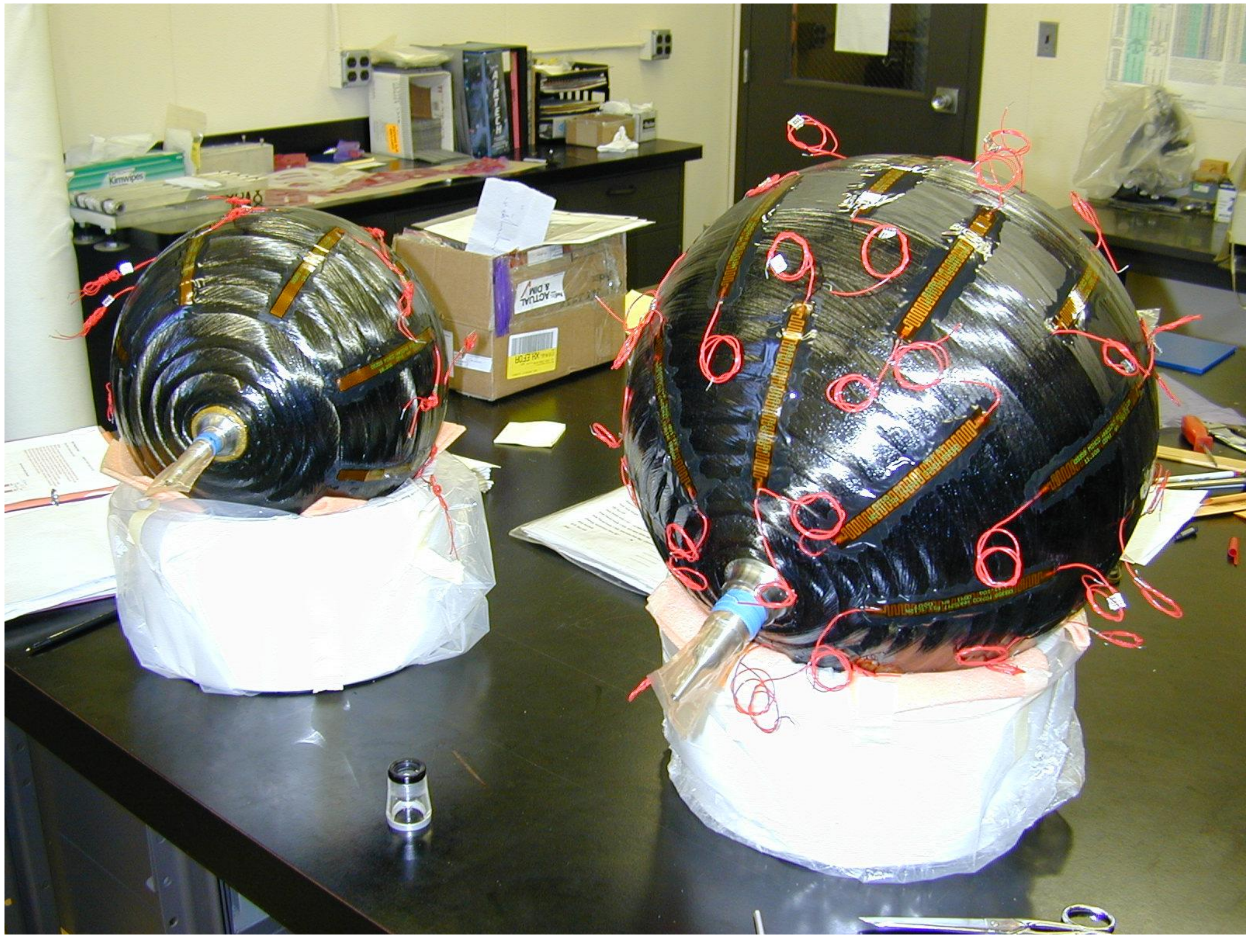
TRD Box C (MDP 29.4 psi Entire Box)



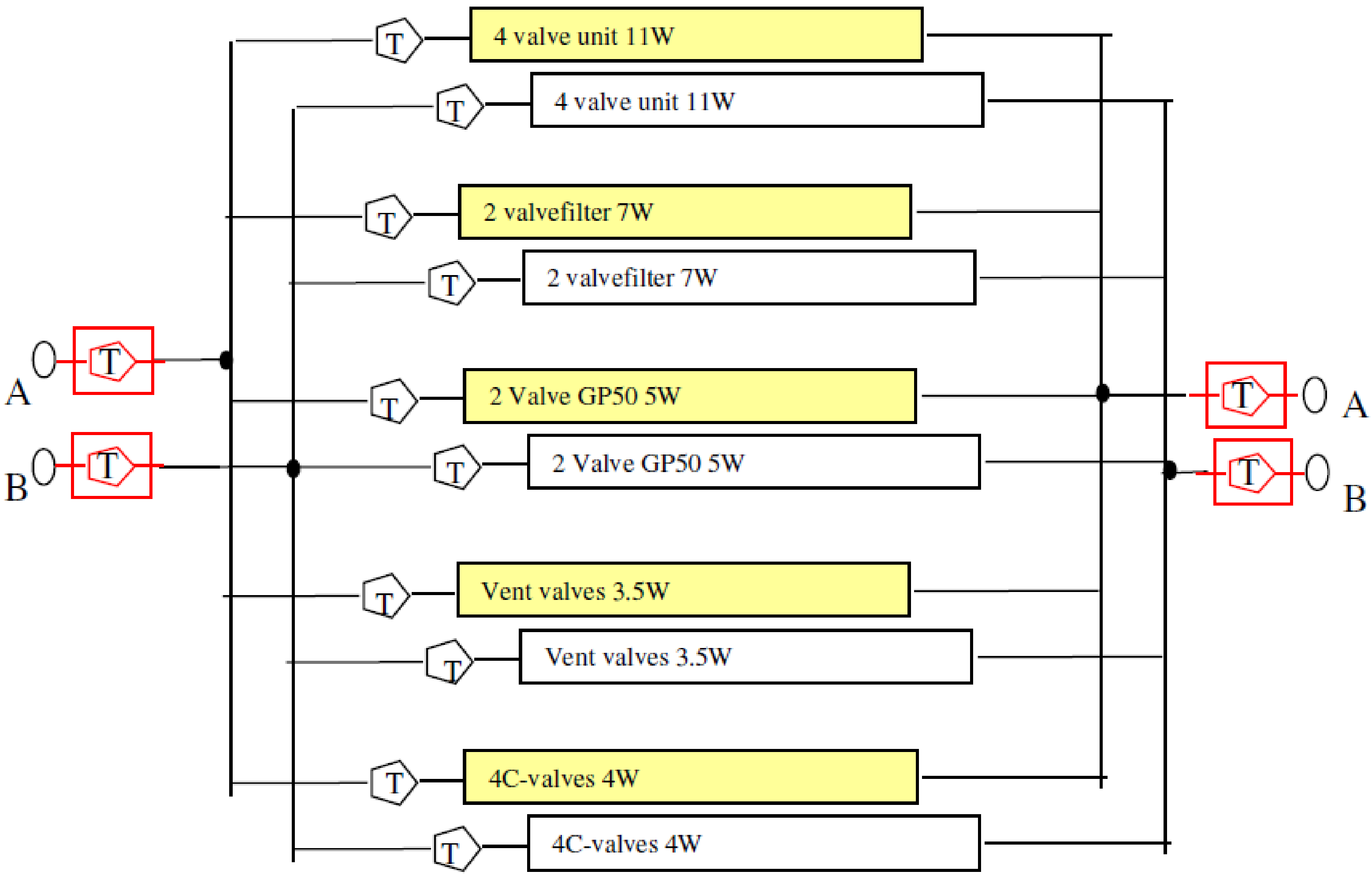
TRD Manifold-Straw Representation (MDP 29.4 psi)



TRD Tank Heaters (28V Heaters)



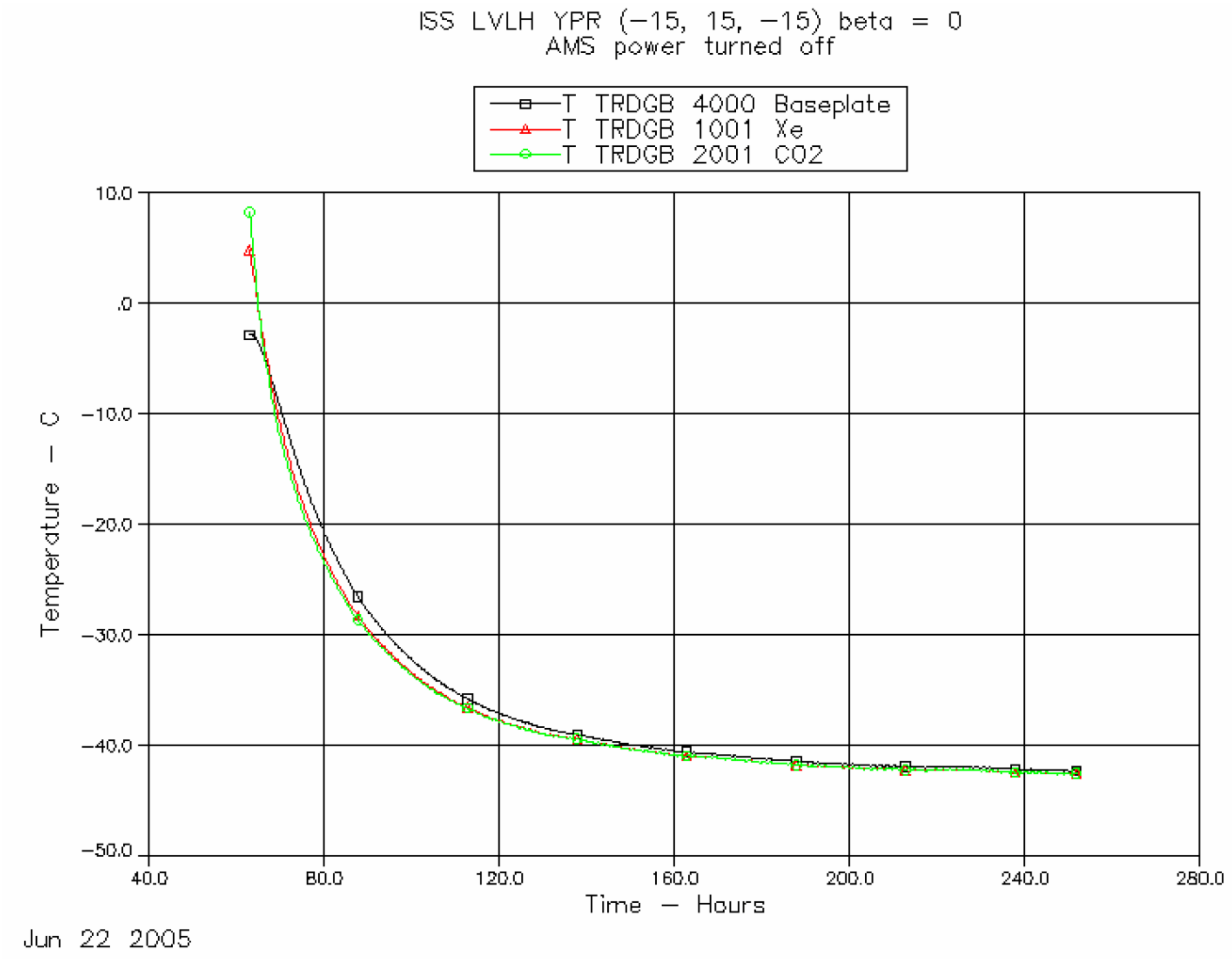
TRD GAS Tanks With Installed Heaters



TRD Gas Valve Block Heater (120V Heaters)

Location	Temperature Range	Tolerance	Average Temperature	T Open	T Close	Number
Xe Tank	20°C-65°C	±2.8°C	42.5°C	49°C	38°C	8
CO2 Tank	34°C-65°C	±2.8°C	48.5°C	54	43	8
Tower	24°C-41°C	±2.8°C	32.5°C	38	27	2
2 Valve Filters, 2 Valve GP50	5°C-39°C	±2.8°C	22°C	27	16	4
4 Valve, Vent Valve	5°C-39°C	±2.8°C	22°C	27	16	4+1
Box C	7°C-24°C	±2.8°C	15.5°C	21	10	2+1
Preheater	34°C -65°C	±2.8°C	48.5°C	54	43	8

TRD Gas Supply Thermostat List



TRD coldest thermal conditions assuming greater than 200 hours in coldest attitude and power off.

B. Tracker Thermal Control System

Tracker Thermal Control System Pressure System Components (Primary Loop)

Description	Material Of Construction	Mass Of fluid		Max. Operating Pressure		MDP[1]		Burst Pressure		Burst SF		Proof Pressure		Proof SF	Analysis Test or Similarity	Reference Document
		kg	lbm	bar	psid	bar	psid	bar	psid	Req[3]	Actual	bar	psid			
RAM feed line	ANSI 316L Stainless Steel	0.0251	0.0553	64.0	928.2	160.0	2320.0	2569.7	37270.0	4.0	16.1	239.9	3480.0	1.5	Analysis[2]	NSTS 1700.7B SSP 30559C
RAM return line	ANSI 316L Stainless Steel	0.0251	0.0553	64.0	928.2	160.0	2320.0	2569.7	37270.0	4.0	16.1	239.9	3480.0	1.5	Analysis[2]	NSTS 1700.7B SSP 30559C
RAM capillary condenser lines	Inconel 718	0.0328	0.0723	64.0	928.2	3009.0	43641.9	13962.0	202501.7	2.5	4.6[14]	240.0	3480.9	1.5	Analysis and Test	AMSTR-NLR-TR-007_TTCS Condenser High Pressure Test Report_Iss01
RAM capillary bypass	VSR-80 Stainless Steel	0.0002	0.0004	64.0	928.2	160.0	2320.0	2569.7	37270.0	4.0	5.8	239.9	3480.0	1.5	Analysis and Test	NSTS 1700.7B SSP 30559C
WAKE feed line	ANSI 316L Stainless Steel	0.0251	0.0553	64.0	928.2	160.0	2320.0	2569.7	37270.0	4.0	16.1	239.9	3480.0	1.5	Analysis[2]	NSTS 1700.7B SSP 30559C
WAKE return line	ANSI 316L Stainless Steel	0.0251	0.0553	64.0	928.2	160.0	2320.0	2569.7	37270.0	4.0	16.1	239.9	3480.0	1.5	Analysis[2]	NSTS 1700.7B SSP 30559C
WAKE capillary condenser lines	Inconel 718	0.0328	0.0723	64.0	928.2	3009.0	43641.9	13962.0	202501.7	2.5	4.6[14]	240.0	3480.9	1.5	Analysis and Test	AMSTR-NLR-TR-007_TTCS Condenser High Pressure Test Report_Iss01
Top Evaporator	ANSI 316L Stainless Steel	0.0535	0.1180	64.0	928.2	160.0	2320.0	927.7	13455.0	4.0	5.8	240.0	3480.9	1.5	Analysis[2]	NSTS 1700.7B SSP 30559C
Top Evaporator feed	ANSI 316L Stainless Steel	0.0093	0.0205	64.0	928.2	160.0	2320.0	2569.7	37270.0	4.0	16.1	239.9	3480.0	1.5	Analysis[2]	NSTS 1700.7B SSP 30559C
Top Evaporator return	ANSI 316L Stainless Steel	0.0093	0.0205	64.0	928.2	160.0	2320.0	2569.7	37270.0	4.0	16.1	239.9	3480.0	1.5	Analysis[2]	NSTS 1700.7B SSP 30559C
Lower Evaporator and Plane 6N	ANSI 316L Stainless Steel	0.0523	0.1153	64.0	928.2	160.0	2320.0	927.7	13455.0	4.0	5.8	240.0	3480.9	1.5	Analysis[2]	NSTS 1700.7B SSP 30559C
Lower Evaporator feed + Transport	ANSI 316L Stainless Steel	0.0164	0.0362	64.0	928.2	160.0	2320.0	2569.7	37270.0	4.0	16.1	239.9	3480.0	1.5	Analysis[2]	NSTS 1700.7B SSP 30559C
Lower Evaporator return + Transport	ANSI 316L Stainless Steel	0.0164	0.0362	64.0	928.2	160.0	2320.0	2569.7	37270.0	4.0	16.1	239.9	3480.0	1.5	Analysis[2]	NSTS 1700.7B SSP 30559C

Tracker Thermal Control System Pressure System Components (Primary Loop)

Description	Material Of Construction	Mass Of fluid		Max. Operating Pressure		MDP[1]		Burst Pressure		Burst SF		Proof Pressure		Proof SF	Analysis Test or Similarity	Reference Document
		kg	lbm	bar	psid	bar	psid	bar	psid	Req[3]	Actual	bar	psid			
Common Evaporator out	ANSI 316L Stainless Steel	0.0028	0.0062	64.0	928.2	160.0	2320.0	1888.2	27386.0	4.0	11.8	240.0	3480.9	1.5	Analysis[2]	NSTS 1700.7B SSP 30559C
Pump_inlet tube	ANSI 316L Stainless Steel	0.0070	0.0155	64.0	928.2	160.0	2320.0	1888.2	27386.0	4.0	11.8	240.0	3480.9	1.5	Analysis[2]	NSTS 1700.7B SSP 30559C
Pressure sensor connecting tubes	ANSI 316L Stainless Steel	0.0021	0.0047	64.0	928.2	160.0	2320.0	2569.7	37270.0	4.0	16.1	239.9	3480.0	1.5	Analysis[2]	NSTS 1700.7B SSP 30559C
Box tubing	ANSI 316L Stainless Steel	0.0131	0.0288	64.0	928.2	160.0	2320.0	2569.7	37270.0	4.0	16.1	239.9	3480.0	1.5	Analysis[2]	NSTS 1700.7B SSP 30559C
Pressure sensors	PT sensor housing Stainless steel 316 L	0.0020	0.0044	64.0	928.2	160.0	2320.0	400.0	5800.0	2.5	2.5	240.0	3480.9	1.5	Similarity or Test	TTCS-SYSU-VER-001-Verification_Table_APS_DPS_iss01
Pump	304L CRES per SAE AMS-QQ-S-763	0.0735	0.1620	64.0	928.2	160.0	2320.0	400.0	5800.0	2.5	2.5	240.0	3480.9	1.5	Analysis and Test	5059-113 SN-01 and 02 “Certificate of Compliance PDT Pumps and Controller S/N 01 and 02” 5059-113 SN-03 and 04 “Certificate of Compliance PDT Pumps and Controller S/N 03 and 04”
Heat Exchanger	Inconel 625	0.0560	0.1235	64.0	928.2	160.0	2320.0	400.0	5800.0	2.5	2.5	240.0	3480.9	1.5	Analysis and Test	AMSTR-NLR-TR-052-053-065-HX_Procedure_Records_FM1
Hydraulic connectors	RES 386 (15--5PH)	0.0050	0.0111	64.0	928.2	160.0	2320.0	827.4	12000.0	2.5	5.2	240.0	3480.9	1.5	by Specification	
Condenser Manifolds	ANSI 316 Stainless Steel	0.0045	0.0099	64.0	928.2	160.0	2320.0	400.0	5800.0	2.5	2.5	240.0	3480.9	1.5	Analysis and Test	AMSTR-NLR-PR-040_FM_Condenser_He_leak_and_proof_pressure_procedure and AMSTR-NLR-PR-

Tracker Thermal Control System Pressure System Components (Primary Loop)

Description	Material Of Construction	Mass Of fluid		Max. Operating Pressure		MDP[1]		Burst Pressure		Burst SF		Proof Pressure		Proof SF	Analysis Test or Similarity	Reference Document
		kg	lbm	bar	psid	bar	psid	bar	psid	Req[3]	Actual	bar	psid			
																004_Cond_Manifold_Brazing_Procedure_Iss04 (including burst test)
Capillary bypass brazed connection	VSR 80 Stainless Steel	0.0005	0.0012	64.0	928.2	160.0	2320.0	400.0	5801.5	2.5	>5.8	240.0	3480.9	1.5	Test	
TTCS Accumulator	A316LN CRES	0.7000	1.5432	64.0	928.2	160.0	2320.6	614.6	8914.0	2.5	3.8	240.0	3480.9	1.5	Analysis and Test	AMSTR-NLR-AMS02-CAST-TTCS-ACC-DR-002_DESIGN OF TTCS ACCUMULATOR_CAST and PR026 TTCB Proof Pressure test procedure (& records)
TTCS Accumulator Heat Pipe outside Accumulator	A316LN CRES	0.0030	0.0066	10.1	146.5	50.2.	728.1	962.0	13952.6	4.0	19.2	76.0	1102.3	1.6	Analysis and Test	AMS02-CAST-TTCS-ACC-DR-002_DESIGN OF TTCS ACCUMULATOR_CAST_.
TTCS Accumulator Heat Pipe inside Accumulator	A316LN CRES	0.0030	0.0066	64.0	928.2	160.0	2319.0	24125.0	349903.5	2.5	150.8	240.0	3480.9	1.5	Analysis and Test	AMS02-CAST-TTCS-ACC-DR-002_DESIGN OF TTCS ACCUMULATOR_CAST_.

Notes:

1) MDP has been established based on worst case thermal profile and where applicable (with mechanisms to fail) worst case two fault condition.

2) Burst Safety Factor is calculated from the material allowable stress and pipe geometry. Complete system is proof pressure tested to 1.5 MDP. Ref: AMSTR-NLR-PR-071_1_0_TTCS_Proof_pressure_test_procedure & Records

3) Heat pipes are part of a pressurized system and are not isolated. Burst Factor of 4.0 is used.

4) Ref TCS Hardware Design Report AMS-OHB-DER-001 issue 2, March 1, 2005

5) Condenser MDP is based on more detailed CO2 melting line data (NIST) at -5 C (3009 bar). The burst pressure is calculated with

6) HP MDP pressure based on 110 C maximum HP temperature (see see AMS02-CAST-TTCS-HP-SF-03 page 6)

7) The burst pressures of the Pumps valves, Pressure sensors and HX are design values. Pump design and HX designers have performed preliminary FEM analyses. Documents need to be written and delivered.

Tracker Thermal Control System Pressure System Components (Primary Loop)

Description	Material Of Construction	Mass Of fluid		Max. Operating Pressure		MDP[1]		Burst Pressure		Burst SF		Proof Pressure		Proof SF	Analysis Test or Similarity	Reference Document
		kg	lbm	bar	psid	bar	psid	bar	psid	Req[3]	Actual	bar	psid			

8) The TTCS Accumulator heat pipe inside the accumulator numbers extracted from AMS-02-CAST-TTCS-HP-SF-001 Issue 2, 14-03-2007 p8.

9) The maximum NH_3 heat pipe working pressure is based on a maximum HP operating Temperature of 25 C

10) The MDP inside the accumulator and onto the outside accu heat pipe is 160 bar. For burst analyses (see AMS-02-CAST-TTCS-HP-SF-001 Issue 2, 14-03-2007 p8)

11) The liquid mass is the mass of pure liquid in the component (this implies the overall mass of this table is larger then the CO_2 mass in the loop)

12) The liquid mass presented is the sum of liquid at -40 C in the components

13) The mass of the accumulator is based on a 969.5 ml volume (see AMS02-CAST-TTCS-ACC-DR-002draft page 28) and is calculated below

14) The Burst SF of the Inconel 718 condenser tubes is based on calculated strain hardening of the tubing during the pressure cycle (See Equation). Hydraulic testing of representative bent tube parts to the condenser will be done to a pressure of 1.5x 3009 = 45135 bar as a "proof" and up to a maximum of 10,000 bar to validate a burst limit. The QM and FM condenser assemblies will be tested up to a pressure of 240 bar because of the connected manifolds (MDP = 160 bar) during the condenser proof pressure tests.

Rho	1.12E+03	Density at lowest temperature (-40 C)
Rho_liq	551.771	Liquid density at highest liquid level 30 C
Rho_vap	352.983	Vapour density at highes liquid level 30 C
Highest liquid level	80%	Highest liquid level in the loop is at BOL, 30 C, low subcooling

$$p_u = \frac{2\sigma_y}{\sqrt{3}}\left(2 - \frac{\sigma_y}{\sigma_u}\right)\ln\frac{r_o}{r_i}$$

	Volume [ml]	Number [-]	Liquid mass [kg]	Vapor mass [kg]	Total [kg]
Accumulator	969.5	1	0.43	0.27	0.70

Tracker Thermal Control System Pressure System Components (Secondary Loop)

Description	Material Of Construction	Mass Of fluid		Operating Pressure		MDP[1]		Burst Pressure		Burst SF		Proof Pressure		Proof SF	Analysis Test or Similarity	Reference Document
		kg	lbm	bar	psid	bar	psid	bar	psid	Req	Actual	bar	psid			
RAM feed line	ANSI 316L Stainless Steel	0.0251	0.0553	64.0	928.2	160.0	2320.0	2569.7	37270.0	4.0	16.1	239.9	3480.0	1.5	Analysis[2]	NSTS 1700.7B SSP 30559C
RAM return line	ANSI 316L Stainless Steel	0.0251	0.0553	64.0	928.2	160.0	2320.0	2569.7	37270.0	4.0	16.1	239.9	3480.0	1.5	Analysis[2]	NSTS 1700.7B SSP 30559C
RAM capillary condenser lines	Inconel 718	0.0328	0.0723	64.0	928.2	3009.0	43641.9	13962.0	202501.7	2.5	4.6[14]	240.0	3480.9	1.5	Analysis and Test	AMSTR-NLR-TR-007_TTCS Condenser High Pressure Test Report_Iss01
RAM capillary bypass	VSR-80 Stainless Steel	0.0002	0.0004	64.0	928.2	160.0	2320.0	2569.7	37270.0	4.0	5.8	239.9	3480.0	1.5	Analysis and Test	NSTS 1700.7B SSP 30559C
WAKE feed line	ANSI 316L Stainless Steel	0.0251	0.0553	64.0	928.2	160.0	2320.0	2569.7	37270.0	4.0	16.1	239.9	3480.0	1.5	Analysis[2]	NSTS 1700.7B SSP 30559C
WAKE return line	ANSI 316L Stainless Steel	0.0251	0.0553	64.0	928.2	160.0	2320.0	2569.7	37270.0	4.0	16.1	239.9	3480.0	1.5	Analysis[2]	NSTS 1700.7B SSP 30559C
WAKE capillary condenser lines	Inconel 718	0.0328	0.0723	64.0	928.2	3009.0	43641.9	13962.0	202501.7	2.5	4.6[14]	240.0	3480.9	1.5	Analysis and Test	AMSTR-NLR-TR-007_TTCS Condenser High Pressure Test Report_Iss01
Top Evaporator	ANSI 316L Stainless Steel	0.0535	0.1180	64.0	928.2	160.0	2320.0	927.7	13455.0	4.0	5.8	240.0	3480.9	1.5	Analysis[2]	NSTS 1700.7B SSP 30559C
Top Evaporator feed	ANSI 316L Stainless Steel	0.0156	0.0343	64.0	928.2	160.0	2320.0	2569.7	37270.0	4.0	16.1	239.9	3480.0	1.5	Analysis[2]	NSTS 1700.7B SSP 30559C
Top Evaporator return	ANSI 316L Stainless Steel	0.0369	0.0813	64.0	928.2	160.0	2320.0	2569.7	37270.0	4.0	16.1	239.9	3480.0	1.5	Analysis[2]	NSTS 1700.7B SSP 30559C
Lower Evaporator and Plane 6N	ANSI 316L Stainless Steel	0.0523	0.1153	64.0	928.2	160.0	2320.0	927.7	13455.0	4.0	5.8	240.0	3480.9	1.5	Analysis[2]	NSTS 1700.7B SSP 30559C
Lower Evaporator feed + Transport	ANSI 316L Stainless Steel	0.0164	0.0362	64.0	928.2	160.0	2320.0	2569.7	37270.0	4.0	16.1	239.9	3480.0	1.5	Analysis[2]	NSTS 1700.7B SSP 30559C
Lower Evaporator	ANSI 316L Stainless	0.0164	0.0362	64.0	928.2	160.0	2320.0	2569.7	37270.0	4.0	16.1	239.9	3480.0	1.5	Analysis[2]	NSTS 1700.7B SSP 30559C

Tracker Thermal Control System Pressure System Components (Secondary Loop)

Description	Material Of Construction	Mass Of fluid		Operating Pressure		MDP[1]		Burst Pressure		Burst SF		Proof Pressure		Proof SF	Analysis Test or Similarity	Reference Document
		kg	lbm	bar	psid	bar	psid	bar	psid	Req	Actual	bar	psid			
return + Transport	Steel															
Common Evaporator out	ANSI 316L Stainless Steel	0.0028	0.0062	64.0	928.2	160.0	2320.0	1888.2	27386.0	4.0	11.8	240.0	3480.9	1.5	Analysis[2]	NSTS 1700.7B SSP 30559C
Pump_inlet tube	ANSI 316L Stainless Steel	0.0070	0.0155	64.0	928.2	160.0	2320.0	1888.2	27386.0	4.0	11.8	240.0	3480.9	1.5	Analysis[2]	NSTS 1700.7B SSP 30559C
Pressure sensor connecting tubes	ANSI 316L Stainless Steel	0.0014	0.0031	64.0	928.2	160.0	2320.0	2569.7	37270.0	4.0	16.1	239.9	3480.0	1.5	Analysis[2]	NSTS 1700.7B SSP 30559C
Box tubing	ANSI 316L Stainless Steel	0.0131	0.0288	64.0	928.2	160.0	2320.0	2569.7	37270.0	4.0	16.1	239.9	3480.0	1.5	Analysis[2]	NSTS 1700.7B SSP 30559C
Pressure sensors	PT sensor housing Stainless steel 316 L	0.0020	0.0044	64.0	928.2	160.0	2320.0	400.0	5800.0	2.5	2.5	240.0	3480.9	1.5	Similarity or Test	TTCS-SYSU-VER-001-Verification_Table_APS_DPS_iss 01
Pump	304L CRES per SAE AMS-QQ-S-763	0.0735	0.1620	64.0	928.2	160.0	2320.0	400.0	5800.0	2.5	2.5	240.0	3480.9	1.5	Analysis and Test	5059-113 SN-01 and 02 “Certificate of Compliance PDT Pumps and Controller S/N 01 and 02” 5059-113 SN-03 and 04 “Certificate of Compliance PDT Pumps and Controller S/N 03 and 04”
Heat Exchanger	Inconel 625	0.0560	0.1235	64.0	928.2	160.0	2320.0	400.0	5800.0	2.5	2.5	240.0	3480.9	1.5	Analysis and Test	AMSTR-NLR-TR-052-053-065-HX_Procedure_Records_FM1
Hydraulic connectors	RES 386 (15--5PH)	0.0050	0.0111	64.0	928.2	160.0	2320.0	827.4	12000.0	2.5	5.2	240.0	3480.9	1.5	by Specification	
Condenser Manifolds	ANSI 316 Stainless Steel	0.0045	0.0099	64.0	928.2	160.0	2320.0	400.0	5800.0	2.5	2.5	240.0	3480.9	1.5	Analysis and Test	AMSTR-NLR-PR-040_FM_Conden

Tracker Thermal Control System Pressure System Components (Secondary Loop)

Description	Material Of Construction	Mass Of fluid		Operating Pressure		MDP[1]		Burst Pressure		Burst SF		Proof Pressure		Proof SF	Analysis Test or Similarity	Reference Document
		kg	lbm	bar	psid	bar	psid	bar	psid	Req	Actual	bar	psid			
																ser_He_leak_and _proof_pressure_ procedure and AMSTR-NLR-PR-004_Cond_Manifold_Brazing_Procedure_Iss04 (including burst test)
Capillary bypass brazed connection	VSR 80 Stainless Steel	0.0005	0.0012	64.0	928.2	160.0	2320.0	400.0	5801.5	2.5	>5.8	240.0	3480.9	1.5	Test	
TTCS Accumulator	A316LN CRES	0.7000	1.5432	64.0	928.2	160.0	2320.6	614.6	8914.0	2.5	3.8	240.0	3480.9	1.5	Analysis and Test	AMSTR-NLR-AMS02-CAST-TTCS-ACC-DR-002_DESIGN OF TTCS ACCUMULATOR_CAST and PR026 TTCB Proof Pressure test procedure (& records)
TTCS Accumulator Heat Pipe outside Accumulator	A316LN CRES	0.0030	0.0066	10.1	146.5	50.2	728.1	962.0	13952.6	4.0	19.2	76.0	1102.3	1.5	Analysis and Test	MS02-CAST-TTCS-ACC-DR-002_DESIGN OF TTCS ACCUMULATOR_CAST_.
TTCS Accumulator Heat Pipe inside Accumulator	A316LN CRES	0.0030	0.0066	64.0	928.2	160.0	2319.0	24125.0	349903.6	2.5	150.8	240.0	3480.9	1.5	Analysis and Test	MS02-CAST-TTCS-ACC-DR-002_DESIGN OF TTCS ACCUMULATOR_CAST_.

Notes:
1) MDP has been established based on worst case thermal profile and where applicable (with mechanisms to fail) worst case two fault condition.

2) Burst Safety Factor is calculated from the material allowable stress and pipe geometry. Complete system is proof pressure tested to 1.5 MDP. Ref: AMSTR-NLR-PR-071_1_0_TTCS_Proof_pressure_test_procedure & Records

3) Heat pipes are part of a pressurized system and are not isolated. Burst Factor of 4.0 is used.

4) Ref TCS Hardware Design Report AMS-OHB-DER-001 issue 2, March 1, 2005

5) Condenser MDP is based on more detailed CO_2 melting line data (NIST) at -5 C (3009 bar). The burst pressure is calculated with

6) HP MDP pressure based on 110 C maximum HP temperature (see see AMS02-CAST-TTCS-HP-SF-03 page 6)

7) The burst pressures of the Pumps valves, Pressure sensors and HX are design values. Pump design and HX designers have performed preliminary FEM analyses. Documents need to be written and delivered.

8) The TTCS Accumulator heat pipe inside the accumulator numbers extracted from AMS-02-CAST-TTCS-HP-SF-001 Issue 2, 14-03-2007 p8.

9) The maximum NH_3 heat pipe working pressure is based on a maximum HP operating Temperature of 25 C

10) The MDP inside the accumulator and onto the outside accu heat pipe is 160 bar. For burst analyses (see AMS-02-CAST-TTCS-HP-SF-001 Issue 2, 14-03-2007 p8)

11) The liquid mass is the mass of pure liquid in the component (this implies the overall mass of this table is larger then the CO_2 mass in the loop)

12) The liquid mass presented is the sum of liquid at -40 C in the components

13) The mass of the accumulator is based on a 969.5 ml volume (see AMS02-CAST-TTCS-ACC-DR-002draft page 28) and is calculated below

14) The Burst SF of the Inconel 718 condenser tubes is based on calculated strain hardening of the tubing during the pressure cycle (see Equation). Hydraulic testing of representative ent tube bards to the condenser will be done to a pressure of 1.5 x 3009 = 45135 bar as a “proof” and up to a maximum 10,000 bar to validate the burst limit. The QM and FM condenser assemblies will be tested up to a pressure of 240 bar because of the connected manifold (MDP = 160 bar) during condenser proof pressure tests.

Rho	1.12E+03	Density at lowest temperature (-40 C)
Rho_liq	551.771	Liquid density at highest liquid level 30 C
Rho_vap	352.983	Vapour density at highes liquid level 30 C
Highest liquid level	80%	Highest liquid level in the loop is at BOL, 30 C, low subcooling

$$p_u = \frac{2\sigma_y}{\sqrt{3}}(2 - \frac{\sigma_y}{\sigma_u})\ln\frac{r_o}{r_i}$$

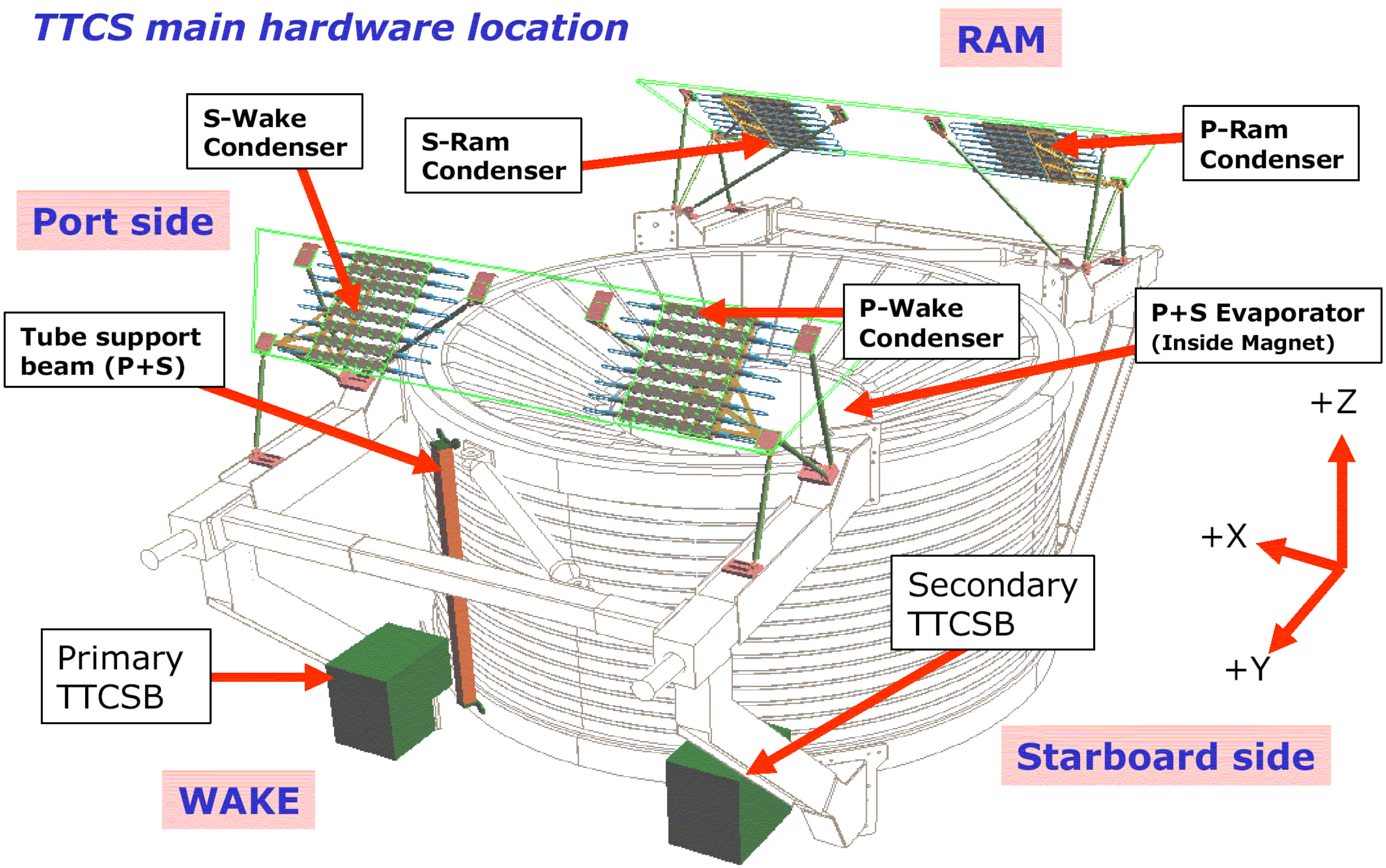
	Volume [ml]	Number [-]	Liquid mass [kg]	Vapor mass [kg]	Total [kg]
Accumulator	969.5	1	0.43	0.27	0.70

Tracker Radiator Heat Pipes Pressure System Components

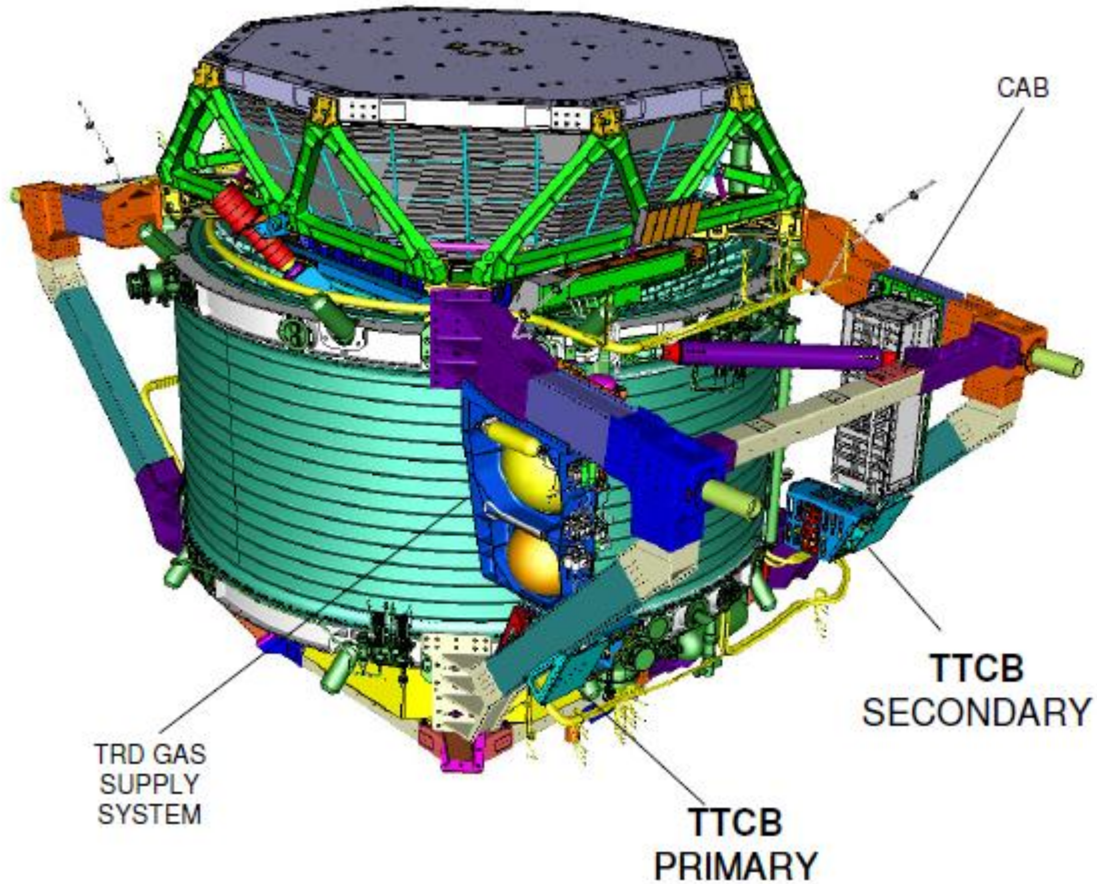
Description	Material Of Construction	Mass Of fluid		Operating Pressure[6])		MDP[1]		Burst Pressure		Burst SF		Proof Pressure		Proof SF	Analysis Test or Similarity	Reference Document
		kg	lbm	bar	psid	bar	psid	bar	psid	Req[3]	Actual	bar	psid			
Embedded Heat Pipes	AL 6063	Note 5		4.0	58.0	20.0	290.0	174.7	2534.0	4.0	8.7	30.0	435.0	1.5	Analysis[2]	NSTS 1700.7B SSP 30559C

Notes:

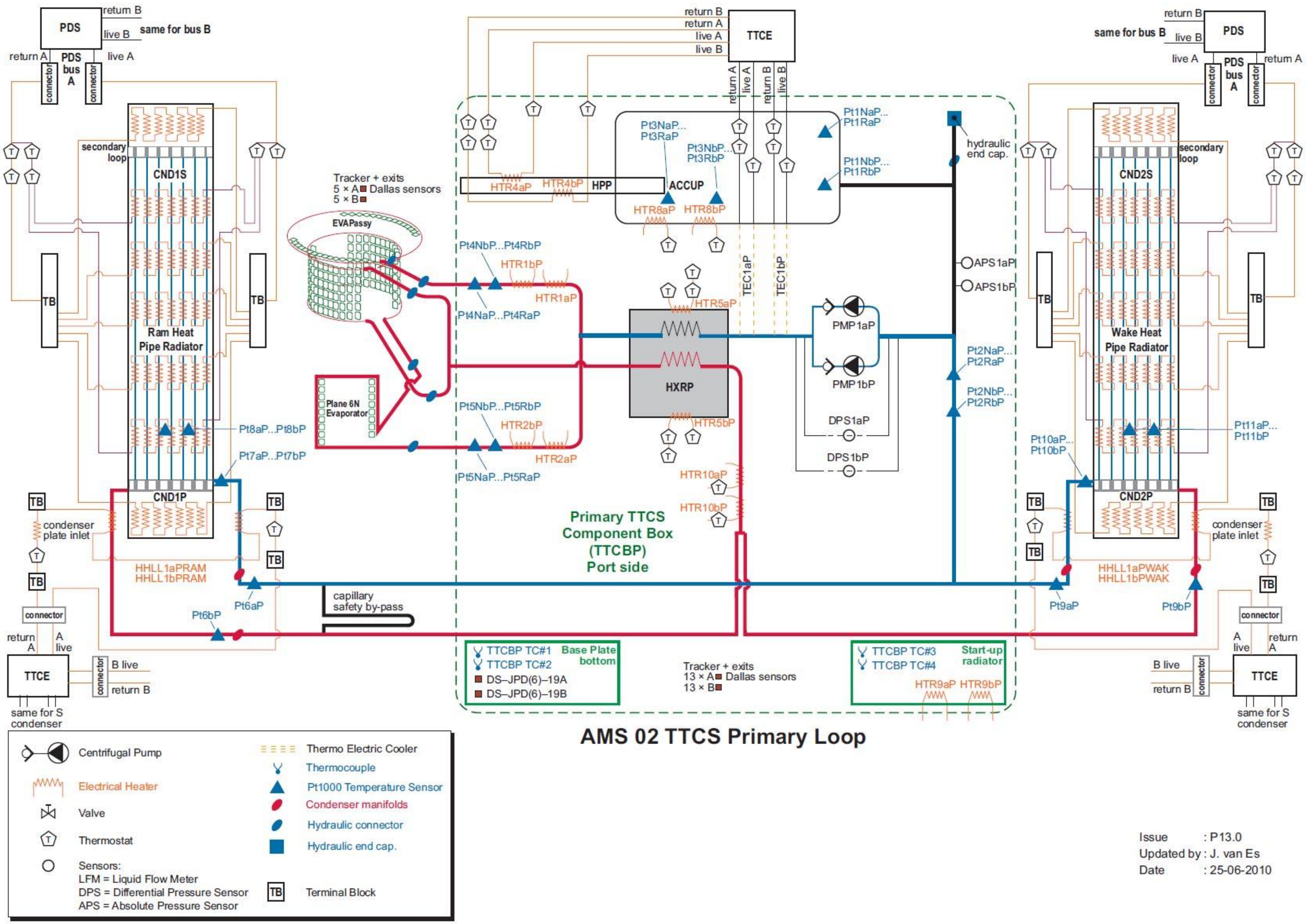
1) MDP has been established based on worst case thermal profile (50°C) and where applicable (with mechanisms to fail) worst case two fault condition.
2) Burst Safety Factor is calculated from the material allowable stress and pipe geometry
3) Heat pipes single components and not a part of a greater pressure system. Burst Factor of 4.0 is used (2.5 could be used for heat pipes as components.).
4) Ref TCS Hardware Design Report AMS-OHB-DER-001 Issue 2, Revision A, May 5, 2005
5) There are 7 embedded heat pipes with different lengths, mass of fluid (ammonia) ranges from 44.6 grams for the shortest to 52.6 grams for the longest
6) Calculated at 0°C, typical working temperature of the tracker cooling loop



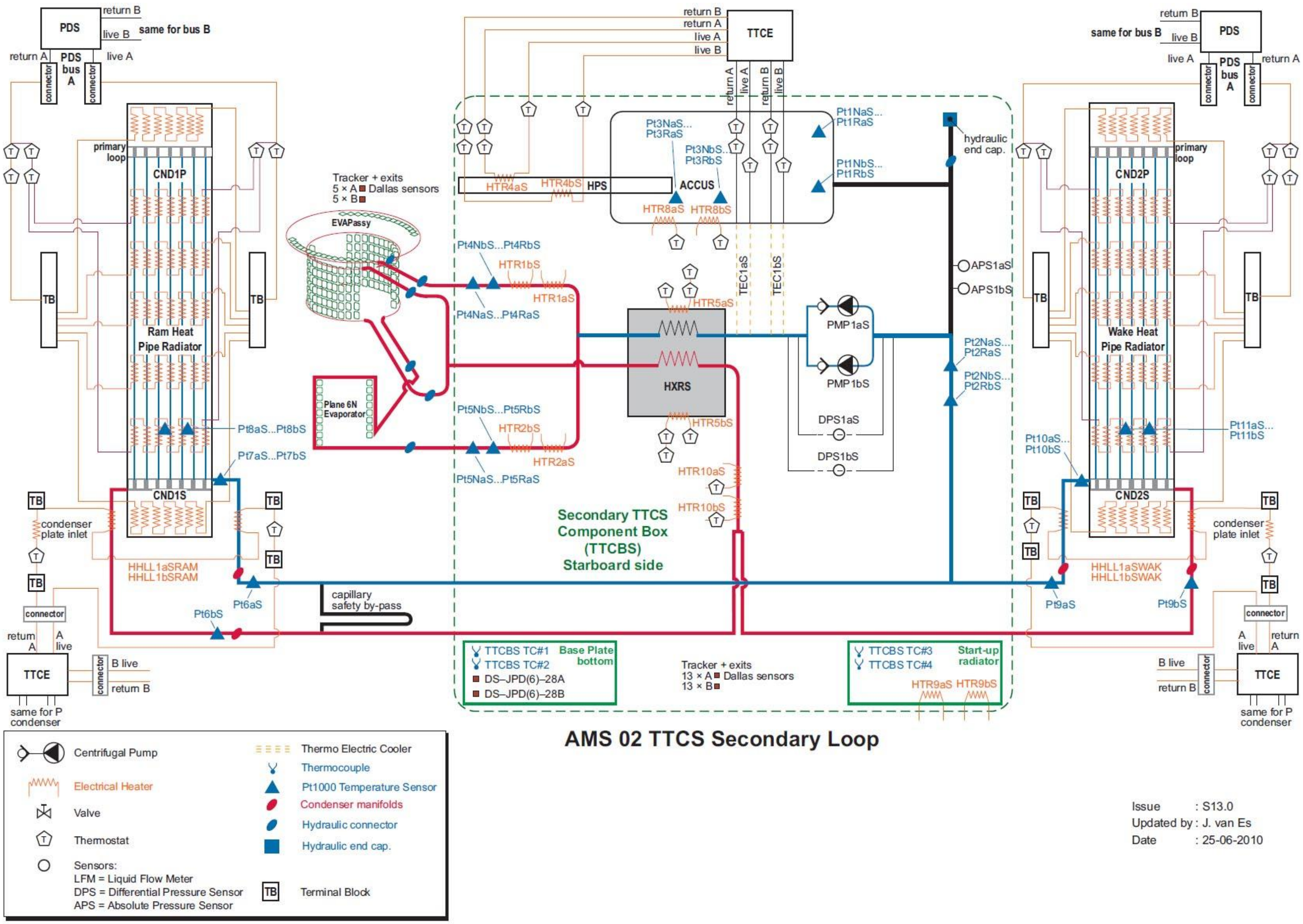
Components of the Tracker Thermal Control System (new Condenser configurations not shown)

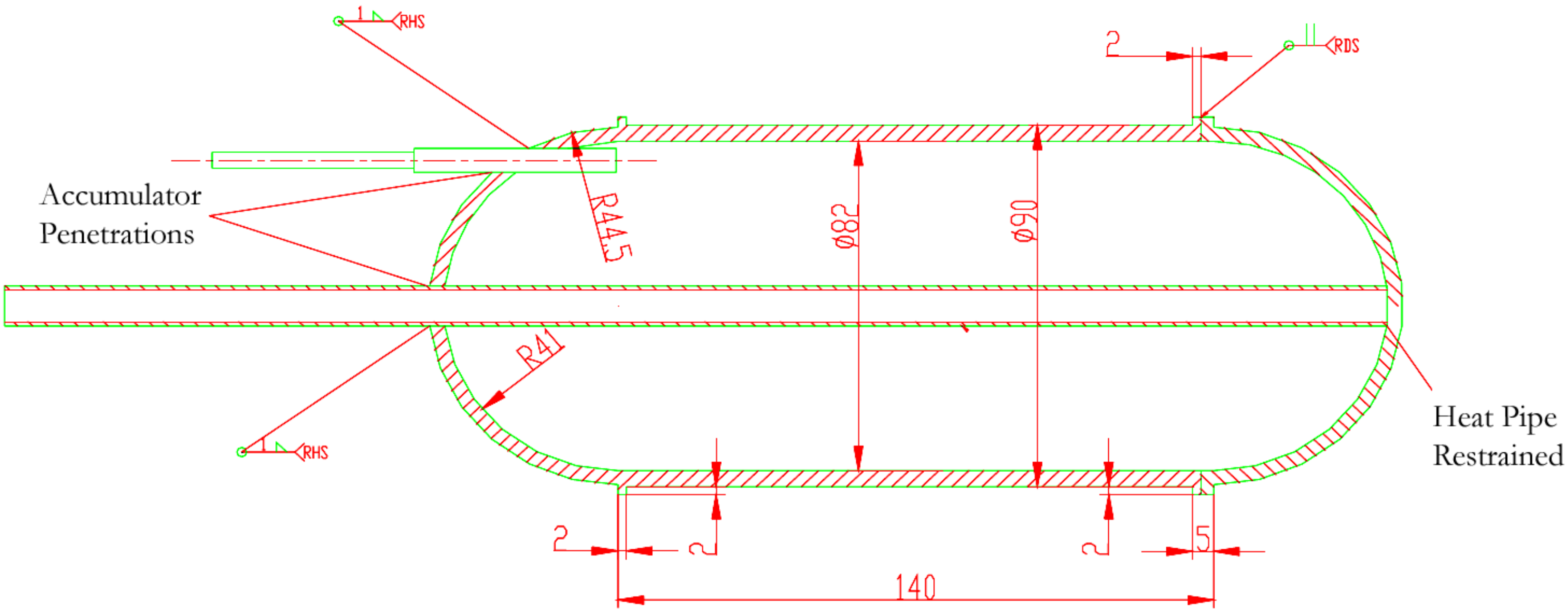


TTCS Box Locations

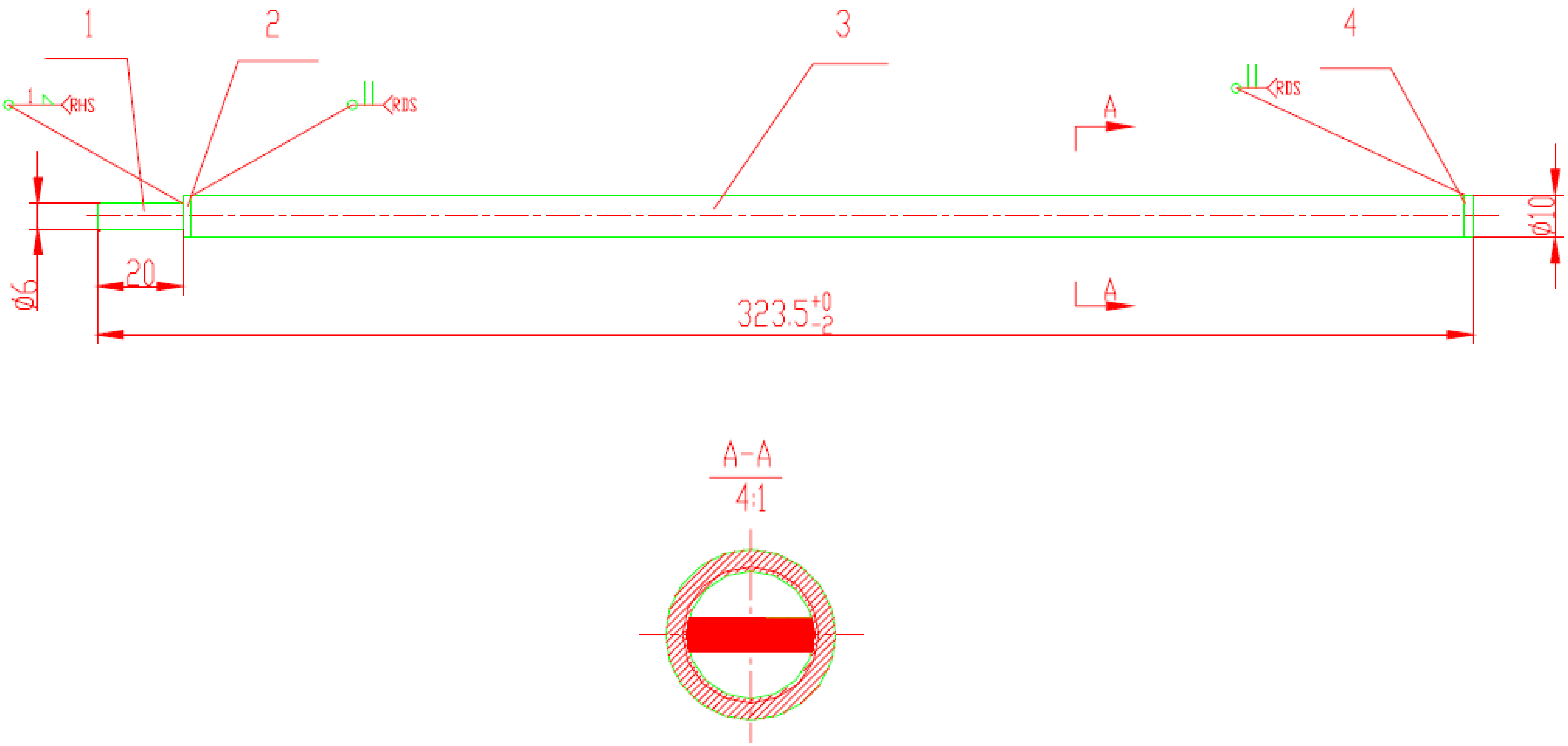


AMS 02 TTCS Primary Loop


AMS 02 TTCS Secondary Loop
PDS
PDS bus A
return A
return B
live A
live B
same for bus B
connector
TTCE
CND1P
CND1S
CND2P
CND2S
primary loop
Ram Heat Pipe Radiator
Wake Heat Pipe Radiator
TB
condenser plate inlet
HHLL1aSRAM
HHLL1bSRAM
HHLL1aSWAK
HHLL1bSWAK
same for P condenser
Tracker + exits
5 × A Dallas sensors
5 × B
EVAPassy
Plane 6N Evaporator
capillary safety by-pass
Pt8aS...Pt8bS
Pt7aS...Pt7bS
Pt6aS
Pt6bS
Pt9aS
Pt9bS
Pt10aS... Pt10bS
Pt11aS... Pt11bS
Pt4NbS...Pt4RbS
Pt4NaS...Pt4RaS
Pt5NbS...Pt5RbS
Pt5NaS...Pt5RaS
HTR1bS
HTR1aS
HTR2bS
HTR2aS
HTR4aS
HTR4bS
HPS
ACCUS
Pt3NaS... Pt3RaS
Pt3NbS... Pt3RbS
Pt1NaS... Pt1RaS
Pt1NbS... Pt1RbS
HTR8aS
HTR8bS
TEC1aS
TEC1bS
hydraulic end cap.
APS1aS
APS1bS
HTR5aS
HTR5bS
HXRS
PMP1aS
PMP1bS
DPS1aS
DPS1bS
Pt2NaS... Pt2RaS
Pt2NbS... Pt2RbS
HTR10aS
HTR10bS
Secondary TTCS Component Box (TTCBS) Starboard side
TTCBS TC#1
TTCBS TC#2
Base Plate bottom
DS–JPD(6)–28A
DS–JPD(6)–28B
Tracker + exits
13 × A Dallas sensors
13 × B
TTCBS TC#3
TTCBS TC#4
Start-up radiator
HTR9aS
HTR9bS
Centrifugal Pump
Electrical Heater
Valve
Thermostat
Sensors:
LFM = Liquid Flow Meter
DPS = Differential Pressure Sensor
APS = Absolute Pressure Sensor
Thermo Electric Cooler
Thermocouple
Pt1000 Temperature Sensor
Condenser manifolds
Hydraulic connector
Hydraulic end cap.
Terminal Block
Issue : S13.0
Updated by : J. van Es
Date : 25-06-2010

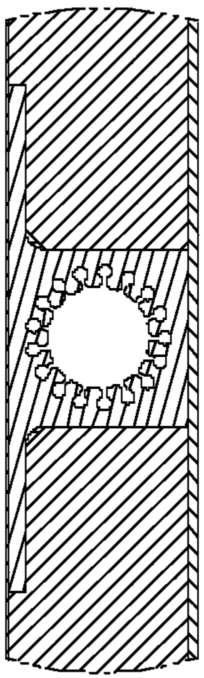


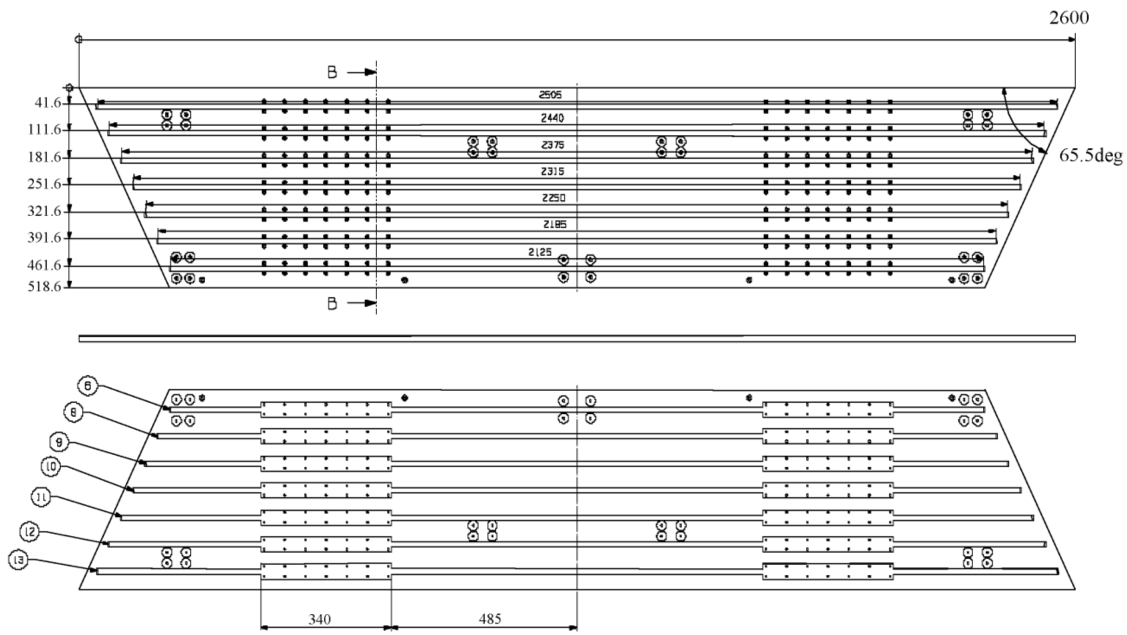
TTCS Accumulator Cross Section with Accumulator Heat Pipe.



TTCE Accumulator Heat Pipe Design

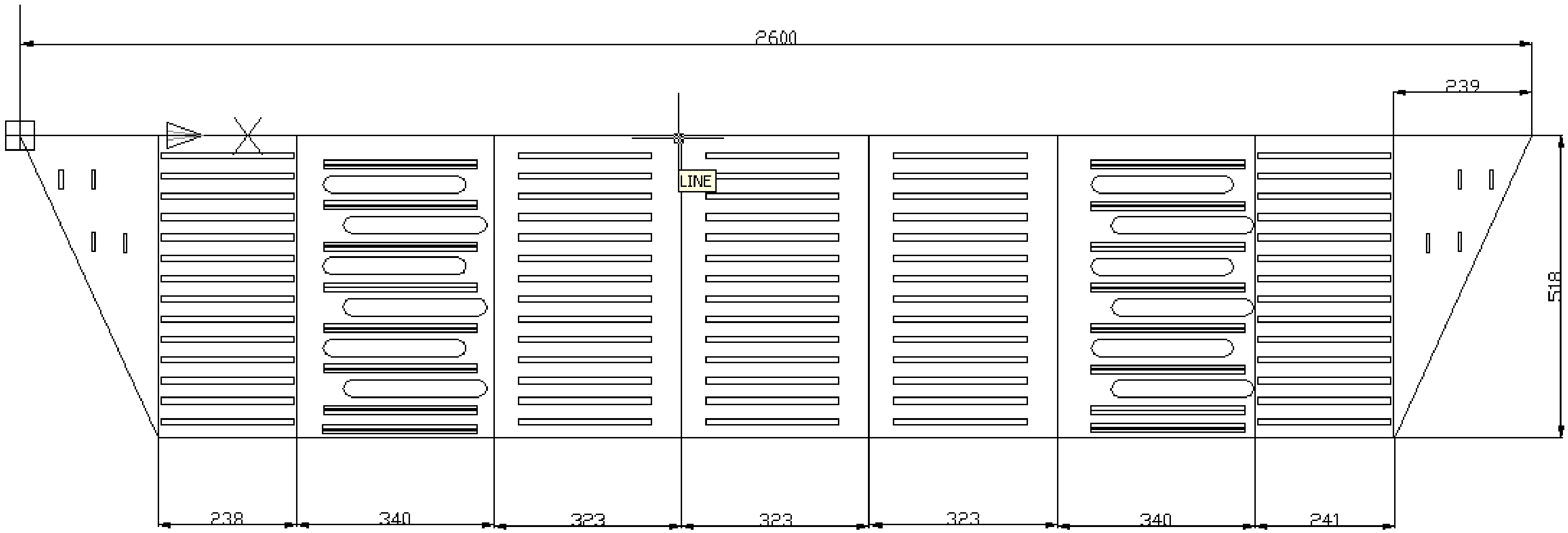
Tracker
Heat
Pipe



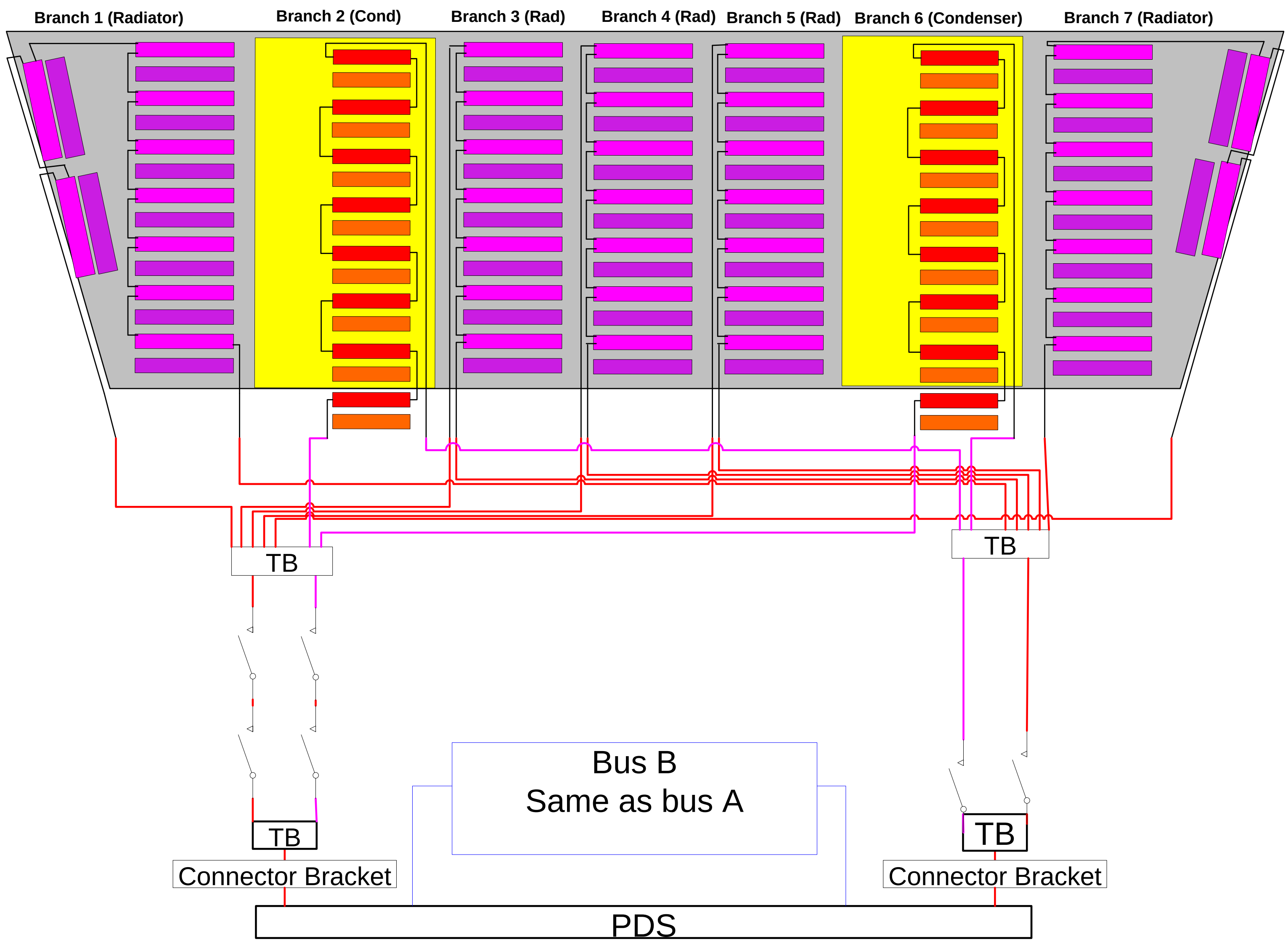


Tracker TTCS Radiators

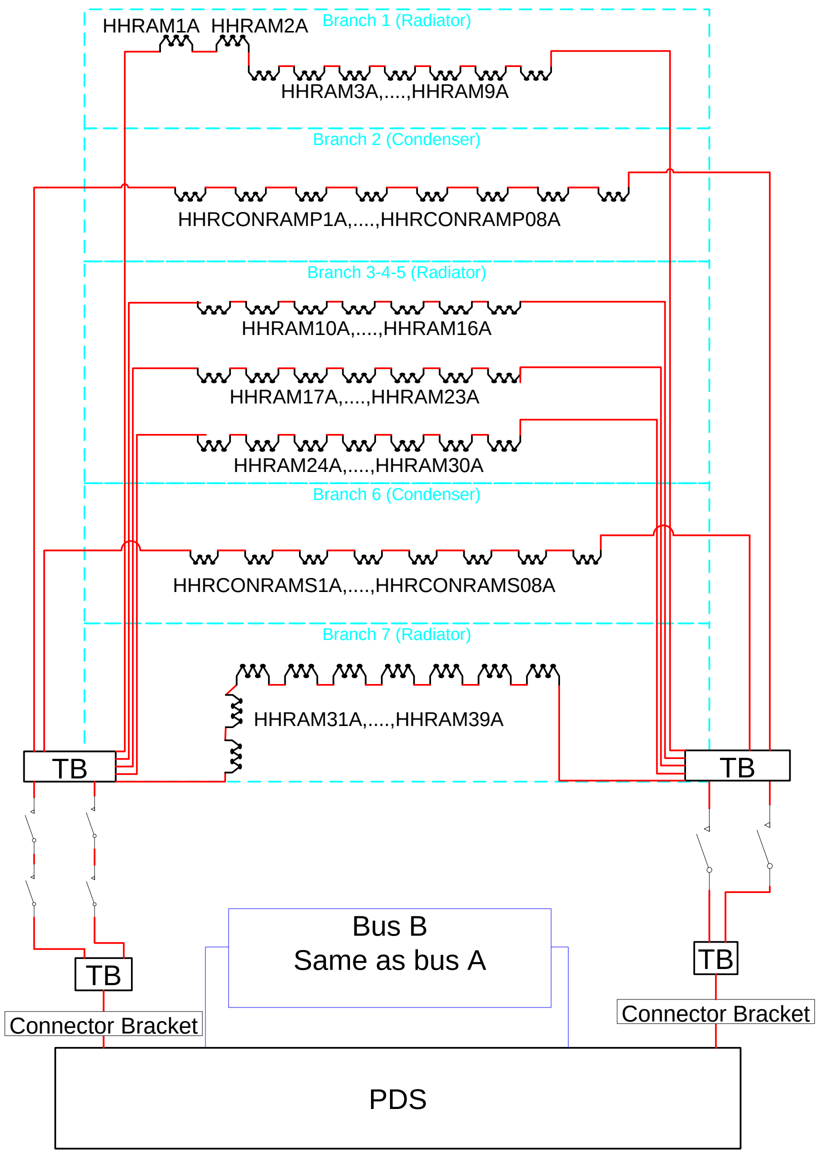
Heat Pipe AGHP-14 (13mm outer, 7 mm inner, 1.25 mm flange)



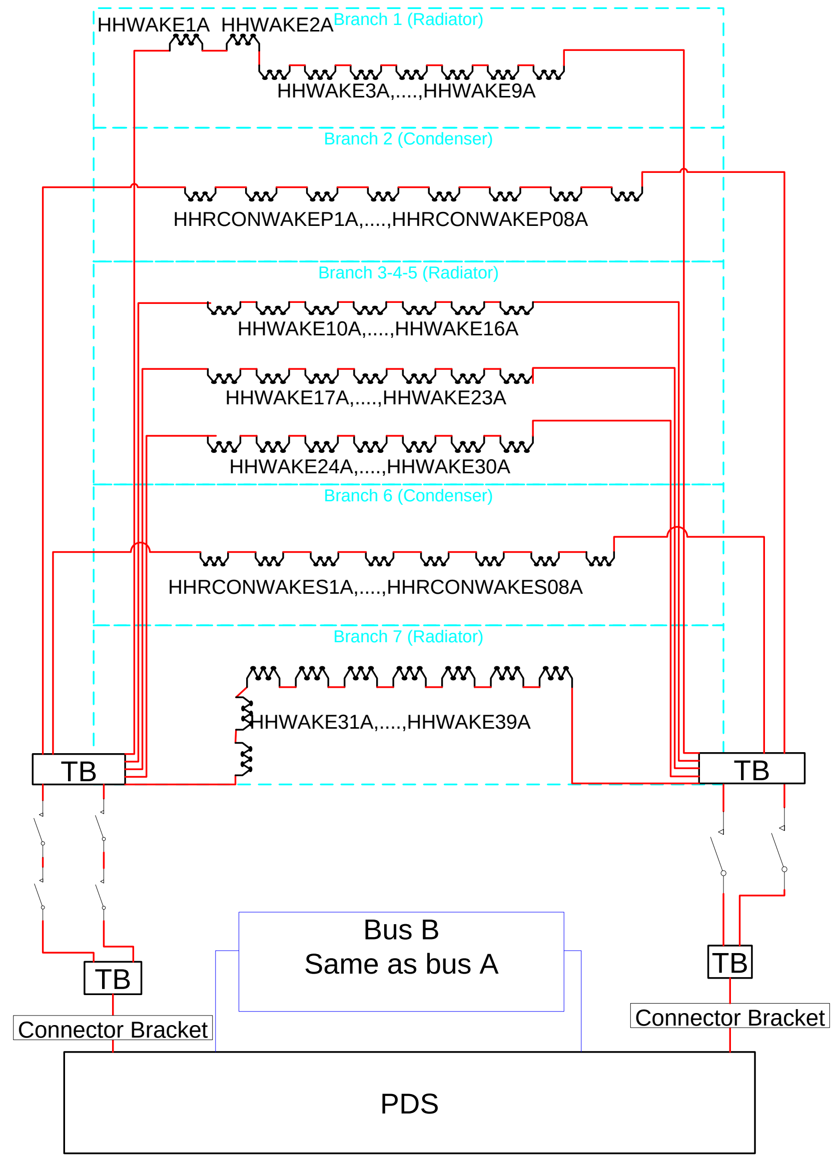
Tracker Radiator Heater Locations



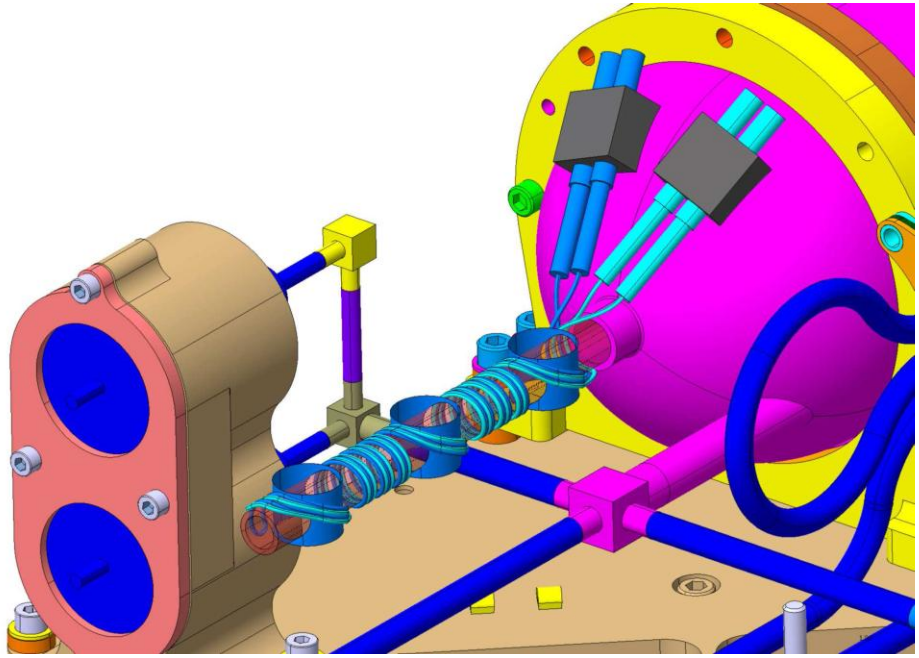
Tracker Radiator Heater Circuits with Thermal Switches.



Tracker Radiator Heater Schematic (RAM)



Tracker Radiator Heater Schematic (Wake)



TTCS Accumulator Location of Heaters and Thermoswitches

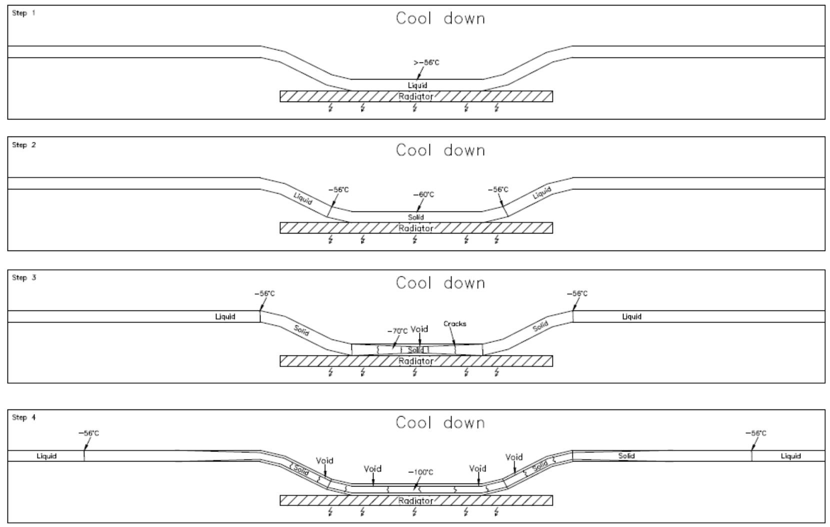


Figure 4-1: Condenser cool down sequence

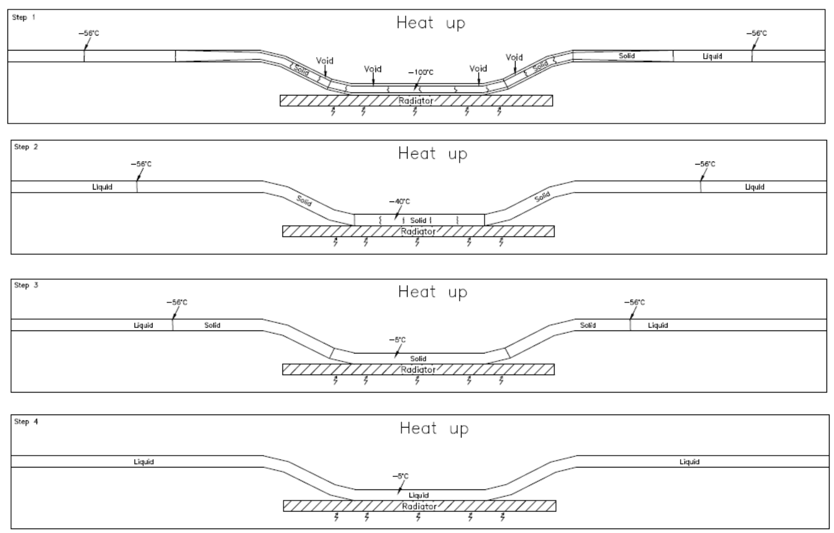
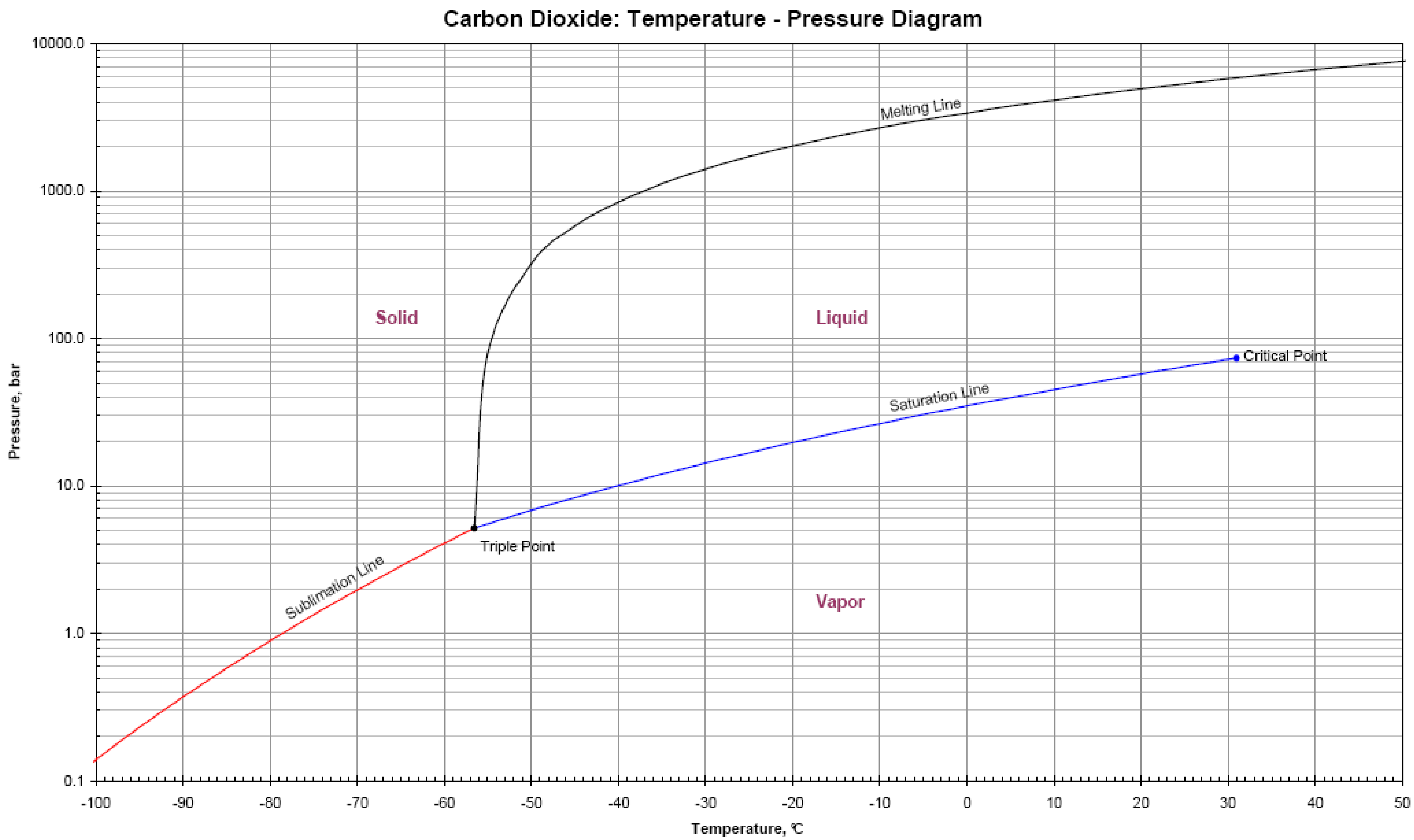
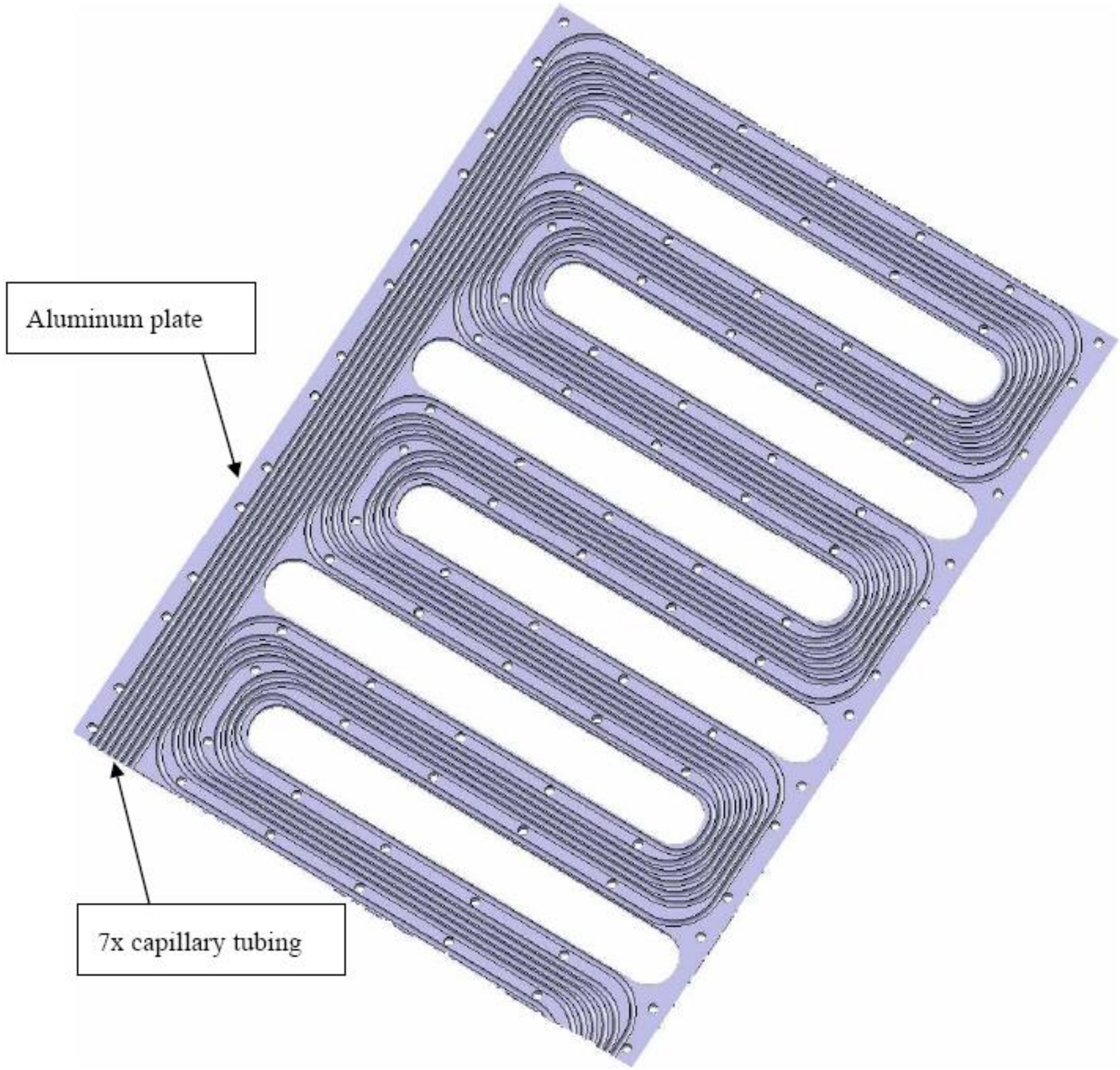


Figure 4-2: Condenser heat up sequence

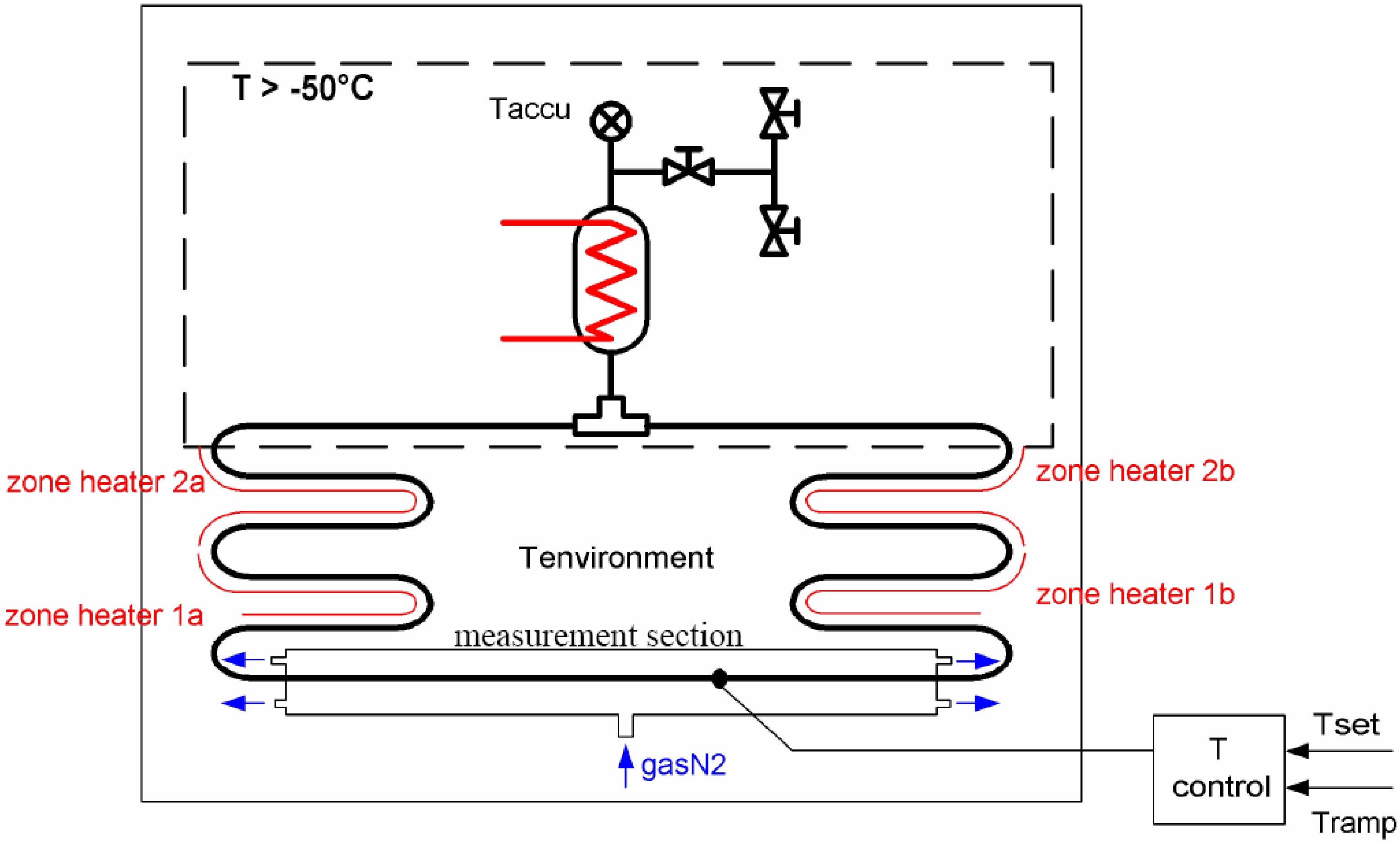
Overview of Thermal Testing of Capillary Tubing for Freeze/Thaw Testing



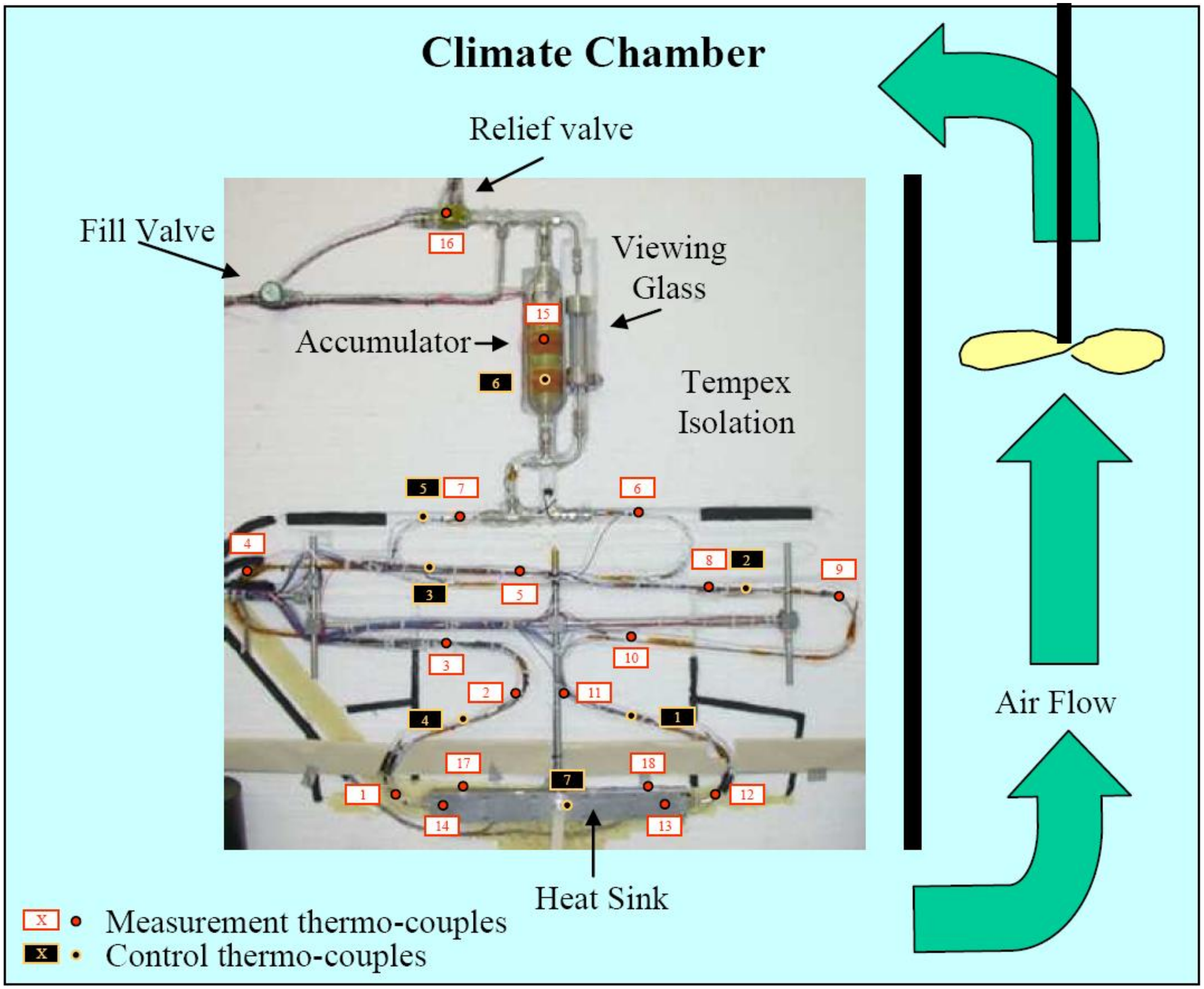
Carbon Dioxide Temperature-Pressure Diagram



Capillary Tube Mounting Plate for Condenser



TTCS Freeze/Thaw Test Configuration (Extracted from NLR Memorandum AMSTR-NLR-TN-039 Issue 02)



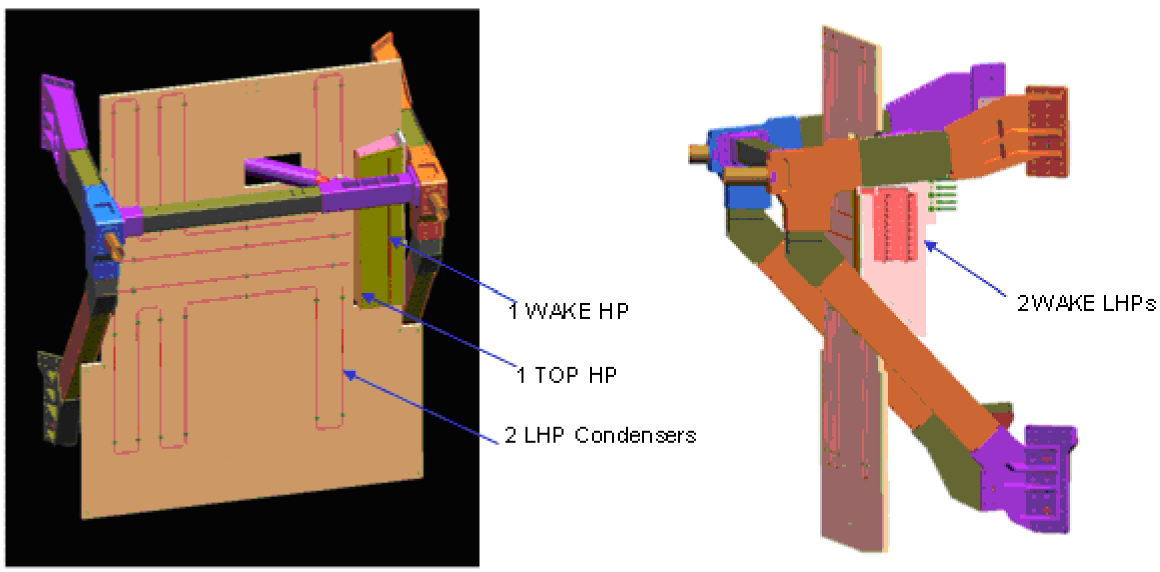
Physical Test Setup for TTCS CO_2 Freeze/Thaw Testing

C. Thermal Control System

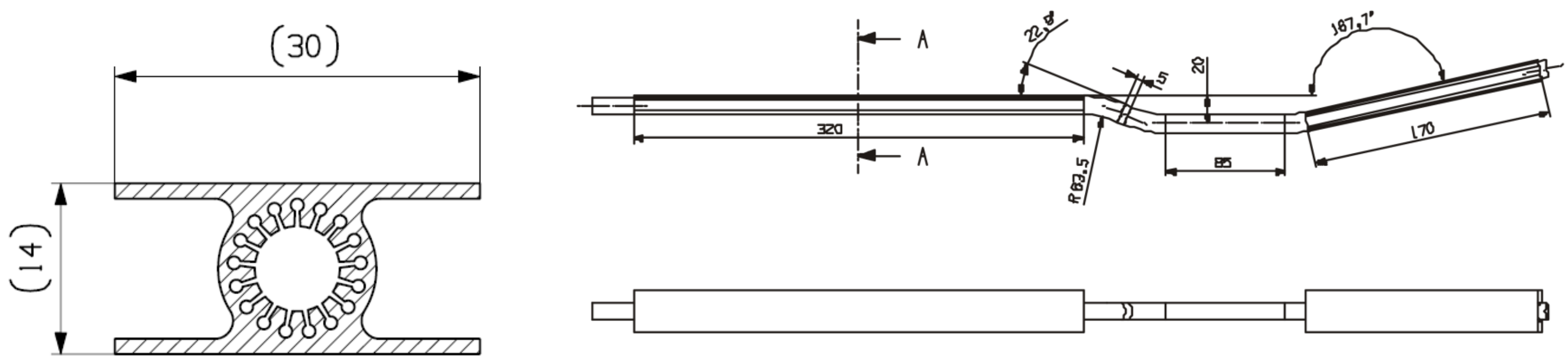
USS-02 Structure Heat Pipes Pressure System Components

Description	Material Of Construction	Mass Of fluid		Operating Pressure[6])		MDP[1]		Burst Pressure		Burst SF		Proof Pressure		Proof SF	Analysis Test or Similarity	Reference Document
		kg	lbm	Bar	psid	bar	psid	bar	psid	Req[3]	Actual	bar	psid			
USS Mounted HP	Al 6063	Note 5		20.0	290.1	26.0	377,2	204	2958.77	4.0	7.8	63	913.73	>1.5	Test[2]	NSTS 1700.7B SSP 30559C

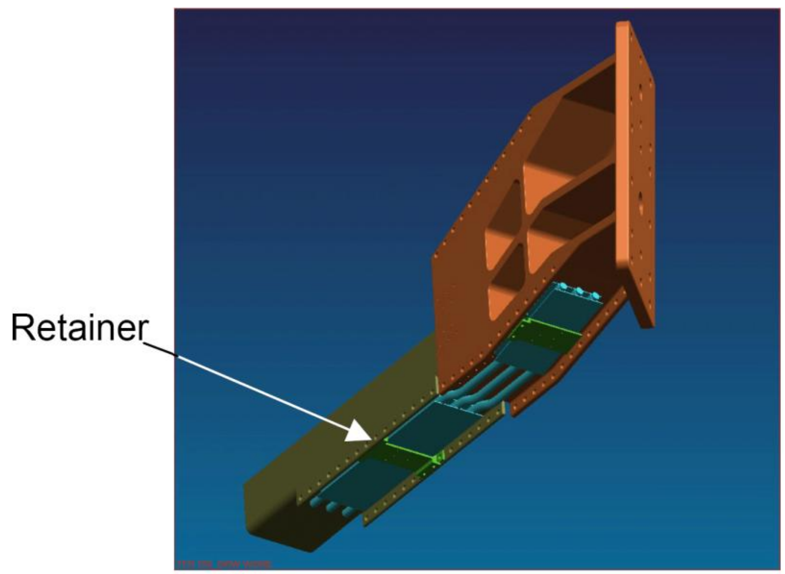
Notes:
1) MDP has been established based on worst case thermal profile and where applicable (with mechanisms to fail) worst case two fault conditions.
2) Burst Safety Factor is calculated from burst test data. Proof safety factor is calculated from proof test data (rif. CG025-ADP-0001-iss2) y
3) Heat pipes single components and not a part of a greater pressure system. Burst Factor of 4.0 is used (2.5 could be used for heat pipes as components.)
4) Ref CAB TCS design report AMSTCS-TN-CGS-010 Issue 1, March 31, 2
5) The USS-02 Structure Heat Pipes consist of three non-embedded heat pipes that each containing 7.6 grams of ammonia.
6) Calculated at 50°C; maximum calculated temperature of USS Part.



CAB Loop Heat Pipe



CAB-USS Heat Pipe Lay Out



USS Heat Pipes (a.k.a CAB-USS Heat Pipes)

Wake and Ram Radiator (Crates) Heat Pipes Pressure System Components

Description	Material Of Construction	Mass Of fluid		Operating Pressure[6])		MDP[1]		Burst Pressure		Burst SF		Proof Pressure		Proof SF	Analysis Test or Similarity	Reference Document
		kg	lbm	bar	psid	bar	psid	bar	psid	Req[3]	Actual	bar	psid			
Embedded Heat Pipes	AL 6063	Note 5		20.0	290.1	81.6	1183.8	204	2958.77	2.5	2.5	153	2219.077	>1.5	Test[2]	NSTS 1700.7B SSP 30559C

Notes:

1) MDP has been established based on worst case thermal profile and where applicable (with mechanisms to fail) worst case two fault conditions. See for reference *Safety thermostats for the main radiators: thermal assessment*, Issue 1, December 5, 2007.

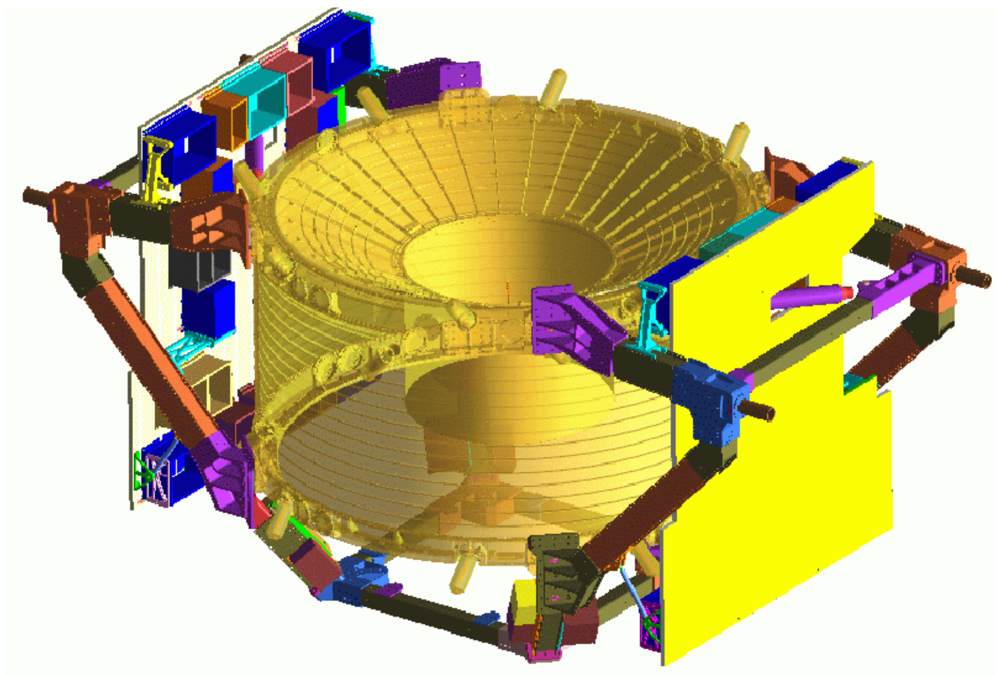
2) Burst Safety Factor is calculated from burst test data. At 204 bar Heat pipes do not break. Proof safety factor is calculated from proof test data (rif. CG0020-ADP-0003-I1 and G0020-ADP-0002-I1)

3) Heat pipes single components and not a part of a greater pressure system. Burst Factor of 2.5 is used.

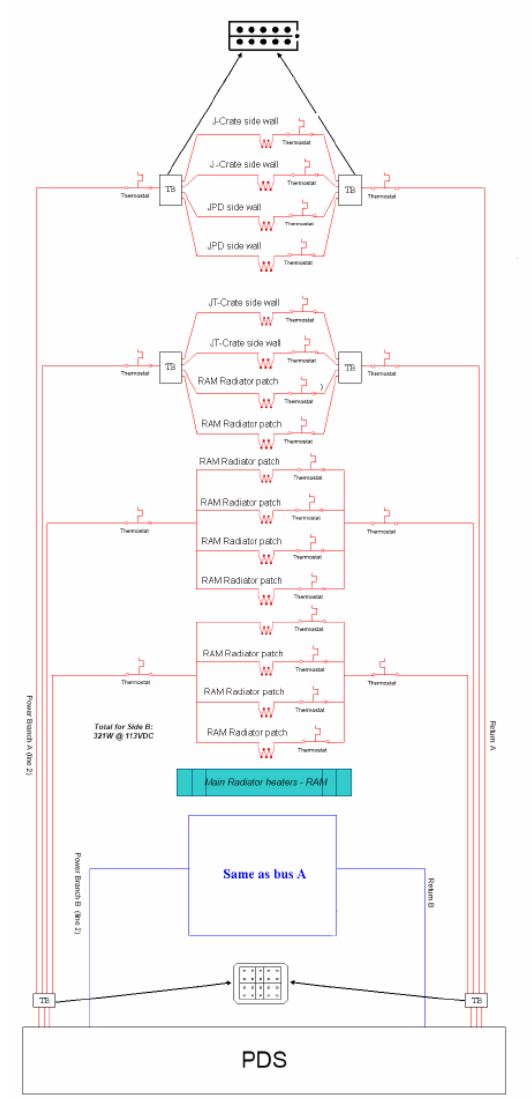
4) Ref Safety thermostats for the main radiators: thermal assessment Issue 1, December 5, 2007

5) There are 24 embedded heat pipes with different lengths on the Wake Radiator, 16 embedded heat pipes with different lengths on the Ram Radiator, mass of fluid (ammonia) ranges from 7.8 grams for the shortest to 32.7 grams for the longest

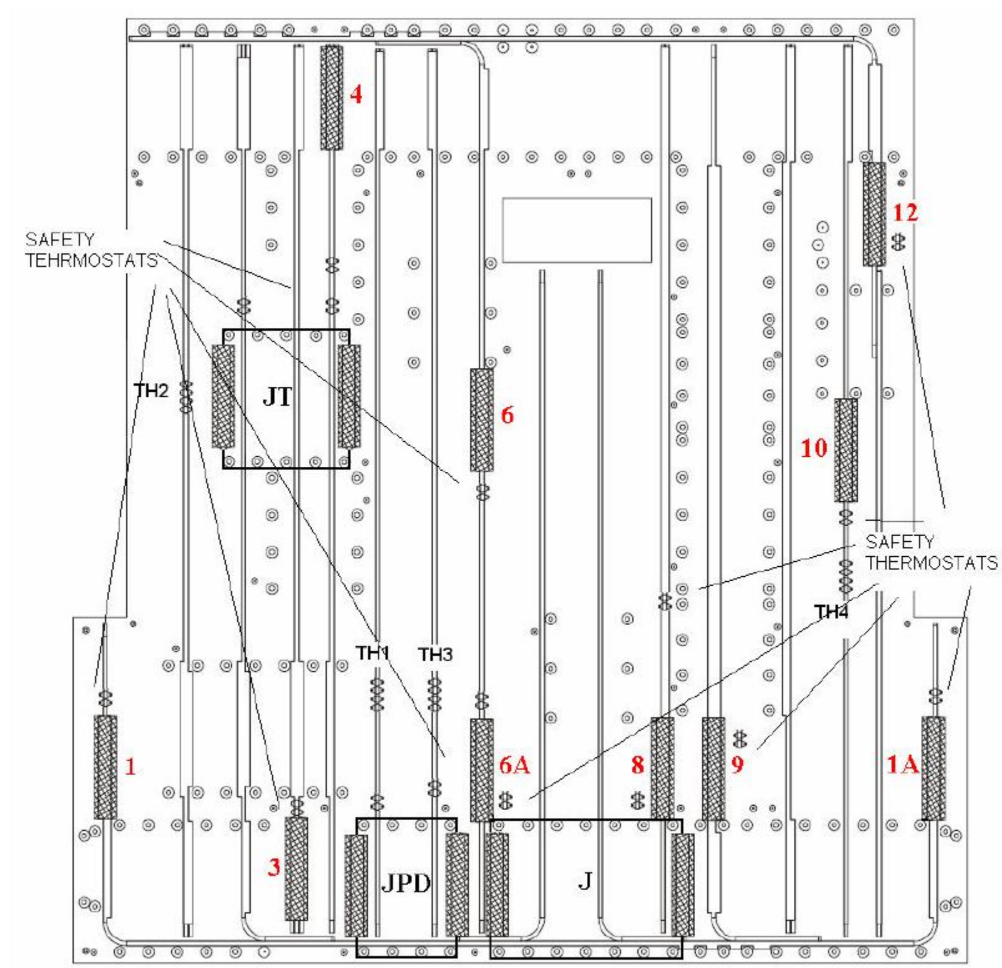
6) Calculated at 50°C, maximum working temperature of the electronic



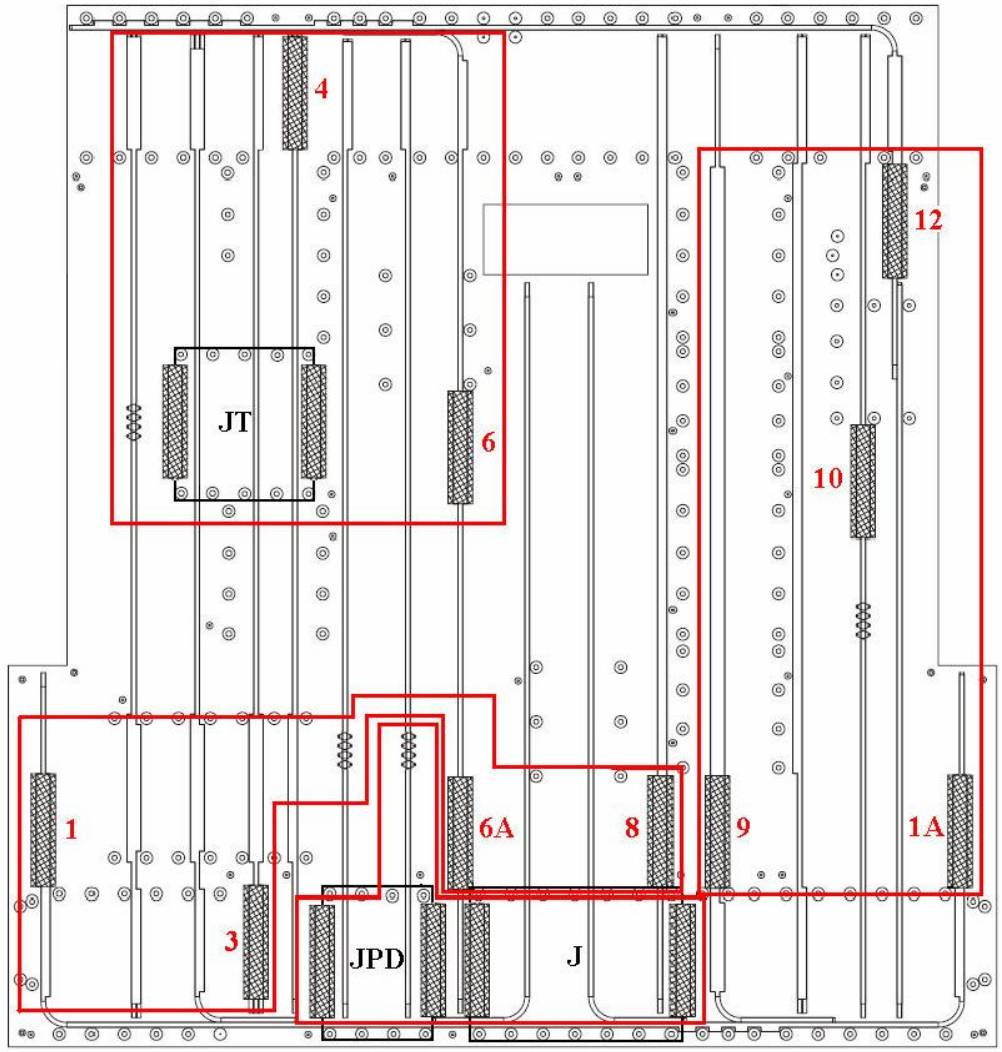
AMS-02 Wake and Ram Radiators



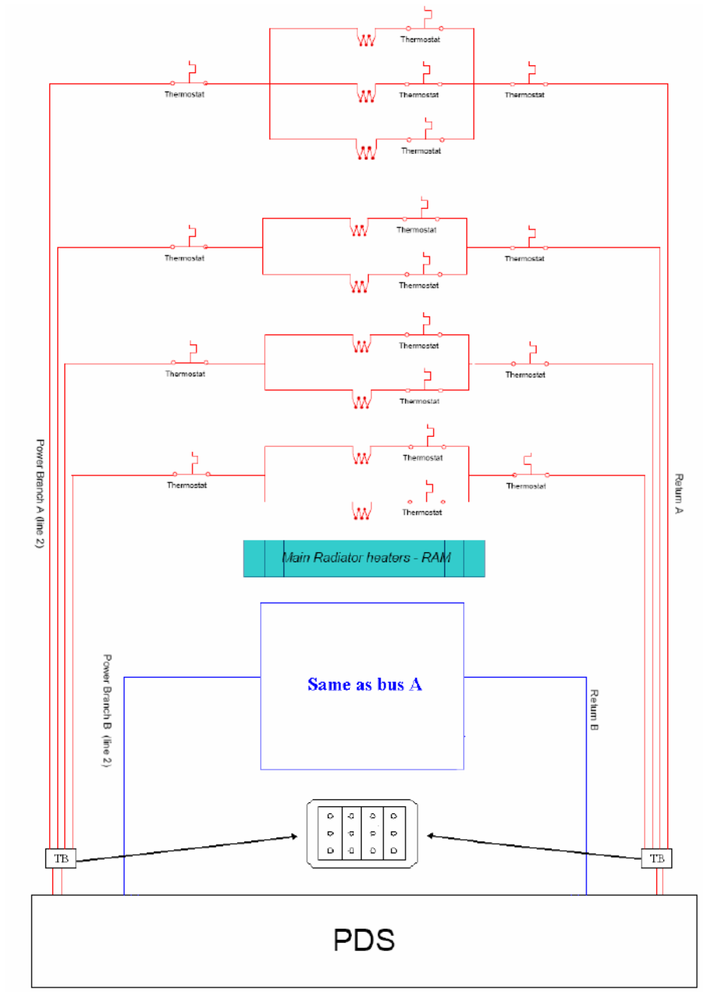
RAM Radiator Heater Set 1 Schematic



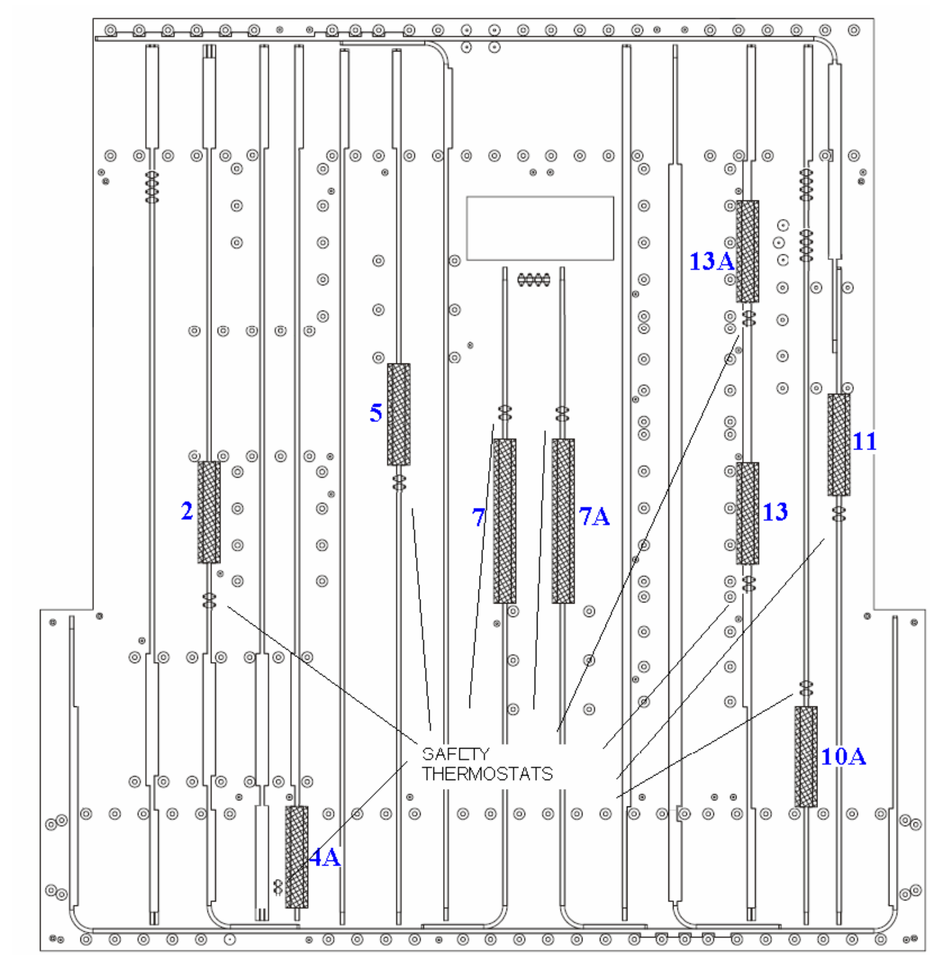
RAM Radiator Heater and Thermostatic Switch Locations (Set 1)



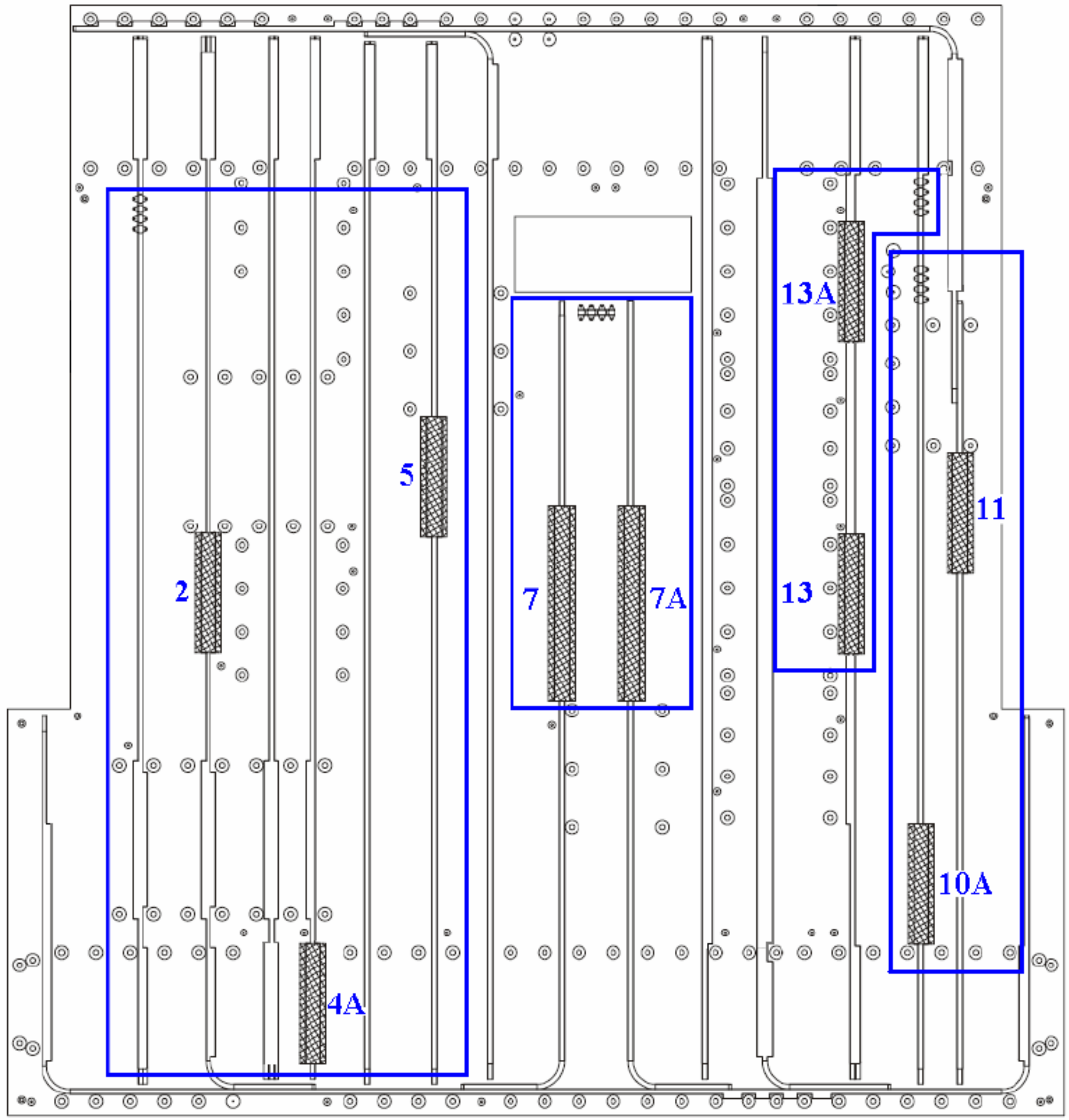
Ram Heater Set 1 Control Zone Layout with Heater Locations



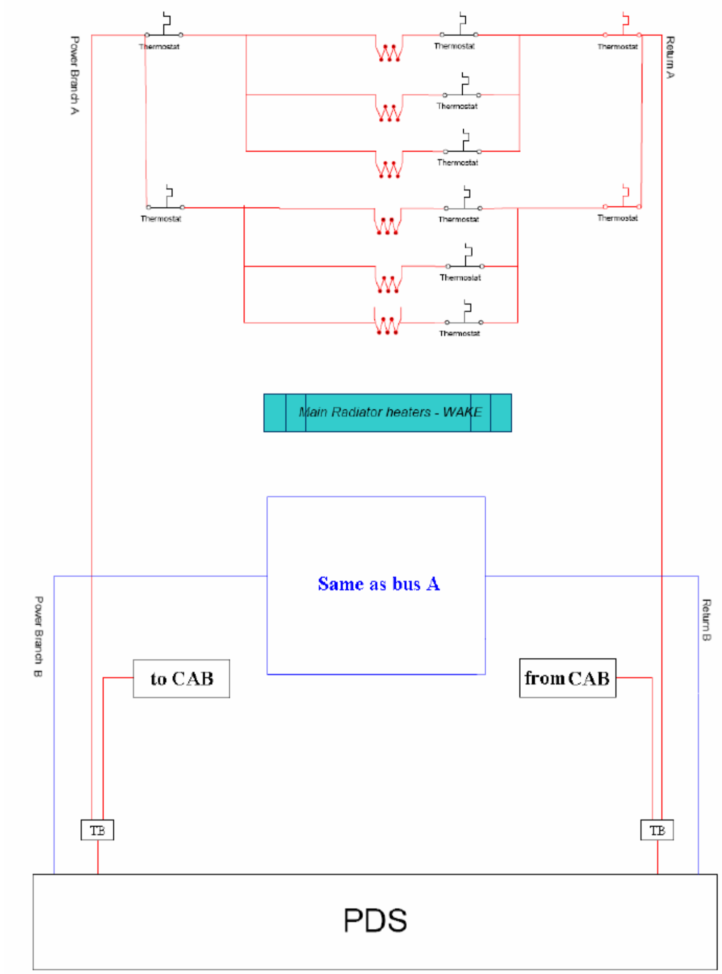
Ram Radiator Heater Set 2 Schematic



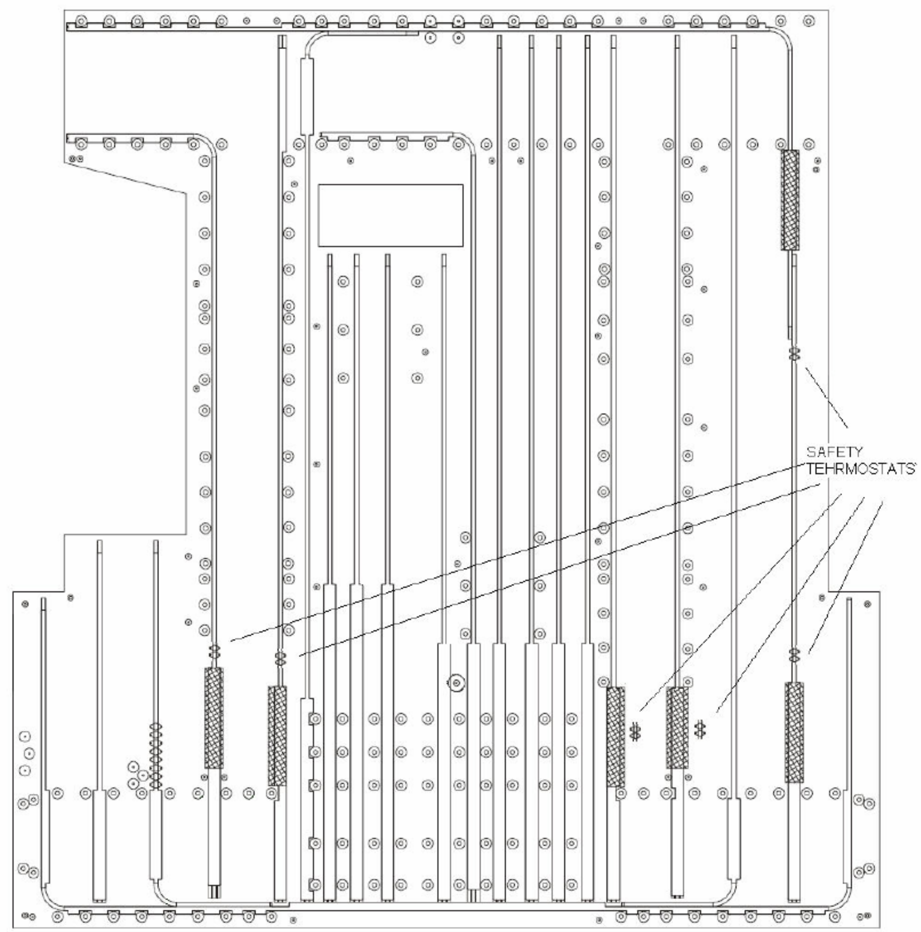
Ram Radiator Heater and Thermostatic Switch Locations (Set 2)



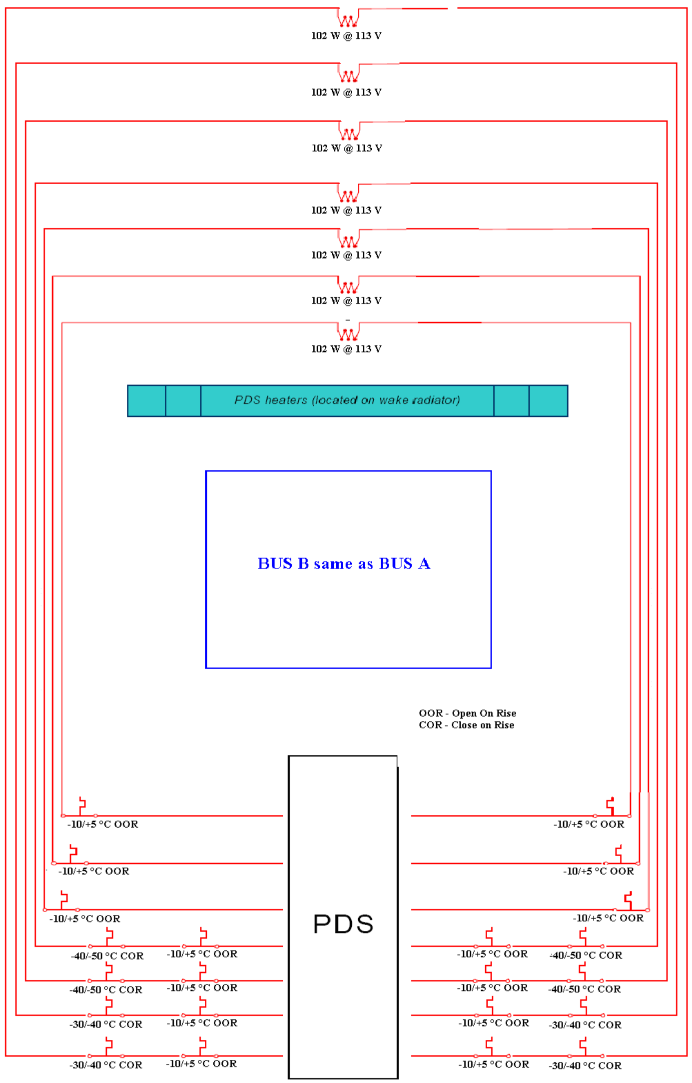
Ram Heater Set 2 Control Zone Layout with Heater Locations



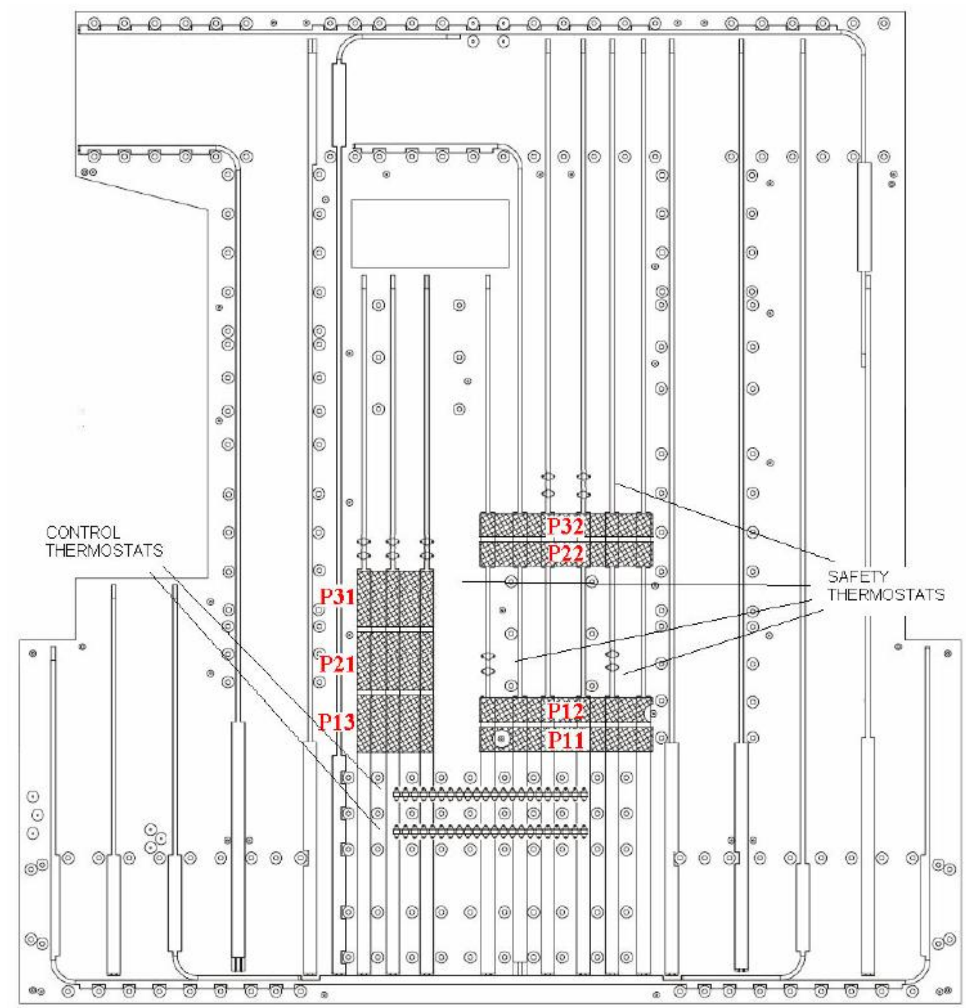
Wake Radiator Schematic



Wake Radiator Heater and Thermostatic Switch Locations



PDS Heaters Schematics



PDS Heaters Location with Thermostats

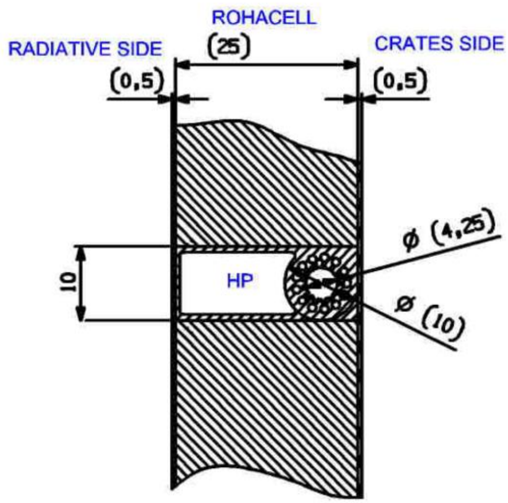
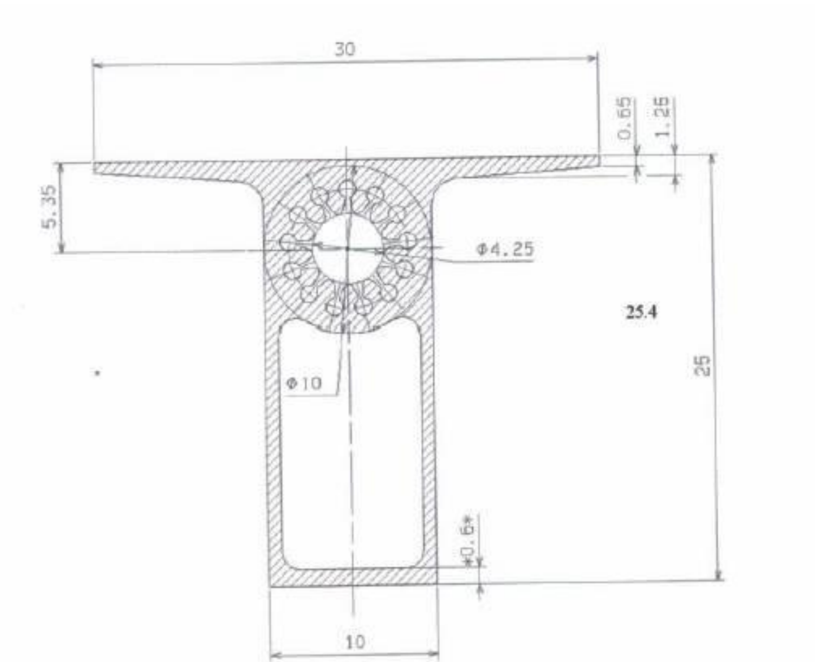
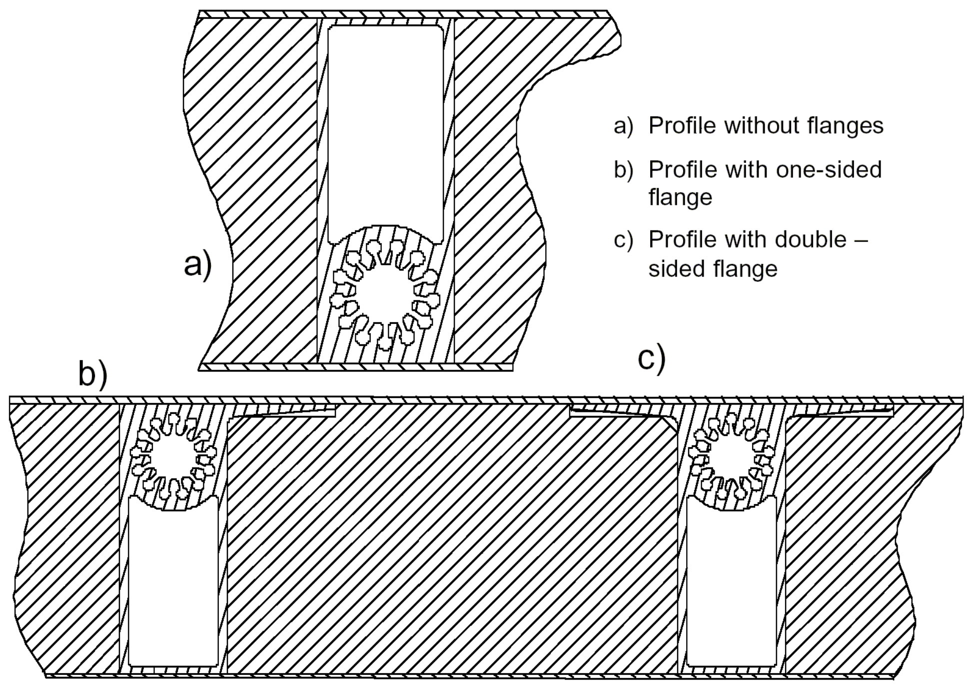


Figure 4-1: Main Dimensions Heat Pipe and Panel Layout



TCS Main Radiator Heat Pipe



Mounting Options for Main Radiator Heat Pipes

Engineering and Science Contract Group
2224 Bay Area Boulevard
Houston, Texas 77058

ESCG-4175-09-REENTES-MEMO-0002
12 February 2009

TO: Leland Hill

FROM: Chris Tutt

SUBJECT: Review of AMS-02 Micrometeoroid and Orbital Debris Analysis

References

[1] NASA Memorandum KX-06-001, *MMOD Requirements for the AMS*, 17 Feb 2006.
[2] JSC 29657 *Hypervelocity Impact Testing of ISS AMS MMOD Shielding*, April 2002.
[3] *Hypervelocity Impact Test Plan for AMS-02 Warm Helium Tank Test Series*, August 2008.

The Alpha Magnetic Spectrometer (AMS-02) will spend a significant amount of time deployed externally on the International Space Station (ISS). Pressure systems within the payload will therefore be potentially susceptible to damage by micrometeoroids and orbital debris (MMOD). This memo reviews the risk analysis associated with this failure mechanism and demonstrates that it meets ISS requirements.

MMOD requirements are based on meeting a minimum Probability of No Penetration (PNP). This is defined as the percentage chance that none of the potentially hazardous volumes will be penetrated by MMOD during the operational lifetime of the payload. NASA memo KX-06-001 defined the minimum requirement for AMS-02 to be 0.9974 over a five year operational lifetime. [1] This is consistent with the recently revised requirements in NSTS 1700.7B ISS Addendum. (At the end of five years, all gas reservoirs on AMS-02 will be empty and MMOD damage to the pressure vessels will no longer create a hazardous situation.)

Five risk areas were identified in the payload:

- Vacuum Case
- Warm Helium Tank
- Xenon Tank
- Carbon Dioxide Tank
- Mixing Tank

The first two items are the helium supply for the superconducting magnet at the heart of AMS-02 and are expected to have a three year on-orbit lifetime. The latter three items are associated with one of the detectors, the Transition Radiation Detector (TRD), and are expected to have a five year on-orbit lifetime. Once one gas supply in a given group is exhausted, the others will be vented in a controlled manner to ensure that no residual pressurized volumes remain.

The largest pressurized volume is the Vacuum Case. 2500 liters of superfluid helium are contained in a 3mm-wall-thickness Al 5083 tank wrapped in multi-layer insulation (MLI). This tank is in turn contained in the 3mm-wall-thickness Al 7075 Vacuum Case. Impact testing of this configuration was performed at White Sands Test Facility to determine an appropriate ballistic limit equation for this configuration [2].

The Warm Helium Tank is a cylindrical Composite Overwrapped Pressure Vessel (COPV) surrounded by a 0.5" thick aluminum foam shield which covers all sides except the surface which directly faces the underside of the Vacuum Case. It is currently being analyzed as an aluminum Whipple shield with a 0.5" spacing. This ballistic limit equation will be verified to be conservative using dedicated impact testing [3].

The remaining three tanks are mounted adjacent to each other on the payload and are protected by the same shields. The outboard side of the tanks is protected by a dedicated MMOD shield. This shield is a standard stuffed Whipple design with 0.1" facesheets made of AL 7075 and an inner barrier consisting of two layers each of Nextel and Kevlar. This is a standard design and uses ballistic limit equations developed by JSC. The inboard side of the tanks will be covered by a 0.5" aluminum foam shield identical in design to the shield surrounding the Warm Helium Tank and has been modeled identically.

Two other areas will have a partial shielding effect which has been included in the analysis. The ram and wake side radiator panels are assumed to stop 75% of the particles which pass through their area, while a dedicated debris shield on the opposite side of AMS-02 from the TRD tanks is assumed to stop 80% of the particles which pass through. These percentages are used instead of ballistic limit equations as the software used in the analysis does not properly account for MMOD shielding located away from the surfaces being analyzed. The exact percentages were provided by the JSC MMOD analysts based on their experience.

The PNP of this configuration has been assessed against the MMOD environment defined in SSP 30425 using the BUMPER code developed by JSC. AMS-02 is in its installed position on the ISS and the station orbit is assumed to be 400 km constant altitude at a 51.6° inclination. The station attitude is an estimate of the Torque Equilibrium Attitude (TEA) at assembly complete: a yaw of -2.99 degrees, a pitch of -3.58 degrees, and a roll of 0.33 degrees. The PNP calculations for each of the pressure systems listed above are given in the table below.

Pressure Vessel	Probability of No Penetration (PNP)			Critical Particle Diameter
	Meteroid	Debris	Combined	
Vacuum Case	0.9998	0.9979	0.9977	3.97mm
Warm Helium Tank	1.0000	0.9999	0.9999	1.48mm
Xenon Tank	1.0000	1.0000	1.0000	7.5mm (Whipple) 1.37mm (Foam)
CO2 Tank	1.0000	0.9998	0.9998	
Mixing Tank	1.0000	1.0000	1.0000	
Total	**0.9998**	**0.9976**	**0.9974**	

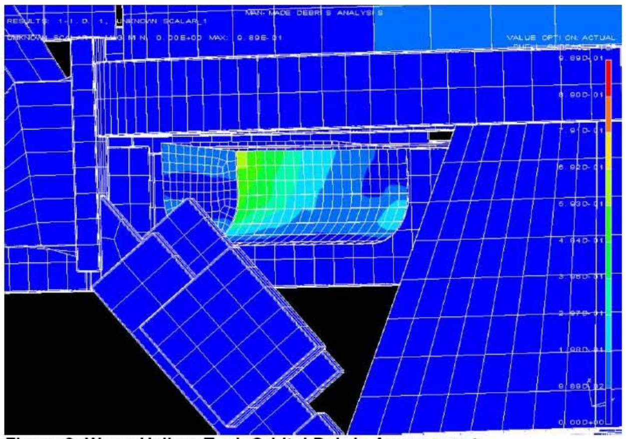


Figure 2: Warm Helium Tank Orbital Debris Assessment

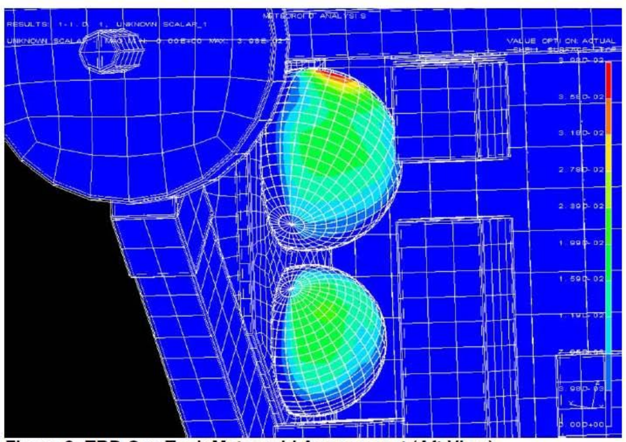


Figure 3: TRD Gas Tank Meteoroid Assessment (Aft View)

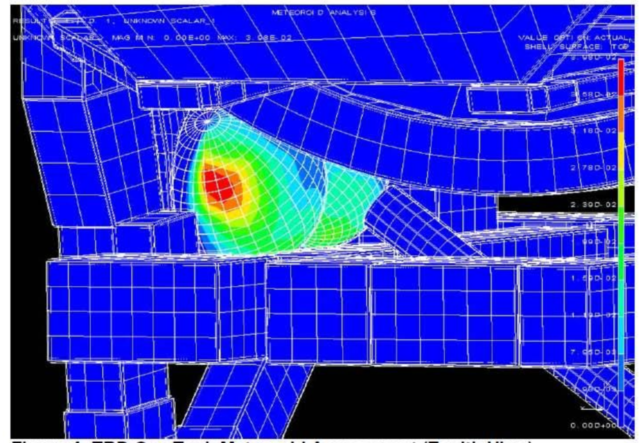


Figure 4: TRD Gas Tank Meteoroid Assessment (Zenith View)

As the table shows, the debris shields on the AMS-02 provide a PNP for the critical areas which meets the requirements of KX-06-001. The AMS-02 payload therefore does not present a risk to the ISS.

This memo is submitted as formal closure of SVM 8.1.1 of HR #3 and SVM 9.1.1 of HR #5.

PAYLOAD FLIGHT HAZARD REPORT			a. NO: AMS-02-F06
b. PAYLOAD	Alpha Magnetic Spectrometer-02 (AMS-02)		c. PHASE: III
d. SUBSYSTEM: Pressure Systems, Magnet		e. HAZARD GROUP: Collision	f. DATE: January 21, 2011
g. HAZARD TITLE:	Excessive Thrust/Overturning Moments		i. HAZARD CATEGORY: CATASTROPHIC **X** CRITICAL
h. APPLICABLE SAFETY REQUIREMENTS:	NSTS 1700.7B, ISS Addendum, 200.1b		
j. DESCRIPTION OF HAZARD:	The AMS-02 has the potential due to the presence of stored gases and magnetic fields to generate excessive loads on the vehicles (Orbiter, ISS) or robotic manipulators (SRMS, SSRMS).		

k. CAUSES

(list)

1. Planned/Controlled Venting
2. Inadvertent/Emergency Venting of Gases
3. Gas Loss by the TRD
4. Excessive Magnetic Fields

o. APPROVAL	PAYLOAD ORGANIZATION	SSP/ISS
PHASE I		
PHASE II		
PHASE III		

PAYLOAD FLIGHT HAZARD REPORT	a. NO: AMS-02-F06
b. PAYLOAD Alpha Magnetic Spectrometer-02 (AMS-02)	c. PHASE: III

l. HAZARD CONTROL (CONTROL), m. SAFETY VERIFICATION METHODS (SVM), n. STATUS OF VERIFICATIONS (STATUS)	OPS CONTROL
1. CAUSE: Planned/Controlled Venting	
1.1 CONTROL: <Deleted. Cryosystem Removed from AMS-02>	
1.2 CONTROL: The TRD utilizes a mixing process to establish the working gas for Box C. Should the gas within Box C be deemed unacceptable for use in the sensing straws, the TRD may release the gas contained within the Box C and straw manifolds through zero-thrust “T” vents through commanding V4 (a, b) and V18 (a, b) to open. 1.2.1 SVM: Review of Design for implementation of non-propulsive vents on TRD Box C vents. 1.2.2 SVM: Inspection of as built hardware for implementation of non-propulsive vents on TRD Box C vents. 1.2.1 STATUS: Closed. ESCG Memorandum ESCG-4175-09-REENTES-MEMO-0044, “Zero-Thrust Vent Design,” dated July 8, 2009. 1.2.2 STATUS: Closed. ESCG Memorandum ESCG-4295-09-CPAS-MEMO-0014, “Review of AMS-02 Vent Locations,” dated November 13, 2009	
1.3 CONTROL: <Deleted. Cryosystem Removed from AMS-02>	
2. CAUSE: Inadvertent/Emergency Venting of Gases	
2.1 CONTROL: All emergency venting locations connecting to gas sources will be equipped with non-propulsive vents. Vents will be located and oriented to preclude impingement effects that could result in unbalanced thrusts from the non-propulsive vents. 2.1.1 SVM: Review of design for implementation of non-propulsive vents on all pressure relief ports. 2.1.2 SVM: Inspection of as built hardware for implementation of non-propulsive vents on all pressure relief locations. 2.1.3 SVM: Impingement analysis of venting 2.1.1 STATUS: Closed. ESCG Memorandum ESCG-4175-09-REENTES-MEMO-0044, “Zero-Thrust Vent Design,” dated July 8, 2009. 2.1.2 STATUS: Closed. ESCG Memorandum ESCG-4195-10-ADV SY-MEMO-0021, “TRD Vent Installation,” dated July 15, 2010	

PAYLOAD FLIGHT HAZARD REPORT	a. NO: AMS-02-F06
b. PAYLOAD Alpha Magnetic Spectrometer-02 (AMS-02)	c. PHASE: III

2.1.3 STATUS: Closed. ESCG Memorandum ESCG-4295-09-CPAS-MEMO-0014, "Review of AMS-02 Vent Locations," dated November 13, 2009 and JSC Correspondence EA3-09-030, "AMS-02 Burst Disk Vent Duct Redesign and Certification," dated November 17, 2009	
2.2 CONTROL: <Deleted. Cryosystem Removed from AMS-02>	
2.3 CONTROL: The Fill and Drain ports on the gas supply tanks (TRD CO2, TRD Xenon,) will utilize a valve and dual seal caps to preclude a gas release. 2.3.1 SVM: Review of design for implementation of fill and drain port check valves and cap seals. 2.3.2 SVM: Inspection of as built hardware for implementation of fill and drain port check valves and cap seals. 2.3.1 STATUS: Closed. ESCG Memorandum ESCG-4175-09-REENTES-MEMO-0012, "Review of AMS-02 Fill Ports," dated March 23, 2009 2.3.2 STATUS: Closed. ESCG Memorandum ESCG-4295-09-CPAS-MEMO-0018, "Review of the AMS-02 Cryomagnet Acceptance Data Package," dated December 21, 2009	
2.4 CONTROL: <Deleted. Cryosystem Removed from AMS-02>	
2.5 CONTROL: <Deleted. Cryosystem Removed from AMS-02>	
3. CAUSE: Gas Loss by the TRD	
3.1 CONTROL: The TRD through nominal operations can lose up to 0.27 liters of xenon/carbon dioxide gas mixture in a day. A worst case loss of 7 liters from one segment failure may occur with the failure of a straw assembly and would leak at approximately 5 liters per hour given the most likely failure mode of seal failure. If such a failure were to occur when the TRD was non-operational due to such conditions as total loss of power, and a seal failure occurred, the segment would not be automatically isolated and a total of 230 liters of gas mixture could be released. This gas will permeate through the TRD structure supporting the proportional tubes and surrounding MLI and exit in a non-propulsive fashion from the multitude of exit paths of the TRD and its surrounding MLI. Even in the inconceivable event of a complete rupture of a straw segment with the system is off-line and incapable of isolating it, the 230 liters of stored gas would take approximately 5 hours to vent and would follow the multiple paths and not generate an overturning moment or thrust. 3.1.1 SVM: Analysis of design to confirm multi-path diffusion release of TRD leaked gases. 3.1.1 STATUS: Closed. Analysis Report, "Venting of Parts of TRD Detector" by Klaus Lubelsmeyer, December	

PAYLOAD FLIGHT HAZARD REPORT	a. NO: AMS-02-F06
b. PAYLOAD Alpha Magnetic Spectrometer-02 (AMS-02)	c. PHASE: III

13, 2004

4. CAUSE: Excessive Magnetic Fields

4.1 CONTROL: While installed on the ISS, the magnetic field of the AMS-02 will interact with the geomagnetic field of the Earth and produce a torque to the ISS through the structural interface with the S3 truss. The factors involved in generating this torque include field strength and area of field. The field strength of the AMS-02 magnetic fields are insufficient to create hazardous loads or orbit affects, but could have the potential for affecting the microgravity environment of the ISS. Torquing potential will be shown to be compatible with CMG Momentum Manager (MM) capabilities to preserve CMG MM operational capabilities.

4.1.1 SVM: Analysis of magnetic torque potential

4.1.2 SVM: Acceptance of calculated torque by ISS Program

4.1.3 SVM: Measurement of actual magnetic fields to confirm predicted magnetic fields of AMS-02

4.1.1 STATUS: Closed. Documented in Boeing Memo TM-990018-05, September 29, 1999

4.1.2 STATUS: Closed. Documented in Boeing Memo TM-990018-05, September 29, 1999

4.1.3 STATUS: Closed. "Study on Dipole Moment in Permanent Magnet used in Space Anti-Matter Detector," by Qiuliang Wang, Tao Song, Chin E. Lin, Housheng Wang, Zheng Wang, Li Kong, Luguan Yan and Samuel C. C. Ting, published in IEEE Transactions on Applied Superconductivity, Vol 18, No. 2, 2008

4.2 CONTROL: The AMS-02 Permanent Magnet's magnetic field will be continuously present during all Orbiter based operations and ISS operations. The field will be shown to be compatible with the Orbiter during all mission phases, SRMS operations and SSRMS operations.

4.2.1 SVM: Analysis of magnetic torque potential

4.2.2 SVM: Acceptance of calculated torque by Shuttle and ISS Program

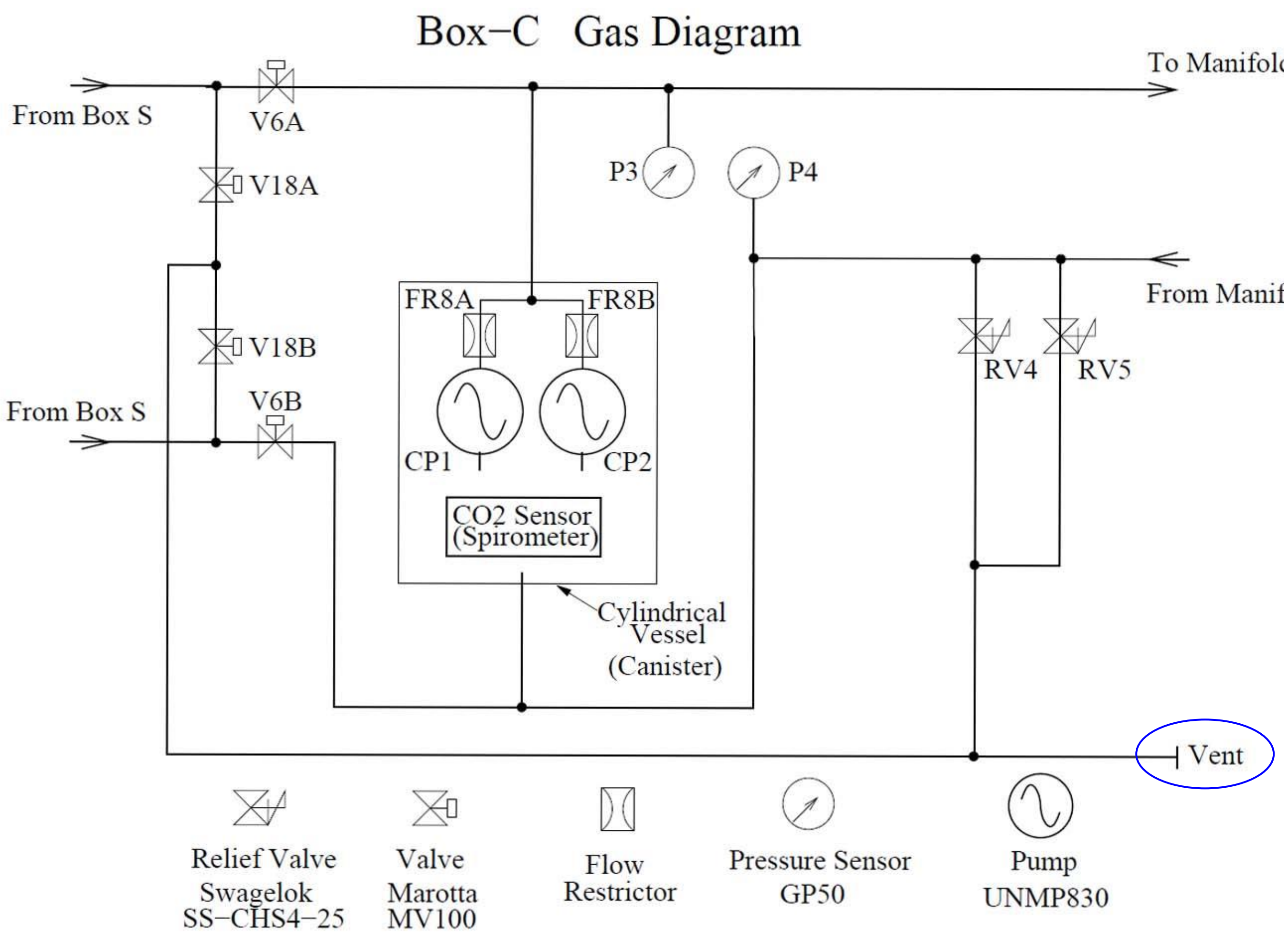
4.2.3 SVM: Measurement of actual magnetic fields to confirm predicted magnetic fields of AMS-02 I

4.2.1 STATUS: Closed. "Study on Dipole Moment in Permanent Magnet used in Space Anti-Matter Detector," by Qiuliang Wang, Tao Song, Chin E. Lin, Housheng Wang, Zheng Wang, Li Kong, Luguan Yan and Samuel C. C. Ting, published in IEEE Transactions on Applied Superconductivity, Vol 18, No. 2, 2008

4.2.2 STATUS: Closed.Shuttle: CR/DIR No. A05889, "DC Magnetic Field Non-Compliance," for the AMS-02 was withdrawn/declined as further investigation showed there was no Non-compliance. Withdrawn/Decline Desposition

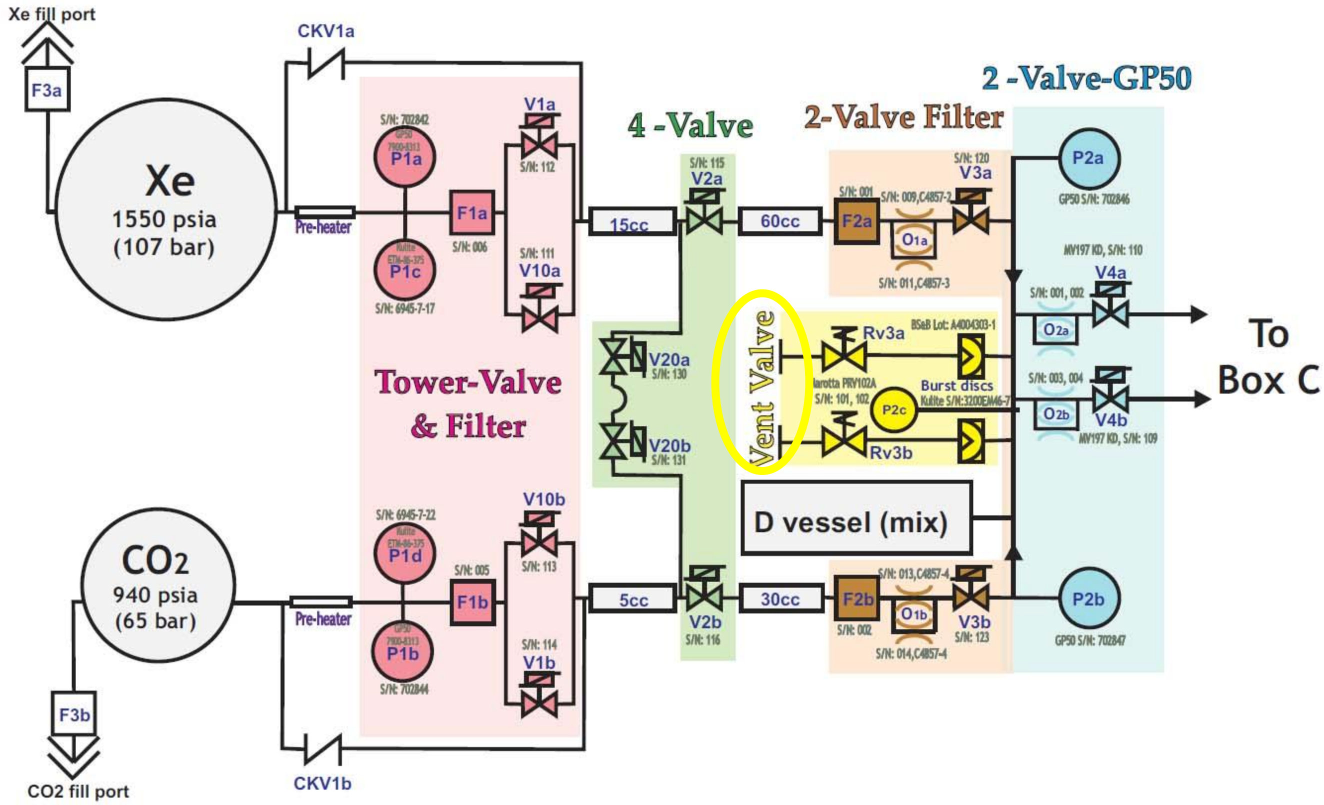
PAYLOAD FLIGHT HAZARD REPORT	a. NO: AMS-02-F06
b. PAYLOAD Alpha Magnetic Spectrometer-02 (AMS-02)	c. PHASE: III
10-19-2010. ISS: PIRN 57213-NA-0014B, “AMS (Alpha Magnetic Spectrometer) – DC Magnetic Field Exceedence,” Approved January 14, 2011 4.2.3 STATUS: Closed. “Study on Dipole Moment in Permanent Magnet used in Space Anti-Matter Detector,” by Qiuliang Wang, Tao Song, Chin E. Lin, Housheng Wang, Zheng Wang, Li Kong, Luguan Yan and Samuel C. C. Ting, published in IEEE Transactions on Applied Superconductivity, Vol 18, No. 2, 2008	
4.3 CONTROL: <Deleted. Cryomagnet Removed from AMS-02>	
4.4 CONTROL: <Deleted.>	
5. CAUSE: <Deleted. Cryosystem Removed from AMS-02>	
5.1 CONTROL: <Deleted>	
Notes:	

ACRONYMS	
°C – degrees Centigrade (Celsius)	mm – millimeter
amp-m^2 – Amperes per square meter	psi – Pounds per square inch
AMS-02 – Alpha Magnetic Spectrometer - 02	SFHe – Superfluid Helium
APCU – Auxillary Power Control Unit	SRMS – Shuttle Remote Manipulator Mechanism
CAB – Cryomagnet Avionics Box	SSRMS – Space Station Remote Manipulator Mechanism
CMG – Control Moment Gyroscope	STP – Standard Temperature and Pressure
CO_2 – Carbon Dioxide	SVM – Safety Verification Method
GSE – Ground Support Equipment	TRD – Transition Radiation Detector
He – Helium	TTCS – Tracker Thermal Control System
MDP – Maximum Design Pressure	USS-02 – Unique Support Structure 02
MLI – Multilayer insulation	Xe – Xenon
MM – (CMG) Momentum Manager	

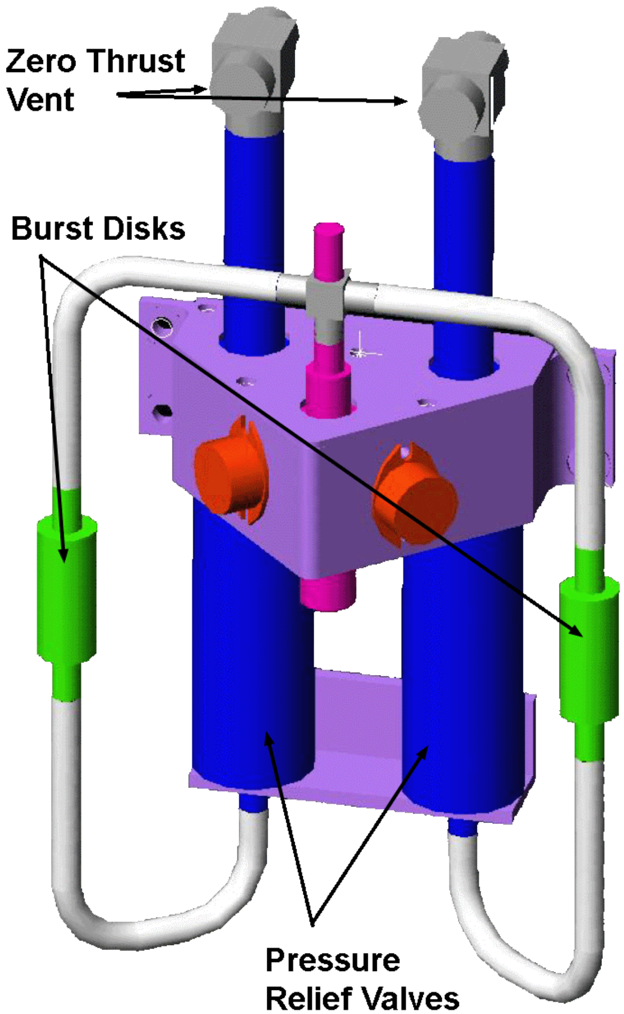


TRD Box C
Vent Location

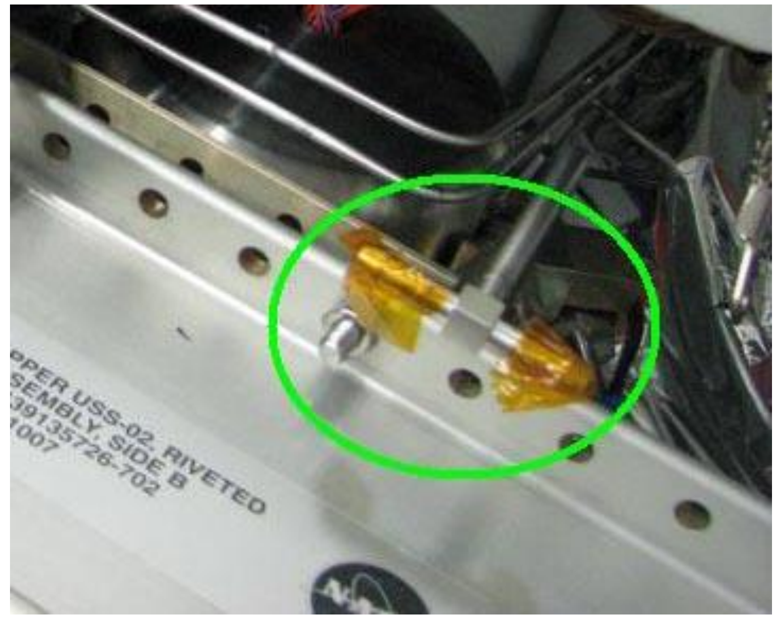
Box S Schematic



TRD Box S Vent Locations
(Yellow Oval)

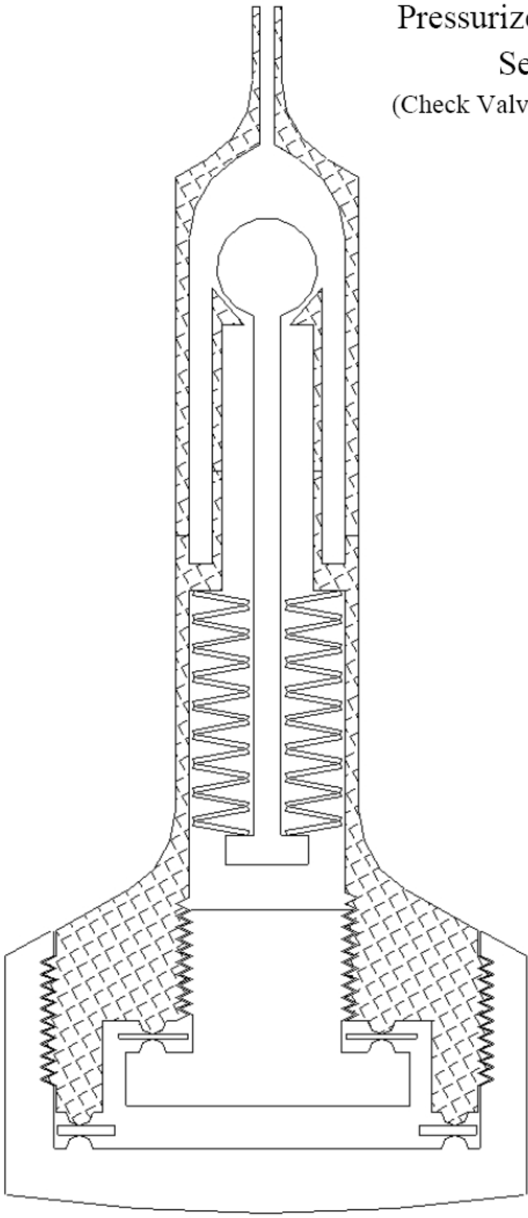


Example of non propulsive "T" vents used in Box S



TRD Box C Vent.

Pressurized Vessel Fill Port
Seal - Sketch
(Check Valve and Two Screw Caps)



TRD Gas Fill and Drain Port/GSE interface

Summation of Findings as Documented in Boeing Memo TM 990018-05

To Meet the CMG Momentum Manager
Magnetic Fields for any payload must be less than:

100,000 amp-m^2 if parallel to the ISS x-axis
40,000 amp-m^2 if parallel to the ISS y-axis
190,000 amp-m^2 if parallel to the ISS z-axis

With conversion of AMS-02 to Permanent Magnet configuration

Measured values of the Permanent Magnet as documented in "Study on Dipole Moment in Permanent Magnet used in Space Anti-Matter Detector," by Qiuliang Wang, Tao Song, Chin E. Lin, Housheng Wang, Zheng Wang, Li Kong, Luguan Yan and Samuel C. C. Ting, published in IEEE Transactions on Applied Superconductivity, Vol 18, No. 2, 2008

The AMS-01 Permanent Magnet (now the AMS-02 Permanent Magnet) X-axis measured Dipole Moment 11550 Am^2 ± 10%.

This value is measured without any attenuation by surrounding structures.

0 amp-m^2 if parallel to the ISS x-axis (AMS-02 y-axis)
11550 amp-m^2 if parallel to the ISS y-axis (AMS-02 x-axis)
0 amp-m^2 if parallel to the ISS z-axis (AMS-02 z-axis)

Actual Alignment to the ISS Axes:

ISS x-axis = 1:1	= 0.0 kAm2	<<	100 kAm2 limit
ISS y-axis = 11.55*cos(12deg) kAm2	= 11.3 kAm2	<	40 kAm2 limit
ISS z-axis = 11.55*sin(12deg) kAm2	= 2.4 kAm2	<<	190 kAm2 limit

THE BOEING COMPANY **_Boeing – Houston_**

TRANSMITTAL MEMO

SUBJECT: ALPHA MAGNETIC SPECTROMETER / CMG MOMENTUM MANAGER INTERACTION ASSESSMENT

ENCL: 1) AMS TIM Presentation charts

TM NO.	**TM-990018-05**
DATE	**29 Sept 1999**
CONTRACT NO.	**NAS9-19100**
SUBCONTRACT NO.	**02C0100001**
LTD NO.	**MDA-99-0018**
STO NO.	**9HECEG4AA**

TO —
NASA/LYNDON B. JOHNSON SPACE CENTER
2101 NASA ROAD 1
HOUSTON, TEXAS 77058
ATTN: Tuyen. Hua/EG

REMARKS:

The Alpha Magnetic Spectrometer (AMS) is an ISS attached payload/experiment used to detect anti-matter, matter, and dark-matter in space. It is currently planned to be manifested on flight UF-4 and mounted on the inboard upper payload attach point on the S3 or P3 truss (location is TDB). The original AMS design (AMS-01) contained a permanent magnet with a magnetic dipole moment of about 13,600 amp-m^2. The currently designed AMS (AMS-02) is a super conducting electromagnet with a worst-case magnetic dipole moment of 136,000 amp-m^2 (10 times the AMS-01 value). Although the AMS magnet can be "turned off", it will take about 4 hours to complete the shutdown cycle. There is a strong desire to maintain continuous operation since recooling the system to cryogenic temperatures requires approximately 1500 liters of super fluid helium. It is planned to operate the AMS on the ISS until it has accumulated 4 years of operation.

Since the AMS magnetic field will interact with the earth's magnetic field, disturbance torques will be produced which will affect the performance of the CMG Momentum Manager (ISS average attitude, attitude variations, and CMG momentum usage). Per request from John Shebalin/Payloads Integration and James Bates/AMS Mission Manager, an assessment was made of the effects of the AMS magnetic disturbance torques on the CMG Momentum Manager (MM) performance and ISS attitude. Bob Henscheid/GN&C presented the assessment results at the AMS Technical Interchange Meeting (TIM) on Sept 13, 1999. It was decided at the TIM, that the magnetic dipole moment would be aligned parallel to the ISS y-axis. Also at the AMS TIM, Prof. Hans Hofer stated that the expected magnetic dipole moment should be only 27,200 amp-m^2 (2 times the AMS-01 value). After the AMS TIM, additional analysis was performed to (a) determine the CMG MM performance with the expected AMS magnetic dipole moment, and (b) determine the maximum AMS magnetic dipole moment, which would allow the CMG MM system to meet its performance requirements (thereby supporting the microgravity requirements). The enclosure of this Transmittal Memo (TM) contains the AMS TIM presentation charts modified to include the analysis performed after the AMS TIM.

James Bates/AMS Mission Manager considers the issue closed based on Prof. Hans Hofer's prediction that the magnetic dipole moment will be only 2 times the AMS-01 value. It is planned to review the issue after the fringe field data is available in October 1999.

Prepared by: ______________________________ ______________________________

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Boeing Transmittal Memo No. TM-990018-05
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*without enclosure(s)

Approved by:

____

Richard H. Seale/C70B
Senior Manager
Engineering, Test, and Analysis Contract

Alpha Magnetic Spectrometer / CMG Momentum Manager Interaction Assessment

Contents

ISS CMG Momentum Manager Overview

- Purposes of CMG Momentum Manager (MM)
  - Minimize propellant usage for long term attitude control
  - Minimize disturbances to microgravity in laboratories during microgravity operations
    - ✓ Provides continuous proportional non-propulsive attitude control torques

Control Moment Gyro (CMG)

- **Control Moment Gyros (CMGs) are double-gimbaled constant speed devices which can produce control torques about 2-axes**
  - At least 2 CMGs are required for 3-axis control
- **CMGs can produce torques in 2 ways:**
  - **CMG gimbal rotations** redirect the angular momentum vector of the rotor creating short-term control torques
    - ✓ When CMG rotors become aligned (parallel), control torques can no longer be produced in all axes (condition known as "saturated")
  - **CMG roll / yaw gyroscopic torques** are produced when CMG system angular momentum is non-zero due to ISS motions (primarily rotations about ISS pitch axis to maintain LVLH attitude)
    - ✓ If a constant CMG system angular momentum is maintained, a constant gyroscopic torque is produced which can be used to modify the "natural" TEA (known as a "biased" attitude)

MM Control Strategy

- **MM must maintain the ISS near a Torque Equilibrium Attitude (TEA) to avoid CMG saturation**
  - TEA is an attitude at which all orbit average environmental torques (aerodynamic, gravity-gradient, magnetic, gyroscopic) are balanced
  - Results in orbit average control torques near zero and zero CMG momentum accumulation
  - MM makes small attitude changes about the TEA adjusting gravity-gradient torques to maintain the desired CMG momentum state (usually zero)
- **If a TEA is poorly defined (e.g., Iy~Iz) or falls outside the allowable attitude envelope, a biased attitude control strategy may be used in the roll and/or yaw axes**
  - Maintains a constant CMG momentum offset which combined with the ISS attitude rate (relative to inertial space) creates a constant gyroscopic torque to maintain the desired (biased) attitude

MM Control Strategy (cont'd)

- **Disturbance filtering is provided to allow tradeoff of attitude variations with CMG momentum usage at certain frequencies**
  - 1* orbit frequency (primarily aerodynamic disturbances due to the atmospheric diurnal bulge **and the AMS**)
  - 2* orbit frequency (primarily aerodynamic disturbances due to the rotating solar arrays)
  - Selectable frequency

Assembly Complete Requirements

- **Microgravity Requirements**
  - ISS shall provide the following microgravity performance for at least 50% of the internal payload locations for 180 days/year for 30 continuous days
    - ✓ Acceleration magnitude < 1 μg
    - ✓ Perpendicular component < 0.2 μg
- **Momentum Manager Requirements**
  - Provide non-propulsive only attitude control for 30 continuous days
    - ✓ ISS attitude must be within +/- 15 deg roll/yaw and +15/-20 pitch
    - ✓ ISS attitude rate < 0.002 deg/sec during microgravity operations (transient disturbances are exempt)
    - ✓ ISS attitude variation / orbit < 2.5 deg peak-peak
    - ✓ Must be 1-fault tolerant (i.e., 3 CMG capability)

System / Payload Disturbances Requirement (SSCN 2664)

Para 3.2.1.1.4.4 Capability: Support microgravity mode

Para 3.2.1.1.4.4.1 Limit Disturbance Induced ISS Attitude Rate

When the ISS is in the microgravity mode, any **non-transitory** disturbance induced on the ISS by individual ISS systems or payloads (including vent impingement on ISS structure) shall have an angular momentum impulse during any continuous 9 minute period less than the per axis values shown in Table IX.

Table IX: Maximum Angular Momentum Impulse (ft-lb-sec)

Hx	Hy	Hz
930	1277	2876

Where Hx, Hy, Hz are the components of the disturbance angular momentum impulse in the ISS analysis coordinate system (specified in SSP 30219, Figure 4.0-1) which shall normally be calculated as the integral of the disturbance torque relative to the ISS center of mass over the specified period of time.

Notes:
[1] For sinusoidal disturbances with a single frequency greater than **2** times orbital frequency, the angular momentum impulse shall be calculated for 1/4 cycle. (H imp=Torque Amplitude * Period / 2π).
[2] For constant, steadily increasing, or steadily decreasing disturbance torques over adjacent periods, the difference in angular momentum impulse of the adjacent periods should be used.
[3] All disturbances are assumed non-transitory unless determined to be transitory by the Microgravity AIT
[4] External robotic operations or EVAs are not allowed during microgravity operations

System / Payload Disturbances Requirement (Cont'd)

Para 3.2.1.1.4.4.2 Limit Disturbance Induced CMG Momentum Usage

When the ISS is in the microgravity mode, any disturbance induced on the ISS by individual ISS systems or payloads (including vent impingement on ISS structure) shall have an angular momentum impulse during any continuous **110** min period which produces an estimated CMG momentum less than **10,000** ft-lb-sec using the following equation:

Hcmg_est = SQRT((1.25*Hx+1069)**2 + (1.25*Hy+6885)**2 + (1.25*Hz+779)**2)

Where Hx, Hy, Hz are the components of the disturbance angular momentum impulse in the ISS analysis coordinate system (specified in SSP 30219, Figure 4.0-1) which shall normally be calculated as the integral of the disturbance torque relative to the ISS center of mass over the specified period of time.

Notes:

[1] For sinusoidal disturbances with a single frequency greater than **0.2** times orbital frequency, the angular momentum impulse shall be calculated for 1/4 cycle. (H imp=Torque Amplitude * Period / 2π).

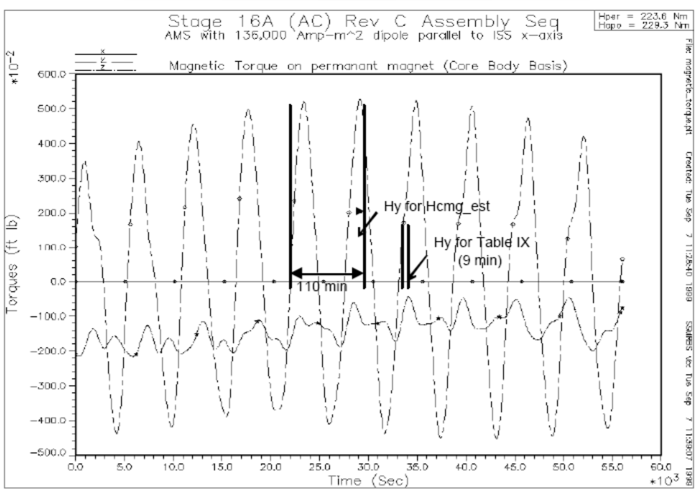
[2] For constant, steadily increasing, or steadily decreasing disturbance torques over adjacent periods, the difference in angular momentum impulse of the adjacent periods should be used.

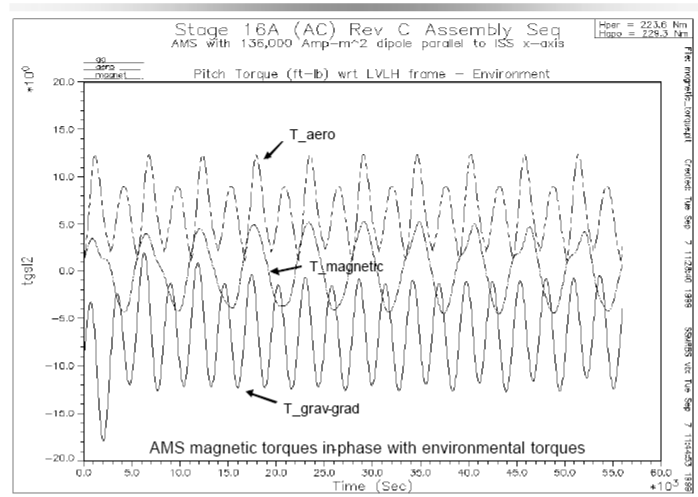
[3] External robotic operations or EVAs are not allowed during microgravity operations

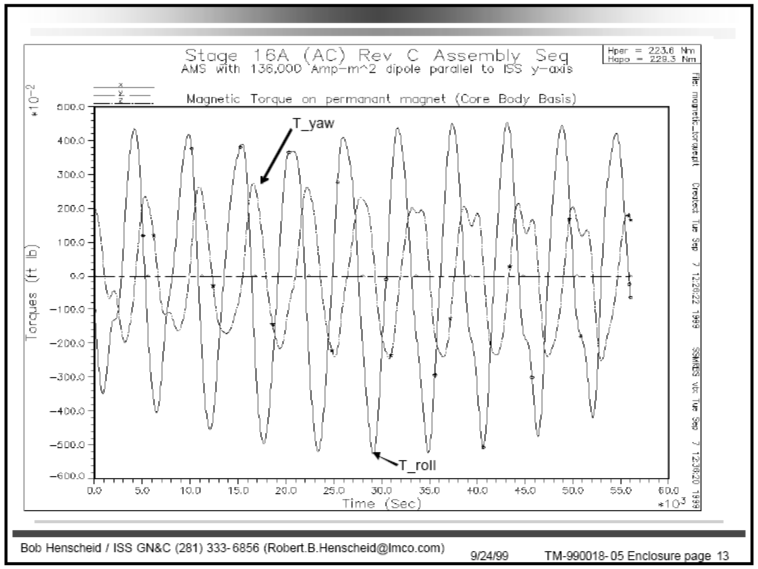
AMS Requirements Compliance Assessment

(SSCN 2664)

- **Used Space Station Multi-Rigid Body Simulator (SSMRBS) to determine magnetic torques time profiles**
  - ISS Mass Properties
    - ✓ Stage c112_16a (Assembly Complete) of the DAC-6 Rev C Assembly Sequence
  - Geomagnetic Field Model
    - ✓ International Geomagnetic Reference Field (IGRF) up to degree 10 and order 10 (used degree 4 and order 4 in analyses)
    - ✓ IGRF year 1995
  - AMS Magnetic Model
    - ✓ Assumed worst case magnetic dipole moment is 136,000 amp-m^2
    - ✓ Magnetic dipole moment aligned along ISS x or y axis
  - Atmospheric Density Model
    - ✓ Marshall Engineering Thermosphere (MET) – Nominal conditions
- **Calculated angular momentum impulse from magnetic torque time profiles and applied as specified in SSCN 2664**
- **Determined maximum magnetic dipole moment which provides compliance with requirements, as necessary**







Stage 16A (AC) Rev C Assembly Seq
AMS with 136,000 Amp-m^2 dipole parallel to ISS y-axis
Hper = 223.6 Nm
Hapo = 229.3 Nm
Magnetic Torque on permanant magnet (Core Body Basis)
Torques (ft lb)
Time (Sec)
T_yaw
T_roll
Bob Henscheid / ISS GN&C (281) 333-6856 (Robert.B.Henscheid@lmco.com)
9/24/99
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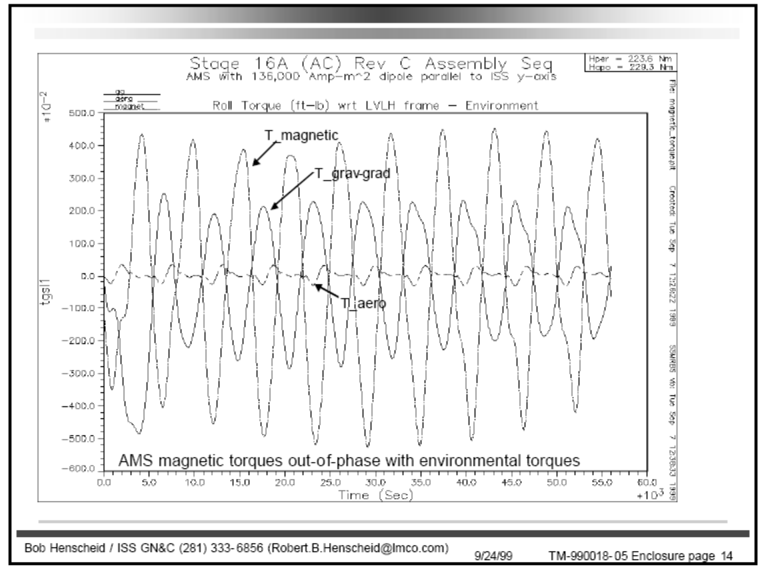

Stage 16A (AC) Rev C Assembly Seq
AMS with 136,000 Amp-m^2 dipole parallel to ISS y-axis
Hper = 223.6 Nm
Hapo = 229.3 Nm
Roll Torque (ft-lb) wrt LVLH frame – Environment
T_magnetic
T_grav-grad
T_aero
AMS magnetic torques out-of-phase with environmental torques
Time (Sec)
Bob Henscheid / ISS GN&C (281) 333-6856 (Robert.B.Henscheid@lmco.com)
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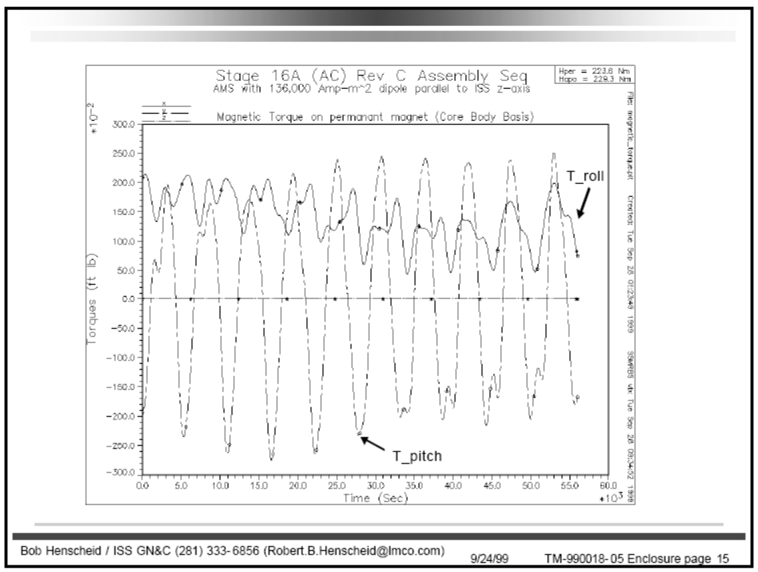

Stage 16A (AC) Rev C Assembly Seq
AMS with 136,000 Amp-m^2 dipole parallel to ISS z-axis
Hper = 223.6 Nm
Hapo = 229.3 Nm
Magnetic Torque on permanant magnet (Core Body Basis)
Torques (ft lb)
Time (Sec)
T_roll
T_pitch
Bob Henscheid / ISS GN&C (281) 333-6856 (Robert.B.Henscheid@lmco.com)
9/24/99
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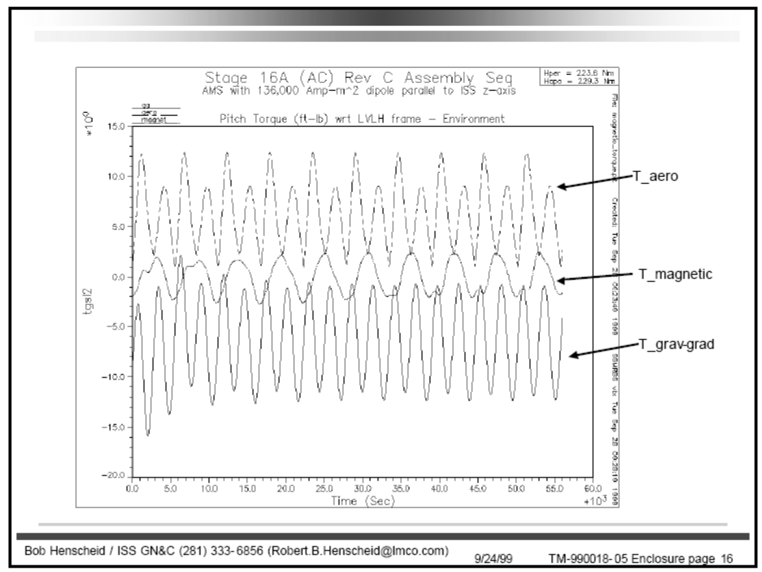

Stage 16A (AC) Rev C Assembly Seq
AMS with 136,000 Amp-m^2 dipole parallel to ISS z-axis
Hper = 223.6 Nm
Hapo = 229.3 Nm
Pitch Torque (ft-lb) wrt LVLH frame – Environment
T_aero
T_magnetic
T_grav-grad
Time (Sec)
Bob Henscheid / ISS GN&C (281) 333-6856 (Robert.B.Henscheid@lmco.com)
9/24/99
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Systems/Payloads Requirements Compliance (SSCN 2664)

System / Payload Disturbance	9 min period Hx	9 min period Hy	9 min period Hz	Hcmg Est	110 min period** Hx	110 min period** Hy	110 min period** Hz
SPP Solar Arrays - Reset*	0	0	1,126	7,302	0	0	1,126
SM Solar Arrays - Reset	0	10	0	7,023	0	10	0
SPP Thermal radiator	138	138	0	7,208	138	138	0
RSA-4 Vozdukh Vent	1	0	62	7,020	1	0	62
RSA-5 MAU Vent	1	0	63	7,020	1	0	63
RSA-6 Elektron Vent	4	44	0	7,066	4	44	0
Thermal Radiators (S1,P1)*	1,082	0	0	7,340	1,082	0	0
Treadmill Gyro Spinup (Lab)	42	0	124	7,041	47	0	138
ACES Flywheel (S3)	0	1,162	0	8,442	0	1,162	0
LAB-1 VES Vent*	41	158	71	7,223	41	158	71
LAB-4 CO2 Vent	27	62	65	7,863	245	564	599
HAB-1 CO2 Vent	tbd	tbd	tbd	tbd	tbd	tbd	tbd
ESA-1 Experiment Vent	32	393	395	7,567	32	393	395
JEM-1a,b Waste Gas Vent*	538	42	757	7,358	538	42	757
JEM-4a,b PM Airlock Vent	4	1	22	7,016	4	1	22
AMS Y-dipole= 136,000 amp-m^2	788		410	9,908	4,125		2,149
AMS X-dipole= 136,000 amp-m^2		739	181	**11,930**		3,867	945
AMS X-dipole= 77,500 amp-m^2		421	103	9,967		2,363	322
Centrifuge Spinup/Spindown (TBD allocated)	775	0	2,862	8,398	775	0	2,862
SSCN 2664 requirements (max values):	**930**	**1,277**	**2,876**	**10,000**			

* Transient disturbances (shaded requirements do not apply)
**Hcmg estimates assume one occurrence per 110 min period

Momentum Manager Requirements Compliance

- Approach using SSMRBS
  - Determine Baseline MM performance
  - Determine delta performance due to parameter uncertainties
  - Determine delta performance due to system / payload disturbances
  - Estimate worst case MM performance
    - = Baseline MM performance
    - \+ Continuous system/payload disturbance performance deltas
    - \+ Root Sum Squared (RSS'd) parameter uncertainty performance deltas
    - \+ RSS'd system/payload disturbance performance deltas (non-continuous)
  - Compare with Momentum Manager Performance Requirements
- Assess worst case AMS magnetic dipole moment (along ISS x or y-axis)
- Determine maximum allowable magnetic dipole moment (along all axes)
- Assess expected AMS magnetic dipole moment (along y-axis)

A.6-17

Uncertainty / Disturbance Description	TEA / Average Attitude (degrees) Roll	Pitch	Yaw	Attitude Variation (peak-peak deg/orbit) Roll	Pitch	Yaw	Max Attitude Rate (mdeg/sec) Roll	Pitch	Yaw	Peak CMG Momentum (ft-lb-sec)
Integrated Vehicle Requirements:	15.0	-20.0	15.0	3.5	3.5	3.5	2.0	2.0	2.0	10500
Flex/thermal Allocation:	0.5	-0.5	0.5	1.0	1.0	1.0				
MM Performance Allocations:	**14.5**	**-19.5**	**14.5**	**2.5**	**2.5**	**2.5**	**2.0**	**2.0**	**2.0**	**10000**
Nominal performance with environmental disturbances										
Nominal performance	0.99	-10.09	-2.09	1.17	0.16	0.19	0.63	0.24	0.1	4943
Parameter Uncertainties (performance deltas)										
Atmospheric density	0.05	1.12	0.00	0.04	1.00	0.02	0.03	0.19	0.01	1456
Diurnal Bulge / Orbit Phasing (DAC7)	0.10	1.43	0.02	0.81	0.08	0.11	0.57	0.23	0.29	561
Aerodynamic model (%diffuse)	0.00	0.12	0.00	0.02	0.03	0.01	0.03	0.08	0.00	323
Projected surface areas (+/- 20%)	0.00	0.03	0.00	0.00	0.01	0.00	0.01	0.01	0.00	37
Mass properties (+/- 2000 lbm)	0.06	0.33	0.01	0.01	0.00	0.00	0.01	0.00	0.00	44
Momentum knowledge error	0.09	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	498
RSS'd Uncertainties	0.16	1.85	0.02	0.81	1.00	0.11	0.57	0.31	0.29	1670
Estimated Worst MM Performance with Parameter Uncertainties:										
Nominal + RSS'd Uncert's	1.15	-11.94	-2.11	1.98	1.16	0.30	1.20	0.55	0.39	6613
Environmental Allocations:	**13.5**	**-18.5**	**13.5**	**2.0**	**1.5**	**1.5**	**1.3**	**0.6**	**0.6**	**7000**
Continuous System / Payload Disturbances (performance deltas)										
Electrical current loops	0.00	0.00	0.00	0.05	0.00	0.01	0.01	0.00	0.01	20
AMS X-dipole=136,000 amp-m^2	0.08	-0.06	-1.49	0.31	0.52	0.01	0.13	0.24	0.03	1996
Transient System / Payload Disturbances (performance deltas)										
Crew pushoff (US-Hab / Lab)	na	na	na	0.00	0.00	0.00	0.24	0.40	0.19	13
Crew pushoff (RS-SM)	na	na	na	0.00	0.00	0.00	0.00	1.14	0.54	1
Crew pushoff (JEM-PM)	na	na	na	0.00	0.00	0.00	0.29	0.76	0.37	24
Crew pushoff (APM)	na	na	na	0.00	0.00	0.00	0.22	0.77	0.37	25
ADS string failure	0.00	0.01	0.08	0.08	0.27	0.13	0.28	0.61	0.20	850
Lab-1 VES vent (US-Lab)	0.00	-0.01	0.00	0.02	0.03	0.01	0.05	0.09	0.01	74
JEM-1 waste gas vent (JEM-PM)	0.00	0.00	0.00	0.27	0.03	0.07	0.33	0.08	0.30	64
ESA-1 experiment vent (APM)	0.01	0.00	0.00	0.04	0.01	0.02	0.04	0.01	0.01	0
SARJ (RS-SPP) - reset event	0.00	0.00	0.00	0.00	0.20	0.00	0.10	0.19	0.72	321
TRRJ (S1/P1)	0.00	0.00	0.00	0.00	0.02	0.02	0.93	0.05	0.20	976
Quasi-steady System / Payload Disturbances (performance deltas)										
Lab-4 CO2 vent (US-Lab)	0.00	-0.02	0.00	0.10	0.07	0.02	0.05	0.07	0.01	160
RSA-6 vents (RS-SM)	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
SARJ - rewind event (RS-SM)	0.00	0.02	0.00	0.00	0.03	0.00	0.00	0.00	0.00	88
SARJ - rewind event (RS-FGB)	na	na	na	na	na	na	na	na	na	na
Treadmill gyro spinup/down (RS-SM)	0.01	0.00	0.00	0.02	0.00	0.01	0.01	0.00	0.01	142
TRRJ (RS-SPP)	Not Assessed - need model									
JEM-4 airlock vent (JEM-PM)	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.01	22
Hab-1 CO2 vent (US-Hab)	0.00	-0.02	0.00	0.03	0.06	0.01	0.02	0.04	0.01	155
Centrifuge (z-axis)(CAM)	0.53	0.02	0.09	0.19	0.01	0.10	0.21	0.28	0.87	1227
Total System/Payload Disturb's	0.61	0.11	1.62	0.58	0.62	0.12	0.36	0.53	0.91	3852
Systems / Payloads Allocations:	**1.0**	**1.0**	**1.0**	**0.5**	**1.0**	**1.0**	**0.7**	**1.4**	**1.5**	**3000**
Estimated Worst MM Performance with Parameter Uncertainties and System / Payload Disturbances										
Excluding transient disturbances	1.76	-12.05	-3.73	2.56	1.78	0.42	1.56	1.07	1.30	10466
MM Performance Allocations:	**14.5**	**-19.5**	**14.5**	**2.5**	**2.5**	**2.5**	**2.0**	**2.0**	**2.0**	**10000**

Momentum Manager Performance Budget With ***Worst Case*** *AMS dipole moment* ***along ISS X-axis*** *(136,000 amp-m^2)*

Uncertainty / Disturbance Description	TEA / Average Attitude (degrees) Roll	Pitch	Yaw	Attitude Variation (peak-peak deg/orbit) Roll	Pitch	Yaw	Max Attitude Rate (mdeg/sec) Roll	Pitch	Yaw	Peak CMG Momentum (ft-lb-sec)
Integrated Vehicle Requirements:	15.0	-20.0	15.0	3.5	3.5	3.5	2.0	2.0	2.0	10000
Flex/thermal Allocation:	0.5	-0.5	0.5	1.0	1.0	1.0				
MM Performance Allocations:	**14.5**	**-19.5**	**14.5**	**2.5**	**2.5**	**2.5**	**2.0**	**2.0**	**2.0**	**10000**
Nominal performance with environmental disturbances										
Nominal performance	0.99	-10.09	-2.09	1.17	0.16	0.19	0.63	0.24	0.1	4943
Parameter Uncertainties (performance deltas)										
Atmospheric density	0.05	1.12	0.00	0.04	1.00	0.02	0.03	0.19	0.01	1456
Diurnal Bulge / Orbit Phasing (DAC7)	0.10	1.43	0.02	0.81	0.08	0.11	0.57	0.23	0.29	561
Aerodynamic model (%diffuse)	0.00	0.12	0.00	0.02	0.03	0.01	0.03	0.08	0.00	323
Projected surface areas (+/- 20%)	0.00	0.03	0.00	0.00	0.01	0.00	0.01	0.01	0.00	37
Mass properties (+/- 2000 lbm)	0.06	0.33	0.01	0.01	0.00	0.00	0.01	0.00	0.00	44
Momentum knowledge error	0.09	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	498
RSS'd Uncertainties	0.16	1.85	0.02	0.81	1.00	0.11	0.57	0.31	0.29	1670
Estimated Worst MM Performance with Parameter Uncertainties:										
Nominal + RSS'd Uncert's	1.15	-11.94	-2.11	1.98	1.16	0.30	1.20	0.55	0.39	6613
Environmental Allocations:	**13.5**	**-18.5**	**13.5**	**2.0**	**1.5**	**1.5**	**1.3**	**0.6**	**0.6**	**7000**
Continuous System / Payload Disturbances (performance deltas)										
Electrical current loops	0.00	0.00	0.00	0.05	0.00	0.01	0.01	0.00	0.01	20
AMS Y-dipole=136,000 amp-m^2	0.03	0.00	-0.02	0.87	0.01	0.18	0.64	0.02	0.07	32
Transient System / Payload Disturbances (performance deltas)										
Crew pushoff (US-Hab / Lab)	na	na	na	0.00	0.00	0.00	0.24	0.40	0.19	13
Crew pushoff (RS-SM)	na	na	na	0.00	0.00	0.00	0.00	1.14	0.54	1
Crew pushoff (JEM-PM)	na	na	na	0.00	0.00	0.00	0.29	0.76	0.37	24
Crew pushoff (APM)	na	na	na	0.00	0.00	0.00	0.22	0.77	0.37	25
ADS string failure	0.00	0.01	0.08	0.08	0.27	0.13	0.28	0.61	0.20	850
Lab-1 VES vent (US-Lab)	0.00	-0.01	0.00	0.02	0.03	0.01	0.05	0.09	0.01	74
JEM-1 waste gas vent (JEM-PM)	0.00	0.00	0.00	0.27	0.03	0.07	0.33	0.08	0.30	64
ESA-1 experiment vent (APM)	0.01	0.00	0.00	0.04	0.01	0.02	0.04	0.01	0.01	0
SARJ (RS-SPP) - reset event	0.00	0.00	0.00	0.00	0.20	0.00	0.10	0.19	0.72	321
TRRJ (S1/P1)	0.00	0.00	0.00	0.00	0.02	0.02	0.93	0.05	0.20	976
Quasi-steady System / Payload Disturbances (performance deltas)										
Lab-4 CO2 vent (US-Lab)	0.00	-0.02	0.00	0.10	0.07	0.02	0.05	0.07	0.01	160
RSA-6 vents (RS-SM)	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
SARJ - rewind event (RS-SM)	0.00	0.02	0.00	0.00	0.03	0.00	0.00	0.00	0.00	88
SARJ - rewind event (RS-FGB)	na	na	na	na	na	na	na	na	na	na
Treadmill gyro spinup/down (RS-SM)	0.01	0.00	0.00	0.02	0.00	0.01	0.01	0.00	0.01	142
TRRJ (RS-SPP)	Not Assessed - need model									
JEM-4 airlock vent (JEM-PM)	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.01	22
Hab-1 CO2 vent (US-Hab)	0.00	-0.02	0.00	0.03	0.06	0.01	0.02	0.04	0.01	155
Centrifuge (z-axis)(CAM)	0.53	0.02	0.09	0.19	0.01	0.10	0.21	0.28	0.87	1227
Total System/Payload Disturb's	0.56	0.05	0.14	1.14	0.11	0.29	0.86	0.31	0.95	1888
Systems / Payloads Allocations:	**1.0**	**1.0**	**1.0**	**0.5**	**1.0**	**1.0**	**0.7**	**1.4**	**1.5**	**3000**
Estimated Worst MM Performance with Parameter Uncertainties and System / Payload Disturbances										
Excluding transient disturbances	1.70	-11.99	-2.26	3.12	1.27	0.59	2.06	0.86	1.34	8502
MM Performance Allocations:	**14.5**	**-19.5**	**14.5**	**2.5**	**2.5**	**2.5**	**2.0**	**2.0**	**2.0**	**10000**

Momentum Manager Performance Budget With ***Worst Case*** *AMS dipole moment* ***along ISS Y-axis*** *(136,000 amp-m^2)*

Uncertainty / Disturbance Description	TEA / Average Attitude (degrees)			Attitude Variation (peak-peak deg/orbit)			Max Attitude Rate (mdeg/sec)			Peak CMG Momentum (ft-lb-sec)
	Roll	Pitch	Yaw	Roll	Pitch	Yaw	Roll	Pitch	Yaw	
Integrated Vehicle Requirements:	15.0	-20.0	15.0	3.5	3.5	3.5	2.0	2.0	2.0	10000
Flex/thermal Allocation:	0.5	-0.5	0.5	1.0	1.0	1.0				
MM Performance Allocations:	**14.5**	**-19.5**	**14.5**	**2.5**	**2.5**	**2.5**	**2.0**	**2.0**	**2.0**	**10000**
Nominal performance with environmental disturbances										
Nominal performance	0.99	-10.09	-2.09	1.17	0.16	0.19	0.63	0.24	0.1	4943
Parameter Uncertainties (performance deltas)										
Atmospheric density	0.05	1.12	0.00	0.04	1.00	0.02	0.03	0.19	0.01	1456
Diurnal Bulge / Orbit Phasing (DACT)	0.10	1.43	0.02	0.81	0.08	0.11	0.57	0.23	0.29	581
Aerodynamic model (Sk/diffuse)	0.00	0.12	0.00	0.07	0.03	0.01	0.03	0.08	0.00	323
Projected surface areas (+/- 20%)	0.00	0.03	0.00	0.00	0.01	0.00	0.01	0.01	0.00	37
Mass properties (+/- 2000 lbm)	0.06	0.33	0.01	0.01	0.00	0.00	0.01	0.00	0.00	44
Momentum knowledge error	0.09	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	498
RSS'd Uncertainties	0.16	1.85	0.02	0.81	1.00	0.11	0.57	0.31	0.29	1670
Estimated Worst MM Performance with Parameter Uncertainties:										
Nominal + RSS'd Uncert's	1.15	-11.94	-2.11	1.98	1.16	0.30	1.20	0.55	0.39	6613
Environmental Allocations:	**13.5**	**-18.5**	**13.5**	**2.0**	**1.5**	**1.5**	**1.3**	**0.6**	**0.5**	**7000**
Continuous System / Payload Disturbances (performance deltas)										
Electrical current loops	0.00	0.00	0.00	0.05	0.00	0.01	0.01	0.00	0.01	20
Max X-dipole=100,000 amp-m2	0.03	0.04	-1.49	0.22	0.43	0.04	0.10	0.22	0.02	1204
Transient System / Payload Disturbances (performance deltas)										
Crew pushoff (US-Hab / Lab)	na	na	na	0.00	0.00	0.00	0.24	0.40	0.19	13
Crew pushoff (RS-SM)	na	na	na	0.00	0.00	0.00	0.00	1.14	0.54	1
Crew pushoff (JEM-PM)	na	na	na	0.00	0.00	0.00	0.29	0.76	0.37	24
Crew pushoff (APM)	na	na	na	0.00	0.00	0.00	0.22	0.77	0.37	25
ADS string failure	0.00	0.01	0.08	0.08	0.27	0.13	0.28	0.61	0.20	850
Lab-1 VES vent (US-Lab)	0.00	-0.01	0.00	0.02	0.03	0.01	0.05	0.09	0.01	74
JEM-1 waste gas vent (JEM-PM)	0.00	0.00	0.00	0.27	0.03	0.07	0.33	0.08	0.30	64
ESA-1 experiment vent (APM)	0.01	0.00	0.00	0.04	0.01	0.03	0.04	0.01	0.01	0
SARJ (RS-SPP) - reset event	0.00	0.00	0.00	0.00	0.20	0.00	0.10	0.19	0.72	321
TRRJ (S1/P1)	0.00	0.00	0.00	0.00	0.02	0.02	0.93	0.05	0.20	576
Quasi-steady System / Payload Disturbances (performance deltas)										
Lab-4 CO2 vent (US-Lab)	0.00	-0.02	0.00	0.10	0.07	0.02	0.05	0.07	0.01	160
RSA-6 vents (RS-SM)	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
SARJ - rewind event (RS-SM)	0.00	0.02	0.00	0.00	0.03	0.00	0.00	0.00	0.00	83
SARJ - rewind event (RS-FGB)	na	na	na	na	na	na	na	na	na	na
Treadmill gyro spinup/down (RS-SM)	0.01	0.00	0.00	0.02	0.00	0.01	0.01	0.00	0.01	142
TRRJ (RS-SPP)	Not Assessed - need model									
JEM-4 airlock vent (JEM-PM)	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.01	22
Hab-1 CO2 vent (US-Hab)	0.00	-0.02	0.00	0.03	0.06	0.01	0.02	0.04	0.01	155
Centrifuge (z-axis)(CAM)	0.53	0.02	0.09	0.19	0.01	0.10	0.21	0.28	0.87	1227
Total System/Payload Disturb's	0.56	0.09	1.61	0.49	0.52	0.15	0.32	0.51	0.90	3060
Systems / Payloads Allocations:	**1.0**	**1.0**	**1.0**	**0.5**	**1.0**	**1.0**	**0.7**	**1.4**	**1.5**	**3000**
Estimated Worst MM Performance with Parameter Uncertainties and System / Payload Disturbances										
Excluding transient disturbances	1.70	-12.03	-3.73	2.47	1.69	0.46	1.53	1.06	1.29	9674
MM Performance Allocations:	**14.5**	**-19.5**	**14.5**	**2.5**	**2.5**	**2.5**	**2.0**	**2.0**	**2.0**	**10000**

Momentum Manager Performance Budget with ***Maximum Allowable*** *magnetic dipole moment* ***along ISS X-axis*** *(100,000 amp-m^2)*

Uncertainty / Disturbance Description	TEA / Average Attitude (degrees)			Attitude Variation (peak-peak deg/orbit)			Max Attitude Rate (mdeg/sec)			Peak CMG Momentum (ft-lb-sec)
	Roll	Pitch	Yaw	Roll	Pitch	Yaw	Roll	Pitch	Yaw	
Integrated Vehicle Requirements:	15.0	-20.0	15.0	3.5	3.5	3.5	2.0	2.0	2.0	10000
Flex/thermal Allocation:	0.5	-0.5	0.5	1.0	1.0	1.0				
MM Performance Allocations:	**14.5**	**-19.5**	**14.5**	**2.5**	**2.5**	**2.5**	**2.0**	**2.0**	**2.0**	**10000**
Nominal performance with environmental disturbances										
Nominal performance	0.99	-10.09	-2.09	1.17	0.16	0.19	0.63	0.24	0.1	4943
Parameter Uncertainties (performance deltas)										
Atmospheric density	0.05	1.12	0.00	0.04	1.00	0.02	0.03	0.19	0.01	1456
Diurnal Bulge / Orbit Phasing (DACT)	0.10	1.43	0.02	0.81	0.08	0.11	0.57	0.23	0.29	581
Aerodynamic model (Sk/diffuse)	0.00	0.12	0.00	0.07	0.03	0.01	0.03	0.08	0.00	323
Projected surface areas (+/- 20%)	0.00	0.03	0.00	0.00	0.01	0.00	0.01	0.01	0.00	37
Mass properties (+/- 2000 lbm)	0.06	0.33	0.01	0.01	0.00	0.00	0.01	0.00	0.00	44
Momentum knowledge error	0.09	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	498
RSS'd Uncertainties	0.16	1.85	0.02	0.81	1.00	0.11	0.57	0.31	0.29	1670
Estimated Worst MM Performance with Parameter Uncertainties:										
Nominal + RSS'd Uncert's	1.15	-11.94	-2.11	1.98	1.16	0.30	1.20	0.55	0.39	6613
Environmental Allocations:	**13.5**	**-18.5**	**13.5**	**2.0**	**1.5**	**1.5**	**1.3**	**0.6**	**0.5**	**7000**
Continuous System / Payload Disturbances (performance deltas)										
Electrical current loops	0.00	0.00	0.00	0.05	0.00	0.01	0.01	0.00	0.01	20
Max Y-dipole= 40,000 amp-m2	0.01	0.00	-0.01	0.25	0.00	0.05	0.14	0.01	0.01	8
Transient System / Payload Disturbances (performance deltas)										
Crew pushoff (US-Hab / Lab)	na	na	na	0.00	0.00	0.00	0.24	0.40	0.19	13
Crew pushoff (RS-SM)	na	na	na	0.00	0.00	0.00	0.00	1.14	0.54	1
Crew pushoff (JEM-PM)	na	na	na	0.00	0.00	0.00	0.29	0.76	0.37	24
Crew pushoff (APM)	na	na	na	0.00	0.00	0.00	0.22	0.77	0.37	25
ADS string failure	0.00	0.01	0.08	0.08	0.27	0.13	0.28	0.61	0.20	850
Lab-1 VES vent (US-Lab)	0.00	-0.01	0.00	0.02	0.03	0.01	0.05	0.09	0.01	74
JEM-1 waste gas vent (JEM-PM)	0.00	0.00	0.00	0.27	0.03	0.07	0.33	0.08	0.30	64
ESA-1 experiment vent (APM)	0.01	0.00	0.00	0.04	0.01	0.03	0.04	0.01	0.01	0
SARJ (RS-SPP) - reset event	0.00	0.00	0.00	0.00	0.20	0.00	0.10	0.19	0.72	321
TRRJ (S1/P1)	0.00	0.00	0.00	0.00	0.02	0.02	0.93	0.05	0.20	576
Quasi-steady System / Payload Disturbances (performance deltas)										
Lab-4 CO2 vent (US-Lab)	0.00	-0.02	0.00	0.10	0.07	0.02	0.05	0.07	0.01	160
RSA-6 vents (RS-SM)	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
SARJ - rewind event (RS-SM)	0.00	0.02	0.00	0.00	0.03	0.00	0.00	0.00	0.00	83
SARJ - rewind event (RS-FGB)	na	na	na	na	na	na	na	na	na	na
Treadmill gyro spinup/down (RS-SM)	0.01	0.00	0.00	0.02	0.00	0.01	0.01	0.00	0.01	142
TRRJ (RS-SPP)	Not Assessed - need model									
JEM-4 airlock vent (JEM-PM)	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.01	22
Hab-1 CO2 vent (US-Hab)	0.00	-0.02	0.00	0.03	0.06	0.01	0.02	0.04	0.01	155
Centrifuge (z-axis)(CAM)	0.53	0.02	0.09	0.19	0.01	0.10	0.21	0.28	0.87	1227
Total System/Payload Disturb's	0.54	0.05	0.13	0.62	0.10	0.16	0.37	0.29	0.89	1864
Systems / Payloads Allocations:	**1.0**	**1.0**	**1.0**	**0.5**	**1.0**	**1.0**	**0.7**	**1.4**	**1.5**	**3000**
Estimated Worst MM Performance with Parameter Uncertainties and System / Payload Disturbances										
Excluding transient disturbances	1.68	-11.99	-2.24	2.60	1.26	0.46	1.57	0.84	1.28	8478
MM Performance Allocations:	**14.5**	**-19.5**	**14.5**	**2.5**	**2.5**	**2.5**	**2.0**	**2.0**	**2.0**	**10000**

Momentum Manager Performance Budget with ***Maximum Allowable*** *magnetic dipole moment* ***along ISS Y-axis*** *(40,000 amp-m^2)*

Uncertainty / Disturbance Description	TEA / Average Attitude (degrees)			Attitude Variation (peak-peak deg/orbit)			Max Attitude Rate (mdeg/sec)			Peak CMG Momentum (ft-lb-sec)
	Roll	Pitch	Yaw	Roll	Pitch	Yaw	Roll	Pitch	Yaw	
Integrated Vehicle Requirements:	15.0	-20.0	15.0	3.5	3.5	3.5	2.0	2.0	2.0	10000
Flex/thermal Allocation:	0.5	-0.5	0.5	1.0	1.0	1.0				
MM Performance Allocations:	**14.5**	**-19.5**	**14.5**	**2.5**	**2.5**	**2.5**	**2.0**	**2.0**	**2.0**	**10000**
Nominal performance with environmental disturbances										
Nominal performance	0.99	-10.09	-2.09	1.17	0.16	0.19	0.63	0.24	0.1	4943
Parameter Uncertainties (performance deltas)										
Atmospheric density	0.05	1.12	0.00	0.04	1.00	0.02	0.03	0.19	0.01	1456
Diurnal Bulge / Orbit Phasing (DACT)	0.10	1.43	0.02	0.81	0.08	0.11	0.57	0.23	0.29	581
Aerodynamic model (Sk/diffuse)	0.00	0.12	0.00	0.07	0.03	0.01	0.03	0.08	0.00	323
Projected surface areas (+/- 20%)	0.00	0.03	0.00	0.00	0.01	0.00	0.01	0.01	0.00	37
Mass properties (+/- 2000 lbm)	0.06	0.33	0.01	0.01	0.00	0.00	0.01	0.00	0.00	44
Momentum knowledge error	0.09	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	498
RSS'd Uncertainties	0.16	1.85	0.02	0.81	1.00	0.11	0.57	0.31	0.29	1670
Estimated Worst MM Performance with Parameter Uncertainties:										
Nominal + RSS'd Uncert's	1.15	-11.94	-2.11	1.98	1.16	0.30	1.20	0.55	0.39	6613
Environmental Allocations:	**13.5**	**-18.5**	**13.5**	**2.0**	**1.5**	**1.5**	**1.3**	**0.6**	**0.5**	**7000**
Continuous System / Payload Disturbances (performance deltas)										
Electrical current loops	0.00	0.00	0.00	0.05	0.00	0.01	0.01	0.00	0.01	20
AMS Z-dipole=190,000 amp-m2	-0.27	0.00	0.05	0.22	0.10	0.01	0.05	0.15	0.01	445
Transient System / Payload Disturbances (performance deltas)										
Crew pushoff (US-Hab / Lab)	na	na	na	0.00	0.00	0.00	0.24	0.40	0.19	13
Crew pushoff (RS-SM)	na	na	na	0.00	0.00	0.00	0.00	1.14	0.54	1
Crew pushoff (JEM-PM)	na	na	na	0.00	0.00	0.00	0.29	0.76	0.37	24
Crew pushoff (APM)	na	na	na	0.00	0.00	0.00	0.22	0.77	0.37	25
ADS string failure	0.00	0.01	0.08	0.08	0.27	0.13	0.28	0.61	0.20	850
Lab-1 VES vent (US-Lab)	0.00	-0.01	0.00	0.02	0.03	0.01	0.05	0.09	0.01	74
JEM-1 waste gas vent (JEM-PM)	0.00	0.00	0.00	0.27	0.03	0.07	0.33	0.08	0.30	64
ESA-1 experiment vent (APM)	0.01	0.00	0.00	0.04	0.01	0.03	0.04	0.01	0.01	0
SARJ (RS-SPP) - reset event	0.00	0.00	0.00	0.00	0.20	0.00	0.10	0.19	0.72	321
TRRJ (S1/P1)	0.00	0.00	0.00	0.00	0.02	0.02	0.93	0.05	0.20	576
Quasi-steady System / Payload Disturbances (performance deltas)										
Lab-4 CO2 vent (US-Lab)	0.00	-0.02	0.00	0.10	0.07	0.02	0.05	0.07	0.01	160
RSA-6 vents (RS-SM)	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
SARJ - rewind event (RS-SM)	0.00	0.02	0.00	0.00	0.03	0.00	0.00	0.00	0.00	83
SARJ - rewind event (RS-FGB)	na	na	na	na	na	na	na	na	na	na
Treadmill gyro spinup/down (RS-SM)	0.01	0.00	0.00	0.02	0.00	0.01	0.01	0.00	0.01	142
TRRJ (RS-SPP)	Not Assessed - need model									
JEM-4 airlock vent (JEM-PM)	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.01	22
Hab-1 CO2 vent (US-Hab)	0.00	-0.02	0.00	0.03	0.06	0.01	0.02	0.04	0.01	155
Centrifuge (z-axis)(CAM)	0.53	0.02	0.09	0.19	0.01	0.10	0.21	0.28	0.87	1227
Total System/Payload Disturb's	0.80	0.05	0.17	0.49	0.20	0.12	0.28	0.44	0.89	2301
Systems / Payloads Allocations:	**1.0**	**1.0**	**1.0**	**0.5**	**1.0**	**1.0**	**0.7**	**1.4**	**1.5**	**3000**
Estimated Worst MM Performance with Parameter Uncertainties and System / Payload Disturbances										
Excluding transient disturbances	1.95	-11.99	-2.29	2.47	1.36	0.43	1.48	0.99	1.28	8916
MM Performance Allocations:	**14.5**	**-19.5**	**14.5**	**2.5**	**2.5**	**2.5**	**2.0**	**2.0**	**2.0**	**10000**

Momentum Manager Performance Budget with ***Maximum Allowable*** *magnetic dipole moment* ***along ISS Z-axis*** *(190,000 amp-m^2)*

Uncertainty / Disturbance Description	TEA / Average Attitude (degrees)			Attitude Variation (peak-peak deg/orbit)			Max Attitude Rate (mdeg/sec)			Peak CMG Momentum (ft-lb-sec)
	Roll	Pitch	Yaw	Roll	Pitch	Yaw	Roll	Pitch	Yaw	
Integrated Vehicle Requirements:	15.0	-20.0	15.0	3.5	3.5	3.5	2.0	2.0	2.0	10000
Flex/thermal Allocation:	0.5	-0.5	0.5	1.0	1.0	1.0				
MM Performance Allocations:	**14.5**	**-19.5**	**14.5**	**2.5**	**2.5**	**2.5**	**2.0**	**2.0**	**2.0**	**10000**
Nominal performance with environmental disturbances										
Nominal performance	0.99	-10.09	-2.09	1.17	0.16	0.19	0.63	0.24	0.1	4943
Parameter Uncertainties (performance deltas)										
Atmospheric density	0.05	1.12	0.00	0.04	1.00	0.02	0.03	0.19	0.01	1456
Diurnal Bulge / Orbit Phasing (DACT)	0.10	1.43	0.02	0.81	0.08	0.11	0.57	0.23	0.29	581
Aerodynamic model (Sk/diffuse)	0.00	0.12	0.00	0.07	0.03	0.01	0.03	0.08	0.00	323
Projected surface areas (+/- 20%)	0.00	0.03	0.00	0.00	0.01	0.00	0.01	0.01	0.00	37
Mass properties (+/- 2000 lbm)	0.06	0.33	0.01	0.01	0.00	0.00	0.01	0.00	0.00	44
Momentum knowledge error	0.09	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	498
RSS'd Uncertainties	0.16	1.85	0.02	0.81	1.00	0.11	0.57	0.31	0.29	1670
Estimated Worst MM Performance with Parameter Uncertainties:										
Nominal + RSS'd Uncert's	1.15	-11.94	-2.11	1.98	1.16	0.30	1.20	0.55	0.39	6613
Environmental Allocations:	**13.5**	**-18.5**	**13.5**	**2.0**	**1.5**	**1.5**	**1.3**	**0.6**	**0.5**	**7000**
Continuous System / Payload Disturbances (performance deltas)										
Electrical current loops	0.00	0.00	0.00	0.05	0.00	0.01	0.01	0.00	0.01	20
AMS Y-dipole= 27,000 amp-m2	0.01	0.00	0.00	0.17	0.00	0.03	0.10	0.01	0.00	5
Transient System / Payload Disturbances (performance deltas)										
Crew pushoff (US-Hab / Lab)	na	na	na	0.00	0.00	0.00	0.24	0.40	0.19	13
Crew pushoff (RS-SM)	na	na	na	0.00	0.00	0.00	0.00	1.14	0.54	1
Crew pushoff (JEM-PM)	na	na	na	0.00	0.00	0.00	0.29	0.76	0.37	24
Crew pushoff (APM)	na	na	na	0.00	0.00	0.00	0.22	0.77	0.37	25
ADS string failure	0.00	0.01	0.08	0.08	0.27	0.13	0.28	0.61	0.20	850
Lab-1 VES vent (US-Lab)	0.00	-0.01	0.00	0.02	0.03	0.01	0.05	0.09	0.01	74
JEM-1 waste gas vent (JEM-PM)	0.00	0.00	0.00	0.27	0.03	0.07	0.33	0.08	0.30	64
ESA-1 experiment vent (APM)	0.01	0.00	0.00	0.04	0.01	0.03	0.04	0.01	0.01	0
SARJ (RS-SPP) - reset event	0.00	0.00	0.00	0.00	0.20	0.00	0.10	0.19	0.72	321
TRRJ (S1/P1)	0.00	0.00	0.00	0.00	0.02	0.02	0.93	0.05	0.20	576
Quasi-steady System / Payload Disturbances (performance deltas)										
Lab-4 CO2 vent (US-Lab)	0.00	-0.02	0.00	0.10	0.07	0.02	0.05	0.07	0.01	160
RSA-6 vents (RS-SM)	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
SARJ - rewind event (RS-SM)	0.00	0.02	0.00	0.00	0.03	0.00	0.00	0.00	0.00	83
SARJ - rewind event (RS-FGB)	na	na	na	na	na	na	na	na	na	na
Treadmill gyro spinup/down (RS-SM)	0.01	0.00	0.00	0.02	0.00	0.01	0.01	0.00	0.01	142
TRRJ (RS-SPP)	Not Assessed - need model									
JEM-4 airlock vent (JEM-PM)	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.01	22
Hab-1 CO2 vent (US-Hab)	0.00	-0.02	0.00	0.03	0.06	0.01	0.02	0.04	0.01	155
Centrifuge (z-axis)(CAM)	0.53	0.02	0.09	0.19	0.01	0.10	0.21	0.28	0.87	1227
Total System/Payload Disturb's	0.53	0.05	0.13	0.44	0.10	0.14	0.33	0.29	0.88	1851
Systems / Payloads Allocations:	**1.0**	**1.0**	**1.0**	**0.5**	**1.0**	**1.0**	**0.7**	**1.4**	**1.5**	**3000**
Estimated Worst MM Performance with Parameter Uncertainties and System / Payload Disturbances										
Including transient disturbances	na	na	na	2.71	1.60	0.60	2.94	2.59	2.41	8475
Excluding transient disturbances	1.68	-11.99	-2.24	2.42	1.26	0.46	1.52	0.84	1.27	na
MM Performance Allocations:	**14.5**	**-19.5**	**14.5**	**2.5**	**2.5**	**2.5**	**2.0**	**2.0**	**2.0**	**10000**

Momentum Manager Performance Budget with ***Expected*** *AMS dipole moment* ***along ISS Y-axis*** *(27,200 amp-m^2)*

Requirements Compliance Summary

- For AMS dipole = 136,000 amp-m^2 parallel with ISS Y-axis
  - MM exceeds "Roll Attitude Variation / Orbit" requirement
  - MM exceeds "Roll Attitude Rate" requirement
- For AMS dipole = 136,000 amp-m^2 parallel with ISS X-axis
  - AMS exceeds "Limit CMG Momentum" requirement (SSCN 2664)
  - MM exceeds "1-fault tolerant CMG momentum" requirement
  - MM exceeds "Roll Attitude Variation / Orbit" requirement
- All MM requirements are met if magnetic dipole moment is less than
  - 100,000 amp-m^2 if parallel to ISS X-axis
  - 40,000 amp-m^2 if parallel to ISS Y-axis
  - 190,000 amp-m^2 if parallel to ISS Z-axis

MM / AMS Interaction Summary

- AMS dipole aligned along ISS X-axis
  - Large pitch magnetic torque in-phase with large pitch aero torque
    - ✓ Produces high CMG momentum usage
      - Requires "momentum emphasis" MM controller design
    - ✓ Pitch axis has **least** CMG momentum margin for disturbances
- AMS dipole aligned along ISS Y-axis
  - Large roll magnetic torque out-of-phase with roll gravity-gradient torque and small roll aero torque
    - ✓ Produces large roll attitude variations / rates
    - ✓ Roll axis has **least** attitude rate margin for disturbances
- AMS dipole aligned along ISS Z-axis
  - Medium pitch magnetic torque out-of-phase with large pitch aero torque

Recommendations

- AMS and other magnetic systems/payloads should have magnetic dipole moments less than:
  - 100,000 amp-m^2 if parallel to ISS X-axis
  - 40,000 amp-m^2 if parallel to ISS Y-axis
  - 190,000 amp-m^2 if parallel to ISS Z-axis
- Incorporate above in appropriate AMS requirements document(s)
- Re-assess AMS/MM requirements compliance when actual magnetic dipole moment is known

PAYLOAD FLIGHT HAZARD REPORT				a. NO:	AMS-02-F07
b. PAYLOAD	Alpha Magnetic Spectrometer-02 (AMS-02)			c. PHASE:	III
d. SUBSYSTEM:	Electrical, Radiation	e. HAZARD GROUP:	Radiation, Injury/Illness	f. DATE:	January 21, 2011
g. HAZARD TITLE:	Excessive Field Strengths: EMI, Magnetic (DC Field)			i. HAZARD CATEGORY:	CATASTROPHIC **X** CRITICAL
h. APPLICABLE SAFETY REQUIREMENTS:	NSTS 1700.7B and ISS Addendum, paragraphs 200.2, 212.2				
j. DESCRIPTION OF HAZARD:	The AMS-02 generates energy fields by way of RF and magnetic fields that may have a hazardous effect on Orbiter Systems, ISS systems and equipment (SSRMS, SPDM), Extravehicular Mobility Unit (EMU), Russian Orlan Suit, Simplified Aid for EVA Rescue (SAFER), EVA tools (including the Pistol Grip Tool) and other safety critical subsystems.				

k. CAUSES

(list)

1. AMS-02 Generates an Excessive Magnetic Field Strength
2. AMS-02 Radiates an Excessive Electromagnetic Radiation (RF) Field Strength
3. AMS-02 Changing Magnetic Fields induces currents in proximity systems <Deleted>

o. APPROVAL	PAYLOAD ORGANIZATION	SSP/ISS
PHASE I		
PHASE II		
PHASE III		

PAYLOAD FLIGHT HAZARD REPORT		a. NO: AMS-02-F07
b. PAYLOAD Alpha Magnetic Spectrometer-02 (AMS-02)		c. PHASE: III
l. HAZARD CONTROL (CONTROL), m. SAFETY VERIFICATION METHODS (SVM), n. STATUS OF VERIFICATIONS (STATUS)		OPS CONTROL
1. CAUSE: AMS-02 Generates an Excessive Magnetic Field Strength		
1.1 CONTROL: The AMS-02 Permanent Magnet has been designed using stacked neodymium-iron-boron (Nd-Fe-B) magnets to create a consistent magnetic field within the bore of the magnet and minimize the exterior field. This is accomplished by stacking approximately 1 inch x 2 inch x 2 inch individual magnets, each uniquely magnetized along a specific field orientation. The magnetic field within the core of the magnet should reach a maximum of ~1200 Gauss while the exterior field should drop off to approximately 3 Gauss at 2.6 meters from the magnet's centerline. 1.1.1 SVM: The magnetic field of the AMS-02 Magnet will be measured and compared to analytic model. 1.1.1 STATUS: .Closed. ESCG Memorandum ESCG-4295-10-ADV SY-MEMO-0013, "AMS Permanent Magnet Magnetic Field Correlation," dated July 6, 2010		
1.2 CONTROL: The AMS-02 magnetic field profile does not exceed the maximum safe exposure limits for ISS subsystems located within the proximity of the AMS-02. TIAs0310/1133, attached to this hazard report, provides a list of ISS subsystems and the field strength they will likely experience. 1.2.1 SVM: An analysis of the final, measured field strength. 1.2.2 SVM: EME Panel Acceptance of TIA of magnetic field strength on ISS Systems. 1.2.1 STATUS: Closed. ESCG Memorandum ESCG-4295-10-ADV SY-MEMO-0013, "AMS Permanent Magnet Magnetic Field Correlation," dated July 6, 2010 1.2.2 STATUS: Closed TIA 0310 (Cryomagnet) Approved 10/24/2001, TIA 1133 (Permanent Magnet) Approved May 14, 2010.		
1.3 CONTROL: The AMS-02 Permanent Magnet will not generate sufficient magnetic field strength to threaten robotic operations for any planned or contingency EVR associated with the AMS-02 or that may be conducted in the proximity of the AMS-02 whether on the Orbiter or ISS. The magnetic field of the AMS-02 will be diminished to below the 10 Gauss limit of the robotic equipment inside of the radius where the grapple fixtures are mounted. 1.3.1 SVM: The magnetic field of the AMS-02 Magnet will be measured and compared to analytic model. 1.3.2 SVM: Magnetic fields intensities will be coordinated with robotic (SRMS, SSRMS) control authorities. 1.3.1 STATUS: Closed. ESCG Memorandum ESCG-4295-10-ADV SY-MEMO-0013, "AMS Permanent Magnet		I

PAYLOAD FLIGHT HAZARD REPORT	a. NO: AMS-02-F07
b. PAYLOAD Alpha Magnetic Spectrometer-02 (AMS-02)	c. PHASE: III

Magnetic Field Correlation,” dated July 6, 2010

1.3.2 STATUS: Closed. SEWG Minutes July 6, 2010, document the acceptance of the AMS-02 10 Gauss Field’s lack of intrusion to EVR worksites or operational volumes as not requiring any special notification of keep out zones.

1.4 CONTROL: The AMS-02 Permanent Magnet will not generate sufficient magnetic field strength to threaten Orbiter operations for any planned or contingency Operation associated with the AMS-02 mission. The magnetic field of the AMS-02 will be diminished to below the 3 Gauss at a radius of 2.6 meters.

1.4.1 SVM: The magnetic field of the AMS-02 Magnet will be measured and compared to analytic model.

1.4.2 SVM: Magnetic fields intensities will be coordinated with Shuttle Program Office.

1.4.1 STATUS: Closed. ESCG Memorandum ESCG-4295-10-ADV SY-MEMO-0013, “AMS Permanent Magnet Magnetic Field Correlation,” dated July 6, 2010

1.4.2 STATUS: Closed. CR/DIR No. A05889, "DC Magnetic Field Non-Compliance," for the AMS-02 was withdrawn/declined as further investigation showed there was no non-compliance. Withdrawn/Decline Disposition 10-19-2010

1.5 CONTROL: <Deleted. Cryomagnet Removed from the AMS-02>

1.6 CONTROL: (EVA Access) The AMS-02 Permanent Magnet will not generate sufficient magnetic field strength to threaten EVA equipment or personnel for any planned or contingency EVAs associated with the AMS-02 or that may be conducted in the proximity of the AMS-02 whether on the Orbiter or ISS.

1.6.1 SVM: <Deleted>

1.6.2 SVM: Magnetic field mapping of flight AMS-02.

1.6.3 SVM: Magnetic field compatibility testing/assessment for EMU, SAFER, PGT and EVA equipment.

1.6.4 SVM: Confirmation of Operational limits of Orlan suit, compatible with magnetic fields 175 gauss or less.

1.6.5 SVM: <Deleted>

1.6.6 SVM: <Deleted>

1.6.7 SVM: <Deleted>

1.6.8 SVM: <Deleted>

PAYLOAD FLIGHT HAZARD REPORT	a. NO: AMS-02-F07
b. PAYLOAD Alpha Magnetic Spectrometer-02 (AMS-02)	c. PHASE: III

1.6.9 SVM: <Deleted> 1.6.1 STATUS: <Deleted> 1.6.2 STATUS: Closed. ESCG Memorandum ESCG-4295-10-ADV SY-MEMO-0013, “AMS Permanent Magnet Magnetic Field Correlation,” dated July 6, 2010 1.6.3 STATUS: Closed. “Extravehicular Mobility Unit (EMU) with 12 Volt Accessories and Tools Magnetic Certification Test Report for the International Space Station/Orbiter Environments”, EMU 1 – 13-054, Contract NAS 9-97150, including Field Engineering Memo, FEM-0032 dated 8/4/2000. 1.6.4 STATUS: Closed. Analysis confirmed by JSC-XA/C. J. Fulcher that Orlan Suit qualified for 175 gauss as documented in Hamilton Sundstrand Engineering Memo (EMUM1-0730), March, 2002. Also Zvezda Test Report (EVA-SS-HS-055ZV), Sept. 2001 "On Assessment of the Effect of a Static Magnetic Field on the Orlan-M spacesuit and SAFER as applied to ISS". Original reports not in AMS-02 File, Fulcher Memo present. 1.6.5 STATUS: <Deleted> 1.6.6 STATUS: <Deleted> 1.6.7 STATUS: <deleted> 1.6.8 STATUS: <Deleted> 1.6.9 STATUS: <Deleted>	
1.7 CONTROL: <Deleted. Cryomagnet Removed from the AMS-02>	I
1.8 CONTROL: <Deleted. Cryomagnet Removed from the AMS-02>	
1.9 CONTROL: <Deleted. Cryomagnet Removed from the AMS-02>	
1.10 CONTROL: The AMS-02 Magnetic Field is sufficiently diminished so as to not interfere with any visiting vehicles to the ISS. Analysis indicates that at a distance of 20 meters (less than the closest docking distance to the S3 Upper Inboard CAS location by approximately 3 meters) the magnetic field for the Cryomagnet, six times stronger than the permanent magnet, was be on the order of 324 nano Tesla. Earth’s magnetic field varies from 30 to 60 micro Tesla at the surface. The AMS-02 magnetic field effect will be approximately two magnitudes less than the Earth’s field’s influence upon any visiting vehicle. 1.10.1 SVM: Magnetic Field Analysis based on ViPER distance analysis with visiting vehicle.	

PAYLOAD FLIGHT HAZARD REPORT	a. NO: AMS-02-F07
b. PAYLOAD Alpha Magnetic Spectrometer-02 (AMS-02)	c. PHASE: III

1.10.1 STATUS: Closed. ESCG Memo ESCG-4390-07-SP-MEMO-0008, “Risk to Visiting Vehicles from the AMS-02 Magnetic Field, 15 August 2007. Analysis based on Cryomagnet Field Intensity, encompassing the permanent magnet potential conservatively.

1.11 CONTROL: The AMS-02 will generate a field in excess of the 10 Gauss field that is the established limit for the ISS robotics system. This zone of magnetic field exceedence for the ISS robotics has been mapped and compared to possible ISS robotics operations. No planned or conceived of robotic activities would require any robotic elements to approach to contact proximity to AMS-02 systems where the 10 Gauss field exists. The AMS-02 does not have any grapple fixtures or EVR interaction points within the 10 Gauss field.

1.11.1 SVM: MAGIK Analysis to show that robotic operations are outside the AMS-02 10 Gauss field.

1.11.1 STATUS: Closed. MAGIK Analysis Action Item 2496, “AMS Magnetic Field Impacts to EVR Access,” October 6, 2010

2. CAUSE: AMS-02 Radiates an Excessive Electromagnetic Radiation (RF) Field Strength

2.1 CONTROL: AMS-02 has been designed such that conducted and emitted electromagnetic fields remain within the allowable levels for the Shuttle and the ISS.

2.1.1 SVM: The AMS-02 will be tested as a unit for excessive RF energy.

2.1.2 SVM: Acceptance of EMI Testing Results by NASA EMEP.

2.1.1 STATUS: Closed. ETS-REP-EMC-3308-Issue 1, “AMS02-FM EMC Test Facility Data Report,” dated March 30, 2010.

2.1.2 STATUS: Closed to SVTL.

3. CAUSE: AMS-02 Changing Magnetic Fields induces currents in proximity systems <Deleted>

3.1 CONTROL: <Deleted. Cryomagnet Removed from the AMS-02>

3.2 CONTROL: <Deleted. Cryomagnet Removed from the AMS-02>

3.3 CONTROL: <Deleted. Cryomagnet Removed from the AMS-02>

3.4 CONTROL: <Deleted. Cryomagnet Removed from the AMS-02>

NOTES:

PAYLOAD FLIGHT HAZARD REPORT		a. NO:	AMS-02-F07
b. PAYLOAD	Alpha Magnetic Spectrometer-02 (AMS-02)	c. PHASE:	III
1 Tesla = 10,000 gauss			

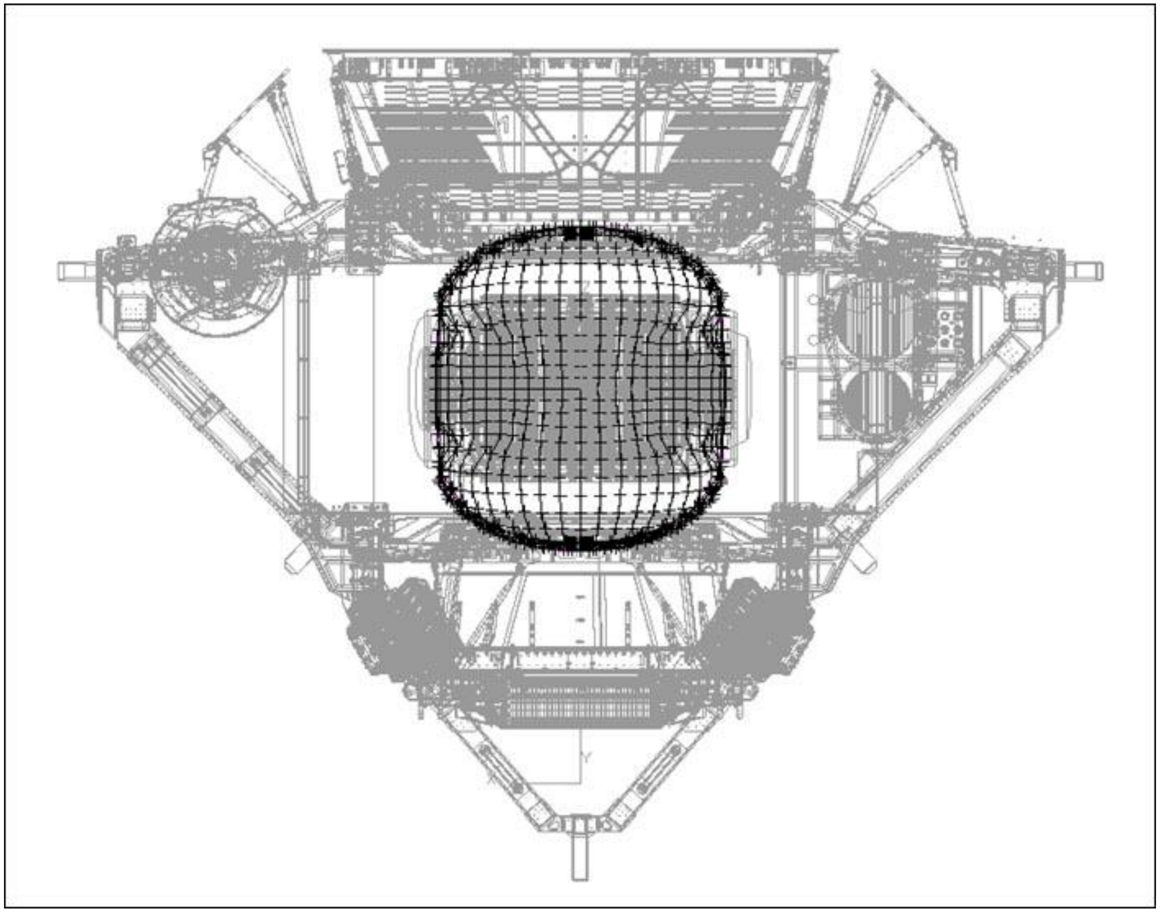
ACRONYMS	
°C – degrees Centigrade (Celsius)	MHz – Mega HertzDC – Direct Current
A – Ampere	MLI – Multilayer insulation
amp-m^2 – Amperes per square meter	MM – (CMG) Momentum Manager
AMS-02 – Alpha Magnetic Spectrometer - 02	mm – millimeter
APCU – Auxillary Power Control Unit	mT – milli Tesla
CAB – Cryomagnet Avionics Box	MT – Mobile Transporter
CCS – Cryomagnet Current Supply	mV – milli Volts
CMG – Control Moment Gyroscope	mWb – milli Weber
CO_2 – Carbon Dioxide	PAS – Payload Attach Site (ISS Side of interface)
CPU – Central Processing Unit	PGT – Pistol Grip Tool
DC – Direct Current	psi – Pounds per square inch
EMC – Electromagnetic Compatibility	RF – Radiofrequency
EMI – Electromagnetic Interference	SAFER – Simplified Aid for EVA Rescue
EMU – Extravehicular Mobility Unit	SFHe – Superfluid Helium
EVA – Extravehicular Activity	SPDM – Special Purpose Dexterous Manipulator
FPGA – Field Programmable Gate Array	SRMS – Shuttle Remote Manipulator Mechanism
GHz – Giga Hertz	SSRMS – Space Station Remote Manipulator Mechanism
GSE – Ground Support Equipment	STP – Standard Temperature and Pressure
He – Helium	SVM – Safety Verification Method
HW, H/W – Hardware	SW, S/W – Software
Hz – Hertz	TRD – Transition Radiation Detector

ACRONYMS	
Imax – I (current) maximum	TTCS – Tracker Thermal Control System
kHz – kilo Hertz	USS-02 – Unique Support Structure 02
MDP – Maximum Design PressureHe – Helium	Xe – Xenon

EMC Requirements Applicable to AMS-02

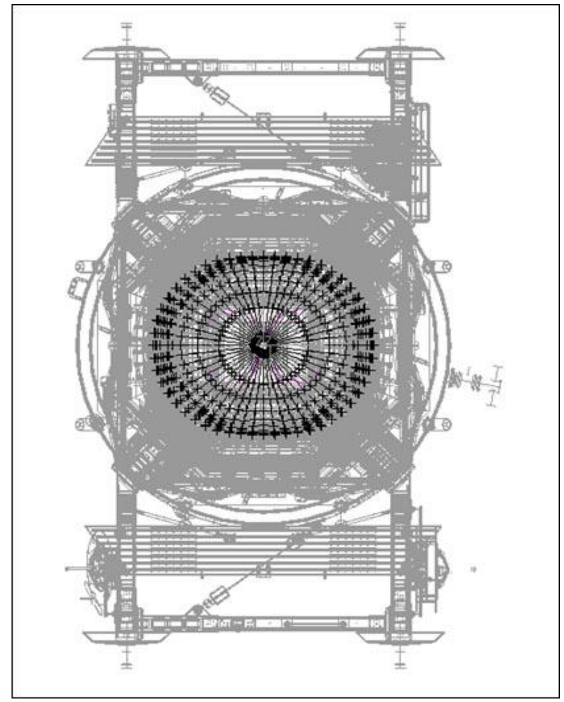
Type of Test/Requirement	Name of Test	Coverage	Applicability to AMS-02	Comments
Conducted Emissions	SSP 30237, Rev F CE01	DC power, lo freq, 30 Hz to 15 kHz.	**Required**	Tailored to +120 VDC bus
Conducted Emissions	SSP 30237, Rev F CE03	DC power, 15 kHz to 50 MHz.	**Required**	Tailored to +120 VDC bus
Conducted Emissions	SSP 30237, Rev F CE07	DC power leads, spikes, time domain.	**Required**	Tailored to +120 VDC bus
Conducted Susceptibility	SSP 30237, Rev F SSP 30237 SSCN 3282 D.2 CS01	DC power leads, 30 Hz to 50 kHz.	**Required**	Invoked by power quality requirements to demonstrate immunity to known ripple voltage and noise conditions on the +120 VDC bus
Conducted Susceptibility	SSP 30237, Rev F SSP 30237 SSCN 3282 D.2 CS02	DC power leads, 50 kHz to 50 MHz.	**Required**	Invoked by power quality requirements to demonstrate immunity to known ripple voltage and noise conditions on the +120 VDC bus
Conducted Susceptibility	SSP 30237, Rev F SSP 30237 SSCN 3282 D.2 CS06	Spikes, power leads.	**Required**	Invoked by Power Quality requirements to demonstrate immuntiy to switching transients on the +120 VDC bus
Radiated Emissions	SSP 30237, Rev F RE02	Electric field, 14 kHz to 10 GHz (narrowband), 13.5 -15.5 GHz.	**Required**	Establishes that equipment unintentional radiated emissions will not interfere with platform mounted sensitive antenna connected receivers; tailored to Space Station requirements
Radiated Susceptibility	SSP 30237, Rev F RS02	Magnetic induction field	Desired by EP4/JSC	Intended to determine immunity from interference inductively coupled from electrical power cables
Radiated Susceptibility	SSP 30237 SSCN 3282 PIRN 57003-NA-0023 RS03PL	Electric field, 14 kHz to 20 GHz.	Desired by EP4/JSC	Demonstrates immunity to known intentionally radiated electromagnetic environment external to Space Station. Use alternate RS level for noncritical attached payloads

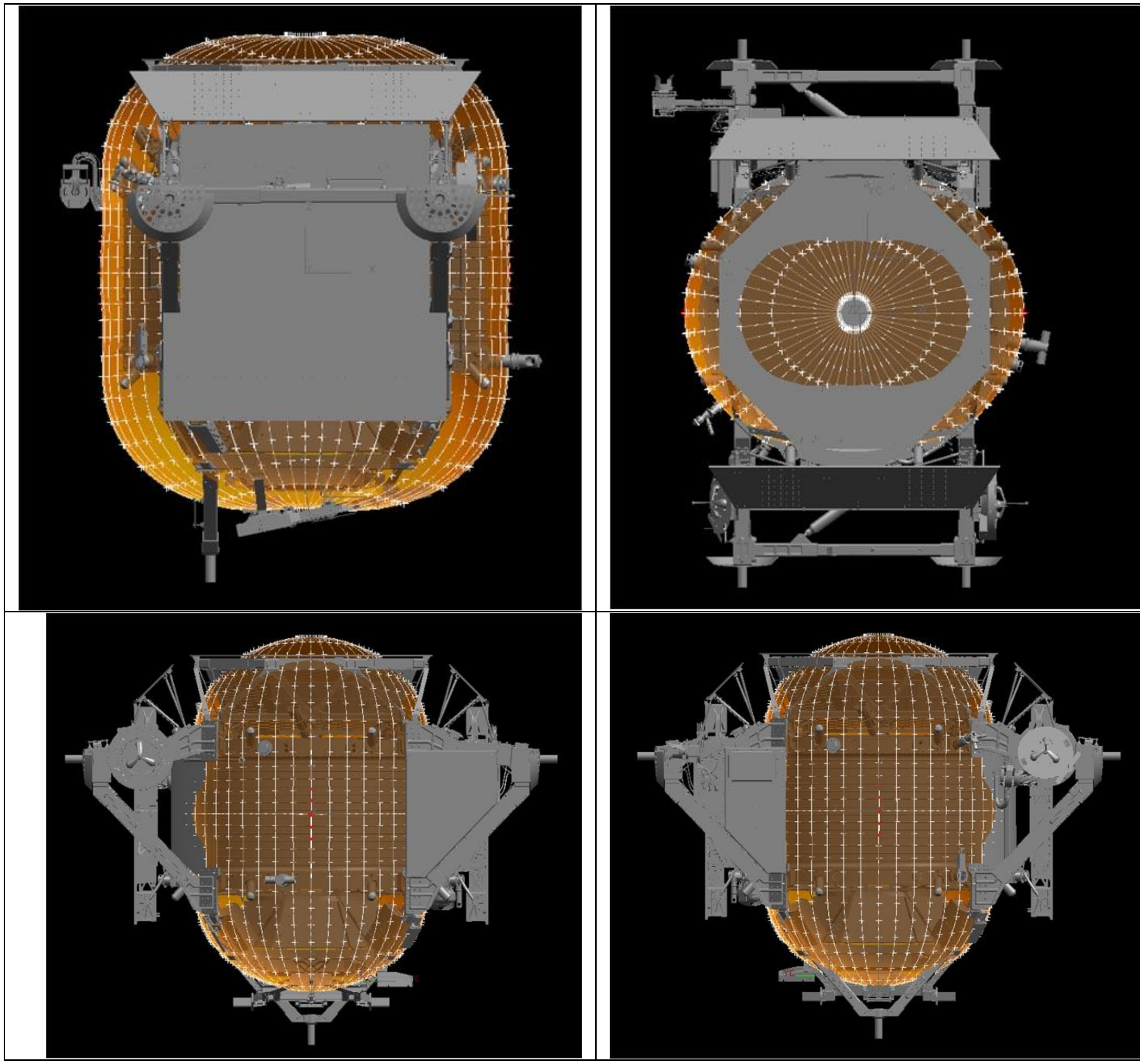
Desired tests will be accomplished.



AMS-02 Permanent Magnet Configuration
300 Gauss Field line,

Fully contained by AMS-02 Structures





AMS-02 with Permanent Magnet
10 Gauss Field Lines

Field lines all away from ISS robotics access points, grapple fixtures.

EBCS does not exceed the 15 Gauss limit that has been established by MDA for it.

AMS-02 Permanent Magnet Configuration Magnetic Dipole Moment (Values ±10%)

ISS Axis	AMS-02 Value	ISS Provided Allowables
X	0	100 kA/m^2
Y	11.3 kA/m^2	40 kA/m^2
Z	2.4 kA/m^2	190 kA/m^2

ISS Electromagnetic Effects Panel
Tailoring/Interpretation Agreement

SUBMITTAL DATE	AGREEMENT NO.	REV.	FLIGHT #(s)	
8/22/00	EMEP TIA # 0310	h	UF-4 + 3 years	**PAGE 1 of** 3

SYSTEM	ORIGINATOR and PHONE NO.	ORGANIZATION / CONTRACTOR
Superconducting Magnet	Jim Bates (281) 483-0657	Alpha Magnetic Spectrometer (AMS) Mission Manager/NASA/SF

END ITEM/CONFIG. ID NO.	PART NUMBER(s)	DESCRIPTION	ASSEMBLY(s)
NA	See RATIONALE below.		

SPECIFICATION NUMBER	SPEC. PARAGRAPH NO.	MANUFACTURER	CRITICALITY
SSP 30237	D.5	ETH, Zurich	

ISSUE DESCRIPTION: (use continuation pages if required)
The AMS magnetic field strength violates the following ISS requirement from SSP 30237:

D.5 Direct Current (DC) Magnetic Fields
The generated DC magnetic fields shall not exceed 170 dB above 1 picotesla (3.16 gauss) at a distance of 7 cm from the surface of the equipment. This applies to electromagnetic and permanent magnetic devices.

A similar requirement is stated in SSP 57003, Attached Payload Interface Requirements Document, para. 3.2.2.4.7.

The Alpha Magnetic Spectrometer (AMS) payload has a super-fluid helium superconducting magnet and will be attached to the S3 truss inboard zenith Payload Attach System (PAS) site. The AMS will launch on UF-4 and will remain on-orbit approximately 3 years. The magnetic field strength is approximately 8600 gauss at its centroid, however, diminishes rather quickly. The magnetic field is non-spherical (~ hour-glass shaped), and a detailed map has been delivered to OZ. The magnetic maximum field strength at the magnet's vacuum case outer surface is approximately 2000 gauss.

TAILORING /INTERPRETATION AGREEMENT: (use continuation pages if required)
The Alpha Magnetic Spectrometer (AMS) payload is allowed to exceed the SSP 30237, paragraph D.5 of 170 dB above 1 picotesla (3.16 gauss) at a distance of 7 cm from the surface of the equipment with a level as defined by the magnetic field map delivered to OZ in October, 1999. The magnetic maximum field strength at the magnet's vacuum case outer surface is approximately 2000 gauss. Although the Truss will be almost completed by the time AMS is launched, AMS will have to accept shutdown of operations in the event unevaluated Criticality 1 H/W is brought into the generated magnetic field. In the event that shutdown of the AMS is considered undesirable then AMS will have to fund the necessary work to qualify the equipment in question to operate in the generated environment.

RATIONALE: (use continuation pages if required)
Preliminary analysis data identifying ISS components in the vicinity of AMS that may be adversely affected by the AMS magnetic field have been provided. Susceptible ISS components in the vicinity of AMS include: 1F70141-1 (UMA), 1F70147-1 (CLA), 10033194-501 (External TV Camera), and A05A0298-1 (Video Luminaire Assy). In addition, the SSRMS and SPDM robotic systems, as well as the Russian orlon EVA suits should be evaluated for magnetic field susceptibility limits. (EMU, SAFER, PGT, and sub-assemblies performance were recently tested at NASA JSC for magnetic field susceptibility limits and test results are available for EME Board review.)

Magnetic susceptibility testing and/or analysis of the above components should be performed to validate their performance limits. (Continued)

AGREEMENT DISPOSITION

PRIME EME	NASA EME	DATE	APPROVE	WITHDRAW	REJECT
K. Rice	M. McCollum	10/24/01	Approved		

Concurrence Need Date:

COMMENTS: (use continuation pages if required)
9/5/00 Deferred for analysis of effects of Magnetic Field
1/9/01 Analysis to be completed by cob 1/12/01
1/23/01 Analysis delayed until 2/6/01
2/20/01 Deferred until 3/6/01 EMEP
3/6/01 Deferred until review of test results
10/24/01 Approved Out of Board

ISS Electromagnetic Effects Panel
Tailoring/Interpretation Agreement Continuation Page

SUBMITTAL DATE	AGREEMENT NO.	REV.	FLIGHT #(s)	
8/22/00	EMEP TIA # 0310	h	UF-4 + 3 years	PAGE 2 of 3

SYSTEM	ORIGINATOR and PHONE NO.	ORGANIZATION / CONTRACTOR
Superconducting Magnet	Jim Bates (281) 483-0657	Alpha Magnetic Spectrometer (AMS) Mission Manager/NASA/SF

Type in Heading of Each Continuation Paragraph **CANADIAN SPACE AGENCY TECHNICAL RESPONSE:**

Definition of MSS keep-out zone in relation to the AMS experimental payload.

The following defines a "keep-out zone" for all MSS mobile equipment (SSRMS, SPDM and MBS).

Should space-station operations require any part of the MSS hardware to enter the defined zone, then the AMS magnet shall first be powered down to avoid any possible adverse effects, and shall only be re-powered after the zone is vacated.

Using the S0 coordinate system of the ISS, and units of inches, the AMS is planned to be located as follows:

Upper Inboard Payload Attach System is at (-33.7, 854.3, -80.9)
The offset to the center of the magnet is (0 , -13.4, -71.9)
Location of magnet center is therefore at (-33.7, 840.9, -152.8)
(The AMS magnetic field is tilted 12 degrees towards inboard.)

In relation to the above defined magnet center, the "keep out zone" is defined as follows:

X-axis (ram-wake direction): plus or minus 152 inches
Y-axis (along the truss): plus or minus 170 inches
Z-axis (earth-space direction): plus or minus 121 inches

Supporting Rationale

Since the MSS design requirement included no magnetic design requirements or related test requirements, then in the absence of any detailed knowledge of the equipment's sensitivity in this regard, it has to be assumed that fields much stronger than the Earth's normal magnetic field might have an adverse effect. Common sense dictates that levels up to approximately ten times the Earth's normal field are of no concern, since these are relatively low levels. Thus the "keep out zone" is based on a 6G (six Gauss) magnetic field strength level.

Rationale: (Continued)
The issue regarding interference between the AMS magnetic field and the ETVCG video camera has been resolved via an operational work around. The resolution was presented to the Chief Engineer's Review out of board on October 11, 2001. The text of this message is included below: (A diagram of the camera locations is available in the TIA folder)

The issue "AMS magnetic field interference with truss mounted equipment" is scheduled for the CER tomorrow, 10/11/01. However, new information on this issue indicates that this problem has been solved operationally by MOD.

The truss mounted equipment of concern are the external cameras and Wireless Video System (WVS). A camera or WVS equipment located at the camera port nearest to AMS (Camera Port 2) would be subjected to an 80 Gauss DC magnetic field when AMS is operating. The current MOD plan for use of the external camera ports excludes use of Camera Port 2 due to proximity to AMS (see attached diagram). PICB action items 1111, 1112, and 1113 pertaining to the assessment of implementation and long term use plan for camera port utilization were closed on 9/27/01. Neldon Costin / D014 (originator of the diagram below) confirmed that this plan will be documented in the operations baseline for each flight and that Camera Port 2 is not planned to be used. The operations baseline will require approval of the program office and the flight director.

Camera Port 2 is the only camera port within the area exposed to 6 Gauss or greater from the AMS magnetic field. No camera or WVS External Transciever Assemblies (WETA) are planned to be placed in this port. Camera Port 1 is nearby on S3, however it outside the 6 Gauss area.

This issue appears to be resolved by operational plans.

ISS Electromagnetic Effects Panel
Tailoring/Interpretation Agreement

SUBMITTAL DATE	AGREEMENT NO.	REV.	FLIGHT #(s)	
8/22/00	EMEP TIA # 0310	h	UF-4 + 3 years	**PAGE 2 of** 3

SYSTEM	ORIGINATOR and PHONE NO.	ORGANIZATION / CONTRACTOR
Superconducting Magnet	Jim Bates (281) 483-0657	Alpha Magnetic Spectrometer (AMS) Mission Manager/NASA/SF

TECHNICAL CONCURRENCE PAGE*

MEMBERS

NAME	DATE	ORGANIZATION
________________________	__________	Space Station Hardware Integration Office, KSC
________________________	__________	Payloads Office, ISSP
________________________	__________	Engineering Directorate, JSC
________________________	__________	Safety and Mission Assurance/Program Risk Office, ISSP
________________________	__________	Independent Assessment Office, ISSP
________________________	__________	NASA Frequency Management Office
________________________	__________	Boeing –Houston
________________________	__________	Boeing Development Site (s)
________________________	__________	
________________________	__________	

AD HOC MEMBERS

________________________	__________	Space Shuttle Program
________________________	__________	Operations Office, ISSP
________________________	__________	Subsystem or Tech. Discipline Area Requirement Owner, NASA ISSP
________________________	__________	Subsystem or Tech. Discipline Area Requirement Owner, Boeing ISSP
________________________	__________	Manager, ISSP Element
________________________	__________	Launch Package/Stage Manager
________________________	__________	Mission Operations Directorate, JSC
________________________	__________	International Partner Representative(s)
________________________	__________	
________________________	__________	
________________________	__________	

ISS Electromagnetic Effects Panel
Tailoring/Interpretation Agreement

SUBMITTAL DATE	AGREEMENT NO.	REV.	FLIGHT #(s)	Page 1 of 3
14 May 2010	TIA # 1133	Orig.	ULF6	
SYSTEM	**ORIGINATOR and PHONE NO.**		**ORGANIZATION / CONTRACTOR**	
AMS-02 Magnet	Robert J. Armstrong/281-226-6132		Boeing/Houston EME	

END ITEM/CONFIG. ID NO.	PART NUMBER(s)	DESCRIPTION	ASSEMBLY(s)	GFE	Payload
Alpha Magnetic Spectrometer	AMS-02	AMS-02 DC Magnetic Field	All ISS Except Russian	No	Yes
SPECIFICATION NUMBER	**SPEC. PARAGRAPH NO.**	**MANUFACTURER**	**CRITICALITY**	**SEVERITY**	
SSP 30237	D5	ETH, Zurich	3	1	

ISSUE DESCRIPTION: (use continuation pages if required)

The Alpha Magnetic Spectrometer-02 (AMS-02) payload utilizes an on-board permanent magnet with a magnetic field strength of 1400 Gauss at the magnetic center that decreases to 10 Gauss at a distance of 61.5 inches from the magnetic center.

SSP 30237, paragraph D5 specifies a maximum magnetic field strength, for permanent magnetic devices, of 3.16 Gauss at a distance of 7 cm (2.76 inches) from the magnetic center.

TAILORING /INTERPRETATION AGREEMENT: (use continuation pages if required)

The Alpha Magnetic Spectrometer-02 (AMS-02) permanent magnet is allowed to meet the requirements of SSP 30237, paragraph D5 (DC Magnetic Fields) with a magnetic field strength of approximately 1400 Gauss at 7 cm (2.76 inches).

This TIA supersedes TIA # 0310, dated 22 August 2000, and approved 24 October 2001 in its entirety.

RATIONALE: (use continuation pages if required)

The AMS-02 permanent magnet's field strength at the magnetic center is 1400 Gauss. The field strength will not be significantly lessened at a distance of 7 cm (2.76 inches). Since the magnetic field strength follows an inverse cube relationship with distance in the far field approximation, the magnetic field strength decreases rapidly with distance. The closest distance from the magnetic center that the magnetic field strength was measured was 61.5 inches that resulted in a 10 Gauss magnetic field.

The AMS-02 will be permanently located on the S4 Truss with the magnet assembly center at ISS coordinates, in inches, of X-33.7, Y-840.9, and Z-152.8. Two ISS assemblies in the near vicinity of these coordinates are the ISS Mobile Transporter (IMT) at a distance of approximately 157 inches and the ExPRESS Logistics Carrier 2 (ELC2) at a distance of approximately 170 inches from magnetic center. The maximum magnetic field strength at the IMT was calculated to be 0.6 Gauss and 0.5 Gauss at the ELC2.

(Continued on page 2)

AGREEMENT DISPOSITION

PRIME EME	NASA EME	DATE	APPROVE	WITHDRAW	REJECT

COMMENTS:

ISS Electromagnetic Effects Panel
Tailoring/Interpretation Agreement Continuation Page

SUBMITTAL DATE	AGREEMENT NO.	REV.	FLIGHT #(s)	Page 2 of 3
14 May 2010	TIA # 1133	Orig.	ULF6	

SYSTEM	ORIGINATOR and PHONE NO.	ORGANIZATION / CONTRACTOR
AMS-02 Magnet	Robert J. Armstrong/281-226-6132	Boeing/Houston EME

Include Heading of Each Continuation Paragraph

RATIONALE: (continued)

The Houston Electromagnetic Effects (EME) Group evaluated the ELC2 equipment and the ISS Mobile Transporter. Both items are able to withstand a DC magnetic field greater than 35 Gauss. The Canadian Space Agency specified the maximum magnetic field strength exposure limit is 6.0 Gauss for the Space Station Robotic Manipulator System (SSRMS). Since the magnetic field strength is 10 Gauss at 61.5 inches and the nearest equipment is over 2.5 times more distant, the AMS-02 permanent magnet will not interfere with proper operation of ISS hardware.

This equipment may be turned off if interference occurs.

This is criticality 3 and severity 1 hardware. This TIA does not impose any operational constraints. This TIA is for all of the ISS except the Russian Segment. This TIA is similar to TIA # 0310.

ISS Electromagnetic Effects Panel
Tailoring/Interpretation Agreement
Technical Concurrence

SUBMITTAL DATE	AGREEMENT NO.	REV.	FLIGHT #(s)	Page 3 of 3
14 May 2010	TIA # 1133	Orig.	ULF6	

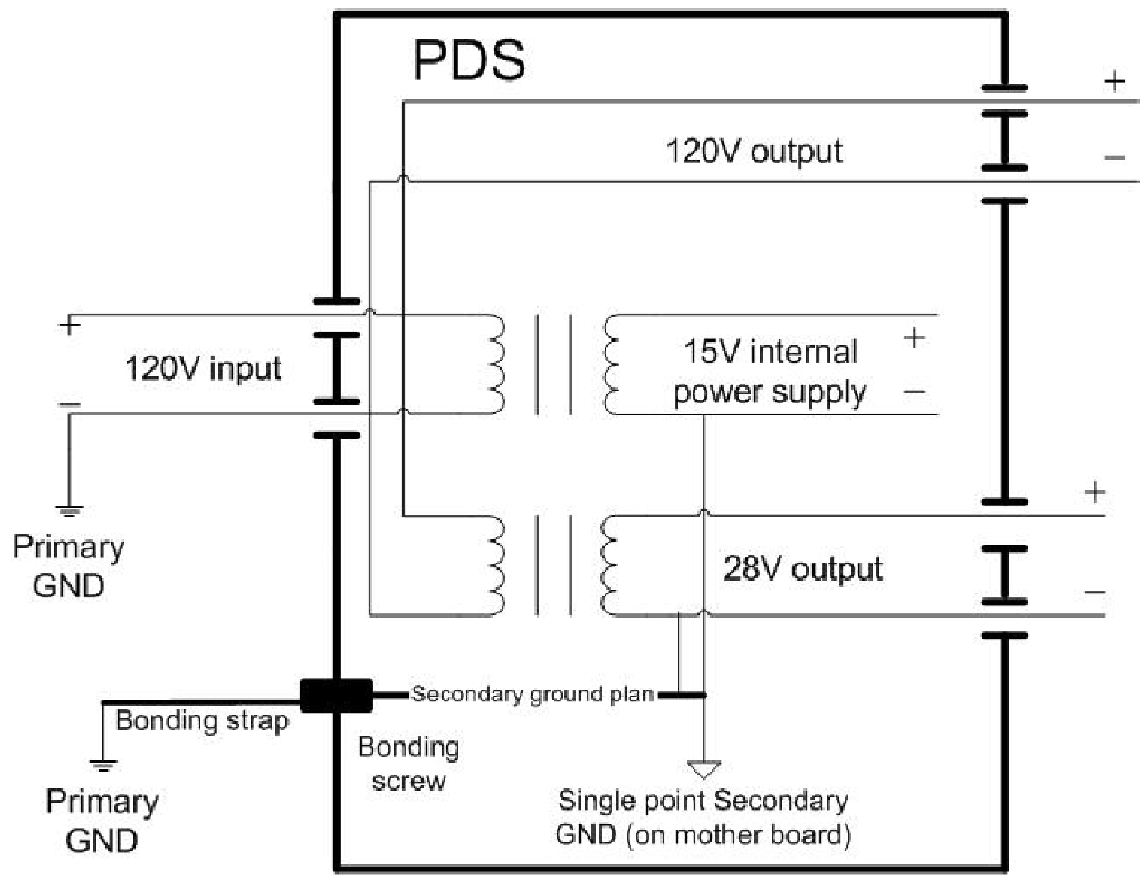
SYSTEM	ORIGINATOR and PHONE NO.	ORGANIZATION / CONTRACTOR
AMS-02 Magnet	Robert J. Armstrong/281-226-6132	Boeing/Houston EME

MEMBERS

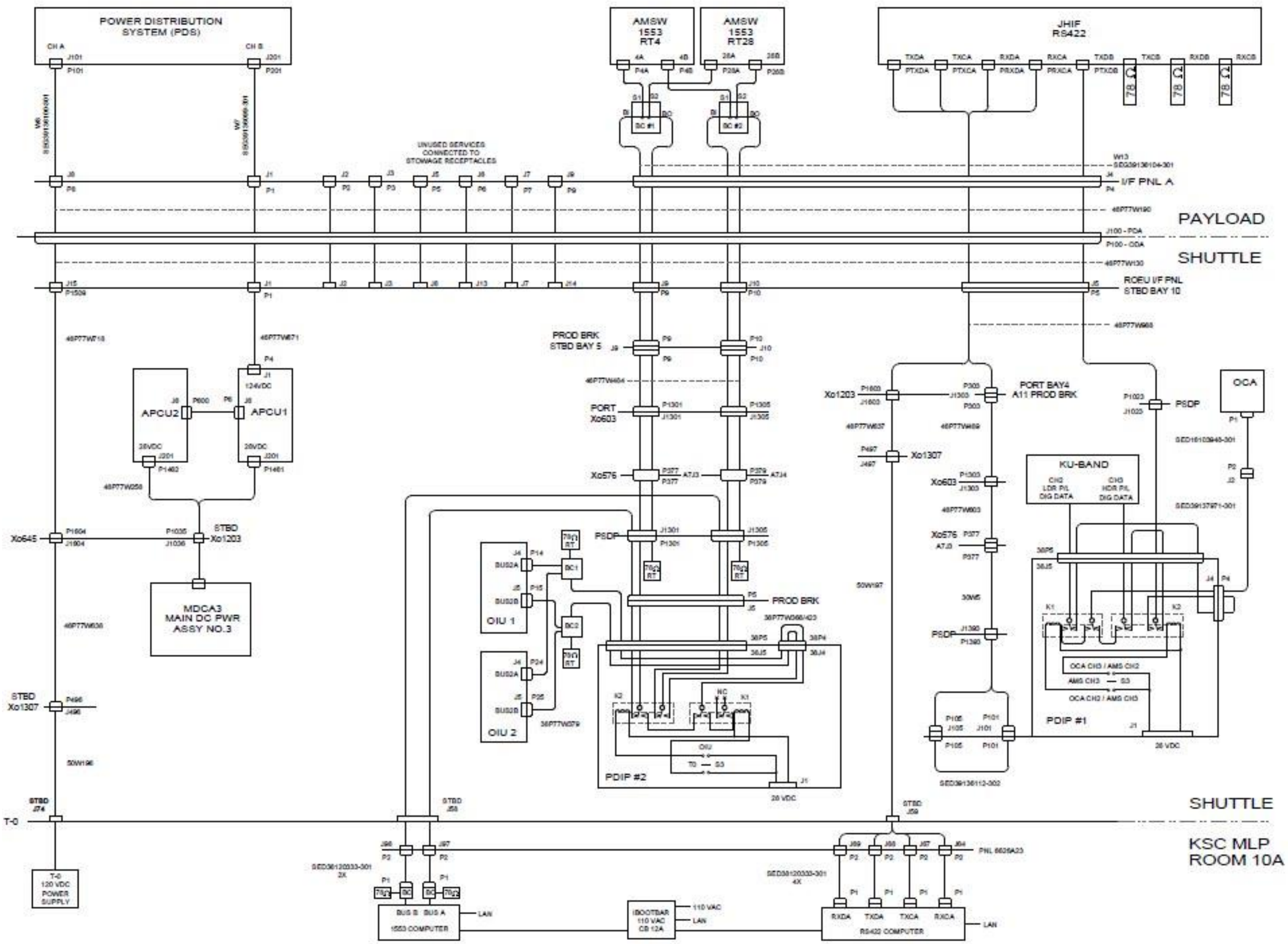
NAME	DATE	ORGANIZATION
		Space Station Office, KSC
		Payloads Office, ISSP
		Engineering Directorate, JSC
		Safety and Mission Assurance/Program Risk Office, ISSP
		NASA Frequency Management Office
		Boeing Development Site – Huntsville
		Electrical Power Systems

AD HOC MEMBERS

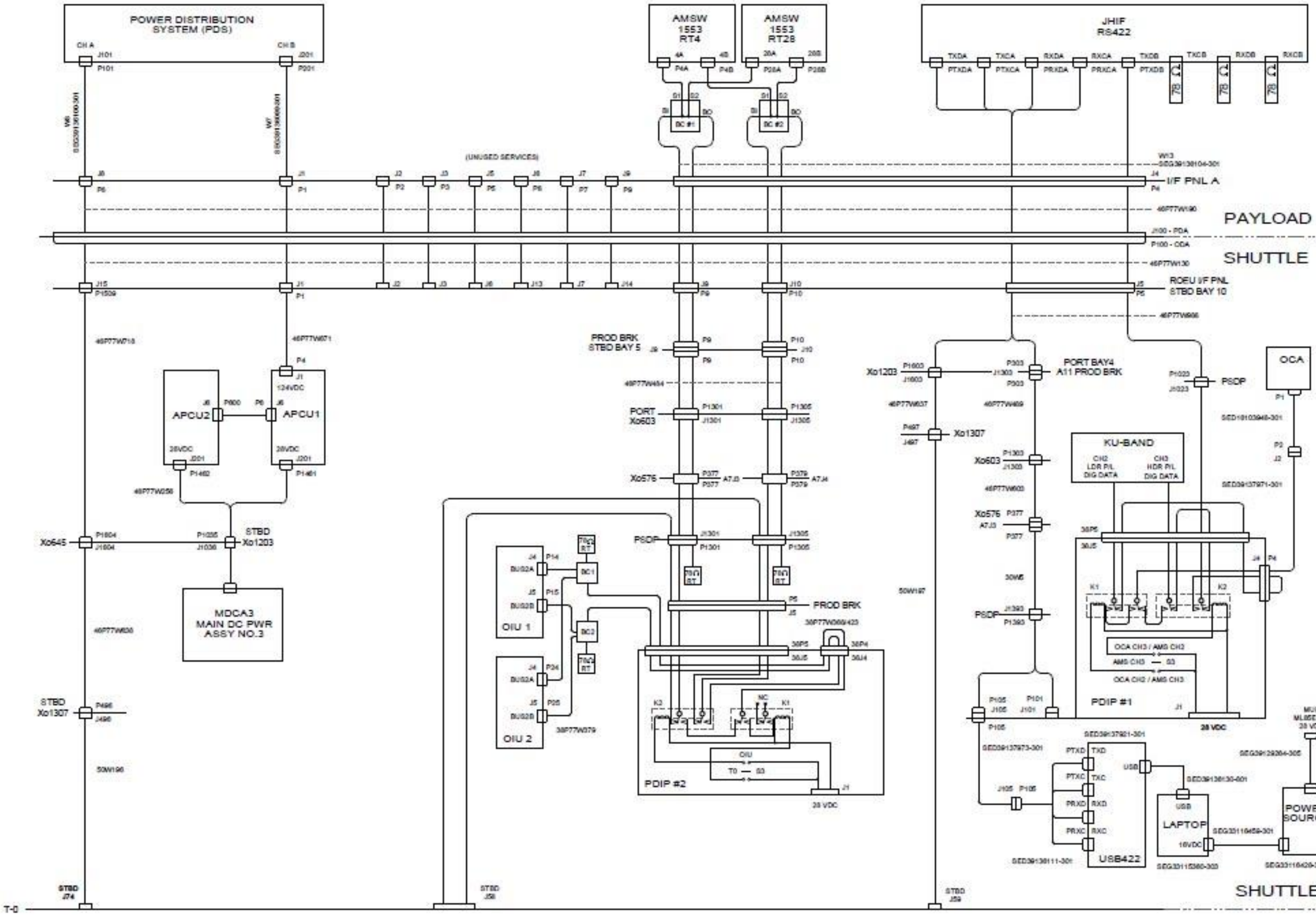
NAME	DATE	ORGANIZATION
		Space Shuttle Program
		Operations Office, ISSP
		Boeing – Houston
		Subsystem or Tech. Discipline Area Requirement Owner, NASA ISSP
		Subsystem or Tech. Discipline Area Requirement Owner, Boeing ISSP
		Manager, ISSP Element
		Launch Package/Stage Manager
		Mission Operations Directorate, JSC
		International Partner Representative(s)



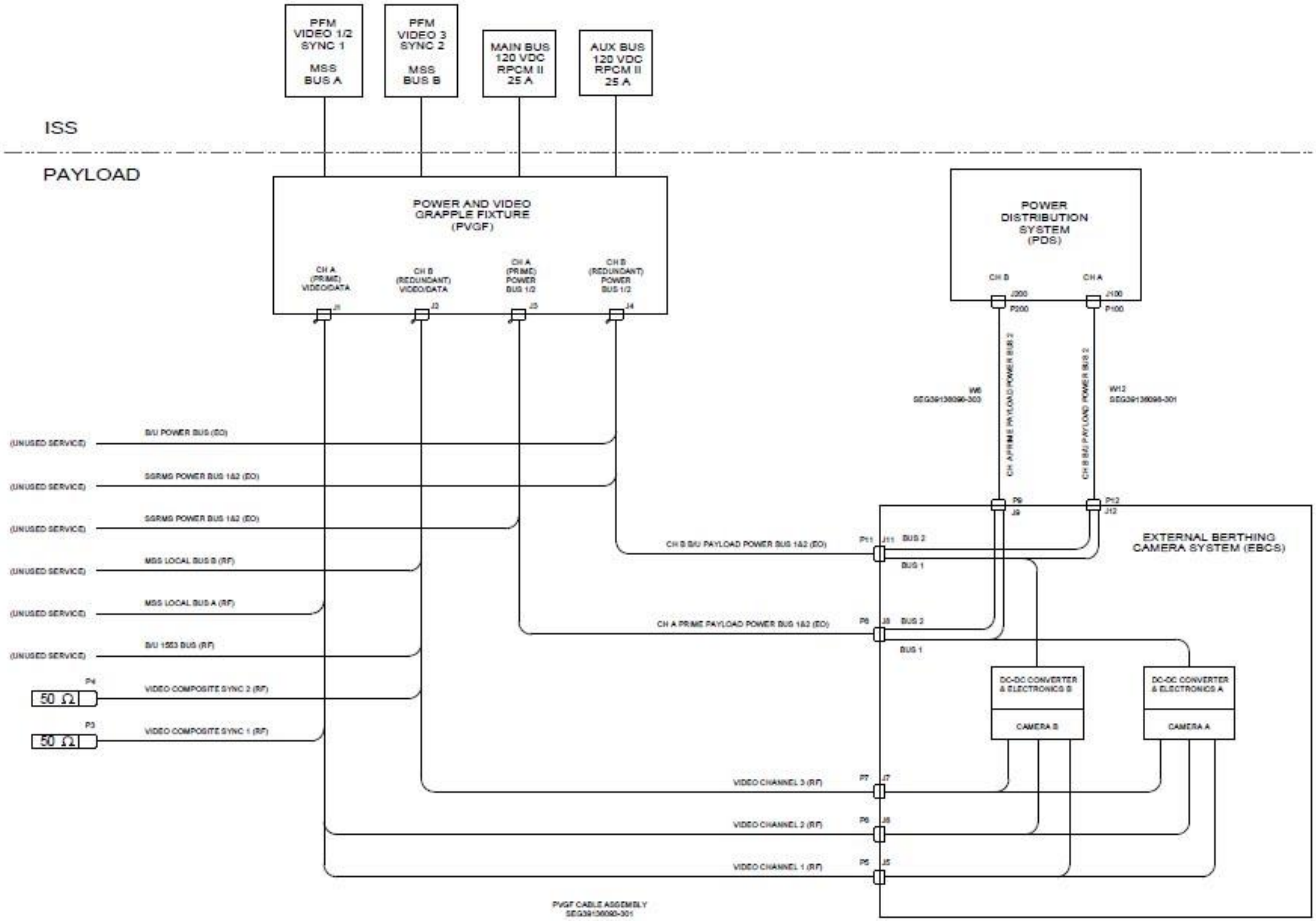
Principle Grounding Path for AMS-02 is through PDS system



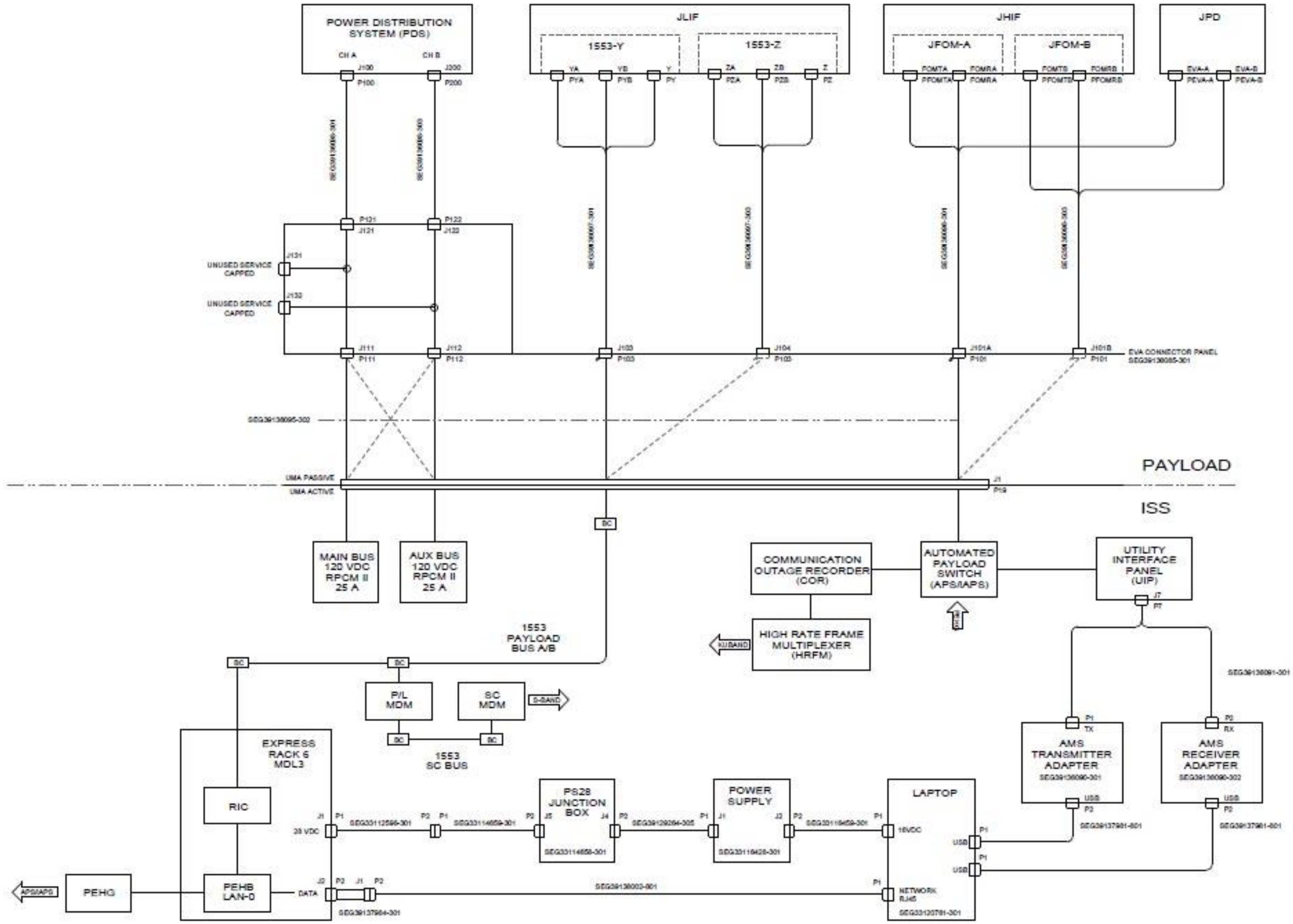
AMS-02 GROUNDING PATH WHILE ON THE PAD



AMS-02 GROUNDING PATH WHILE ON THE ORBITER DURING FLIGHT PHASE



AMS-02 GROUNDING PATH WHILE ON THE ISS SSRMS



AMS-02 GROUNDING INTERFACE WHILE INSTALLED ON ISS PAS LOCATION

**EXTRAVEHICULAR MOBILITY UNIT (EMU)
WITH 12 VOLT ACCESSORIES AND TOOLS
MAGNETIC
CERTIFICATION TEST REPORT
FOR THE
INTERNATIONAL SPACE STATION / ORBITER
ENVIRONMENTS**

DRL 13

CONTRACT: NAS 9-97150

Conclusion:
The Extra Vehicular Mobility Unit (EMU) with ISS 12 Volt Accessory equipment, Space Station EMU Radio (SSER), EMU SAFER, and Pistol Grip Tool (PGT) completed testing for Magnetic Environments for the International Space Station and Shuttle/Orbiter Missions. Tests were conducted in four parts at the NASA Lyndon B. Johnson Space Center Facilities, Sonny Carter Facility, Advanced Space Propulsion Lab, in June 2000, August 2000, and at the Hamilton Sundstrand Space Systems EMC Facility, December 2001 in accordance with JSC TPS; 1K0020064 (ED-0918), 130020078 (ED-0918), and TS0020124 (ED-0918), and ED-1012.

Recommendation:
Certification is recommended for operation of the Extra Vehicular Mobility Unit (EMU) with 12 Volt Accessory equipment (WVS, REBA, and ILCVR), Space Station EMU Radio (SSER),EMU SAFER, and Pistol Grip Tools (PGT) in the Magnetic environment with exposure up to a maximum of 300 Gauss and protection limits as specified herein.

The Magnetic environment defined for the International Space Station and Shuttle/Orbiter Missions may include static DC Magnetic sources including the Alpha Magnetic Spectrometer, AMS-02 with magnetic fields in excess of 2000 Gauss. Exposure to these levels of static magnetic field may be hazardous to both equipment and crew. The EMU EVA exposure to magnetic fields shall be limited, not to exceed 300 Gauss applied at the perimeter of the flight equipment for any axis of exposure. In addition, magnetic attraction may be a hazard. Therefore, protective barriers or specific tethering of the EVA crewmember and tools shall be implemented surrounding powerful magnetic sources to assure that the magnetic field exposure limits shall not be exceeded. An interface or environmental requirement for exposure levels to static DC magnetic field is not currently specified in the NASA documents governing ISS or Orbiter. A requirement to limit EVA exposure of the EMU with accessory equipment and tools is recommended for addition to NASA interface documents NSTS 07700 Volume X Book 2 and NSTS-21000-IDD-ISS.

Observations:
Tests were conducted in four phases to accommodate availability of GFE Power Grip Tools, PGT and EMU radio, SSER and separate test of SAFER. Later development of the EMU 12 Volt Glove Heater with Voltage regulator (ILCVR) was tested in December 2001. Final test results reported herein include results for each Phase Magnetic performance.

1. Maximum recommended EMU exposure limits are provided for both Shuttle and ISS mission use for both ORU and non-ORU configuration.

2. Maximum exposure limits include a 6 dB safety margin for EMU equipment as specified in NASA specifications SL-E-0001 and SSP 30243. EMU equipment, SSER, 12 Volt accessories, SAFER, and PGT were tested at 600 Gauss level.

3. Exposure limits provided are for EMU equipment operation. Human maximum safe exposure limits are provided in . *"Guidelines on Limits of Exposure to Static Magnetic Fields". Health Physics 66: 100-106 (1994), Source: International Commission on Non-Ionizing Radiation Protection*

Summary:

- Exposure limit is 2000 G
- Nausea, symptoms @ 4T
- Generates voltage in blood
- Circadian rhythm disruption @ 1/2 G
- Special medical considerations:
- Pacemaker users keep out >5 G
- Have users of other prostheses checked before entering areas where field >30 G
- Tool controls begin @ 30 G
- Use a tied-paper clip, or equivalent, survey to locate where tool hazards actually exist and post these areas

requirements or the test plan malfunction criteria when the spike as shown in Figure 11 is applied to the power leads.

3.3.2.2.5.2.7 Radiated Suspectibility, Magnetic Induction Fields

The equipment shall not exhibit any malfunction or degradation of performance beyond its specification requirments or the test plan malfunction criteria when subjected to the following fields:

a) Power Frequency Test - Twenty (20) amperes applied to test wire at 400 Hz.

b) Spike Test - The spike shape as shown in Figure 11 where E = 100 volts across 5 ohms shall be applied to the test wire.

The test method RS 02 of MIL-STD-462 shall be used.

3.3.2.2.5.2.8 Radiated Susceptibility, Electric Field

The radiated susceptibility shall meet the requirements of NSTS-07700-VOL-XIV Payload-to-EMU limit curve and NSTS-21000-IDD-ISS ISS to EVA curve in accordance with Figures 12a and 12b. Note: The radiated susceptibility requirements do not apply to temporary location sensitive EMU outages which include shifts in the SOP pressure sensor output voltage.

3.3.2.2.5.2.9 Magnetic Field Susceptibility

The EMU System shall operate without degradation or malfunction from nominal performance beyond its operational specification when exposed to magnetic fields and sources as follows:

Magnetic Field Strength of 63 Gauss.

The magnetic force is applied at the face of the electronic EMU equipment from a dc magnetic source and varied from 0 to 63 Gauss to a rate of up to 5 Hertz (this simulates the motion during EVA of the EMU moving past a fixed magnetic force of 63 Gauss.

Verification of this requirement is performed by test, using an applied magnetic field generated by an electromagnet of 63 Gauss as measured with a Gaussmeter. The electromagnet is placed on the face of each electronic EMU equipment and on each exposed side while the equipment is operated and performance is monitored for malfunction. The applied magnetic field is removed and replaced, at a rate up to 5 Hz, simulating a varying magnetic field as encountered during EVA movement past a fixed source.

3.3.2.2.5.3 Applicability of Requirements

The subsystem shall be designed and tested to meet all the requirements as stated in paragraph 3.3.2.2.5.2. Transducers such as thermistors and potentiometers which do not contain any active electronic componets shall be exempt from meeting paragraph 3.3.2.2.5.2. All other transducers

Replace Paragraph 3.3.2.2.5.2.9 with:

3.3.2.2.5.2.9 Static DC Magnetic Field Susceptibility

The EMU System shall operate without degradation or malfunction from nominal performance beyond its operational specification when exposed to static DC magnetic fields and sources with a field strength of up to 300 Gauss.

Verification of this requirement is performed by test. Testing shall be performed at levels up to 600 Gauss to assure an operational safety margin of 6dB above the certification level.

The magnetic field is applied at the external perimeter of the EMU flight equipment from a DC magnetic source. The EMU equipment is moved and rotated through the magnetic field to simulate EVA motion. Each orthogonal axis of the equipment shall be verified with the equipment slowly rotated and held in position in 45 degree increments of rotation while equipment operation is monitored to verify nominal performance.

to, including any single failure (e.g., shut-off valve leakage, regulator failure, etc.).

The Space Suit Assembly (SSA) of the EMU shall be designed to withstand a proof pressure equal to at least 1.5 times the normal operating pressure, and an unlimited pressure equal to at least 2.0 times the normal operating pressure. The normal operating pressure for the low pressure system is the maximum EVA operational pressure (reference 4.4 psid). The SSA shall be designed to withstand an ultimate pressure equal to at least 1.5 times the maximum pressure the system can be subjected to, including any single failure.

3.6.2.3 High Pressure Systems

High pressure systems (above 40 psi) of the EMU shall be designed to have the same factors of safety as the low pressure systems, except that metallic lines and fittings less than 1.5 inches in diameter shall be designed to withstand an ultimate pressure of 4.0 times the maximum operating pressure. Maximum operating pressure for high pressure systems is the maximum pressure the system can be subjected to, including any single failure (e.g., shut-off valve leakage, regulator failure, etc.). The proof and ultimate factors of safety of metallic lines and fittings less than 1.5 inches in diameter may be reduced to 1.5 and 2.0, respectively, if the rigor of design analysis and verification testing performed is equivalent to that applied to other critical systems/components. Also, the affected system/components shall be identified along with a brief description of the analysis and testing applied in order to justify adequacy and acceptability of the lower factor of safety.

3.6.2.4 Bends Treatment Operation

During bends treatment operation (reference 8.8 psig maximum operating suit pressure) the EMU shall be designed to withstand a proof pressure of at least 1.1 times the maximum operating pressure, and an ultimate pressure of at least 1.5 times the maximum operating pressure, including any single failure. SSA man-loads for this condition shall be based on an at rest, or relaxed, crew person.

3.6.3 Electrical Systems

All electrical systems of the EMU shall satisfy the requirements of MIL-STD-461A as amended by SL-E-0002B and SSP 30237, the procedures of MIL-STD-462, and the definitions of MIL-STD-463, with the following exception: The radiated susceptibility shall meet the requirements of NSTS-07700-VOL-XIV Payload-to-EMU limit and NSTS-21000-IDD-ISS in accordance with Figures 7a and 7b.

The EMU System shall operate without degradation or malfunction from nominal performance beyond its operational specification when exposed to magnetic fields and sources as follows:

a) Magnetic Field Strength of 63 Gauss.

The magnetic force is applied at the face of the electronic EMU equipment from a dc magnetic source and varied from 0 to 63 Gauss to a rate of up to 5 Hertz (this simulates the motion during EVA of the EMU moving past a fixed magnetic force of 63 Gauss).

Verification of this requirement is performed by test, using an applied magnetic field generated by an electromagnet of 63 Gauss as measured with a Gaussmeter. The electromagnet is placed on the face

Revise paragraph 3.6.3 with the following:

of each electronic EMU equipment and on each exposed side while the equipment is operated and performance is monitored for malfunction. The applied magnetic field is removed and replaced, at a rate up to 5 Hz, simulating a varying magnetic field as encountered during EVA movement past a fixed source.

Note: The radiated susceptibility requirements do not apply to temporary location sensitive EMU outages which include shifts in the SOP pressure sensor output voltage, EVC distortion, serial data dropout, and CPU reset.

All electrical systems of the EMU shall also satisfy the requirements of MIL-B-5087B and NHB5300.4 (3A-1) as supplemented by JSC-08800.

3.6.4 Mechanical Locks

All adjustments for calibration shall have adequate mechanical locks to prevent change in EMU or component performance.

3.6.5 Connectors

All electrical and mechanical connectors shall be keyed and/or color coded or alignment marked to preclude the possibility of incorrect connection. Connections shall be in accordance with SC-E-0006. Redundant interlocks (lock-locks) shall be incorporated as required to prevent loss of suit pressure. EMU connections that must be made and broken in flight must not exceed 30 pounds force, except for the engagement force of the Body Seal Closure (BSC) which shall not exceed 36 pounds force.

3.6.5.1 Protective Covers or Caps

Electrical plugs and receptacles of flight equipment and ground equipment that connects with flight equipment shall be protected at all times. The protective covers or caps shall be designed to:

1) Be resistant to abrasion, chipping, or flaking.
2) If permanently attached and used in flight, be of the same finish and material as the connectors to which they attach and be secured by lanyards.
3) If not used in flight, be brightly colored so as to easily disconcernable and command attention.
4) Be maintained at a level of cleanliness equivalent to the plugs or receptacles on which they are used.
5) Be made of material which is compatible with the connector material.

The HUT Multiple Water Connector shall be covered by a soft protective cap which, during flight, shall be capable of being removed and stowed.

3.6.5.2 Hot Connectors

Equipment shall be designed so that the "hot" Power supplying leads shall have protected terminals.

3.6.6 Soft Goods Attachment

In the attachment and mounting of hardware components to the basic pressure garment structure (i.e., neck ring, glove connectors, body seal closure, etc.) a mechanical attachment (i.e., flange/compression

3.6.3 Electrical Systems

All electrical systems..............
....................with Figure 7a and 7b.

The EMU shall operate in its EVA environment without degradation or malfunction from nominal performance beyond its operational specification when exposed to static DC magnetic fields or sources of up to 300 Gauss.

Verification of this requirement is performed by test. Testing shall be performed at levels up to 600 Gauss to assure an operational safety margin of 6dB above the certification level.

The magnetic field is applied at the external perimeter of the EMU flight equipment from a DC magnetic source. The EMU equipment is moved and rotated through the magnetic field to simulate EVA motion. Each orthogonal axis of the equipment shall be verified with the equipment slowly rotated and held in position in 45 degree increments of rotation while equipment operation is monitored to verify nominal performance.

Note: The radiated susceptibility.......................

..............as supplemented by JSC-08800.

FIELD ENGINEERING MEMO

TITLE:		REPORT NO. FEM-0032	PAGE 1 OF 5
PREPARED BY	**GROUP APPROVAL**	**REPORT DATE: 8/4/2000**	
Dennis Dawson, Edward Whitcomb		**DISTRIBUTION**	
Certification Test for Integrated EMU w/Flight Accessories/ AMS-02 Magnetic Exposure			DOCUMENT CENTER

Initiator: HSWL/ HSMS/ XA

Test Date: 5 June 2000, through 9 June 2000

Test Subject: None

Test Procedure: TPS 1K0020064 – Certification Procedure for EMU w/Flight Accessories / AMS-02 Magnetic Certification. Perform AMS-02 Magnetic Susceptibility / Threshold Evaluation per ED-0918, Evaluation of NASA Extravehicular Mobility Unit: EMU Electrical Components and Flight Accessories With SAFER For ISS Mission: Alpha Magnetic Spectrometer, AMS-02 Magnetic Field Exposure, CONTRACT: NAS 9-97150

Test Site: JSC Sonny Carter Facility, Advanced Space Propulsion Lab, ASPL

Background: The Alpha Magnetic Spectrometer, AMS-02 will be installed on the ISS S3 truss, at the upper inboard attached payload site. It emits a strong DC magnetic field developed by a liquid helium cooled superconducting magnet. Magnetic (B) field levels at the perimeter of the AMS-02 package may be as high as 2000 Gauss. EMU equipment is currently certified to a 63 Gauss level. AMS-02 Program requested XA support to extend EMU certification to allow EVA operations in proximity to the AMS Experiment in order to service an ISS Express Pallet installed adjacent to the AMS-02 Payload and to allow crew translation around the operational magnet. Powering the AMS-02 magnet down to reduce the Magnetic field will adversely affect the life of the experiment (limited cryogenic helium resource). The AMS-02 Program requested a new EMU certification to support an AMS-02 ISS Safety review. Tests performed for EMU and Accessory components provided susceptibility threshold data used to establish the 600 gauss level for the EMU system and Accessory tests.

Objective: The purpose of these tests is to evaluate EMU System level, Flight Accessory, SAFER and PG Tool equipment operation for exposure to magnetic (B) field exposure during EVA flight use. The results shall be used to certify the equipment performance at elevated levels of magnetic field above the current EMU certification level of 63 gauss. Results shall establish limits for EMU accessory equipment. Magnetic field levels will be defined for EMU System level exposure, Flight Accessory, SAFER and PGT Magnetic flight exposure. This EMU System level Magnetic Exposure test is conducted for development of Certification and Keep Out Zone limits for EVA in proximity to the ISS AMS-02 Spectrometer or other magnetic sources.

Summary: Magnetic exposure tests were conducted for the EMU and flight accessory equipment as it was operated to simulate EVA use. Tests included exposure to the DC magnetic field up to a level of 600 Gauss in each orthogonal axis for the equipment. Tests were performed for EMU and Accessory components and provided susceptibility threshold data used to establish the 600 gauss level for this test.

The equipment was suspended in front of the ASPL test magnet from the facility crane using straps and was moved through the magnetic field to simulate EVA motion as performance was monitored. Tests were performed for the EMU with helmet mounted ERCA, the PG Tool, and the SAFER. The EMU radio, SSER was not included in the tests due to a conflict and will be tested at a later date. An additional test, the measurement of the magnets effect (body force) on each flight item was also performed using a force gage as the measurement device. The EMU operates when exposed to the 600 Gauss level. Fan speed and current are elevated when the magnetic coupling to those EMU components is optimized. SAFER is not affected by the 600 Gauss exposure. The flight accessory ERCA and PG Tool do not operate during the 600 Gauss exposure as noted, however they are not permanently degraded, operation is restored when the magnetic field is reduced. These items are not critical to operate while exposed in the AMS-02 magnetic field. Results of the tests are summarized in the Table below.

Magnetic Exposure Summary Results:

EMU/ SAFER & Accessories:	Nomenclature Flight Item Tested	Part Number/ Type	Magnetic Test TPS No.	Test Date/ Susceptibility Indicators/ Thresholds
EMU	SEMU S/N 3015		1K0020064	6/8-6/9/00 EMU operates at 600 Gauss exposure, elevated fan/pump speed, current w/specific exposures, returns to nominal following exposure. Body Force (EMU vertical DCM) at exposure; 600 Gauss – 1lb12oz.; 300Gauss – 5 oz. (EMU vertical DCM) at exposure; 600 Gauss – 2lb 11oz.; 300Gauss – 1lb 1 oz
SSER	N/A	N/A	N/A	Radio test schedule TBD, Component tests show no degradation of magnetic components < 750 Gauss exposure.
12 Volt Accessories	**Nomenclature Flight Item Tested**	**Part Number/ Type**	**Magnetic Test TPS No.**	**Test Date/ Susceptibility Indicators/ Thresholds**
ERCA	EMU RF Camera Assembly	Cert. SED 33111710-301	330020196	6/8-6/9/00 Loss of control to switch lens >350 Gauss exposure, video nominal, survives 600 Gauss exposure, no operational degradation . Body Force at exposure; tested integral w/EMU
SAFER	SAFER	SED 33105900-305	TS0020124	6/8/00 non operational SAFER survives 600 gauss exposure, operates nominally after exposure. Body Force at exposure; 600 Gauss – 1lb10oz.; 300Gauss - no reading,<1lb
PG Tool	Engineering Model Pistol Grip Tool	EM/ PGT	PG Tool Procedure, SAI-PROC-861	6/5-6/7/00 Tool Motor does not operate with exposure >250 Gauss, Tool survives 600 Gauss exposure, no degradation. Body Force at exposure; 600 Gauss – 3lb5oz.; 300Gaussno reading,<1lb

Recommendations:

Plan and perform magnetic test of the SSER independently, using a battery simulator power source.
Determine F/P/S maximum current allowed and speed while subjected to a magnetic flux.
Calculate projected AMS-02 keep-out zones that will be recommended for ISS EVA procedures.
Prepare Certification Test Report(s) for EMU flight hardware. Present results to AMS-02 team.
Prepare EC to the EMU specification SVHS7800 to incorporate elevated magnetic exposure certification that reflects a safety margin of 6 decibels (dB).

Discussion:

Item SEMU: The SEMU was operated as a system with 12 Volt accessory helmet mounted EMU RF Camera Assembly (ERCA), the rechargeable EMU Battery REBA,, but without the Space to Space EMU Radio (SSER). The SSER was not available to support the system test and will be scheduled for a test at a later date. The SEMU operates when exposed in magnetic fields up to 600 gauss. It was noted at different orientations where the fan/pump/separator was closest to the magnet and ideally coupled that fan speed and current were effected by a noticeable change. The fan speed and current returned to normal operation when the field is exited or removed. Exposure of EMU flight systems requires that a safety margin of 6 decibels (dB) or half the level of susceptibility be allowed for flight exposure.

Body force on the EVA crew due to magnetic exposure/ attraction was measured and will be a significant factor when the result of all flight components are summed. A tether or guard around the magnets may be required to assure that EVA standoff distances are maintained.

Item ERCA, EMU RF Camera Assembly; This item includes a motor that switches lenses. The motor will not operate at levels above 350 Gauss. The video operation is not affected.. The operation is restored when the magnetic field is reduced. This item is not mission critical for EVA. The unit is not degraded when exposed in magnetic fields up to 600 Gauss.

Item SSER: The radio was not available for test and will be scheduled at a later date. Magnetic components within the SSER (circulator) was tested as a component. This item begins to increase in signal loss at levels above 750 Gauss. Operation of this item is restored when the field is reduced. The unit is not damaged by magnetic exposure up to 2000 Gauss.

Item PG Tool: Tool Motor does not operate with exposure >250 Gauss. Tool survives 600 Gauss exposure while not operating with no degradation. Body force from magnetic exposure of the PG Tool is significant.

Item SAFER: SAFER is non operational during translation past the magnet, but survives 600 gauss exposure and operates nominally after exposure.

IDR's/DR's Generated: Following the test, four (4) DR's were opened to document the test anomalies.

DR #	Description
1K0020052	SEMU S/N 3015 charged with Nitrogen.
1K0020053	SEMU S/N 3015 High fan current recorded.
1K0030054	SEMU S/N 3015 Fan RPM's fluctuating.
1K0030056	SEMU S/N 3015 experienced a 56.6 volt ground fault.
1K0030057	SEMU S/N 3015 exposed to 600 gauss disposition: close since the operation of the fan was verified after the test.

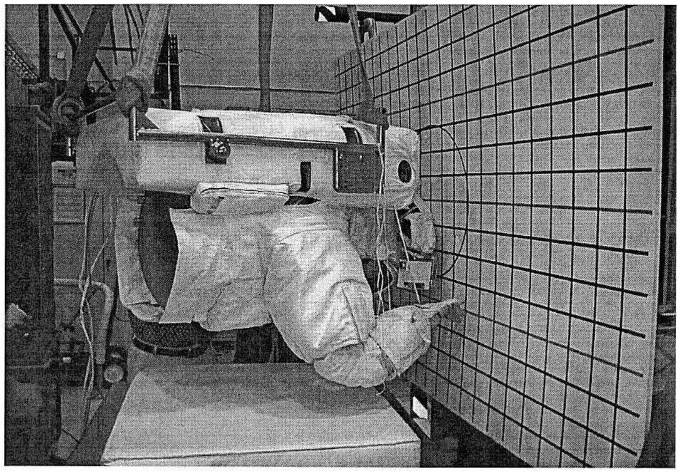


Figure 1 EMU w/ ERCA setup in Horizontal Mode at ASPL Magnet

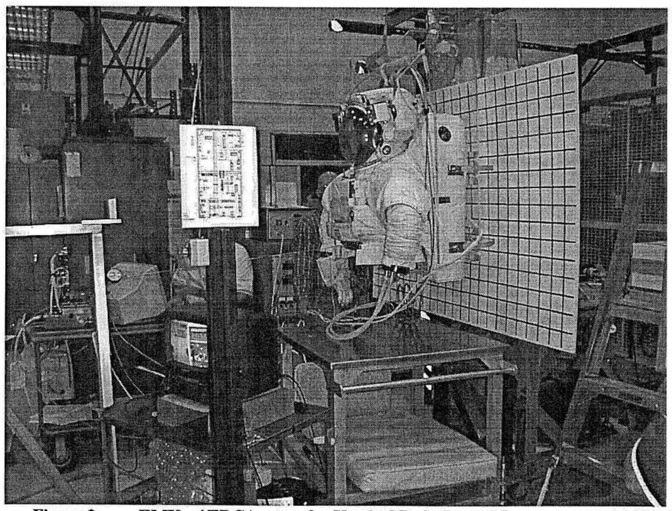


Figure 2 EMU w/ ERCA setup for Vertical Body Force Measurement at ASPL Magnet

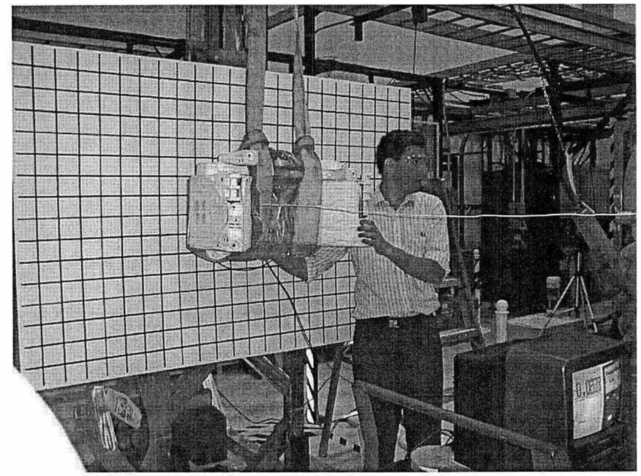


Figure 3 SAFER setup for Exposure at ASPL Magnet

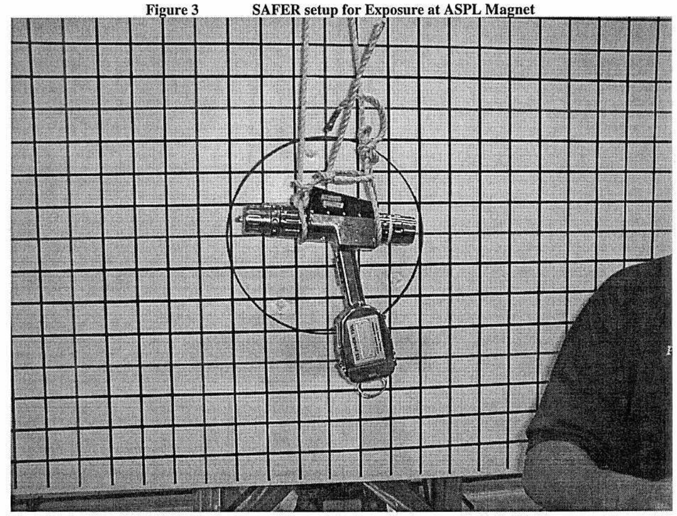


Figure 4 PG Tool setup at ASPL Magnet

PAYLOAD FLIGHT HAZARD REPORT				a. NO: AMS-02-F08
b. PAYLOAD	Alpha Magnetic Spectrometer-02 (AMS-02)			c. PHASE: III
d. SUBSYSTEM:	Electrical	e. HAZARD GROUP:	Electric Shock. Injury/Illness	f. DATE: August 4, 2010
g. HAZARD TITLE:	Electric Shock/Discharge			i. HAZARD CATEGORY: CATASTROPHIC **X** CRITICAL
h. APPLICABLE SAFETY REQUIREMENTS:	NSTS 1700.7B and ISS Addendum, paragraph 102.1, 200.1b			
j. DESCRIPTION OF HAZARD:	Incidental contact by an EVA crewmember with the high voltages and currents of the AMS-02 systems (TRD, TOF, ACC, Tracker, RICH, and ECAL could result in damage to the EMU/Orlan and/or physiological effects on the crewmember. Electrical Discharge of high voltage sources through a rarified atmosphere can damage EVA equipment, payload hardware, SSP and ISS systems and injure the EVA Crew. Table of HV Applications Attached			

k. CAUSES

(list)

1. Defective design, component, wire, insulation and/or workmanship
2. Exposed terminals, Connectors, energized conductive surfaces.
3. Coronal Discharge
4. Hazardous Alteration of ISS Plasma Environment

o. APPROVAL	PAYLOAD ORGANIZATION	SSP/ISS
PHASE I		
PHASE II		
PHASE III		

PAYLOAD FLIGHT HAZARD REPORT	a. NO: AMS-02-F08
b. PAYLOAD Alpha Magnetic Spectrometer-02 (AMS-02)	c. PHASE: III

l. HAZARD CONTROL (CONTROL), m. SAFETY VERIFICATION METHODS (SVM), n. STATUS OF VERIFICATIONS (STATUS)	OPS CONTROL
1. CAUSE: Defective design, component, wire, insulation and/or workmanship	
1.1 CONTROL: <Deleted> See AMS-02-F12	I, S
1.2 CONTROL: <Deleted. UPS Removed from AMS-02>	
1.3 CONTROL: Defective components, wires and insulation will be screened out by inspection of the individual components as they are received and installed. 1.3.1 SVM: Review of Design. 1.3.2 SVM: Inspection of as built hardware. 1.3.1 STATUS: Closed. ESCG Memorandum ESCG-4175-09-REENTES-MEMO-0029, “AMS-02 Component and Wire Inspection and Testing Summary,” dated June 4, 2009 1.3.2 STATUS: Closedto SVTL.	
1.4 CONTROL: HV insulation and potting will be selected to be compatible with the HV source voltages and for compatibility with the operating environment. 1.4.1 SVM: Review of Design. 1.4.2 SVM: Inspection of as built hardware. 1.4.1 STATUS: Closed. ESCG Memorandum ESCG-4175-REENTES-MEMO-0020, “Review of AMS-02 Hight Voltage Design,” dated April 24, 2009 1.4.2 STATUS: Closed to SVTL.	
2. CAUSE: Exposed terminals, connectors, energized conductive surfaces.	
2.1 CONTROL: All exposed connectors will either have automatic covers that preclude contact with energized circuits when demated (UMA, PVGF), or diodes and drain resistors will be used to prevent presence of power at unshielded connectors (ROEU-PDA). 2.1.1 SVM: Review of design. 2.1.2 SVM: Functional testing of covers.	

2.1.3 SVM: Testing of exposed connectors for proper diode blocking.

2.1.1 STATUS: Closed. ESCG Memorandum ESCG-4175-09-REENTES-MEMO-0005 "Electric Shock/Discharge", dated March 4, 2009

2.1.2 STATUS: Closed to SVTL.

2.1.3 STATUS: Closed to SVTL.

2.2 CONTROL: All AMS-02 electrical components will be grounded/bonded through the AMS-02 Unique Support Structure through nickel plated guide vanes and through the nominal power distribution system. These bonding paths to the Orbiter shall be in accordance with NSTS 21000-IDD-ISS, Rev A. Bonding paths to the ISS upon installation will be made through the Payload Attach System (PAS) per SSP 57003A.

2.2.1 SVM: Review of design.

2.2.2 SVM: Testing of integration grounding of AMS-02 Components to integration hardware.

2.2.3 SVM: Testing of Interface paths to the Shuttle and ISS (UMA & Nickel Plated Guide Vanes).

2.2.1 STATUS: Closed. ESCG Memorandum ESCG-4175-REENTES-MEMO-0020, "Review of AMS-02 High Voltage Design," dated April 24, 2009

2.2.2 STATUS: Closed to SVTL.

2.2.3 STATUS: Closed to SVTL.

2.3 CONTROL: All high voltage power supplies (>120VDC) will be located in fully potted avionics boxes that are properly bonded to the AMS-02 structure and grounding paths.

2.3.1 SVM: Review of Design.

2.3.2 SVM: Testing of enclosure's grounding path connectivity.

2.3.1 STATUS: Closed. ESCG Memorandum ESCG-4175-REENTES-MEMO-0020, "Review of AMS-02 High Voltage Design," dated April 24, 2009

2.3.2 STATUS: Closed to SVTL.

2.4 CONTROL: The TRD high voltage (1600VDC maximum) components implement high voltage insulation and potting to control high voltage exposure. HV power supply for the TRD is current limited to 100µA per HV channel. The TRD will be covered by a grounded MLI blanket enclosing the entire TRD octagon.

PAYLOAD FLIGHT HAZARD REPORT	a. NO: AMS-02-F08
b. PAYLOAD Alpha Magnetic Spectrometer-02 (AMS-02)	c. PHASE: III

2.4.1 SVM: Review of design for potting and insulation of high voltage sources. 2.4.2 SVM: Inspection of flight hardware to assure proper potting and insulation. 2.4.3 SVM: Review of Design for MLI grounding points to structure. 2.4.4 SVM: Testing of MLI grounding resistance. 2.4.1 STATUS: Closed. ESCG Memorandum ESCG-4175-REENTES-MEMO-0020, "Review of AMS-02 High Voltage Design," dated April 24, 2009 2.4.2 STATUS: Closed. Review of TRD ADP (Maintained in AMS-02 Project files) confirmed by email on July 16, 2010 from ESCG/J. C. Tutt 2.4.3 STATUS: Closed. ESCG Memo ESCG-4390-07-SP-MEMO-0018, "Grounding of the TRD MLI Blanket", dated November 12, 2007 2.4.4 STATUS: Closed to SVTL. ESCG Memo ESCG-4390-07-SP-MEMO-0018, "Grounding of the TRD MLI Blanket", dated November 12, 2007	
2.5 CONTROL: PMT applications utilize potting and conformal coating to preclude exposure of high voltage connectors, components and wiring. PMTs are isolated from any potential exterior contact. Cabling carrying high voltages to the PMTs are all space rated and qualified for voltages in excess to the maximum voltages present. 2.5.1 SVM: Review of design for potting and insulation of high voltage applications and wiring. 2.5.2 SVM: Inspection to verify that there is no exterior accessibility of the PMT or their circuitry. 2.5.3 SVM: Inspection of flight hardware to assure proper use of potting and high voltage wiring. 2.5.1 STATUS: Closed. ESCG Memorandum ESCG-4175-REENTES-MEMO-0020, "Review of AMS-02 High Voltage Design," dated April 24, 2009 2.5.2 STATUS: Closed. Photographic Survey inspection performed by ESCG/P. Mott, 7/21/2010 2.5.3 STATUS: Closed to SVTL.	
2.6 CONTROL: The Orbiter side of the ROEU (GFE hardware) will be depowered for the disconnect operation and remain unpowered once the umbilical is separated from the AMS-02. Any EVA subsequent to this separation could come in contact with this connector. AMS-02 procedures will call out the removal of power for disconnecting the ROEU and will not include any procedures that will require power to be resumed to the connector without reconnection of the ROEU to the ROEU-PDA. Design of the ROEU connector is certified GFE and is being used within its certification. NOTE: If power is	S

to be reapplied to the ROEU for some reason, a Shuttle based Flight Rule to enact a keep out zone would be implemented independent of AMS-02 operational requirements.

2.6.1 SVM: Formal Acceptance of procedural requirement by MOD through an OCAD(OCAD 67864) .

2.6.1 STATUS: Closed. OCAD Closure reported to AMS-02 Project on 6/4/2010 by JSC-DA8/B. O'Keeffe.

2.7 CONTROLS: Avionics and heaters operating from up to 120 VDC from the ISS or Shuttle APCU utilizes properly insulated wiring/cabling that are potted/conformally coated to preclude incidental shorting. Insulation rating of the heaters minimized the potential for shorting or exposing high voltages.

2.7.1 SVM: Review of HV designs.

2.7.2 SVM: Review of 120V heater design.

2.7.3 SVM: Inspection of as built hardware of HV design

2.7.4 SVM: Inspection of as built hardware of 120V heater design

2.7.1 STATUS: Closed. ESCG Memorandum ESCG-4175-REENTES-MEMO-0020, "Review of AMS-02 High Voltage Design," dated April 24, 2009

2.7.2 STATUS: Closed. ESCG Memorandum ESCG-4175-REENTES-MEMO-0020, "Review of AMS-02 High Voltage Design," dated April 24, 2009

2.7.3 STATUS: Closed to SVTL

2.7.4 STATUS: Closed to SVTL

2.8 CONTROL: All exposed conductive surfaces will be bonded through the AMS-02 Unique Support Structure. These bonding paths to the Orbiter shall be in accordance with NSTS 21000-IDD-ISS, Rev A. Bonding paths to the ISS upon installation will be made through the Payload Attach System (PAS) per SSP 57003A.

2.8.1 SVM: Review of design.

2.8.2 SVM: Testing of bonding of AMS-02 Conductive surfaces to integration hardware.

2.8.3 SVM: Testing of Interface paths to the Shuttle and ISS (UMA & Nickel Plated Guide Vanes).

2.8.1 STATUS: Closed. ESCG Memorandum ESCG-4295-10-ADV SY-MEMO-0028, "Bonding of AMS-02 Flight Hardware Conductive Surfaces – Review of Design," dated July 21, 2010

2.8.2 STATUS: Closed to SVTL.

PAYLOAD FLIGHT HAZARD REPORT	a. NO: AMS-02-F08
b. PAYLOAD: Alpha Magnetic Spectrometer-02 (AMS-02)	c. PHASE: III

2.8.3 STATUS: Closed to SVTL.	
3. CAUSE: Coronal Discharge	
3.1 CONTROL: During ascent and entry, high voltage sources will not be powered. 3.1.1 SVM: Confirmation of AMS-02 Status prior to launch, science systems unpowered for launch. 3.1.2 SVM: Formal acceptance of procedural requirements to turn off high voltages on AMS-02 by MOD through an OCAD (OCAD 67865). (Note: Ascent Checklist and Reentry) 3.1.1 STATUS: Closed. OMRSD File II, Volume 2 (P507 – ISS-ULF6 Baseline), requirement # P507KC.020 requires procedure for powering off AMS-02. 3.1.2 STATUS: Closed. OCAD Closure reported to AMS-02 Project on 6/4/2010 by JSC-DA8/B. O'Keeffe.	S
NOTE: The potential effects of coronal discharges upon the AMS-02 are degradation of HV circuitry and EMI, conducted and radiated, "white noise" being generated. All HV sources will be depowered as a consequence of nominal power removal when any EVA involving the AMS occurs on the ISS.	
3.2 CONTROL: AMS-02 high voltage sources will be potted and conformally coated and/or insulated using high voltage insulating compounds. All cabling carrying high voltage utilizes insulation that is properly rated for the voltages that are to be carried. High voltage systems will implement the design practices suggested in MSFC-STD-531 to minimize the potential for corona effects. 3.2.1 SVM: Review of design. 3.2.2 SVM: Inspection of as built hardware. 3.2.3 SVM: Corona testing/analysis. 3.2.4 SVM: Functional testing of AMS-02 in flight configuration in thermal-vacuum chamber. 3.2.1 STATUS: Closed. ESCG Memorandum ESCG-4175-REENTES-MEMO-0020, "Review of AMS-02 High Voltage Design," dated April 24, 2009 3.2.2 STATUS: Closed to SVTL. 3.2.3 STATUS: Closed. ESCG Memorandum ESCG-4175-09-REENTES-MEMO-0018, "AMS-02 Coronal Discharge Testing," Dated April 14, 2009 documents ESCG Review of testing and analysis of coronal discharge potential of AMS-02.	

PAYLOAD FLIGHT HAZARD REPORT	a. NO: AMS-02-F08
b. PAYLOAD Alpha Magnetic Spectrometer-02 (AMS-02)	c. PHASE: III

3.2.4 STATUS: Closed. Thermal Vacuum Testing Report, "ETS Facility Data report AMS-02 Thermal Vacuum Test," ETS-REP-THER-3326 Issue 1, dated July 5, 2010, indicates no anomalies associated with Coronal Discharge.	
4. CAUSE: Hazardous Alteration of ISS Plasma Environment	
4.1 CONTROL: AMS-02 limits their potential impact to the ISS plasma environment by limiting gas releases to only neutral gases (carbon dioxide, xenon, helium. The AMS-02 generates a magnetic field that does not extend out with sufficient distance and intensity to adversely impact the voltage potentials of the ISS and the local plasma environment. 4.1.1 SVM: Analysis of AMS-02 gas releases and magnetic field by ISS Environments AIT. 4.1.1 STATUS: Closed. AG-92-J3EU-RJA-2009-01, "ISS AMS-02 On-Orbit EME Analysis," dated October 1, 2009. Email confirmation of acceptability from Boeing/OA/R.R. Mikatarian by email to USA/OZ2/R. Miley, dated June 1, 2010.	
Notes:	

ACRONYMS	
ACC – Anti-Coincidence Counter	PDS – Power Distribution System
AMS-02 – Alpha Magnetic Spectrometer 02	PMT – Photomultiplier Tube
APCU – Auxiliary Power Control Unit	PVGF – Power Video Grapple Fixture
CAB – Cryomagnet Avionics Box	RHVx – Specific Crate Designator (RICH HV Supply (brick))
CC1, CC2, CC3, CC4 – Cryocooler 1-4	RICH – Ring Imagining Cherenkov (detector)
CCEB – Cryocooler Electronics Box	ROEU – Remotely Operated Electrical Umbilical
CCS – Cryomagnet Current Source	ROEU-PDA - Remotely Operated Electrical Umbilical Power Data
CDD-P, S – Cryomagnet Dump Diodes (Port, Starboard)	SHVx – S-Crate High Voltage (brick)
COV – Coronal Onset Voltage	SVM – Safety Verification Method

ACRONYMS	
CSP – Cryomagnet Self Protection	TBS – To Be Supplied
ECAL – Electromagnetic Calorimeter	TOF – Time of Flight
EHVx – Specific Crate Designator (ECAL HV Supply (brick))	TPD – Tracker Power Distribution
EMI – Electromagnetic Interference	TRD – Transition Radiation Detector
EVA – Extravehicular Activity	UHVG – Specific Crate Designator (TRD HV Supply)
GFE – Government Furnished Equipment	UMA – Umbilical Mating Adapter
HV – High Voltage	UPD – Specific Crate Designator (TRD Power Supply)
LTOF – Lower Time of Flight	UPS – Uninterruptible Power Supply
LUSS – Lower Unique Support Structure	UTE – Specific Crate Designator (TRD Tube End Board)
MLI – Multilayer Insulation	UTOF – Upper Time of Flight
nA – nano Ampere	V – Volts
PAS – Payload Attach System	

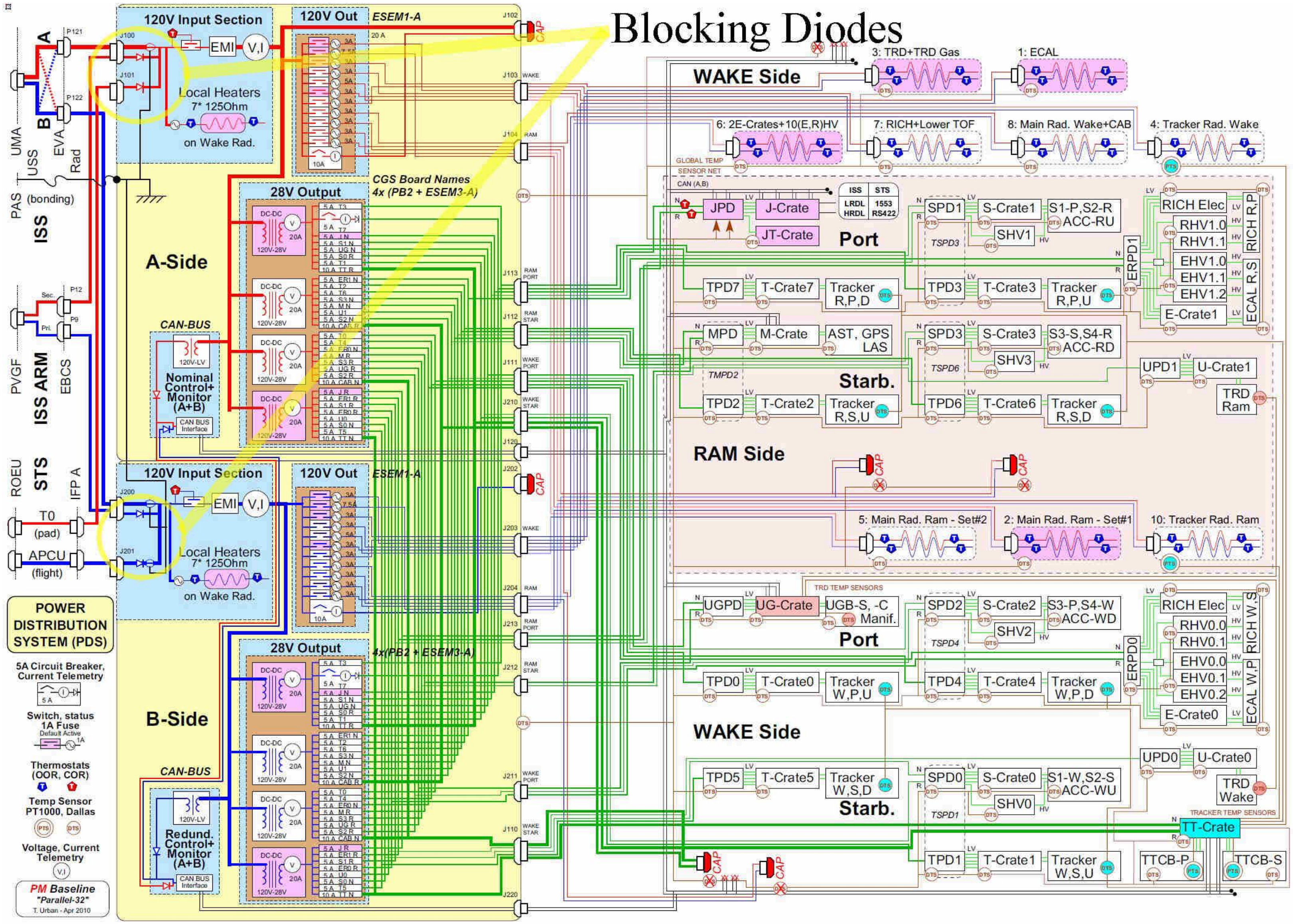
High Voltages (and Currents) in AMS-02. M.Capell 03-01-2007

Item	Subsystem	Source	Load	Voltage	Current	AWG
14	ECAL	EHV0-0	55 ECAL PMTs	<1000VDC	<250uA	Coax-26
15	ECAL	EHV0-1	55 ECAL PMTs	<1000VDC	<250uA	Coax-26
16	ECAL	EHV0-2	55 ECAL PMTs	<1000VDC	<250uA	Coax-26
17	ECAL	EHV1-0	55 ECAL PMTs	<1000VDC	<250uA	Coax-26
18	ECAL	EHV1-1	55 ECAL PMTs	<1000VDC	<250uA	Coax-26
19	ECAL	EHV1-2	55 ECAL PMTs	<1000VDC	<250uA	Coax-26
20	Interface	ISS	AMS-PDS	120VDC	<25A	8
21	Interface	ISS/PVGF	AMS-PDS	120VDC	<15A	12
22	Interface	ISS/T0	AMS-PDS	120VDC	<25A	12
23	Interface	STS/APCU	AMS-PDS	120VDC	<25A	8
24	Power	PDS	CCS in CAB	120VDC	<20A	12
25	Power	PDS	CCEB	120VDC	<7.5A	12
26	RICH	RHV0-0	40 RICH PMTs	<1000VDC	<80uA	Coax-26
27	RICH	RHV0-1	40 RICH PMTs	<1000VDC	<80uA	Coax-26
28	RICH	RHV1-0	40 RICH PMTs	<1000VDC	<80uA	Coax-26
29	RICH	RHV1-1	40 RICH PMTs	<1000VDC	<80uA	Coax-26
30	S:TOF+ACC	SHV0	34 TOF+4 ACC PMTs	<2500VDC	<50uA	Coax-26
31	S:TOF+ACC	SHV1	34 TOF+4 ACC PMTs	<2500VDC	<50uA	Coax-26
32	S:TOF+ACC	SHV2	38 TOF+4 ACC PMTs	<2500VDC	<50uA	Coax-26
33	S:TOF+ACC	SHV3	38 TOF+4 ACC PMTs	<2500VDC	<50uA	Coax-26
34	Thermal	PDS	ECAL Heaters	120VDC	<3A	20
35	Thermal	PDS	Ram Heaters	120VDC	<7.5A	20
36	Thermal	PDS	TRD Heaters	120VDC	<3A	20
37	Thermal	PDS	Tracker Wake Heaters	120VDC	<3A	20
38	Thermal	PDS	Wake Heaters	120VDC	<5A	20
39	Thermal	PDS	LUSS Boxes	120VDC	<3A	20
40	Thermal	PDS	RICH Heaters	120VDC	<3A	20
41	Thermal	PDS	LTOF Heaters	120VDC	<3A	20

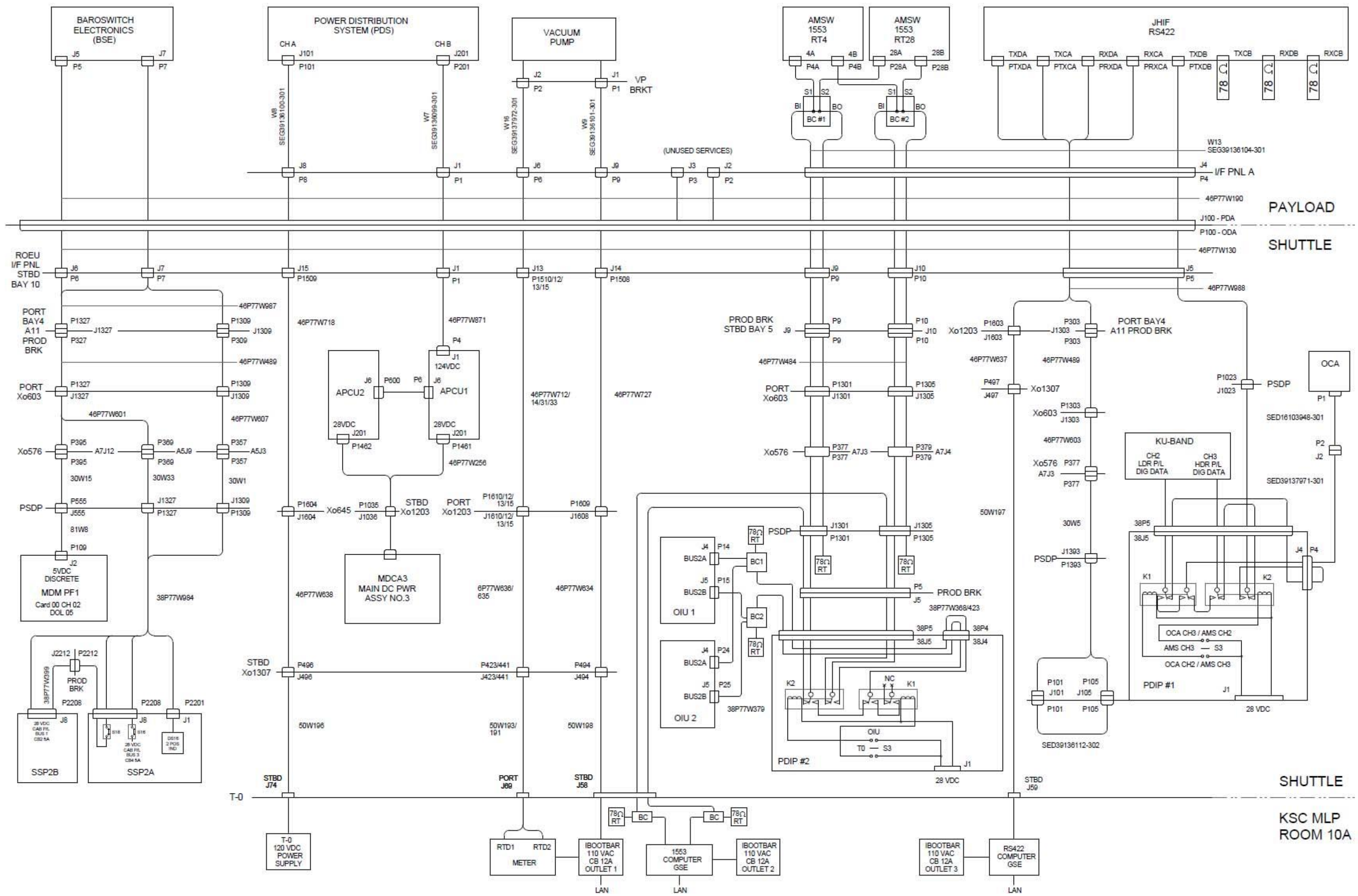
High Voltages (and Currents) in AMS-02. M.Capell 03-01-2007

Item	Subsystem	Source	Load	Voltage	Current	AWG
43	Thermal	PDS	Tracker Ram Heaters	120VDC	<3A	20
45	Tracker	TPD0	2 TBS in T0-Crate	<120VDC	<10mA	22
46	Tracker	TPD1 in TSPD1	2 TBS in T1-Crate	<120VDC	<10mA	22
47	Tracker	TPD2 in TMPD2	2 TBS in T2-Crate	<120VDC	<10mA	22
48	Tracker	TPD3 in TSPD3	2 TBS in T3-Crate	<120VDC	<10mA	22
49	Tracker	TPD4 in TSPD4	2 TBS in T4-Crate	<120VDC	<10mA	22
50	Tracker	TPD5	2 TBS in T5-Crate	<120VDC	<10mA	22
51	Tracker	TPD6 in TSPD6	2 TBS in T6-Crate	<120VDC	<10mA	22
52	Tracker	TPD7	2 TBS in T7-Crate	<120VDC	<10mA	22
53	Tracker	2 TBS in T0-Crate	24 Tracker Ladders	<80VDC	<10mA	26
54	Tracker	2 TBS in T1-Crate	24 Tracker Ladders	<80VDC	<10mA	26
55	Tracker	2 TBS in T2-Crate	24 Tracker Ladders	<80VDC	<10mA	26
56	Tracker	2 TBS in T3-Crate	24 Tracker Ladders	<80VDC	<10mA	26
57	Tracker	2 TBS in T4-Crate	24 Tracker Ladders	<80VDC	<10mA	26
58	Tracker	2 TBS in T5-Crate	24 Tracker Ladders	<80VDC	<10mA	26
59	Tracker	2 TBS in T6-Crate	24 Tracker Ladders	<80VDC	<10mA	26
60	Tracker	2 TBS in T7-Crate	24 Tracker Ladders	<80VDC	<10mA	26
61	TRD	UPD0	6 UHVG in U0-Crate	<120VDC	<35mA	22
62	TRD	UPD1	6 UHVG in U1-Crate	<120VDC	<35mA	22
63	TRD	6 UHVG in U0-Crate	2624 TRD Straw Tubes	<1800VDC	<100uA	Coax-26
64	TRD	6 UHVG in U1-Crate	2624 TRD Straw Tubes	<1800VDC	<100uA	Coax-26
65	TRD-Gas	UGPD	UHVG in UG-Crate	<120VDC	<35mA	22

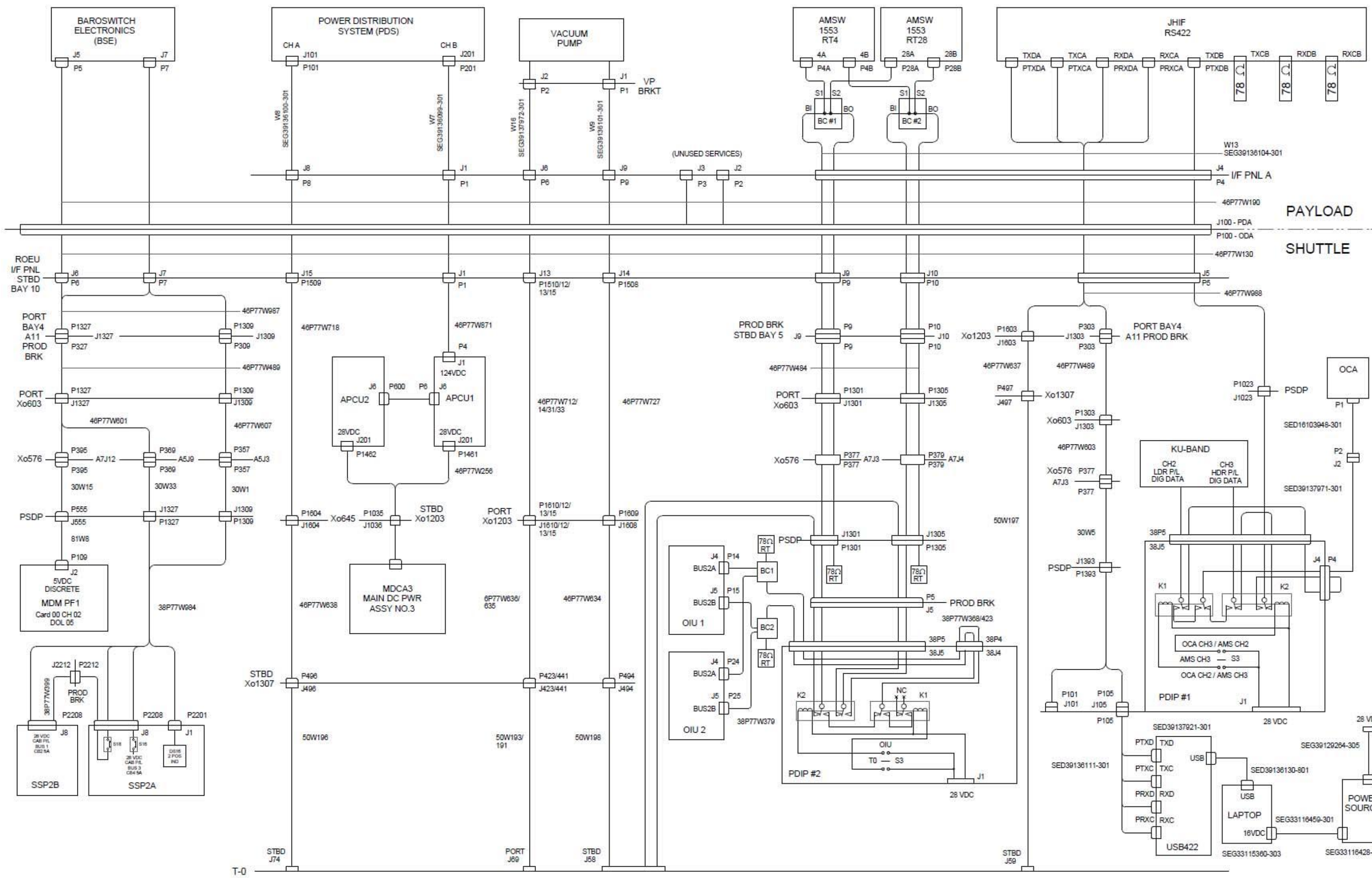
ISS, STS Voltages after EMI filter



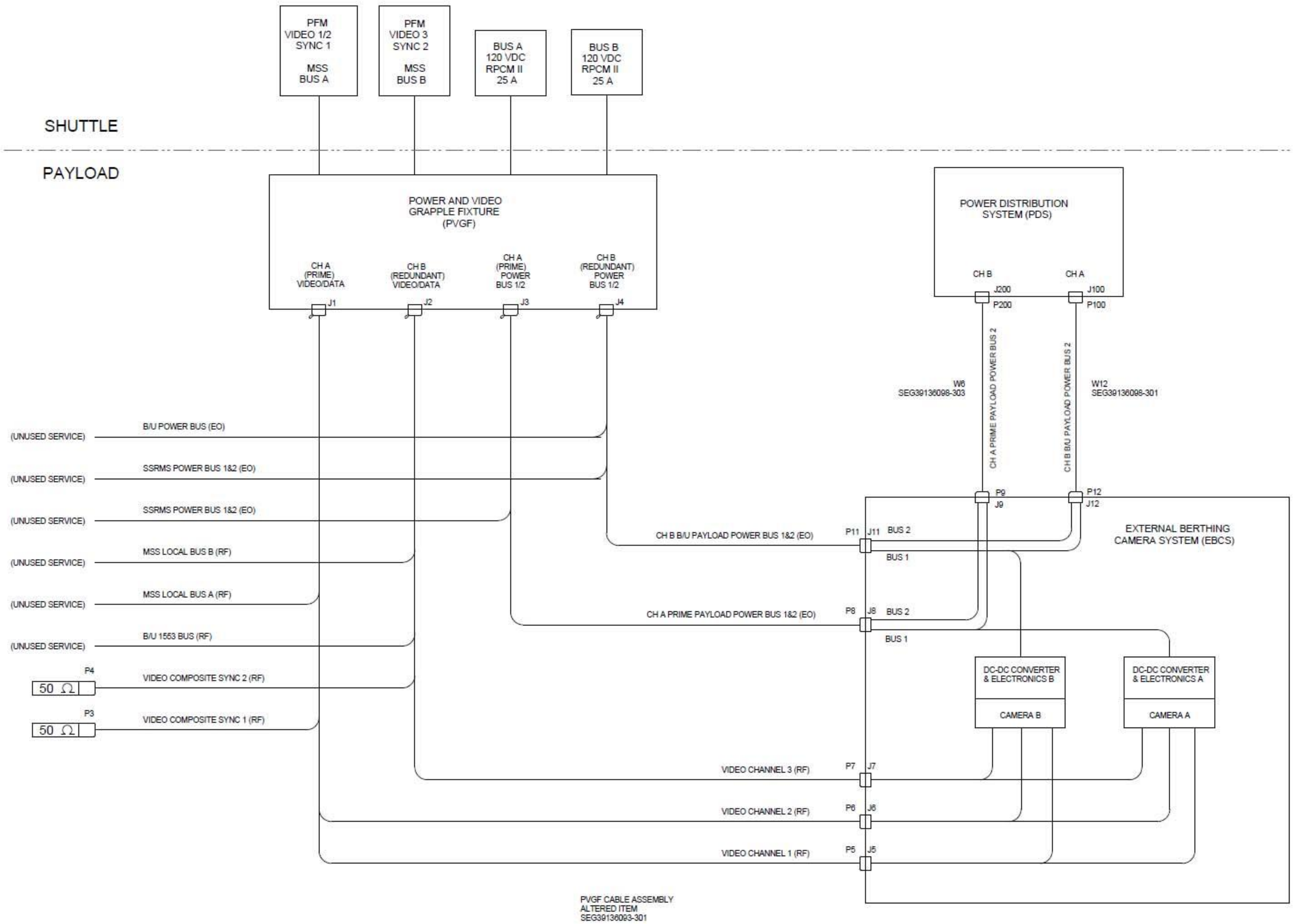
Blocking Diodes isolating ROEU and PVGF connectors from alternate power sources.



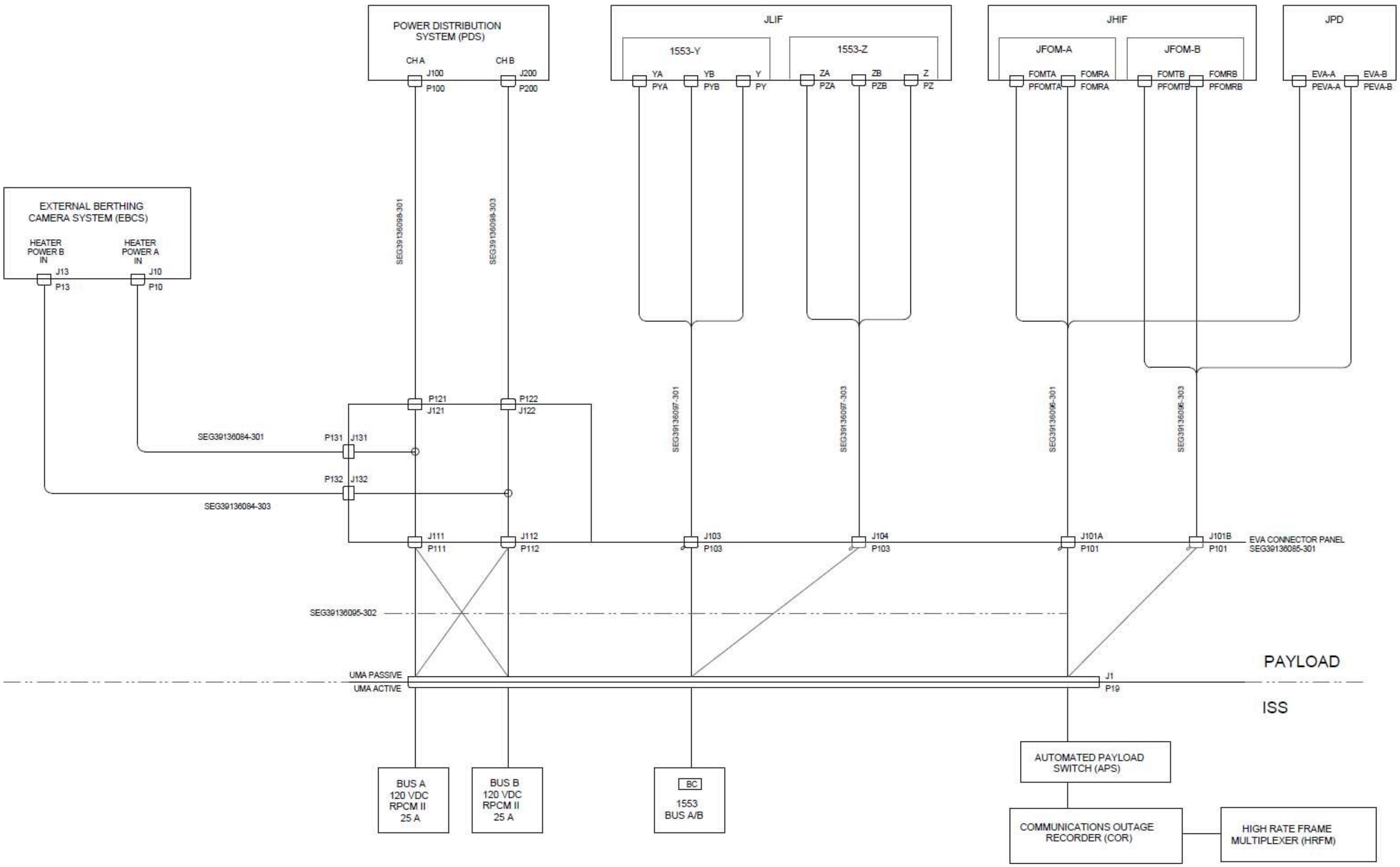
AMS-02 Power Interface with T-0 Power



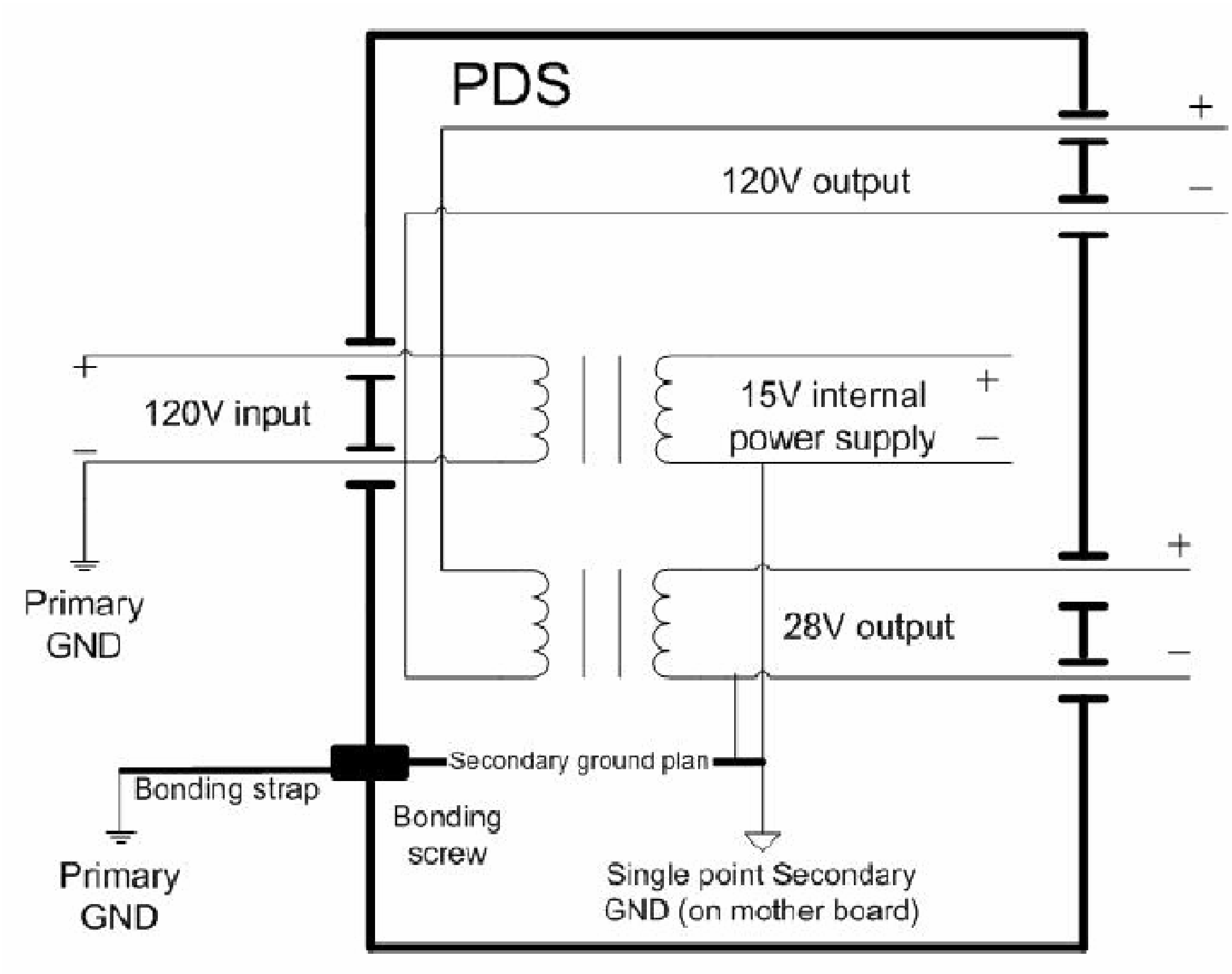
AMS-02 Power Interface with STS Orbiter



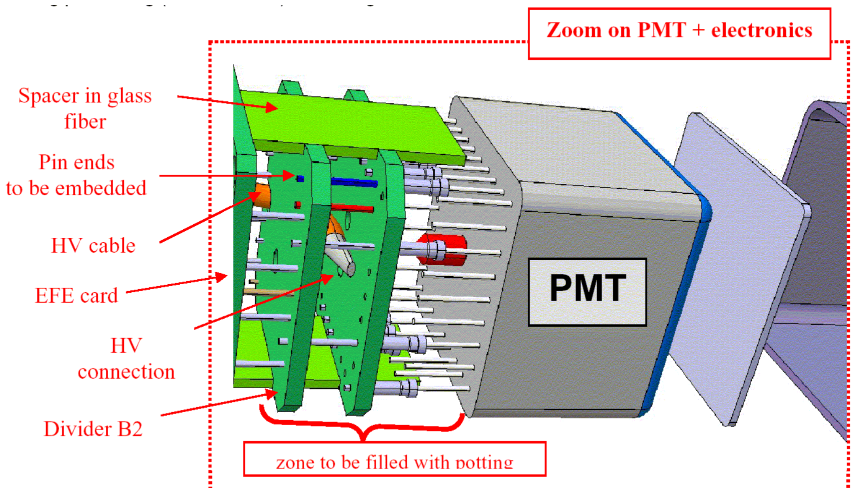
AMS-02 Power Interface with Space Station Remote Manipulator System



AMS-02 Power Interface with ISS at berthing location

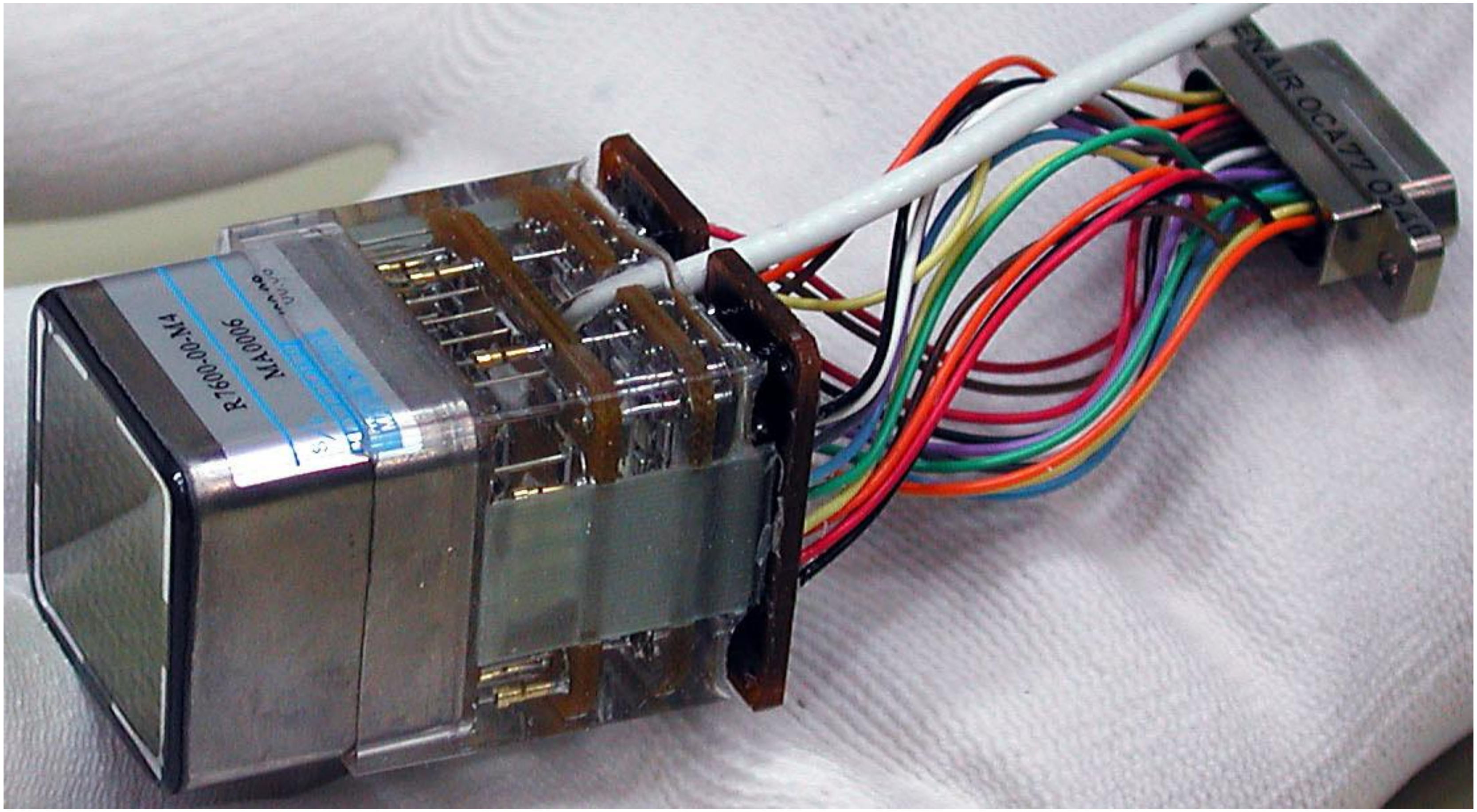


PDS Bonding Diagram

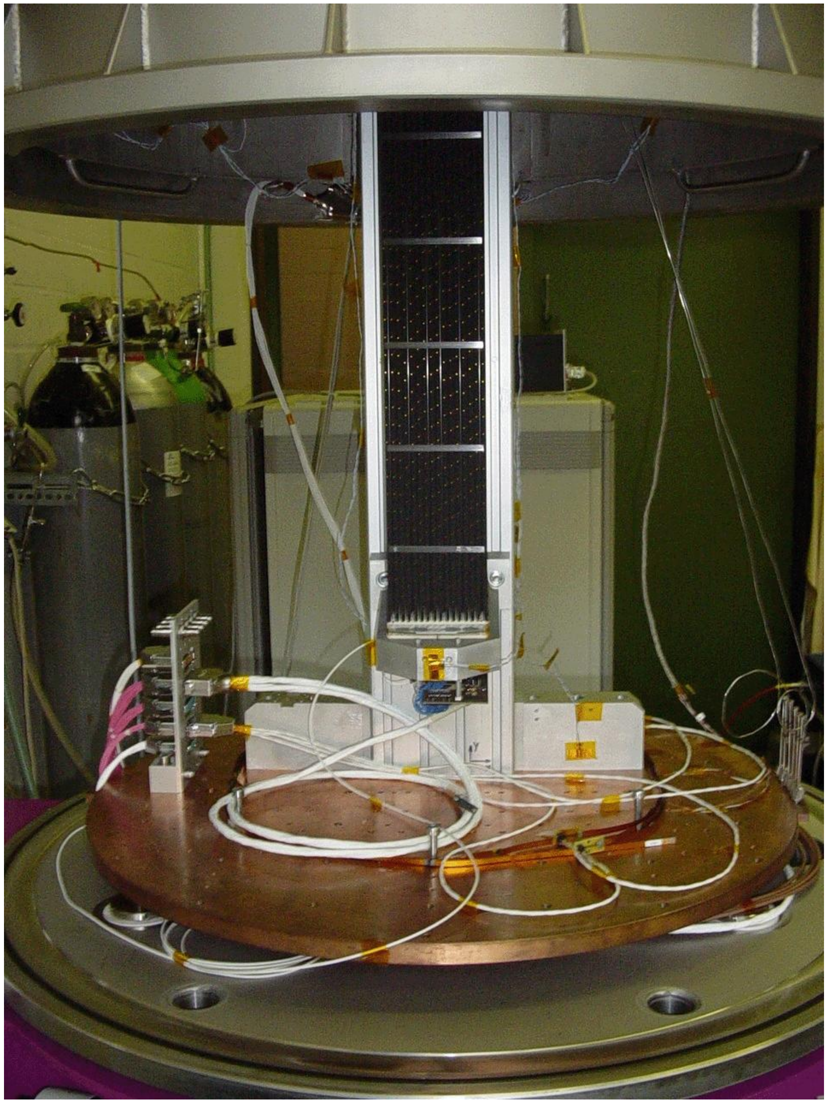


Example of High Voltage Component Potting.

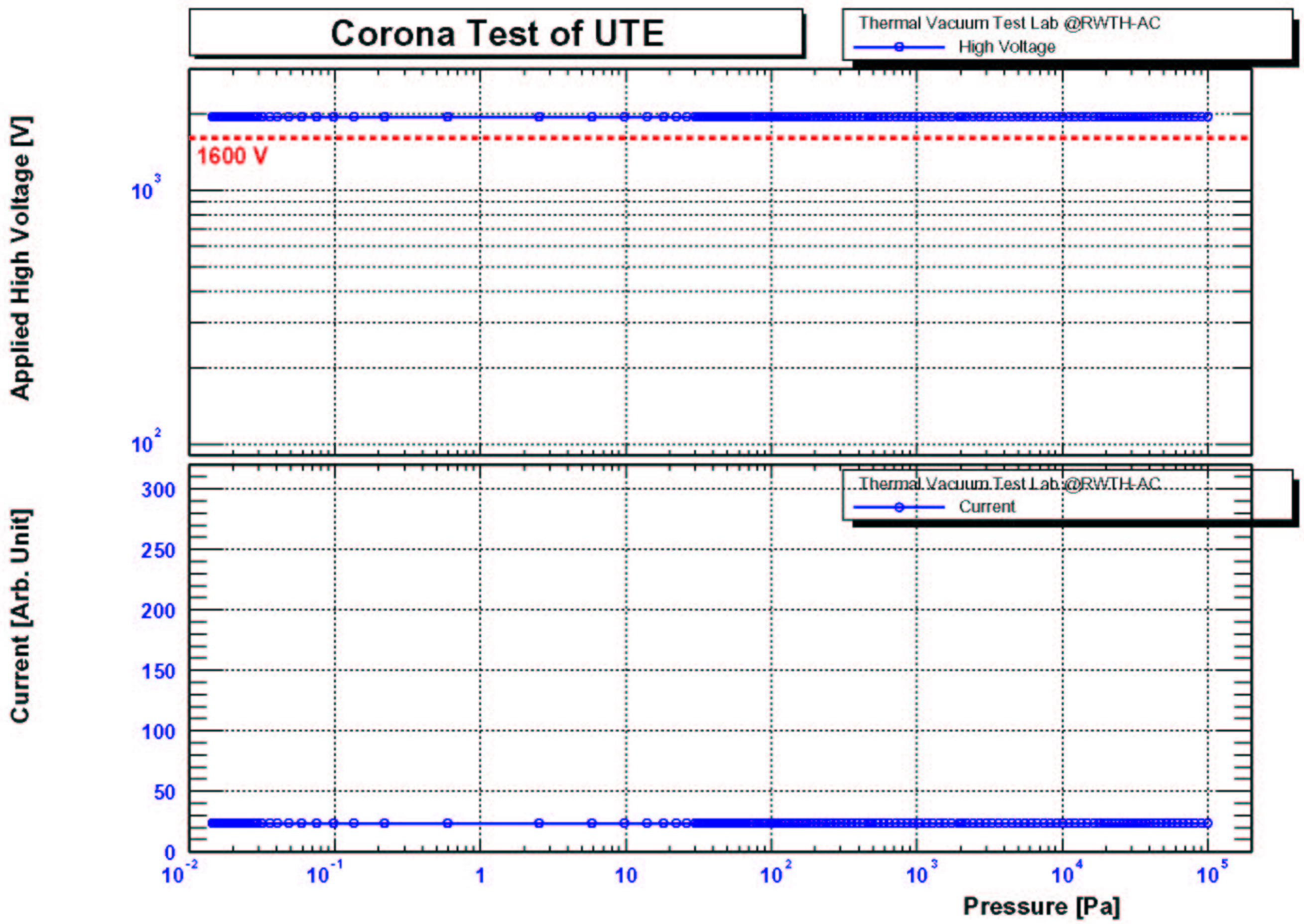
RICH Photo Multiplier Tube



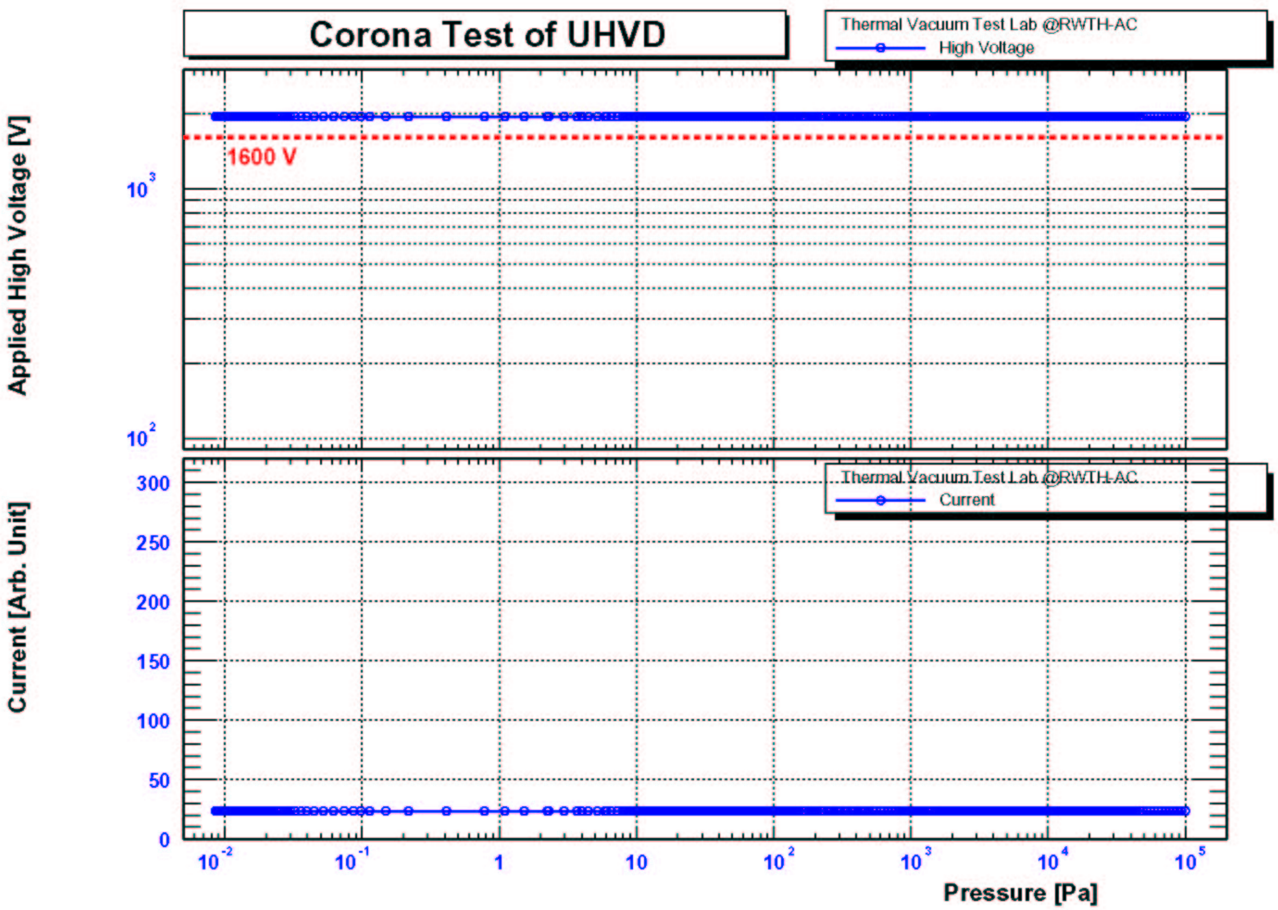
Example of High Voltage Component Potting.
ECAL Photo Multiplier Tube Potting



Coronal Discharge Testing of TRD
High Voltage Straws.



Corona Test Results for TRD UTE



Coronal Testing Results for TRD UHVD

260-0121-1000(A) D/E 600 PLUG CABLE ASSY

TELEDYNE REYNOLDS LTD
A Teledyne Technologies Company

ITEMS LIST for

Drawing Title: D/E 600 PLUG CABLE ASSY
Drawing No: 260-0121-1000(A)

CN: 3213
date: 21/10/05

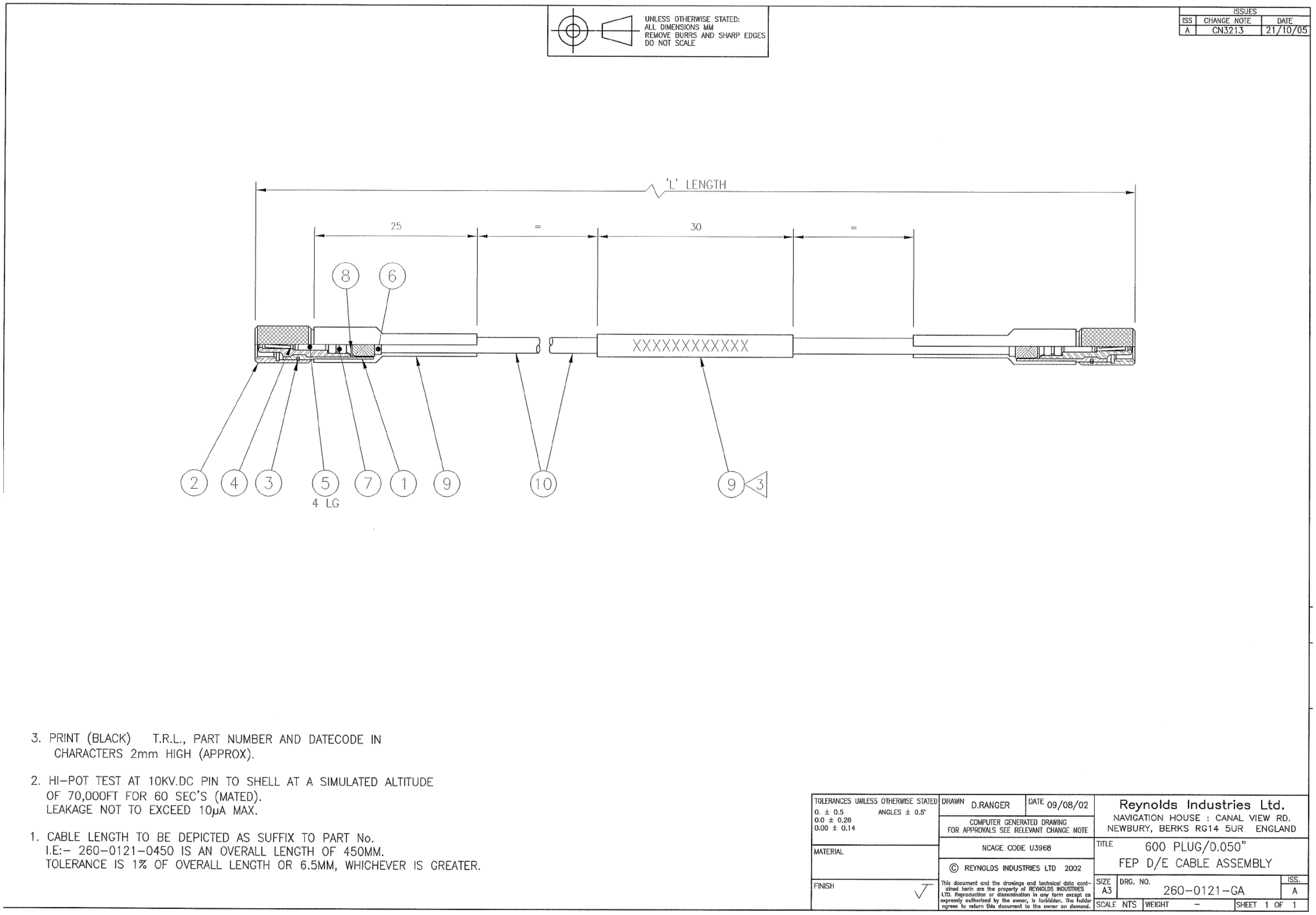
Page 1 of 1

ItemNo	Ident	Qty	UOM	PartNumber	PartDesc	SuppliersDesc	SupplierCode
			DOC	260-0121-GA(A)	ASSEMBLY DRAWING		
			DOC	260-0121-PS(A)	PROCESS SPEC.		
1		2	EA		600 BODY ASSEMBLY, MOLDED		
2		2	EA		600 COUPLING NUT		
3		2	EA		600 RING RETAINER		
4		2	EA		600 FEMALE CONTACT		
5		0.008	MT		KYNAR 1.5 CLR	KYNAR-1/16-X	
6		2	EA		600 'U' SLEEVE		
7		2	EA		600 DOUBLE 'O' RING SEAL		
8		2	EA		WASHER 600		
9		0.080	MT		KYNAR 4.8 CLR	KYNAR-3/16-X	
10		1.000	MT	167-2896	CABLE .050 FEP SPC SHIELDED		

DRAWN: D.Ranger DATE: 21/10/05
NCAGE CODE U3968
COMPUTER GENERATED ITEMS LIST
FOR APPROVAL SEE RELEVANT CHANGE NOTE

TELEDYNE REYNOLDS Ltd.
NAVIGATION HOUSE, CANAL VIEW RD.
NEWBURY, BERKS RG14 5UR. ENGLAND

Typical Construction of HV Cable (1 of 2)



Typical Construction of HV Cable (2 of 2)

PAYLOAD FLIGHT HAZARD REPORT				a. NO:	AMS-02-F10
b. PAYLOAD	Alpha Magnetic Spectrometer-02 (AMS-02)			c. PHASE:	III
d. SUBSYSTEM:	Materials, Thermal Control System	e. HAZARD GROUP:	Fire/Flammability	f. DATE:	January 21,2011
g. HAZARD TITLE:	Flammable Materials in the Payload Bay			i. HAZARD CATEGORY:	CATASTROPHIC **X** CRITICAL
h. APPLICABLE SAFETY REQUIREMENTS:	NSTS 1700.7B 209.2				
j. DESCRIPTION OF HAZARD:	Use of flammable materials, solid or gaseous, in the Orbiter Payload Bay can present an uncontrolled fire hazard to the Orbiter and other payloads. Note: Shuttle Cabin flammability issues are addressed in STD-AMS-02-F02.				

k. CAUSES

(list)

1. Use of flammable materials in the construction of the AMS-02
2. Use of flammable fluids/gases in the AMS-02 Thermal Control System
3. Ignition of Flammable Cargo Bay Environment (Non-AMS-02 Source Flammable Material)

o. APPROVAL	PAYLOAD ORGANIZATION	SSP/ISS
PHASE I		
PHASE II		
PHASE III		

PAYLOAD FLIGHT HAZARD REPORT	a. NO: AMS-02-F10
b. PAYLOAD Alpha Magnetic Spectrometer-02 (AMS-02)	c. PHASE: III

l. HAZARD CONTROL (CONTROL), m. SAFETY VERIFICATION METHODS (SVM), n. STATUS OF VERIFICATIONS (STATUS)	OPS CONTROL
1. CAUSE: Use of flammable materials in the construction of the AMS-02	
1.1 CONTROL: Materials used in the construction of the AMS-02 hardware to be locate in the shuttle payload bay will be “A” rated for flammability as rated in the MAPTIS database or will be included in a flammability assessment per NSTS 22648. 1.1.1 SVM: Review of design. 1.1.2 SVM: Inspection of as built hardware. 1.1.3 SVM: Material Certification by JSC ES4. 1.1.1 STATUS: Closed. JSC Materials and Fracture Control Certification MATL-11-009, "Alpha Magnetic Spectrometer -02 (AMS-02) Payload Assembly," Approved December 10, 2010 1.1.2 STATUS: Closed. JSC Memorandum EA3-11-004, "Inspection of AMS-02 Materials," dated January 20, 2011 1.1.3 STATUS: Closed. JSC Materials and Fracture Control Certification MATL-11-009, "Alpha Magnetic Spectrometer -02 (AMS-02) Payload Assembly," Approved December 10, 2010	
2. CAUSE: Use of flammable fluids/gases in the AMS-02 Thermal Control System	
2.1 CONTROL: The Tracker radiators/thermal control system radiators incorporate heat pipes that utilize ammonia as a working fluid. There are 7 individual heat pipes in each of the Tracker radiators each containing 24.2 to 28.5 grams of ammonia. Ram and Wake Tracker radiators heat pipes are identical with regards to ammonia and heat pipe use. All of these heat pipes are qualified under NSTS 1700.7B 208.4C Pressurized Lines, Fittings and Components. Reference AMS-02-F05. 2.1.1 SVM: Review of design to establish flammable material quantity. 2.1.2 SVM: Flammability assessment on the use of ammonia in the payload bay. 2.1.1 STATUS: Closed. ESCG-4470-09-TEAN-DOC-0121, “AMS-02 Heat Pipes and Loop Heat Pipes Fluid Fill Quantities,” dated September 1, 2009 2.1.2 STATUS: Closed. ESCG Memorandum ESCG-4480-09-MAAN-MEMO-0039, “Flammability Assessment of Flammable Gases in Orbiter Payload Bay for AMS-02 Phase III Safety Data Package (SDP),” from C. Chang,	

PAYLOAD FLIGHT HAZARD REPORT	a. NO: AMS-02-F10
b. PAYLOAD Alpha Magnetic Spectrometer-02 (AMS-02)	c. PHASE: III

Concurrence ES4/M. Pedley, September 22, 2009

2.2 CONTROL: The Electronics Crate thermal control system radiators (Ram and Wake) incorporate heat pipes that utilize ammonia as a working fluid. There are 22 individual heat pipes in the Wake Radiator with a maximum ammonia quantity of 32.7 grams and 16 individual heat pipes with the maximum ammonia quantity of 32.7 grams in the Ram Radiator. All of these heat pipes are qualified under NSTS 1700.7B 208.4C Pressurized Lines, Fittings and Components. Reference AMS-02-F05.

2.2.1 SVM: Review of design to establish flammable material quantity.

2.2.2 SVM: Flammability assessment on the use of ammonia in the payload bay.

2.2.1 STATUS: Closed. ESCG-4470-09-TEAN-DOC-0121, "AMS-02 Heat Pipes and Loop Heat Pipes Fluid Fill Quantities," dated September 1, 2009

2.2.2 STATUS: Closed. ESCG Memorandum ESCG-4480-09-MAAN-MEMO-0039, "Flammability Assessment of Flammable Gases in Orbiter Payload Bay for AMS-02 Phase III Safety Data Package (SDP)," from C. Chang, Concurrence ES4/M. Pedley, September 22, 2009

2.3 CONTROL: <Deleted. Cryocooler Loop Heat Pipes Removed from AMS-02>

2.4 CONTROL: <Deleted. CAB Loop Heat Pipes Removed from AMS-02>

2.5 CONTROL: The USS heat pipes (3) utilize 7.6 grams of ammonia as a working fluid. The USS heat pipes are a closed system that does not incorporate any nominal venting means. The USS heat pipes are qualified under NSTS 1700.7B, 208.4C Pressurize Lines, Fittings and Components. Reference AMS-02-F05.

2.5.1 SVM: Review of design to establish flammable material quantity.

2.5.2 SVM: Flammability assessment on the use of ammonia in the payload bay.

2.5.1 STATUS: Closed. ESCG-4470-09-TEAN-DOC-0121, "AMS-02 Heat Pipes and Loop Heat Pipes Fluid Fill Quantities," dated September 1, 2009

2.5.2 STATUS: Closed. ESCG Memorandum ESCG-4480-09-MAAN-MEMO-0039, "Flammability Assessment of Flammable Gases in Orbiter Payload Bay for AMS-02 Phase III Safety Data Package (SDP)," from C. Chang, Concurrence ES4/M. Pedley, September 22, 2009

2.6 CONTROL: The TTCS Accumulator Heat Pipes utilize 36 grams (maximum) of ammonia as a working fluid. The

PAYLOAD FLIGHT HAZARD REPORT		a. NO: AMS-02-F10
b. PAYLOAD Alpha Magnetic Spectrometer-02 (AMS-02)		c. PHASE: III
TTCS Accumulator Heat Pipe is a closed system that does not incorporate any nominal venting means. The TTCS Accumulator Heat Pipe is qualified under NSTS 1700.7B, 208.4C Pressurized Lines Fittings and Components. Reference AMS-02-F05. 2.6.1 SVM: Review of design to establish flammable material quantity. 2.6.2 SVM: Flammability assessment on the use of ammonia in the payload bay. 2.6.1 STATUS: Closed. ESCG-4470-09-TEAN-DOC-0121, "AMS-02 Heat Pipes and Loop Heat Pipes Fluid Fill Quantities," dated September 1, 2009 2.6.2 STATUS: Closed. ESCG Memorandum ESCG-4480-09-MAAN-MEMO-0039, "Flammability Assessment of Flammable Gases in Orbiter Payload Bay for AMS-02 Phase III Safety Data Package (SDP)," from C. Chang, Concurrence ES4/M. Pedley, September 22, 2009		
3. CAUSE: Ignition of Flammable Cargo Bay Environment (Non-AMS-02 Source Flammable Material)		
3.1 CONTROL: The AMS-02 will be depowered for ascent with no powered systems active. 3.1.1 SVM: Review of prelaunch power configuration for AMS-02 3.1.1 STATUS: Closed. OMRSD File II, Volume 2 (P507 – ISS-ULF6 Baseline), requirement # P507KC.020 requires procedure for powering off AMS-02.		
NOTES:		

ACRONYMS	
ACOP – AMS Crew Operations Post	MAPTIS - Materials and Processes Technical Information System
AMS-02 – Alpha Magnetic Spectrometer -02	SVM – Safety Verification Method
CAB – Cryomagnet Avionics Box	TCS – Thermal Control System
DFMR – Design for Minimum Risk	USS – Unique Support Structure

Summary of Flammable Gas/Fluid use in AMS-02 Heat Pipes

System	Number of Heat Pipes	Quantity per HP	Construction
Wake Crate Radiator	Twenty-two heat pipes of various lengths and bends fitted to radiator	Total: 498.4 grams Largest single ammonia quantity: 32.7 grams	Aluminum alloy face sheets of each 0.5 mm thickness, ROHACELL 51 core of 25 mm height (density 51 kg/m3) with embedded heat pipes, aluminum tubes with internal capillary structure Identical internal heat pipe profile
Ram Crate Radiator	Sixteen heat pipes of various lengths and bends fitted to radiator	Total: 316.7 grams Largest single ammonia quantity:32.7 grams	Aluminum alloy face sheets of each 0.5 mm thickness, ROHACELL 51 core of 25 mm height (density 51 kg/m3) with embedded heat pipes, aluminum tubes with internal capillary structure Identical internal heat pipe profile
Tracker Radiator Wake	Seven heat pipes varying in length from 2125 mm to 2505 mm	Total quantity: 184.2 grams Individual heat pipes range from 24.2 to 28.5 grams ammonia	Aluminum alloy face sheets of 0.8 mm thickness on radiating side and 0,2 mm on opposite side. ROHACELL 51 core of 15 mm height (density 51 kg/m3) with 7 embedded heat pipes. Extruded aluminum with internal capillary structure heat pipes
Tracker Radiator Ram	Seven heat pipes varying in length from 2125 mm to 2505 mm	Total quantity: 184.2 grams Individual heat pipes range from 24.2 to 28.5 grams ammonia	Aluminum alloy face sheets of 0.8 mm thickness on radiating side and 0,2 mm on opposite side. ROHACELL 51 core of 15 mm height (density 51 kg/m3) with 7 embedded heat pipes. Extruded aluminum with internal capillary structure heat pipes
USS Heat Pipes	Three heat pipes	7.6, 7.6, 7.5 grams of Ammonia per pipe.	Axial groove heat pipes constructed of Al 6063
TTCS Accumulator Heat Pipe	Two heat pipes, one per accumulator	3.6, 3.3 grams of Ammonia	Stainless 316L tube with internal wicking materials. 232 mm long, OD 10.06 mm, ID 7.6 mm

Flammable Fuels in the Payload Bay

- Memo ES5-91-289 addressed the flammability of gases in the Payload Bay.
- The following equation is used to calculate the weight of gas required to achieve a flammable mixture:

$$W_f = 27.05 * LFL * V_f * MW$$

Where,
W_f = weight of fuel to produce a flammable mixture
LFL = Lower Flammability Limit
V_f = Free Volume Fraction
MW = Molecular Weight (g/mol)

AMS-02 Coolant Summary

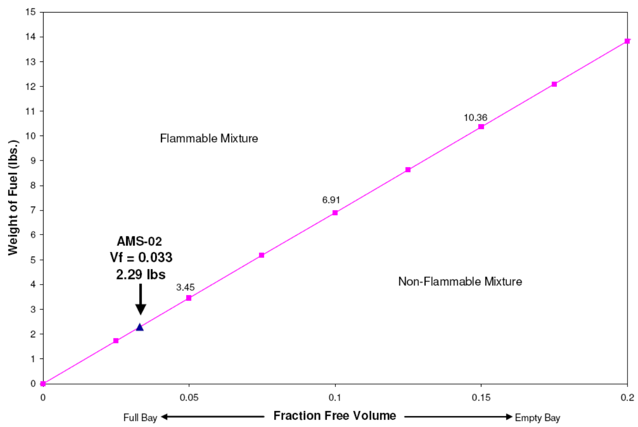
- The various AMS-02 thermal control systems use both Ammonia and Propylene as coolant materials.
- Quantities:

Fluid/Gas	Largest Single Qty	Total Qty
Ammonia	53 grams	1037.7 grams
Propylene	42 grams	168 grams

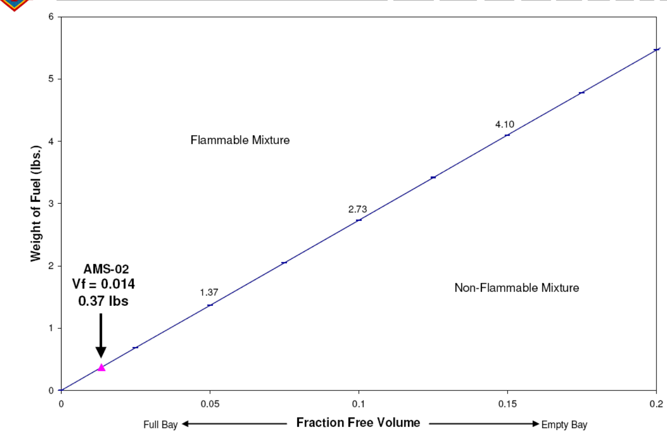
TOTAL Ammonia = 1037.7 grams = 2.3 lbs.
TOTAL Propylene = 168 grams = 0.4 lbs.

*Note: "Largest Single Qty" implies the largest amount used in any individual DFMR system.

Ammonia in the Payload Bay



Propylene in the Payload Bay

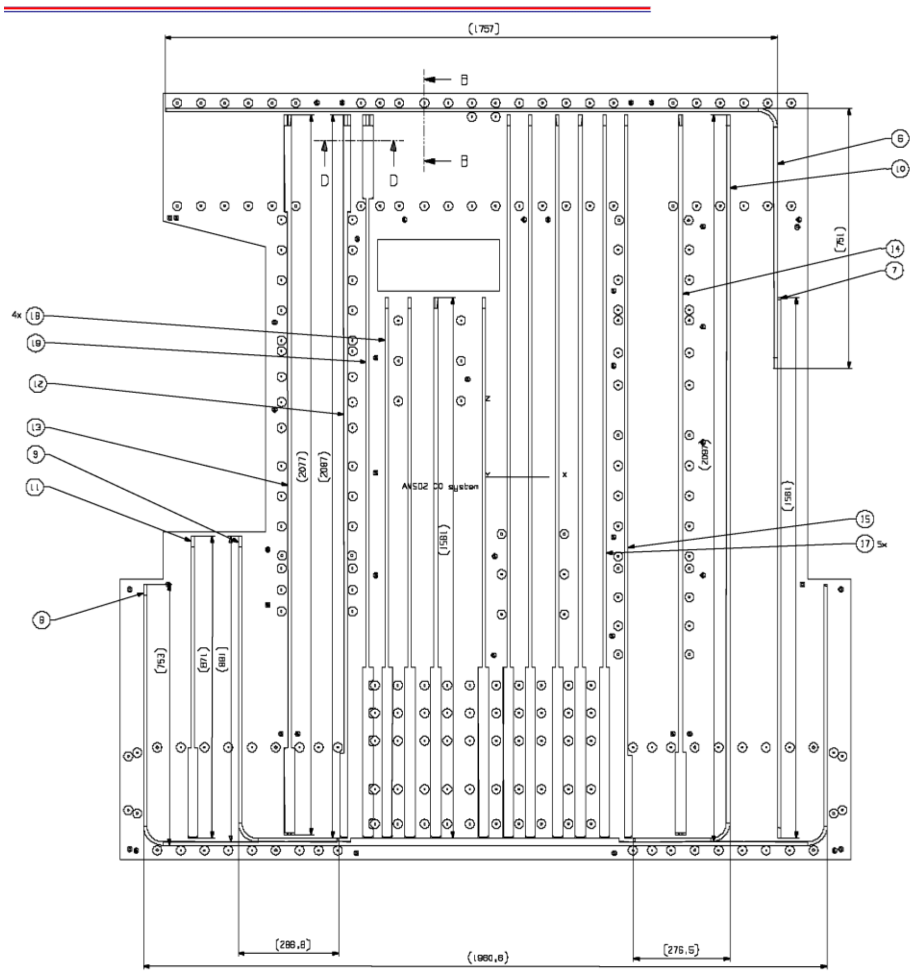


Flammable Gas Conclusion

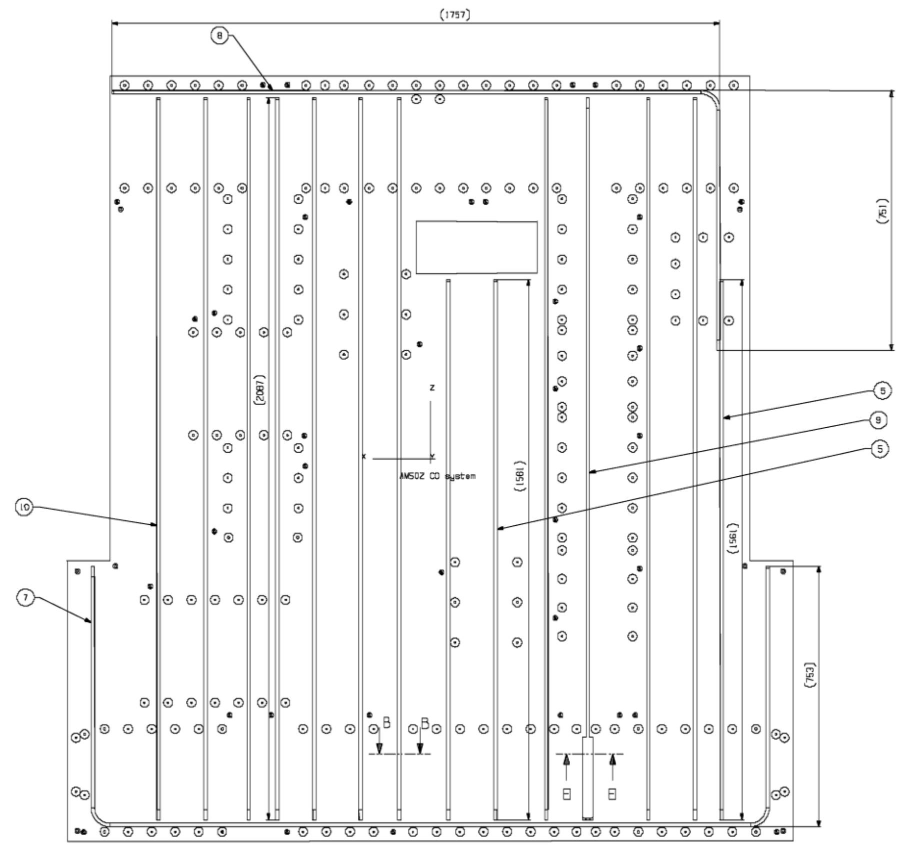
- Summary
  - AMS-02 uses 2.3 lbs of Ammonia and 0.4 lbs of Propylene
  - The largest quantity in any single DFMR system is 0.12 lbs of Ammonia and 0.09 lbs of Propylene.
  - The "critical" Free Volume Fractions are as follows:
    - 2.3 lbs of Ammonia - $V_f = 3.3\%$
    - 0.4 lbs of Propylene - $V_f = 1.4\%$
  - Preliminary Payload Bay configurations predict a Free Volume Fraction of greater than 50%
- Conclusion
  - AMS-02 does not present a flammable gas hazard in the Payload Bay. The total quantities of coolant available do not present a hazard if released until the Payload Bay is over 95% full.

6/08/2005 Tim Schniepp 5

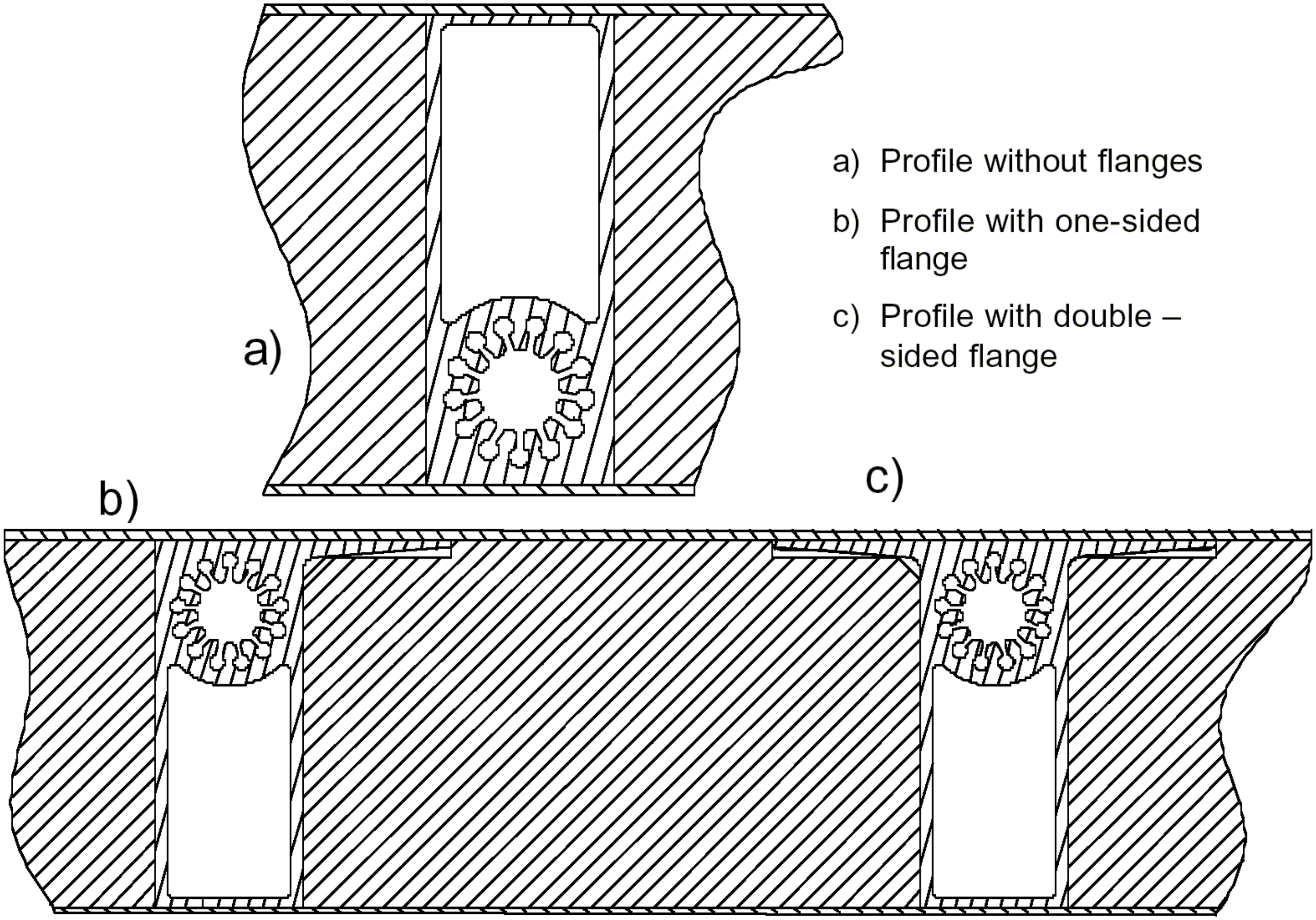
Worst case analysis of total release of flammable gasses indicates that the quantities of flammable gases used in the design of the AMS-02 are significantly below any flammability threshold.



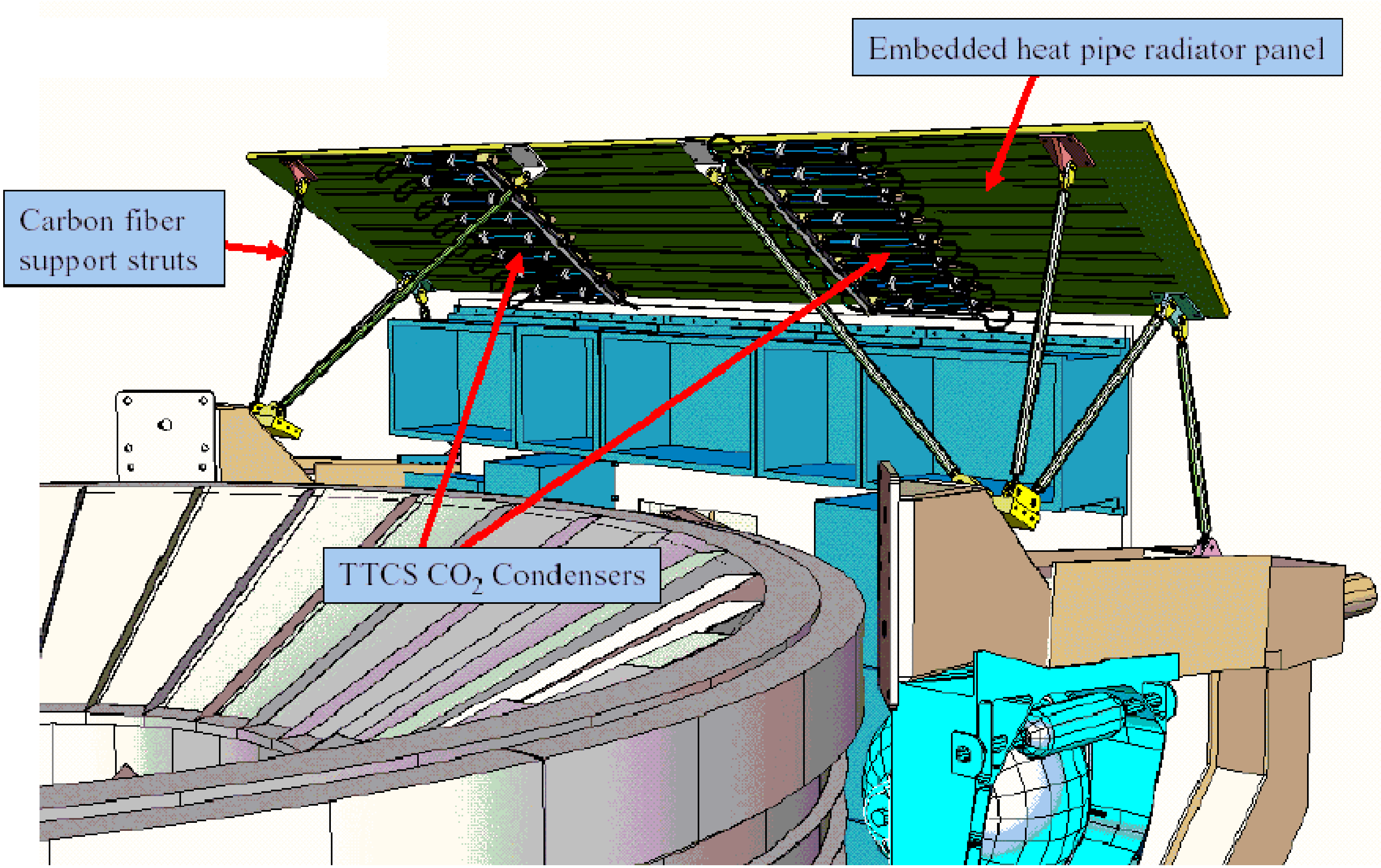
TCS – Wake Side Radiator for Avionics Crates



TCS – Ram Side Radiator for Avionics Crates

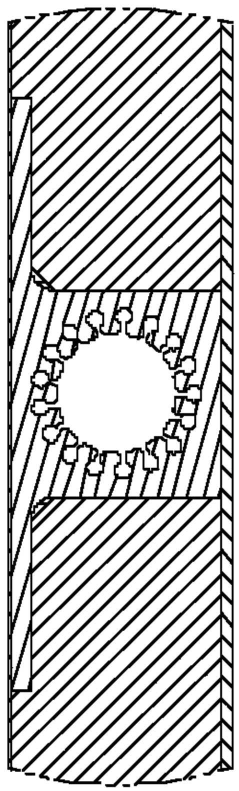


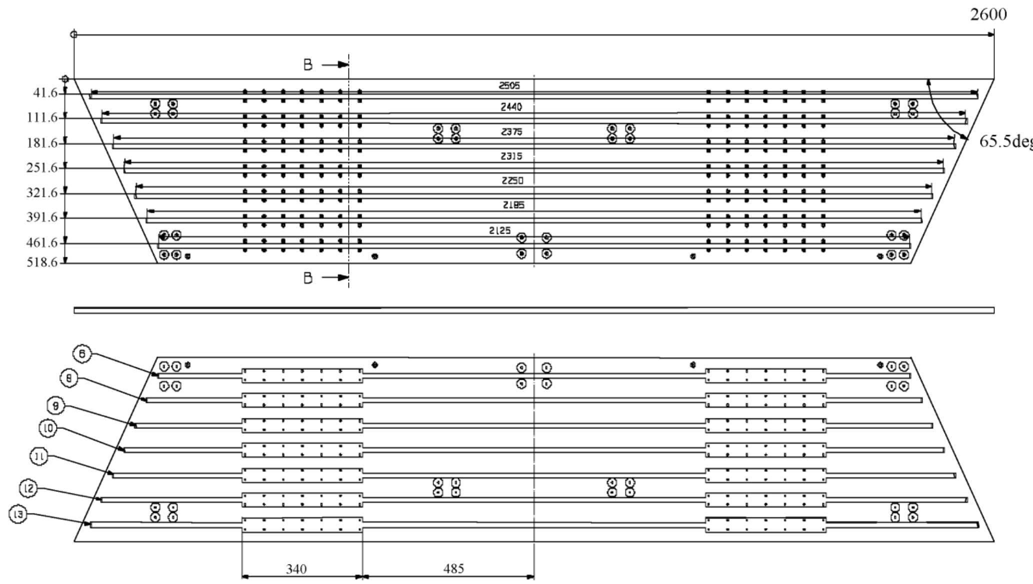
TCS Heat Pipe Profile – Axial Grooved



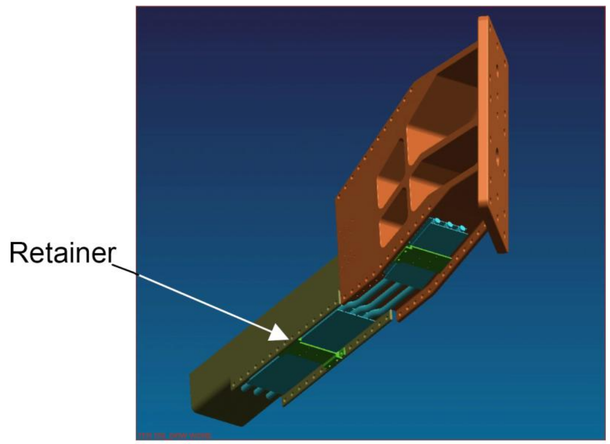
Tracker TCS Radiator

Tracker
Heat
Pipe

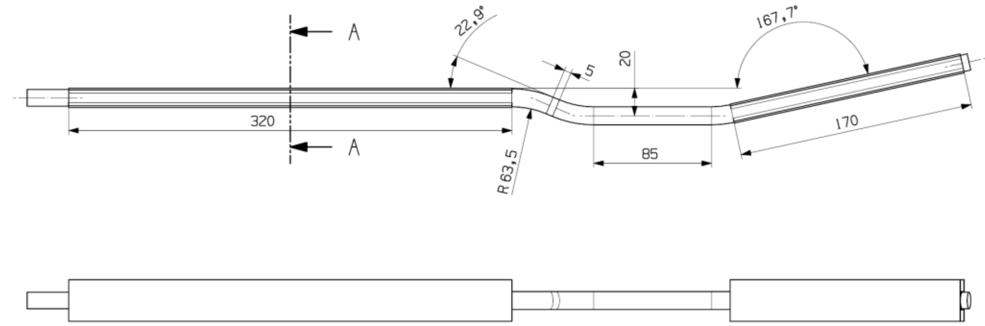




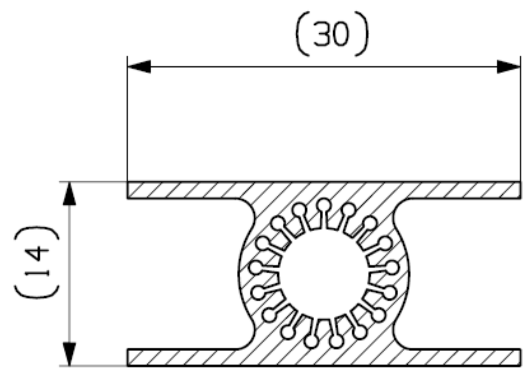
Tracker TCS Layout



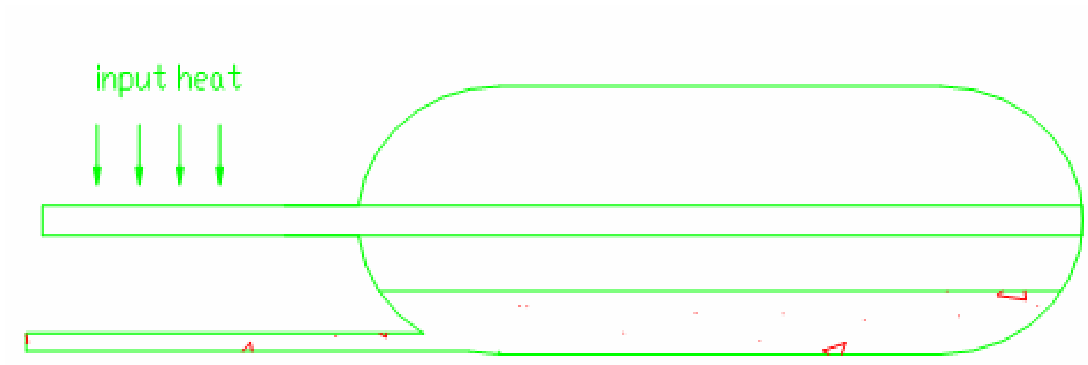
USS Heat Pipes on USS-02



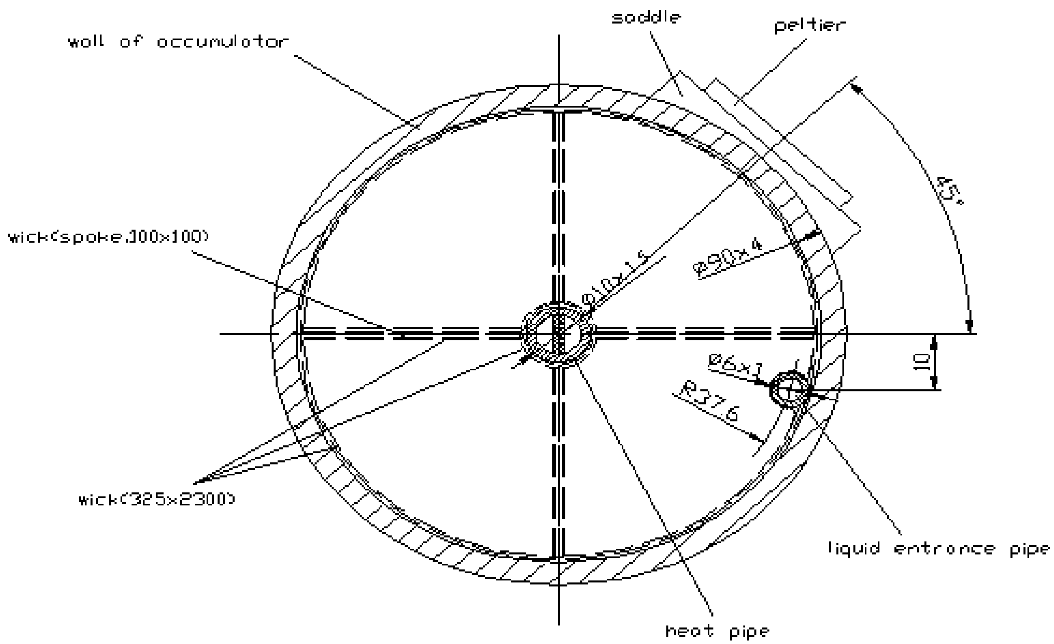
USS Heat Pipe Construction (mm)



USS Heat Pipe Cross section, (mm)



TTCS Accumulator Heat Pipe Cross Section



TTCS Accumulator Heat Pipe Cross Section

Engineering & Science Contract GROUP

ENGINEERING MEMORANDUM

Title: AMS-02 Preliminary Flammability Assessment for Phase II Safety Data Package (SDP)			**EM Number:** ESCG-4480-05-MAAN-MEMO-0083
Author: Timothy J. Schniepp (ESCG)	**Concurrence:** Nick Martinez (ESCG)	**Concurrence:**	**Approver:** John Knesek (ESCG)

PURPOSE

This memo will serve as the AMS-02 Preliminary Flammability Assessment and demonstrates compliance with the requirements of Section 7.4.2 of NSTS/ISS 13830 (Payload Safety Review and Data Submittal Requirements).

ASSESSMENT

To date, the preliminary assessment has included the following analyses:

1) A preliminary flammability assessment was performed per the requirements of JSC 29353 (formerly NSTS 22648), Flammability Configuration Analysis for Spacecraft Applications.
2) A Materials Usage and Identification List (MIUL) has been compiled with preliminary Declared Materials Lists from AMS-02 sub-system groups. Materials documented in the MIUL have been reviewed for compliance with the requirements of JSC 27301, Materials Control Plan for JSC Flight Hardware, and NSTS 1700.7B, Safety Policy and Requirements for Payloads Using the Space Transportation System. Those materials not listed in the Materials and Processes Technology Information System (MAPTIS) and MSFC-HDBK-527F/JSC 09604 (Materials Selection List for Space Hardware Systems) as being "A" rated in their use environment shall require a Materials Usage Agreement (MUA).
3) An analysis of flammable gases in the payload bay was performed using NASA Materials Branch Memo ES5-91-289, Flammable Gases in the Payload Bay, as a guide. Potentially flammable gases utilized in AMS-02 included in this analysis included ammonia, propylene, and nitrous oxide coolants.

RESULTS

The results of each of the three aforementioned analyses are as follows:

1) A flammability assessment per JSC 29353 for AMS-02 experiment hardware was completed based on preliminary data submittals from the AMS-02 sub-system groups and found the hardware to be acceptable.
2) A list of materials/components that potentially require an MUA for flammability based on preliminary information has been compiled and may be seen in Table I. A request for additional information has been sent to each responsible sub-system to clarify the usage and acceptance rationale of the listed material/component.
3) All three AMS-02 coolants were found to be acceptable in the Shuttle Payload Bay based on declared material quantities and the projected free volume fraction for Shuttle at launch.

Subsystem	Component	Material
Cryomag	Helium Vessel Insulation	Cryocoat UL79 Epoxy
ACC	Scintillator	BC-414 Polystyrene
ACC	WL-Shifter Fiber	Kuraray Y-11 fiber
ACC	Clear Fiber	BCF-98 Polystyrene
ACC	Optical Cement	BC600 Epoxy
ACC	Venting Plug, PMT Housing	S90 Polyurethane foam
TTCS	Core Insulation	Scotchcast 5555 Epoxy Powder
TTCS	Lacing Tape	"Super Gude-Space PT"
TTCS	Encapsulant	IM-436 Epoxy
TTCS	Conformal Coating	Humiseal 2-A64 Polyurethane
TTCS	Shrink Tubing	Polyolefin
TTCS	Lacing Tape	Nylon

Note: Cryomag = Cryomagnet subsystem hardware
ACC = Ani-Coincidence Counter subsystem hardware
TTCS = AMS Tracker Thermal Control System subsystem hardware

Table I. Potential MUA List for Flammability for AMS-02 Experiment Hardware

CONCLUSIONS

Based on preliminary information and data provided by AMS-02 experiment hardware sub-system groups, the flammability assessment per JSC 29353 for the Phase II SDP shows the hardware to be acceptable. However, it should be clearly understood that all analyses are preliminary. A complete and final analysis will not be possible until final materials information and lists have been provided by all sub-system groups. Final analysis and hardware certification is required and will be completed as part of the Phase III SDP. To date, the potential need for flammability MUAs has been identified for 12 AMS-02 components. All coolant materials used for AMS-02 that could produce a flammable gas hazard in the Shuttle Payload Bay have been found to be acceptable in the known quantities and Payload Bay free volume fraction.

REFERENCES

-NSTS/ISS 13830 Payload Safety Review and Data Submittal Requirements
-JSC 29353 Flammability Configuration Analysis for Spacecraft Applications
-JSC 27301 Materials Control Plan for JSC Flight Hardware
-NSTS 1700.7B Safety Policy and Requirements for Payloads Using the Space Transportation System
-MSFC-HDBK-527F/JSC 09604 Materials Selection List for Space Hardware Systems
-MAPTIS database Materials and Processes Technology Information System
-ES5-91-289 Flammable Gases in the Payload Bay

Engineering and Science Contract Group

2224 Bay Area Boulevard
Houston, Texas 77058

ENGINEERING & SCIENCE CONTRACT GROUP
JACOBS
ERC | Barrios | GeoControl | Hamilton Sundstrand | MEI

ESCG Memo Number: ESCG-4480-09-MAAN-MEMO-0039
Date: September 22, 2009

TO: J. C. Tutt/ESCG

FROM: C. Chang/ESCG

SUBJECT: Flammability Assessment of Flammable Gases in Orbiter Payload Bay for AMS-02 Phase III Safety Data Package (SDP)

PURPOSE
Propylene used in the Zenith Radiator/Cryocooler loop heat pipes and anhydrous ammonia used in various AMS-02 heat pipes and loop heat pipes are flammable. Leakage of these flammable gases in the Payload Bay could be a fire safety hazard and needs to be addressed. This memorandum provides a flammability assessment of flammable gas leakage of AMS-02 payload in Orbiter Payload Bay.

ASSESSMENT
The flammable range of a gas is defined as the range of concentration of a gas that will burn in air if an ignition source is introduced. Below the flammable range the gas mixture is too lean to burn and above the upper flammable limit the gas mixture is too rich to burn. The limits are called the Lower Flammability Limit (LFL) and the Upper Flammability Limit (UFL). The equation using the Lower Flammability Limit (LFL) of gas to calculate the minimum amount of gas required to produce a flammable mixture in a given volume is given as:

$$W_i = 27.05 * LFL * V_{frac} * MW \qquad (1)$$

Where:
W_i = weight of gas to produce a flammable mixture in lbs
LFL = lower flammability limit of gas
MW = molecular weight of the gas in g/mole
V_{frac} = fraction of free volume in the payload bay

This equation referenced in JSC Materials Branch Memo ES5-91-229 will be used for the analysis of flammable gases in the Payload Bay.

The total amounts of flammable gases used in AMS-02 thermal control system are 1377.8 g (3.03 lbs) of ammonia and 430.6 g (0.95 lb) of propylene. Three worst leakage scenarios of these flammable gases are considered.

1st leakage scenario (ammonia leakage only):
The ammonia gas properties were obtained from Air Liquide Gas Encyclopaedia. Ammonia's molecular weight is 17.03 g/mole, its LFL is 15%, and its specific volume at 14.7 psi and 70 F is 1.411 m^3/kg. The plot of the weight of ammonia required to achieve a flammable mixture as a function of the fraction of free volume in the payload bay is shown in Figure 1, Attachment 1. The critical fraction free volume is 0.044 as shown in the plot. The estimated fraction of free volume is 0.38 in the Orbiter payload bay for STS-134. Since ammonia has more free volume to dilute, the resultant gas mixture (ammonia and air) falls in the non-flammable mixture region. The leakage of ammonia in the payload bay will not support a fire.

2nd leakage scenario (propylene leakage only):
The propylene gas properties were obtained from Air Liquide Gas Encyclopaedia. Propylene gas molecular weight is 42.08 g/mole, its LFL is 2%, and its specific volume at 14.7 psi and 70F is 0.587 m^3/kg. The plot of the weight of propylene required to achieve a flammable mixture as a function of the fraction of free volume in the payload bay is shown in Figure 2, Attachment 1. The critical fraction free volume is 0.042 as shown in the plot. The estimated fraction of free volume is 0.38 in the Orbiter payload bay for STS-134. Since propylene gas has more free volume to dilute, the resultant gas mixture (propylene and air) falls in the non-flammable mixture region. The leakage of propylene gas in the payload bay will not support a fire.

3rd leakage scenario (ammonia and propylene leakage):
It is acceptable to assume ammonia, propylene, and air gas molecules as ideal gases. One can consider the mixture of ammonia and propylene an ideal gas mixture. For a gas mixture, equation 1 becomes:

$$W_i = 27.05 * MLFL * V_{frac} * MW_a \qquad (2)$$

Where:
W_i = weight of gas to produce a flammable mixture in lbs
MLFL = lower flammability limit of gas mixture
MW_a = apparent molecular weight of the gas mixture in g/mole
V_{frac} = fraction of free volume in the payload bay

The lower flammability limit of gas mixture can be calculated by LeChatelier's rule:

MLFL = 100/ ($\sum$ (C_i / LFL_i)

Where:
MLFL = lower flammability limit of gas mixture, vol %
C_i = volume fraction of component i in gas mixture on an air-free basis, vol %
LFL_i = lower flammability limit of component I in gas mixture, vol %

For the gas mixture of 3.03 lbs of ammonia and 0.56 lb of propylene, the volume fraction of ammonia is calculated to be 0.78 and the volume fraction of propylene is 0.22. The lower flammability limit of ammonia-propylene gas mixture is calculated to be 6.17%.

The apparent molecular weight of ammonia-propylene mixture is defined as:

MWa = $\sum y_i M_i$

Where:
MWa = apparent molecular weight of gas mixture
y_i = mole fraction of gas component i
M_i = molecular weight of gas component i

For ideal gas mixture, the mole fraction, the pressure fraction, and the volume fraction of a component are identical. The apparent molecular weight of ammonia-propylene mixture is calculated to be:

MWa = 0.78 (17.03 g/mole) + 0.22 (42.08 g/mole) = 22.54 g/mole

Using equation 2, the apparent molecular weight of 22.54 g/mole, and the lower flammability limit of ammonia-propylene mixture, the weight of ammonia-propylene mixture required to achieve a flammable mixture as a function of the fraction of free volume in the payload bay is plotted in Figure 3, Attachment 1. The critical fraction free volume for the ammonia-propylene mixture is 0.106. The estimated fraction of free volume is 0.38 in the Orbiter payload bay for STS-134. Since propylene gas has more free volume to dilute, the resultant gas mixture (ammonia-propylene and air) falls in the non-flammable mixture region. The leakage of ammonia and propylene gases in the payload bay will not support a fire.

DISCUSSION:
This flammability analysis assumes full mixing of the flammable gases with the air in the Payload Bay. Even though full mixing does not result in a flammable environment, transient localized flammable areas may exist in the vicinity of a relatively rapid leak. The transient localized leakage of flammable gases is not likely to occur because each heat pipe and loop heat pipe are qualified for pressurized components and designed for minimum risk.

The transient localized leakage is not considered in this analysis because such leakage is small and the ignition sources are minimized and controlled in the Payload Bay.

CONCLUSION:
Leakage of the total quantities of ammonia and propylene of AMS-02 payload in the Orbiter payload bay will not present a fire hazard for STS-134.

REFERENCES
1. JSC Materials Branch Memo ES5-91-229, Flammable Gases in the Payload Bay
2. Air Liquide Gas Encyclopaedia
3. Calculation of Flash Points and Flammability Limits of Substances and Mixtures
4. ESCG Memo ESCG-4470-09-TEAN-DOC-0121, AMS-02 Heat Pipes and Loop Heat Pipes Fluid Fill Quantities

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Attachment 1

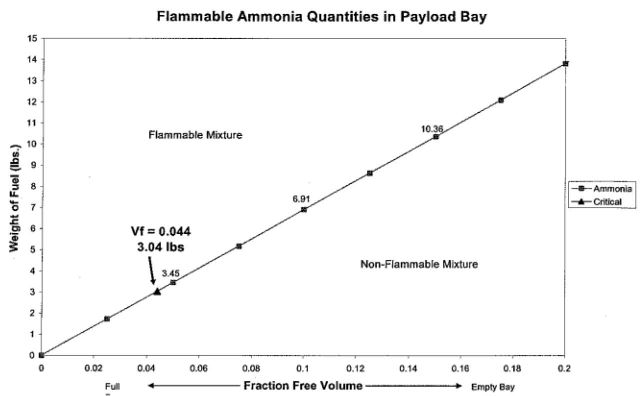


Figure 1: Plot of weight of ammonia required to achieve a flammable mixture as a function of fraction of free volume in Orbiter payload bay

Attachment 1 (Cont.)

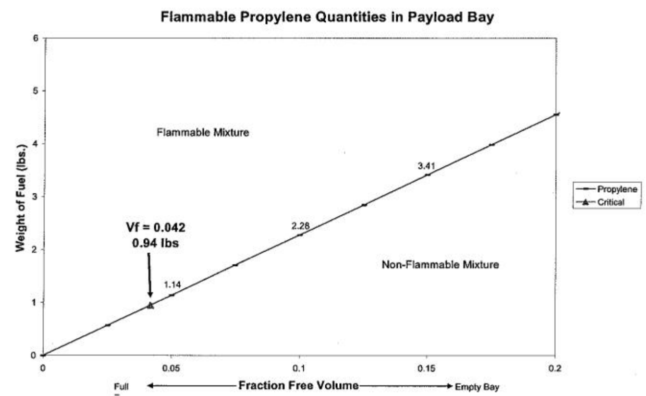


Figure 2: Plot of weight of Propylene required to achieve a flammable mixture as a function of fraction of free volume in Orbiter payload bay

Attachment 1 (Cont.)

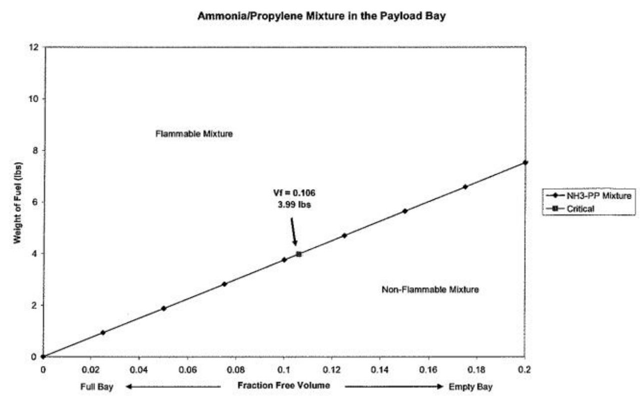


Figure 3: Plot of weight of ammonia-propylene required to achieve a flammable mixture as a function of fraction of free volume in Orbiter payload bay

PAYLOAD FLIGHT HAZARD REPORT		a. NO:	AMS-02-F11
b. PAYLOAD	Alpha Magnetic Spectrometer-02 (AMS-02)	c. PHASE:	III
d. SUBSYSTEM: Structural, Mechanical	e. HAZARD GROUP: Impact, Collision	f. DATE:	August 4, 2010
g. HAZARD TITLE:	Mechanism Failure	i. HAZARD CATEGORY:	CATASTROPHIC **X** CRITICAL **X**
h. APPLICABLE SAFETY REQUIREMENTS:	NSTS 1700.7B and ISS Addendum, 200.1b, 200.2, 200.3		
j. DESCRIPTION OF HAZARD:	Failure of these mechanisms could place the AMS-02 in conditions that pose a risk of inadequate structural load conditions or damage to vehicle systems. The AMS-02 is complying with ICD requirements for Shuttle and ISS interfaces and is subject to integrated hazard analyses performed by the applicable Programs.		
k. CAUSES *(list)*	1. Inability to Open/Close Orbiter Payload Retention Latch Assembly (PRLA)/ Keel Latch. 2. Inability to Operate the ROEU. (Critical Only) 3. Improper Installation of Grapple Fixtures. 4. Inability to fully capture/release the Payload Attach System, including the UMA. 5. Inadvertent release of Payload Attach System EVA Release Mechanism. 6. Inability to Secure ROEU Support Structure.		

o. APPROVAL	PAYLOAD ORGANIZATION	SSP/ISS
PHASE I		
PHASE II		
PHASE III		

PAYLOAD FLIGHT HAZARD REPORT	a. NO: AMS-02-F11
b. PAYLOAD Alpha Magnetic Spectrometer-02 (AMS-02)	c. PHASE: III

l. HAZARD CONTROL (CONTROL), m. SAFETY VERIFICATION METHODS (SVM), n. STATUS OF VERIFICATIONS (STATUS)	OPS CONTROL
1. CAUSE: Inability to Open/Close Orbiter Payload Retention Latch Assembly (PRLA).	
1.1 CONTROL: The AMS-02 interface to the PRLAs, the Trunnions, Scuff Plates and keel pin are constructed and installed in accordance with NSTS 21000-IDD-ISS. Trunnions and keel pin are constructed of custom 455 stainless steel and the scuff plates are constructed of aluminum 7050. Integrated hazard analysis to be performed by Shuttle Program to establish fault tolerance of integrated cargo to establish secured PRLA conditions for a contingency return or assure that a complete release of the AMS-02. 1.1.1 SVM: Review of design 1.1.2 SVM: Inspection of as built hardware 1.1.3 SVM: AMS-02 Installation into Orbiter 1.1.1 STATUS: Closed. Memorandum ESCG-4390-06-SP-MEMO-0008, "USS-02 Trunnion Interfaces," dated 13 March 2006, AMS-02 Chief Engineer Chris Tutt. 1.1.2 STATUS: Closed to SVTL. 1.1.3 STATUS: Closed to SVTL.	
1.2 CONTROL: In the event that one or more Orbiter PRLA is unable to open during the AMS-02 deploy sequence, the AMS-02 is designed to be compatible with an unscheduled EVA to open/close the PRLAs. AMS-02 hazard report AMS-02-F14 indicates the constraints to EVA activities; none of these no touch areas/keep out zones will impact the ability of the crew to access the PRLAs for EVA operations. The unscheduled EVA to open/close PRLA is a standardized EVA operation for the Shuttle, no unique operations are required for the AMS-02. 1.2.1 SVM: Review of design. 1.2.2 SVM: Inspection of as built hardware. 1.2.1 STATUS: Closed. ESCG Memorandum 4295-09-CPAS-MEMO-0006, “AMS-02 EVA Access,” dated October 8, 2009. 1.2.2 STATUS: Closed to SVTL.	
1.3 CONTROL: The AMS-02 is safe to return only with all PRLAs and the Active Keel (latch) Assembly closed. 1.3.1 SVM: Structural Analysis to confirm safe return configuration of PRLA and KEEL latches.	S

PAYLOAD FLIGHT HAZARD REPORT	a. NO: AMS-02-F11
b. PAYLOAD Alpha Magnetic Spectrometer-02 (AMS-02)	c. PHASE: III

1.3.2 SVM: Formal acceptance of safety criteria for safety return configuration by MOD by way of OCAD acceptance. (OCAD 67866) 1.3.1 STATUS: Closed. ESCG-4005-05-AMS-0039, "Strength and Stability Assessment of the Alpha Magnetic Spectrometer-02 (AMS-02) Unique Support Structure (USS-02), Vacuum Case, Payload Attach System (PAS), and STS and ISS Integration Hardware," August 12, 2009 1.3.2 STATUS: Closed. OCAD Closure reported to AMS-02 Project on 6/4/2010 by JSC-DA8/B. O'Keeffe.	
NOTE: Nominal generic flight rules for PRLA/AKA operations (A10-281) are all applicable for the AMS-02.	
2. CAUSE: Inability to Operate the ROEU. (Critical Only)	
2.1 CONTROL: In the event that the ROEU fails to separate, the AMS-02 can provide access and all required EVA interfaces to support an unscheduled EVA to access the ROEU EVA interfaces to either disengage or reengage the ROEU. 2.1.1 SVM: Review of Design. 2.1.2 SVM: Inspection of as built hardware. 2.1.1 STATUS: Closed. ESCG Memorandum 4295-09-CPAS-MEMO-0006, "AMS-02 EVA Access," dated October 8, 2009. 2.1.2 STATUS: Closed to SVTL.	
2.2 CONTROL: The inability to reattach the ROEU will not create a scenario where a hazardous condition will exist for the AMS-02 or the Orbiter, however there is a damage potential for AMS-02 scientific hardware that will preclude its reuse (Mission Success Only). If possible the use of an unscheduled EVA to reattach the ROEU is encouraged, but not required. 2.2.1 SVM: Review of design to confirm no safety impact to loss of power and communication for return configuration. 2.2.1 STATUS: Closed. ESCG Memorandum ESCG-4175-09-REENTES-MEMO-0022, "AMS-02 Potential Abort Landing Configurations," dated April 28, 2009	
2.3 CONTROL: The design and installation of the AMS-02 passive half of the ROEU is compatible with the requirements of NSTS 21000-IDD-ISS for interface, alignment, strength and deflection. 2.3.1 SVM: Review of design. 2.3.2 SVM: Inspection of as built hardware.	

2.3.3 SVM: Structural Analysis.

2.3.1 STATUS: Closed. ESCG Memorandum ESCG-4175-09-REENTES-MEMO-0019, "Review of the AMS-02 ROEU Bracket Design," Dated April 24, 2009

2.3.2 STATUS: Closed to SVTL.

2.3.3 STATUS: Closed. ESCG-4005-05-AMS-0039, "Strength and Stability Assessment of the Alpha Magnetic Spectrometer-02 (AMS-02) Unique Support Structure (USS-02), Vacuum Case, Payload Attach System (PAS), and STS and ISS Integration Hardware," August 12, 2009

3. CAUSE: Improper Installation of Grapple Fixtures.

3.1 CONTROL: Grapple fixtures are located and mounted in accordance with NSTS 21000-IDD-ISS and SSP 57003 for clearances, mass, CG offset and visibility. Grapple fixture locations have been selected to facilitate the exchange of the AMS-02 between SRMS and SSRMS and SSRMS berthing activities.

3.1.1 SVM: Review of design.

3.1.2 SVM: Inspection of as-built hardware.

3.1.1 STATUS: Closed. ESCG Memorandum ESCG-4175-REENTES-09-MEMO-0023, "Review of AMS-02 FRGF and PVGF Bracket Design," dated April 28, 2009

3.1.2 STATUS: Closed to SVTL.

4. CAUSE: Inability to fully capture/release the Payload Attach System, including the UMA.

4.1 CONTROL: The AMS-02 passive half of the Payload Attach System (PAS), including the UMA interface has been built to comply with the requirement of SSP57213 (AMS-02 to ISS ICD) and through the ICD, SSP 57003 and SSP 57004. NOTE: The AMS-02 is unable to control operations or design of the ISS side of the interface and this must be covered in an integrated ISS hazard report. It is understood that the active PAS with regards to inadvertent release of the ISS mechanism is established by the ISS to be equivalent to a two fault tolerant event.

4.1.1 SVM: Review of design.

4.1.2 SVM: Inspection of as-built hardware.

4.1.3 SVM: AMS-02 PAS interface testing between flight Passive (AMS-02) and flight Active (ISS) components.

4.1.4 SVM: UMA electrical connectors verified to be mechanically and electrically compatible across the UMA

PAYLOAD FLIGHT HAZARD REPORT	a. NO: AMS-02-F11
b. PAYLOAD Alpha Magnetic Spectrometer-02 (AMS-02)	c. PHASE: III

interface.

4.1.5 SVM: AMS-02 will be tested prior to installation into the Orbiter on the Active Common Attach System Simulator (ACASS) to confirm proper mating and interface.

4.1.1 STATUS: Closed. Memo ESCG-4390-06-SP-MEMO-0001, "Mechanical Design of the Payload Attach System (PAS)", Dated 8 January, 2006 from AMS-02 Chief Engineer.

4.1.2 STATUS: Closed. Memo ESCG-4390-06-SP-MEMO-0003, "Quality Inspection of the Payload Attach System" dated 03 March 2006, from AMS-02 Chief Engineer Chris Tutt.

4.1.3 STATUS: Closed. On March 10-11, 2003, PAS was placed in position on S3 truss (flight) and capture claw was fully closed and reopened three times. All mechanical interfaces operated successfully. Closure Reference Memorandum ESCG-4390-05-SP-MEMO-0012, "Functional Testing of the Payload Attach System (PAS)", dated 28 December 2005 from AMS-02 Chief Engineer Chris Tutt.

4.1.4 STATUS: Closed to SVTL. 4.1.5 STATUS: Closed to SVTL.

4.2 CONTROL: The AMS-02 passive interface to the Payload Attach System includes an EVA release mechanism capable of releasing the stored energy of the maximum preload of 6430 lbs and removing the capture bar to release the AMS-02 from the ISS. EVA operated, screw driven ramps release the preload created by the capture of the Passive PAS capture bar. Once the loads are released, an EVA release bar allows for the extraction of the capture bar from the Active PAS.

4.2.1 SVM: Review of Design.

4.2.2 SVM: Inspection of as-built hardware.

4.2.3 SVM: Functional testing of the EVA Release mechanism.

4.2.1 STATUS: Closed. Memo ESCG-4390-06-SP-MEMO-0001, "Mechanical Design of the Payload Attach System (PAS)", Dated 8 January, 2006 from AMS-02 Chief Engineer.

4.2.2 STATUS: Closed. Memo ESCG-4390-06-SP-MEMO-0003, "Quality Inspection of the Payload Attach System" dated 03 March 2006, from AMS-02 Chief Engineer Chris Tutt.

4.2.3 STATUS: Closed. On February 12-14, 2003, the PAS capture bar release mechanism was successfully used to release the loaded PAS as part of the general PAS qualification testing. On March 10-11, 2003, the PAS was placed in position on S3 truss (flight) with the capture claw fully closed and the capture bar mechanism was also successfully used to release the loaded PAS. Closure Reference Memorandum ESCG-4390-05-SP-MEMO-0012, "Functional Testing of the Payload Attach System (PAS)", dated 28 December 2005 from AMS-02 Chief Engineer

PAYLOAD FLIGHT HAZARD REPORT	a. NO: AMS-02-F11
b. PAYLOAD Alpha Magnetic Spectrometer-02 (AMS-02)	c. PHASE: III

Chris Tutt.

4.3 CONTROL: To assure that the appropriate preload is present when the AMS-02 is interfaced with the active PAS, a travel limiting screw is adjusted prior to flight to provide the appropriate placement of the capture bar, utilizing the 10° ramp to raise and lower the capture bar. When positioned correctly the capture position of the latch and the required displacement of the bar generated the preload. This travel limiter (with two forms of backout prevention (locking nut and locking insert with preload torque) allows for the EVA crew to readily replace the capture bar once it is removed and make the passive PAS of the AMS-02 capable of being installed in a functioning active PAS. Reinstallation of the mechanism is the reversal of the removal process with the restoration/reinsertion of the capture bar and handle then reversing the EVA bolt rotation using the release bolt turn counts to establish the appropriate number of rotations to drive to hardstops (driving to hardstops, if past the original counts is preferred cessation point).

I

4.3.1 SVM: Review of Design

4.3.2 SVM: Inspection of as built hardware. (MIP)

4.3.3 SVM: Functional testing of preload set travel limiter.

4.3.4 SVM: Final setting/check of preload position of latching bar.

4.3.5 SVM: Acceptance of OCAD by MOD (OCAD 67868)

4.3.6 SVM: EVA IPT acceptance of SSCN 1819 EVA Fastener and Threaded Insert Data

4.3.1 STATUS: Closed. Memo ESCG-4390-06-SP-MEMO-0001, “Mechanical Design of the Payload Attach System (PAS)”, Dated 8 January, 2006 from AMS-02 Chief Engineer.

4.3.2 STATUS: Closed. Memo ESCG-4390-06-SP-MEMO-0003, “Quality Inspection of the Payload Attach System” dated 03 March 2006, from AMS-02 Chief Engineer Chris Tutt.

4.3.3 STATUS: Closed. During integration testing with S3 Truss February 12-14, 2003 and March 10-11, 2003 travel limiters were confirmed. Closure Reference Memorandum ESCG-4390-05-SP-MEMO-0012, “Functional Testing of the Payload Attach System (PAS)”, dated 28 December 2005.

4.3.4 STATUS: Closed. JSC DR 2A0830036, Closed August 21, 2008

4.3.5 STATUS: Closed to SVTL

4.3.6 STATUS: Closed. Email confirmation of acceptance of submitted bolt data by MOD and EVA IPT provided by XO/M. Tullar, July 16 2010.

PAYLOAD FLIGHT HAZARD REPORT	a. NO: AMS-02-F11
b. PAYLOAD Alpha Magnetic Spectrometer-02 (AMS-02)	c. PHASE: III

5. CAUSE: Inadvertent release of Payload Attach System EVA Release Mechanism.

5.1 CONTROL: To release the AMS-02 from the ISS PAS the EVA Releasable Capture Bar must be withdrawn from the latched PAS mechanism, the AMS-02 is two fault tolerant to inadvertent release of the AMS-02 by way of the AMS-02 PAS mechanism. Once latched, the preload generated by the capture event and the design of the AMS-02 is 5650 lbs nominal/6430 lbs maximum to prevent gapping of the AMS-02. To relieve this load, two independent load relief devices must be operated to drive apart two wedges. The sliding of these wedges apart releases the energy of the interface and lowers the guides through which the capture bar runs. The capture bar cannot be extracted due to interference with the alignment brackets that lock the capture bar in place until the bar is lowered by each of the load relief devices. Each EVA Load Release Screws have a separate spring operated lock to preclude the 7/16th inch EVA bolt head from turning until depressed by the EVA tool. NOTE: The AMS-02 is unable to control operations or design of the ISS side of the interface and this must be covered in an integrated ISS hazard report. It is understood that the active PAS with regards to inadvertent release of the ISS mechanism is established by the ISS to be equivalent to a single fault tolerant event.

Thus to release the AMS-02 from the PAS by AMS-02 fault, the following must occur:

- Failure of first EVA Load Release Screw locking mechanism
- Fault operation of first EVA Load Release Screw and wedges to release the 5650 lb (nominal) preload and lower the guides
- Failure of second EVA Load Release Screw locking mechanism
- Fault operation of second EVA Load Release Screw and wedges to release the 5650 lb (nominal) preload and lower the guides
- Fault extraction of the EVA Releasable Capture Bar from PAS latch.

5.1.1 SVM: Review of Design.

5.1.2 SVM: Inspection of as built hardware.

5.1.3 SVM: Functional testing of EVA Release Mechanism,

5.1.4 SVM: Final setting/check of Load Release Screw Locking Mechanism.

5.1.1 STATUS: Closed. Memo ESCG-4390-06-SP-MEMO-0001, “Mechanical Design of the Payload Attach System (PAS)”, Dated 8 January, 2006 from AMS-02 Chief Engineer.

PAYLOAD FLIGHT HAZARD REPORT	a. NO: AMS-02-F11
b. PAYLOAD Alpha Magnetic Spectrometer-02 (AMS-02)	c. PHASE: III

5.1.2 STATUS: Closed. Memo ESCG-4390-06-SP-MEMO-0003, “Quality Inspection of the Payload Attach System” dated 03 March 2006, from AMS-02 Chief Engineer Chris Tutt.

5.1.3 STATUS: Closed. On February 12-14, 2003, the PAS capture bar release mechanism was successfully used to release the loaded PAS as part of the general PAS qualification testing. On March 10-11, 2003, the PAS was placed in position on S3 truss (flight) with the capture claw fully closed and the capture bar mechanism was also successfully used to release the loaded PAS. Closure Reference Memorandum ESCG-4390-05-SP-MEMO-0012, “Functional Testing of the Payload Attach System (PAS)”, dated 28 December 2005 from AMS-02 Chief Engineer Chris Tutt.

5.1.4 STATUS: Closed to SVTL.

5.2 CONTROL: <DELETED> — I

5.3 CONTROL: `The Capture Bar is design to preclude a complete release of the bar by a physical interference to complete extraction from the support structure.

5.3.1 SVM: Review of design.

5.3.2 SVM: Inspection of as built hardware.

5.3.1 STATUS: Closed. Memo ESCG-4390-06-SP-MEMO-0001, “Mechanical Design of the Payload Attach System (PAS)”, Dated 8 January, 2006 from AMS-02 Chief Engineer.

5.3.2 STATUS: Closed. Memo ESCG-4390-06-SP-MEMO-0003, “Quality Inspection of the Payload Attach System” dated 03 March 2006, from AMS-02 Chief Engineer Chris Tutt.

5.4 CONTROL: The AMS-02 will maintain the SSP 57003 required stiffness of the AMS-02 to ISS interface by accurately positioning the AMS-02 PAS Capture Bar during ground processing prior to flight. Preflight testing has established the proper spring constant required to exceed the required stiffness and the AMS-02 PAS is configured specifically to provide this stiffness capability. When the capture bar is lowered, this stiffness is reduced. The AMS-02 is equipped with anti-rotation devices to preclude the wedge drive screws from backing out. Although structurally isolated from significant vibrational and acoustic loading, the design of the anti-rotation device was analyzed to establish its sensitivity to directly applied random vibrational loads. The natural frequency of the anti-rotation device, based on the spring constant of the design, is 36.6 Hz. The design of the anti-rotation device requires a compressive force of 4.88 lbs. A maximum acceleration of the induced random vibrations at 36.6 Hz generates a acceleration of 4.79g, resulting in an applied force of 0.63 lbs to the anti-rotation device. Using the maximum Power Spectral Density level anywhere (well outside what is possible for this equipment), the maximum applied force of 1.58 lb is calculated (again assuming direct application of the loads). This is a factor of three less than that required to depress the anti-rotation device even if the structure of the AMS-02 did not attenuate the transmission of these random loads to the mechanisms. A broken spring analysis has shown that the spring (with coil lost) is capable of providing sufficient force to retain the anti-rotation function making it equivalent of single fault tolerant)

NOTE: Given that the design of the anti-rotation device did not preclude the rotation, the drive screws have a measured minimum running torque of 3 in-lbs that would resist rotation and a minimum "break" torque of 5 in-lbs. Assuming that the anti-rotation devices can be overcome or experience failure, and the rotation of the drive shafts were to occur, to lose the preload of the AMS-02 passive PAS to the ISS active PAS, the shafts driving the wedges that support the capture bar must rotate through a minimum of 12.7 rotations. Given that the exposure to a vibration load (again ignoring the attenuation of the AMS-02 structure that essentially makes the forces at the anti-rotation mechanism insignificant) lasts for approximately 20 seconds, the statistical probability to rotate the shafts sufficiently during launch to reposition the capture bar to reduce the stiffness/preload to below the SSP 57003 allowable is 10^{38} to 1 against or 5.877×10^{-39} chance.

No mechanism for removal of the preload has been identified as credible for any other mission phase.

5.4.1 SVM: Preflight Inspection for proper configuration of preload mechanism.

5.4.2 SVM: Analysis of anti-rotation devices on EVA Release Mechanism of AMS-02 PAS.

5.4.3 SVM: Testing of EVA Release Mechanism for Breaking Torque and Running Torque.

5.4.4 SVM: Analysis of AMS-02 Preload to rotation of EVA Release Mechanism drives.

5.4.5 SVM: Approval of ISS Mechanism Working Group/Mechanical Systems Working Group.

5.4.6 SVM: Preflight Inspection of Anti-Rotation Devices to assure Anti-Rotation Device is properly engaged for launch.

5.4.7 SVM: Post testing inspection to assure anti-rotation device has not worn during any testing/operational uses.

5.4.8 SVM: Broken Spring Analysis.

5.4.1 STATUS: Closed to SVTL.

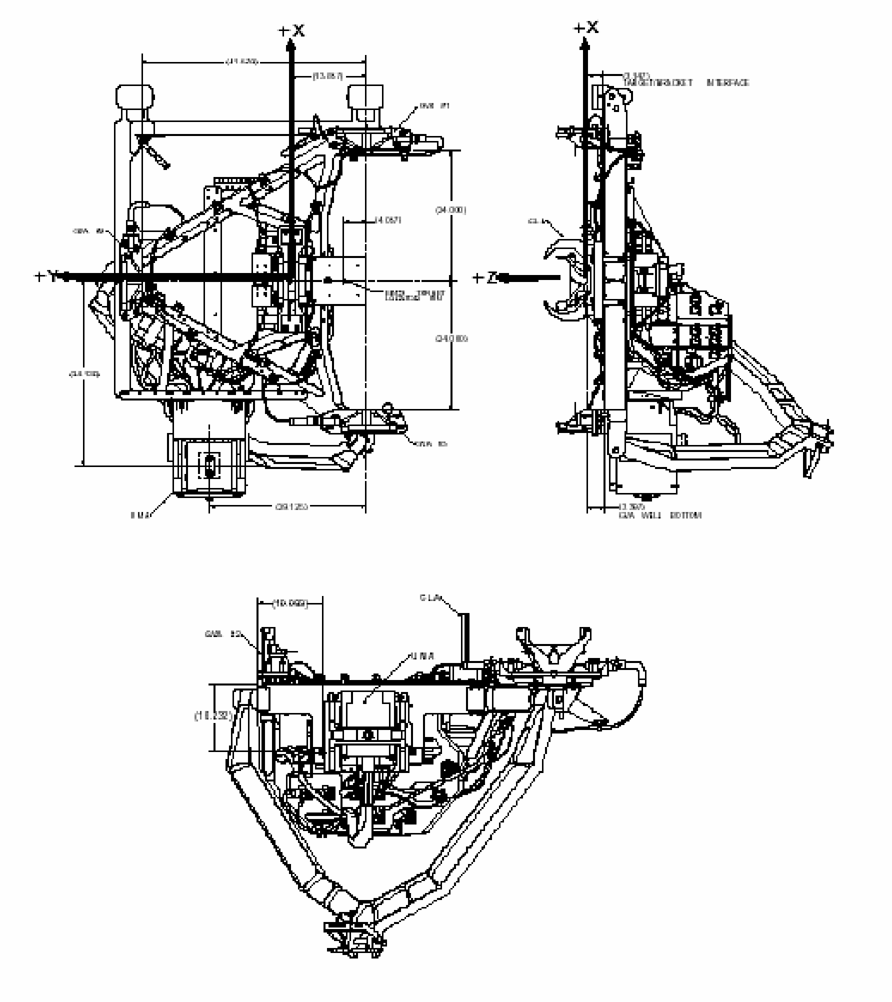
PAYLOAD FLIGHT HAZARD REPORT	a. NO: AMS-02-F11
b. PAYLOAD Alpha Magnetic Spectrometer-02 (AMS-02)	c. PHASE: III
5.4.2 STATUS: Closed. Memo ESCG-4390-06-SP-MEMO-0017, superseded by ESCG Memorandum ESCG-4390-07-SP-MEMO-0006, “Safety Analysis of the PAS Anti-Rotation Device,” dated August 8, 2007. 5.4.3 STATUS: Closed. TPS 2A0720243, Completed October 26, 2007 confirms breaking torque and running torque of the EVA release mechanism. 5.4.4 STATUS: Closed. ESCG Memo ESCG-4390-07-SP-MEMO-0006, “Safety Analysis of the PAS Anti-Rotation Device”, August 8, 2007 5.4.5 STATUS: Closed. Email Acceptance of AMS-02 AMS-02-F11 approach from JSC/ES5/S. Ross to JSC/EA3/T. Martin, et al, titled “AMS-02 Hazard Report 11” dated January 25, 2010. 5.4.6 STATUS: Closed to SVTL. 5.4.7 STATUS: Closed. JSC DR 2A0830036, Closed August 21, 2008 5.4.8 STATUS: Closed. ESCG Memo ESCG-4390-07-SP-MEMO-0006, “Safety Analysis of the PAS Anti-Rotation Device”, August 8, 2007	
Note: ISS requirements imposed on the AMS-02 and other external payloads to attach to the PAS only require that a means of EVA release from the PAS be provided, not that the release be multiply fault tolerant. The AMS-02 PAS EVA Release mechanism is designed to be zero-fault tolerant in its operation and not represent a multiple fault tolerant approach.	
6. CAUSE: Inability to Secure ROEU Support Structure.	
Note: The AMS-02 EVA operation to rotate the ROEU Support Structure to maximize the distance between the AMS-02 and the adjacent PAS payload envelope is a contingency operation that will only be performed if required by the specific installation of an adjacent payload or ISS External Logistics Carrier (ELC). With the redesigned ELC information, the ROEU on the AMS-02 is no longer a driving factor for clearances.	
6.1 CONTROL: The AMS-02 ROEU Support Structure had been designed to reduce the protrusion of the ROEU from the SSP 57003, 3.1.3.1.1.1 defined payload envelope. MAGIK Analysis of the extended (worst case protrusion) of the ROEU from the AMS-02 indicates that there is no longer an identified contact issue from the ROEU and the worst case displaced (translation and rotation) SSRMS installation of a full size payload next to the AMS-02. NOTE: As there is no residual issue with the proximity of the extended ROEU, the folding mechanism has been fixed with fasteners and is no longer EVA reconfigurable. 6.1.1 SVM: <deleted>	

PAYLOAD FLIGHT HAZARD REPORT	a. NO: AMS-02-F11
b. PAYLOAD Alpha Magnetic Spectrometer-02 (AMS-02)	c. PHASE: III
6.1.2 SVM: Installation testing of AMS-02 PAS interface on flight hardware confirming AMS-02 berthing accuracy and by extension, positional accuracy of the ROEU. 6.1.3 SVM: Geometric Analysis of Installation Process (MAGIK). 6.1.4 SVM: Inspection of as built hardware for AMS-02 Geometry compliance. 6.1.1 STATUS: <Deleted> 6.1.2 STATUS: Closed. Tests conducted February 12-14, 2003 and March 10-11, 2003. Test results are discussed in detail in ATA Reports 53013 and 53013A respectively. 6.1.3 STATUS: Closed. Published MAGIK Analysis Action Item #1705 Report dated May 12, 2003, Published MAGIK Analysis Action Item #2172 Revision A dated February 27, 2007 6.1.4 STATUS: Closed to SVTL.	
6.2 CONTROL: <Deleted>	
Notes:	

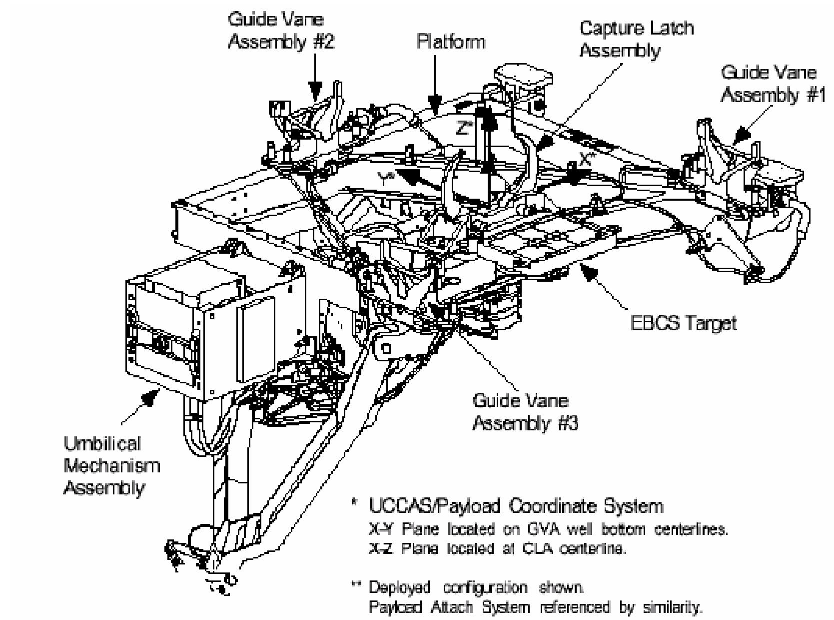
ACRONYMS	
ACASS – Active Common Attach Site Simulator	PAS – Payload Attach System, Payload Attach Site
AKA – Active Keel Assembly	PRLA – Payload Retention Latch Assembly
AMS-02 – Alpha Magnetic Spectrometer - 02	ROEU – Remotely Operated Electrical Umbilical
BCS – Berthing Camera System	SRMS – Shuttle Remote Manipulator System
DFMR – Design for Minimum Risk	SSRMS – Space Station Remote Manipulator System
ELC – External Logistics Carrier	SVM – Safety Verification Method
EVA – Extravehicular Activity	UMA – Umbilical Mating Assembly
MSWG – Mechanical Systems Working Group	

Mechanisms Associated With the AMS-02

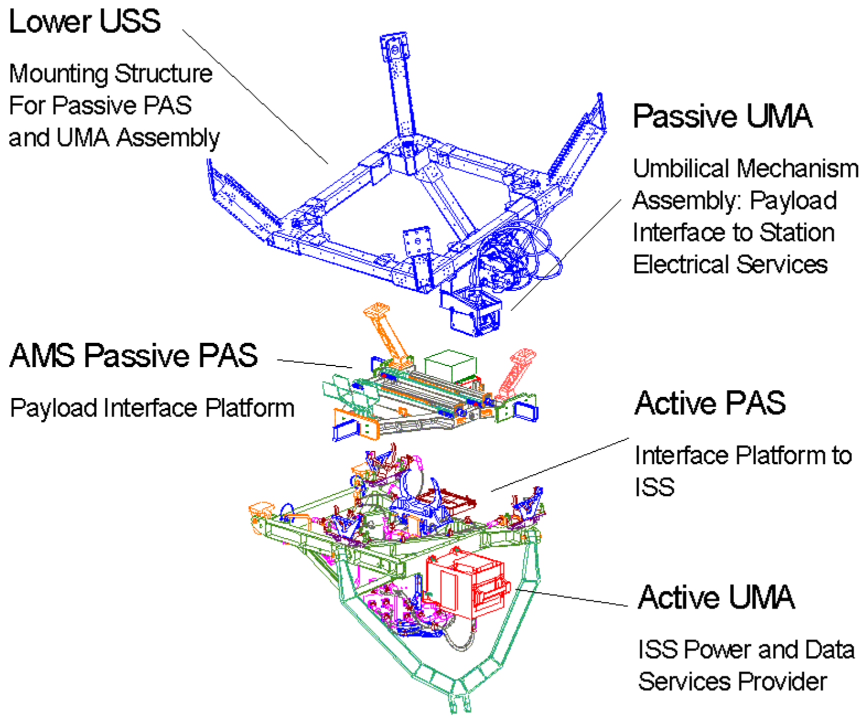
Mechanisms	Type	Operated by
Orbiter PRLA	GFE	Electrical/EVA
Orbiter Keel Latch	GFE	Electrical
Orbiter ROEU	GFE	Electrical/EVA
SRMS Grapple Fixture (FRGF)	GFE	Physical Interface to SRMS, EVA Release Capable
SSRMS Grapple Fixture (PVGF)	GFE	Physical Interface to SSRMS, EVA Release Capable
Active Payload Attach System	ISS System/GFE	Electrical
EVA Releasable Passive Payload Attach System	Payload Hardware	Passive interface to ISS. EVA interfaces (two preload relief interfaces and Capture Bar retraction)
UMA Interface	GFE	Electrical, EVA



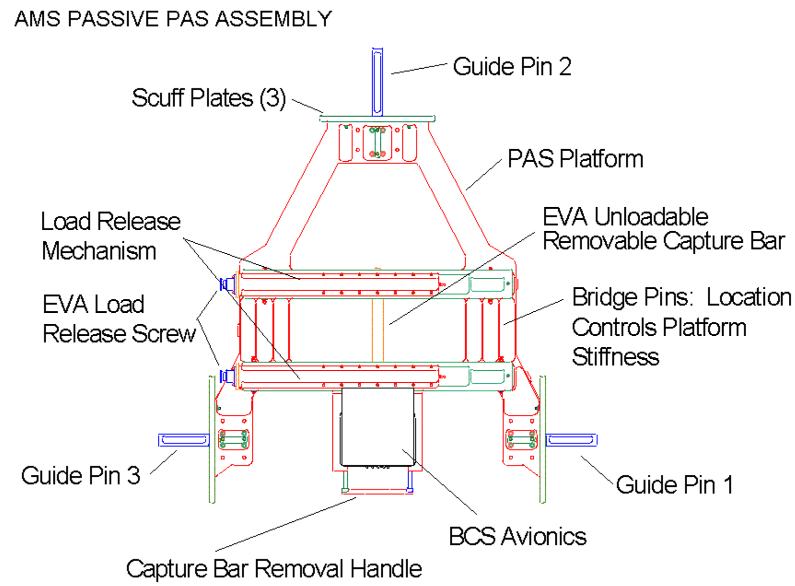
ISS Payload Attach Site



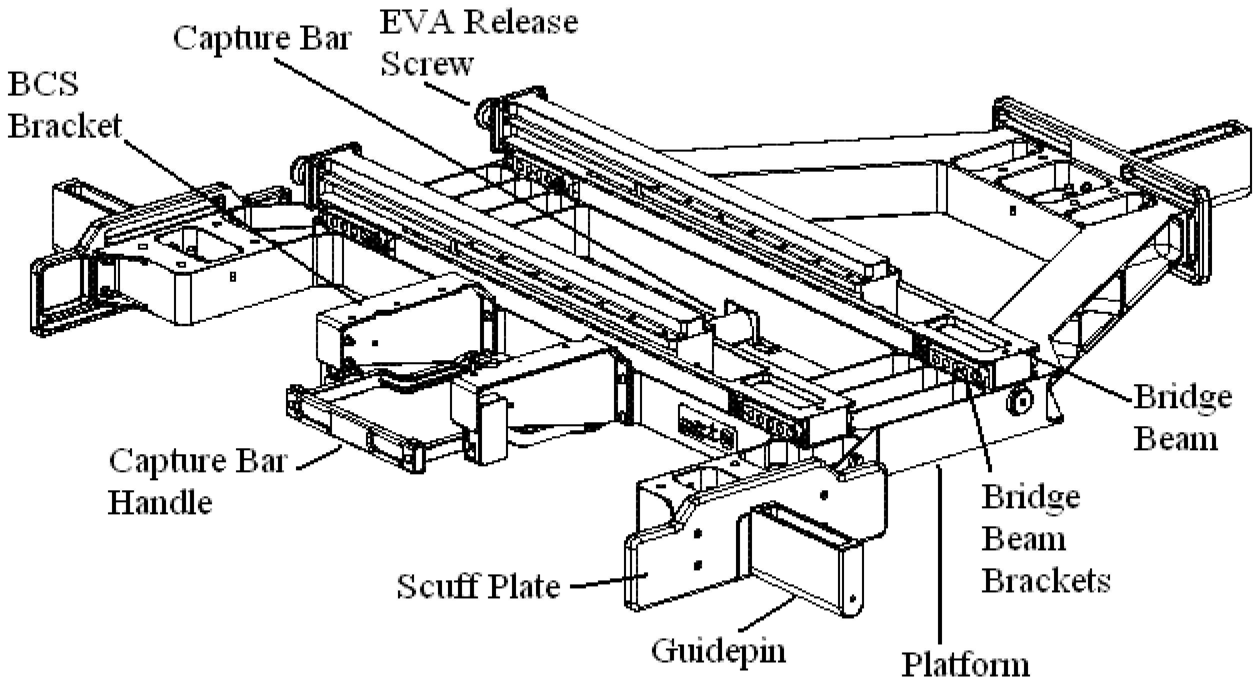
ISS Payload Attach Site



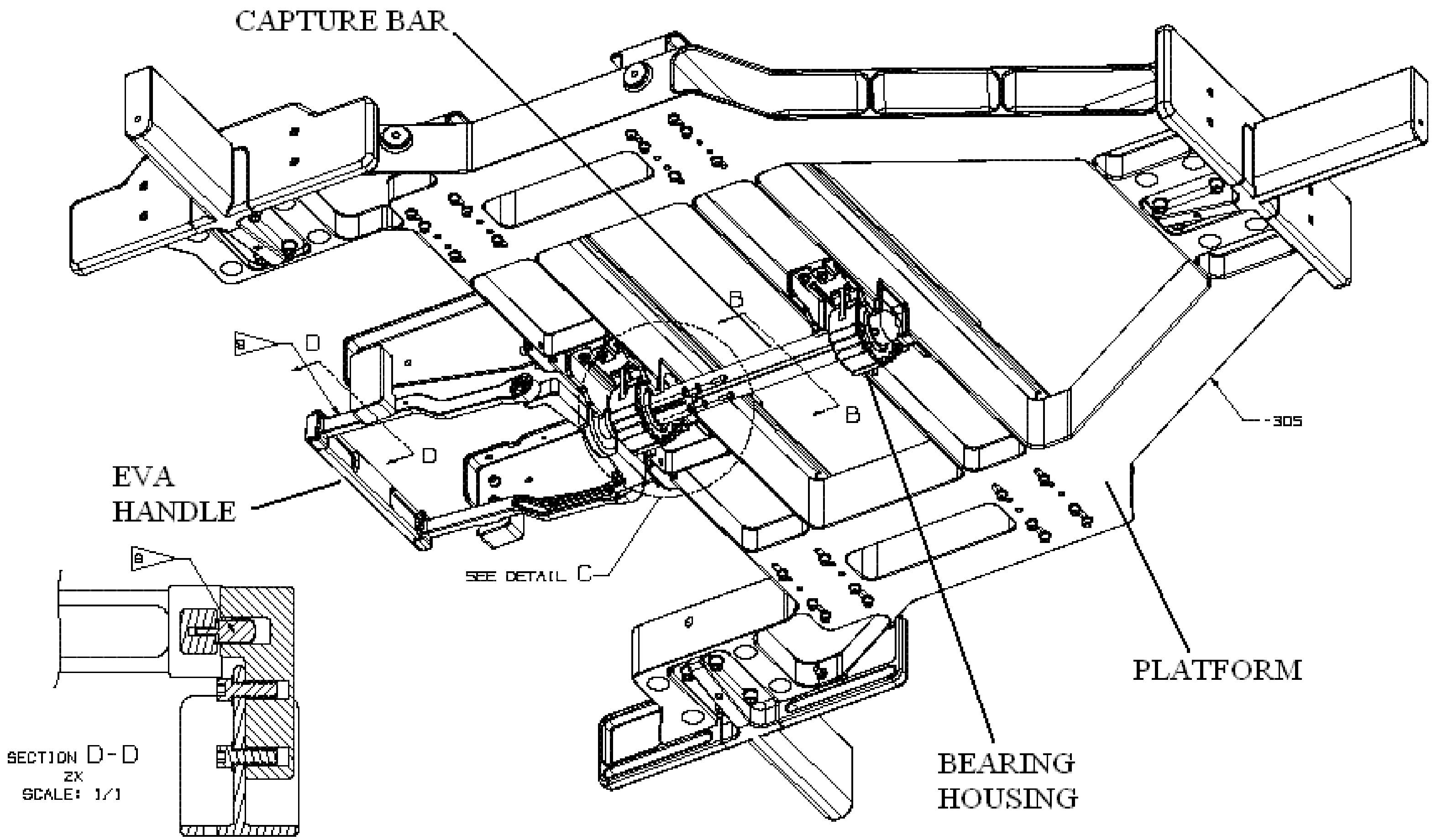
AMS-02 Interface to ISS Payload Attach Site



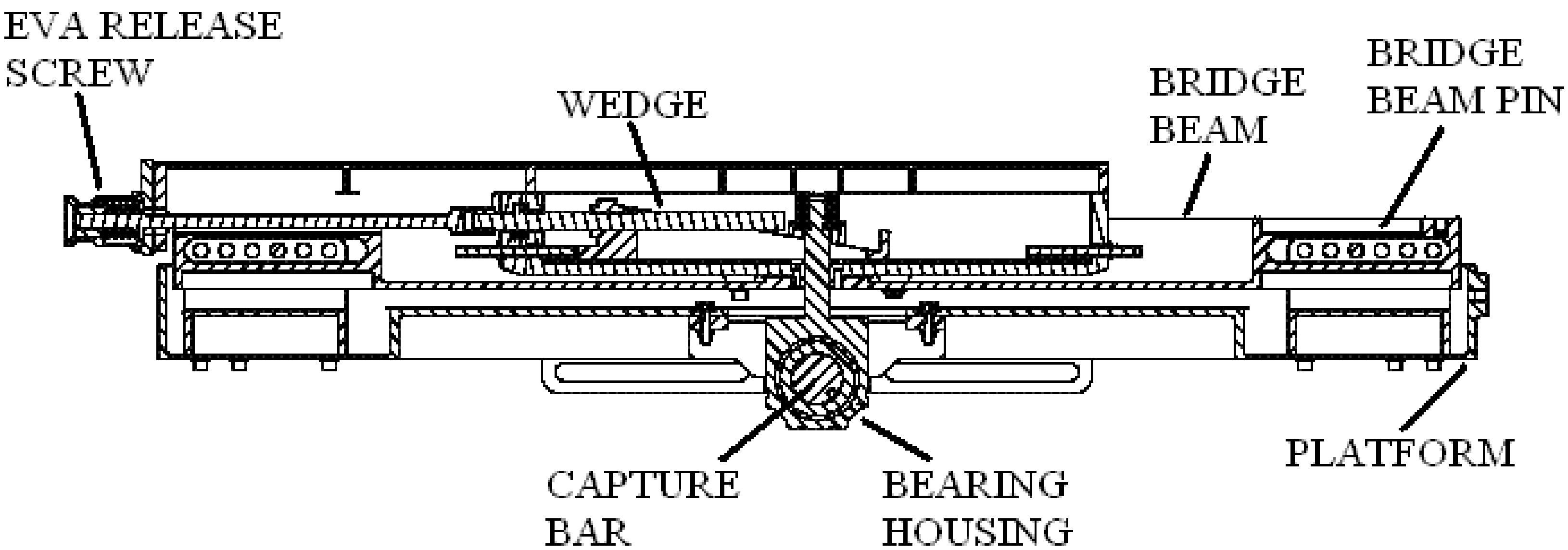
AMS-02 Passive PAS Assembly with EVA Release Mechanism



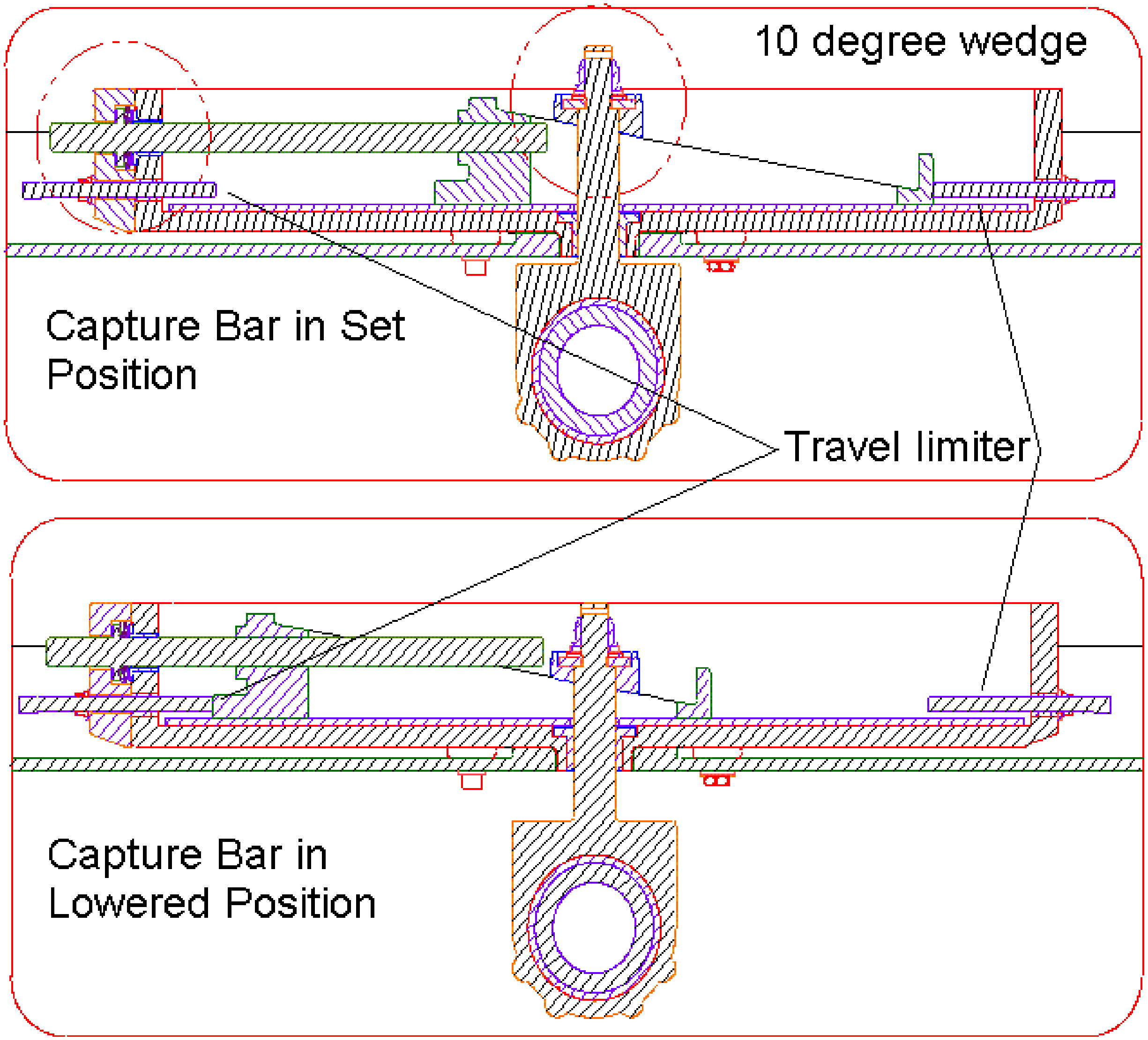
AMS-02 Passive Attach System with EVA Release Mechanism



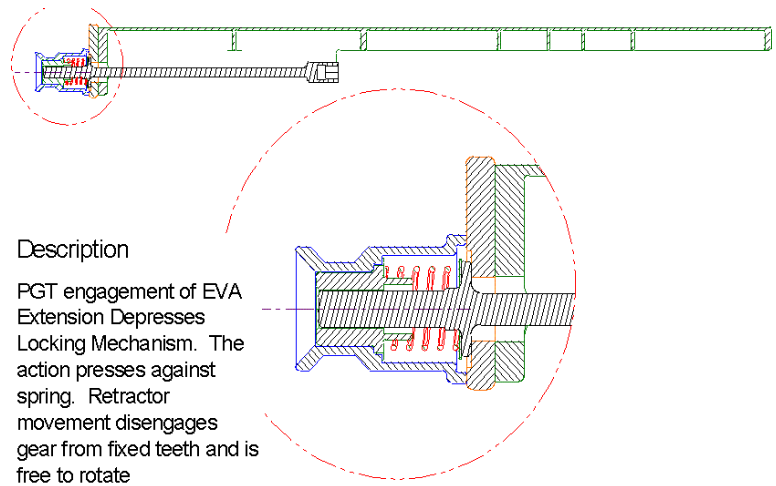
AMS-02 Passive Attach Mechanism with EVA Release Mechanism (View from ISS PAS)



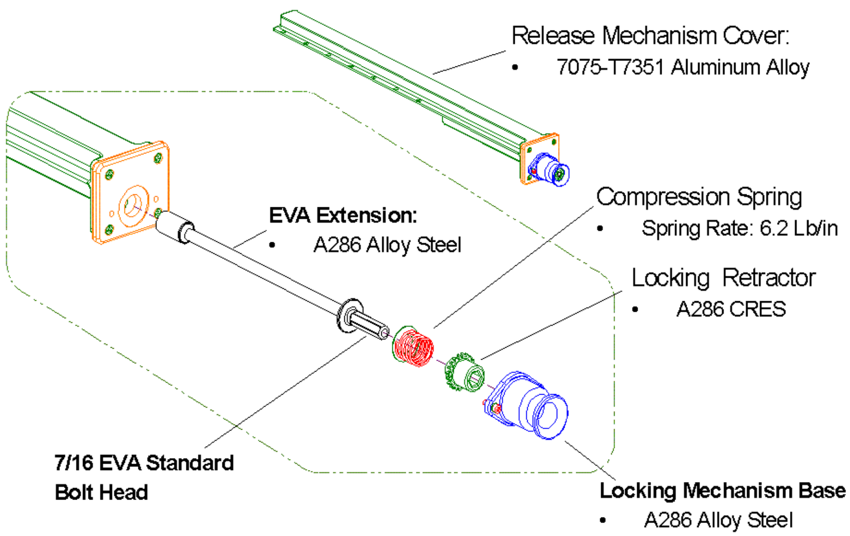
AMS-02 PAS Preload Release Mechanism with EVA Release Screw



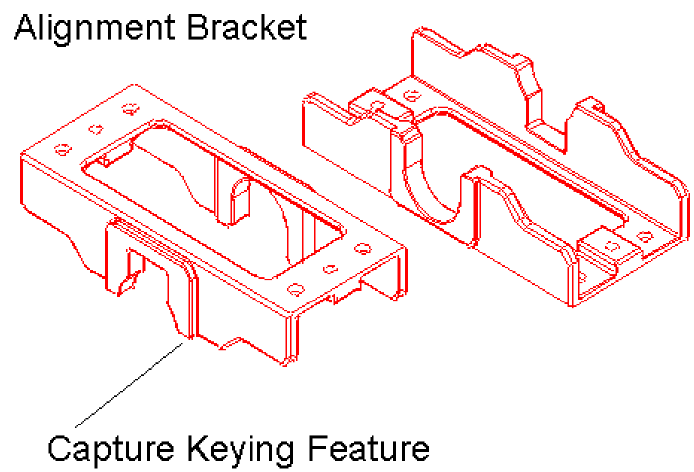
AMS-02 PAS Load Relief Wedge Operation



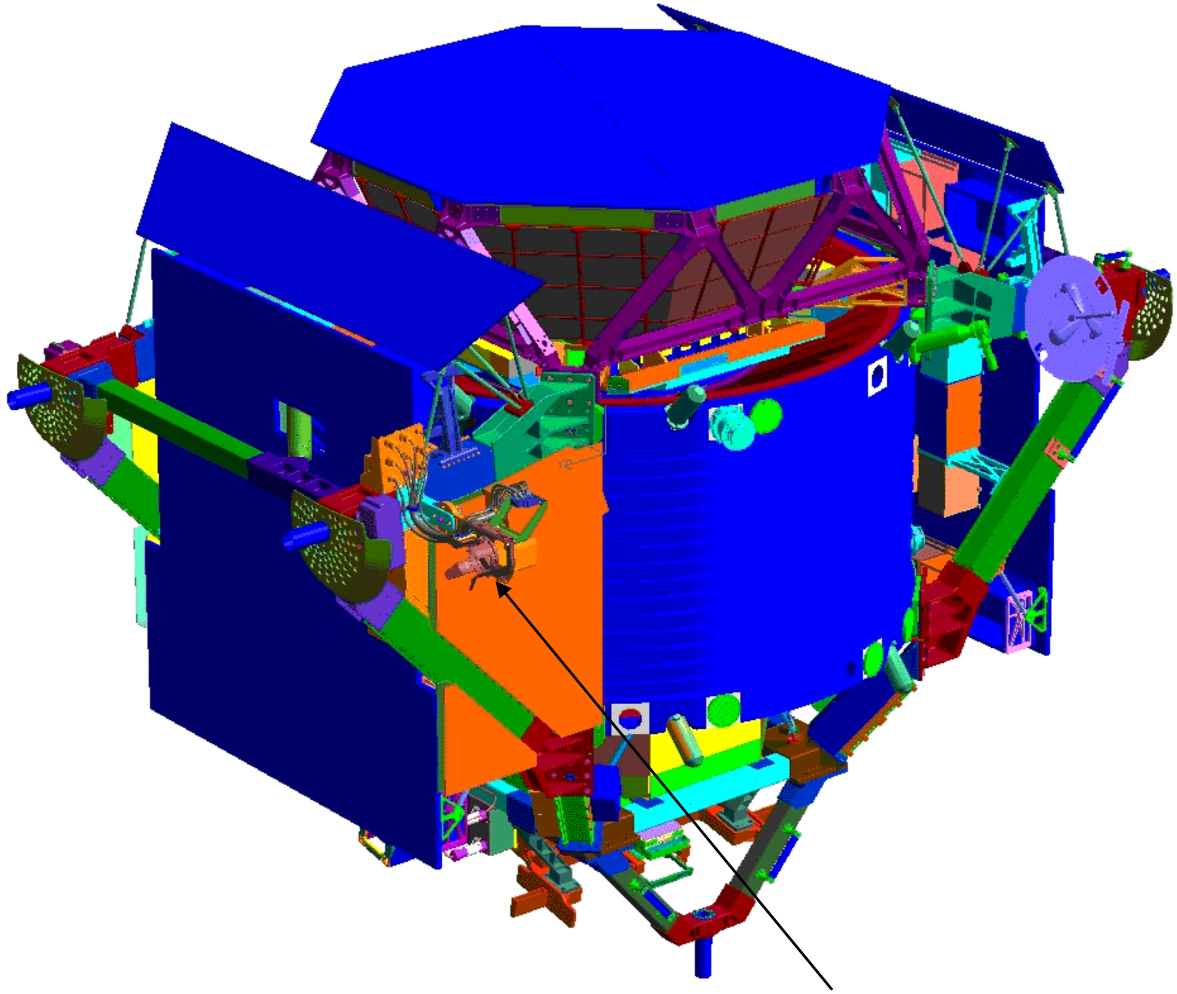
AMS-02 PAS EVA Release Screw Locking Mechanism



AMS-02 PAS EVA Screw Interface Design

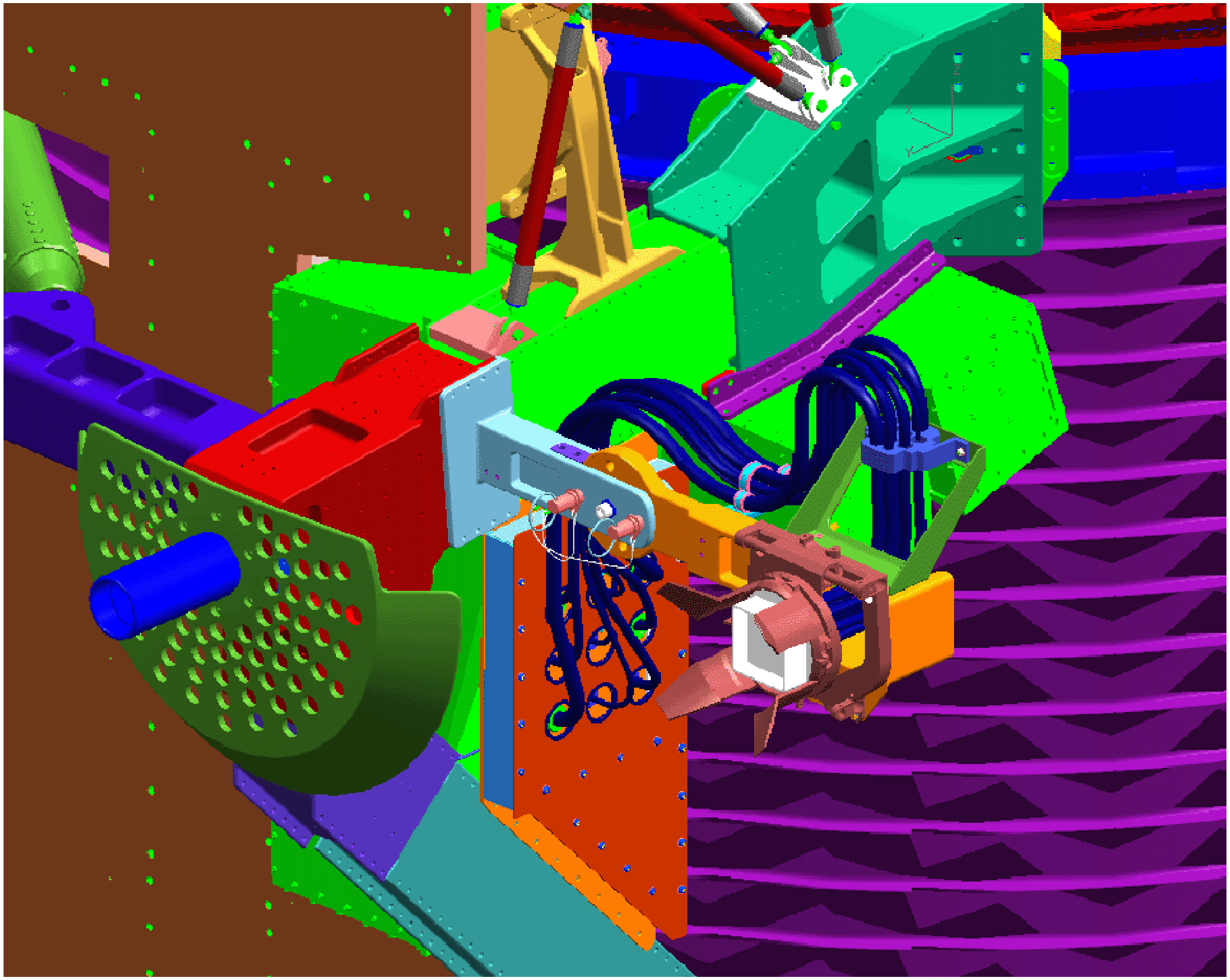


Capture Bar Capture Feature

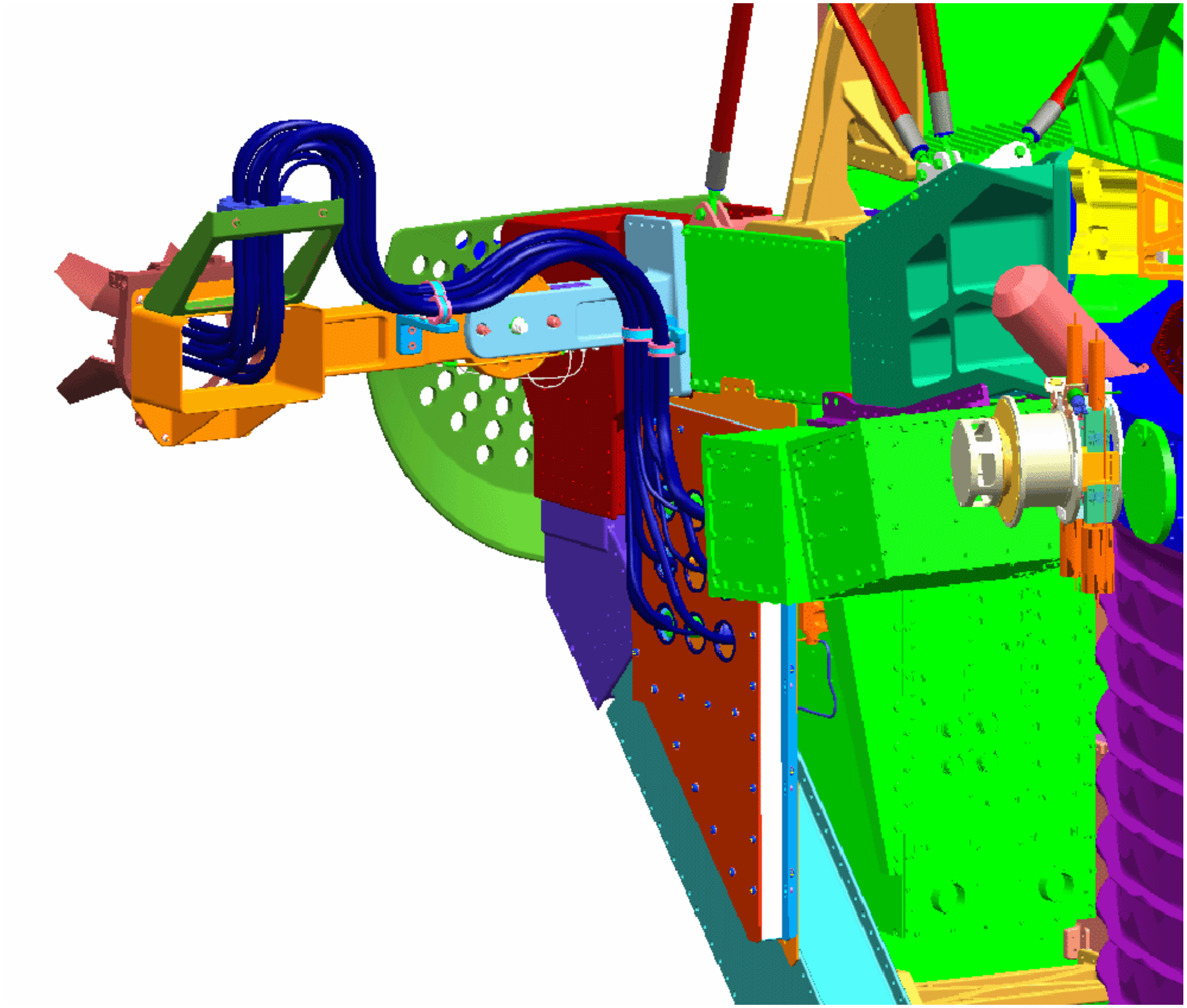


AMS-02 ROEU Folding Bracket

(Electrical Panel in Old position above the ROEU Bracket, following pictures reflect updated position of electrical panel.)



ROEU Bracket with Panel (Pip Pins have been replace with threaded fasteners)



Alternate View of ROEU

TO:	Bob Miley (281) 244-4968
NASA Contact:	Cal Brogdon/OM7 (281) 244-7058
Analyst:	Alicia Mooty/MAGIK Team (281) 483-8491
DATE:	February 27, 2007
RE:	Misalignment Clearances Between AMS and ELC During Berthing, Revision A
CC:	Michael Brown/Boeing, John Cook/Boeing, Trent Martin/EA, Chris Tutt/Jacobs, Paul Nemeth/Jacobs, Gene Cook/OZ, Vic Sanders/Boeing, Stacey Dries/Boeing, AJ Alfonzo/Boeing, Rodney Nabizadeh/OM, Paula Morris/ER, Larry Grissom/ER, Shakeel Razvi/OM, RS Library
PAGES:	10 **Action Item: 2172, Revision A**

Abstract:

The MAGIK Robotic Analysis Team has completed an action to determine the clearances between the Alpha Magnetic Spectrometer – 02 (AMS) payload and the ExPRESS Logistics Carrier (ELC) during the berthing of AMS to the S3 Upper Inboard Payload Attach Site (PAS) and during the berthing of the ELC to the S3 Upper Outboard PAS.

It was determined that the clearances between AMS and the ELC are less than the required 24 inches of clearance, with a minimum clearance during AMS berthing operations of approximately 11 inches and **12** inches during ELC berthing. Note that certain misalignment cases produce contact between the S3 longeron and both the AMS and ELC guide pins.

Revision A updated the minimum clearances between the AMS and the ELC payloads for the ELC berthing to S3 (Part 2), resulting from additional analysis evaluating a 2 degree wobble of the ELC towards the AMS payload during berthing.

Assumptions:

- ISS Flight 19A configuration (based on SSCB Approved Assembly Sequence dated February 22, 2006) was used for the analysis.
- The AMS CAD model used in this analysis was created by the MAGIK Team from a high fidelity model received from the ISS CAD Modeling Team in May, 2003.
- The ELC CAD model used in this analysis was created by the MAGIK Team from a high fidelity model received from Rodney Nabizadeh in October, 2006.
- Pedigree information for pertinent models may be obtained from the MAGIK Team upon request.
- This analysis addresses clearance issues by measuring distances between 3D graphic models. Areas not addressed in this document - lighting, viewing, EVA/EVR tasks, thermal and/or pressure effects on elements, and dynamics - could have a significant influence on the measurements and overall feasibility.

- 3D graphical models used in this analysis are a result of the MAGIK Team's "best efforts" to obtain accurate models reflecting actual volumetric dimensions of the various ISS elements and/or create in the best possible manner an encompassing low fidelity model representative of the hardware and kinematically applicable to MAGIK analyses. Applicability is defined by the probability of interaction with the robotic arm(s), EVA on the arm, or a robotically moved hardware."Best efforts" include obtaining/creating models directly from the ISS CAD Modeling Team, the hardware designers, a 3rd party (a source other than the hardware designers), drawings/information from hardware designer or customer, or the ISS External Cargo Handbook (D684-11233-01). The MAGIK created models are lower fidelity, comparative to the source model, consisting of less detail. For applicable areas, the encompassing shape has a tolerance of +0.5/ -0.1 inch with respect to the source model; meaning the nearest source surface should be no greater than 0.5 inch from the surface on the encompassing shape. Non-applicable areas are modeled to tolerances of +1.5/ -0.1 inch.

Discussion and Results:

A berthing misalignment analysis was performed for two scenarios. Part 1 of this analysis looked at misalignments and resulting clearances for berthing the AMS payload to the S3 Upper Inboard PAS with an ELC on the adjacent S3 Upper Outboard PAS location. Part 2 analyzed the misalignments and clearances for berthing the ELC to the S3 Upper Outboard PAS with the AMS payload on the adjacent S3 Upper Inboard PAS. The misalignment cases evaluated are based on information provided by Michael Brown/Boeing - End to End Berthing Integration Team (EBIT) in MAGIK Action Item 2044.

Figure 1 - Figure 4 show the AMS payload and the ELC both installed on S3 (fully berthed with no misalignments). Table 1 summarizes the clearances between the AMS payload and the ELC payloads with both the AMS and ELC fully berthed with no misalignments and also at 2, 4 and 6 inch interface separation distances with no misalignments.

Table 1: Minimum Clearances Between AMS and ELC Payloads - No Misalignments

Interface Separation Distance (in)	Misalignment Case Wobble, Roll, Lateral Offset (deg, deg, in)	ELC Payload 1	ELC Payload 2	ELC Payload 3	ELC Payload 4	ELC Payload 5	ELC Payload 6
0	0, 0, 0	45	23	16	16	29	45
2	0, 0, 0	45	23	16	16	28	45
4	0, 0, 0	45	23	16	16	28	44
6	0, 0, 0,	43	23	16	16	28	43

The maximum misalignments used in the analysis (2 degrees wobble, 2.5 inches lateral offset, and 5.5 degrees roll) were provided by EBIT/Boeing. This analysis evaluated misalignment cases for separation distances of 2 inches, 4 inches and 6 inches.

Part 1

For Part 1, the AMS payload was misaligned to a set of cases and the clearances between the AMS payload and adjacent hardware, including ISS envelopes, was evaluated. Misalignments were applied about a point located at the center of the bottom of the AMS capture bar.

The minimum distances between the ELC payloads and AMS were found at an interface separation distance of 6 inches and a misalignment case of 2 degrees wobble, 0 degrees roll and -2.5 inches lateral offset, as illustrated in Figure 5. Figure 6 shows the orientation of the ELC payloads on the side adjacent to AMS when installed on S3. This produced the minimum clearance for all payloads simultaneously. The minimum clearances for this case, as well as additional cases producing the same minimum clearances, are noted in Table 2.

Table 2: Minimum Clearances Between AMS and ELC Payloads During AMS Berthing

Interface Separation Distance (in)	Misalignment Case Wobble, Roll, Lateral Offset (deg, deg, in)	ELC Payload 1	ELC Payload 2	ELC Payload 3	ELC Payload 4	ELC Payload 5	ELC Payload 6
6	2, 0, -2.5	36	17	11	11	22	36
6	2, 2, -1.5	37	17	12	13	24	38
4	2, 0, -2.5	37	17	11	11	23	37
4	2, 2, -1.5	37	17	12	13	24	38

Note that several of the cases analyzed produced contact (or clearances of less than an inch) between the AMS guide pin and the S3 longeron.

Clearances between AMS and the following ISS hardware (or envelopes) were also found to be less than the required 24 inches:

- -S1 Outboard Upper Camera Sweep Envelope (Camera Port (CP) 2)*
  - Minimum clearance = Contact
  - (Fully berthed with no misalignments and several other cases)
- -Floating Potential Measurement Unit (FPMU) installed at CP2*
  - Minimum clearance = 14 inches
  - (No misalignments – fully berthed and at 2 inch interface separation distance)
- -AMS to S1 Thermal Control System Radiator Sweep Envelope
  - Minimum clearance = 20 inches
  - (Fully berthed with no misalignments)
- -AMS to S1 Bulkhead
  - Minimum clearance = 16 inches
  - (Fully berthed with no misalignments and several other cases)
- -AMS to S3 Grapple Fixture
  - Minimum clearance = 18 inches
  - (Fully berthed with no misalignments and several other cases)

** CP2 should remain vacant if AMS is installed on the S3 Upper Inboard PAS according to the ISS Configuration Document, SSP 50504, Revision C.*

Part 2

For Part 2, the ELC was misaligned to a set of cases and the clearances between the ELC and adjacent hardware, including AMS and ISS envelopes, was evaluated. Misalignments were applied about a point located at the center of the bottom of the ELC capture bar. **Revision A added cases to evaluate a wobble of 2 degrees in the direction of the AMS payload.**

The minimum clearances between the ELC payloads and AMS, and their corresponding misalignment cases, are noted in Table 3. Figure 7 illustrates a misalignment case of 6 inch interface separation distance, 2 degrees wobble (away from AMS), 0 degrees roll and 2.5 inches lateral offset. Figure 8 and Figure 9 **illustrate a misalignment case of 4 inch interface separation distance, -2 degrees wobble (towards AMS), 0 degrees roll and 2.5 inches lateral offset.**

Table 3: Minimum Clearances Between AMS and ELC Payloads During AMS Berthing

Interface Separation Distance (in)	Misalignment Case Wobble, Roll, Lateral Offset (deg, deg, in)	ELC Payload 1	ELC Payload 2	ELC Payload 3	ELC Payload 4	ELC Payload 5	ELC Payload 6
0	0, 0, 0	45	23	16	16	28	45
2	0, 0, 0	46	23	16	16	29	46
2	2, 1, -0.5	53	27	18	17	17	52
4	0, 0, 0	47	23	16	16	29	47
4	2, 0, 2.5	50	24	15	15	30	50
4	2, 5.5, 0	55	29	20	15	30	51
4	2, -5.5, 0	51	24	15	20	35	55
4	2, 2, 1.5	52	26	17	15	30	51
4	2, -2, 1.5	51	24	15	17	32	52
6	0, 0, 0.	48	23	16	16	29	48
6	2, 0, 2.5	51	24	15	15	30	51
6	2, 5.5, 0	56	39	20	15	30	51
6	2, -5.5, 0	51	24	15	20	35	56
6	2, 2, 1.5	53	26	17	15	30	51
6	2, -2, 1.5	51	24	15	17	32	53
4	-2, 0, 2.5	39	17	11	11	23	39
4	-2, 5.5, 0	44	23	17	11	23	39
4	-2, -5.5, 0	39	16	11	17	28	44
4	-2, 2, 1.5	41	19	13	12	23	39
4	-2, -2, 1.5	39	17	12	13	24	41
6	-2, 0, 2.5	40	17	12	12	23	40
6	-2, 5.5, 0	45	23	17	11	23	40
6	-2, -5.5, 0	40	17	11	17	28	45
6	-2, 2, 1.5	42	19	13	12	23	40

Note that several of the cases analyzed produced contact (or clearances of less than an inch) between the ELC guide pin and the S3 longeron.

Clearances between the ELC hardware and the following ISS hardware were also found to be less than the required 24 inches:

- -ELC Power and Video Grapple Fixture (PVGF) #2 to S3
  - Minimum clearance = 10 inches
  - (Fully berthed with no misalignments)
- -ELC Deck to S3
  - Minimum clearance = 13 inches
  - (Fully berthed with no misalignments)

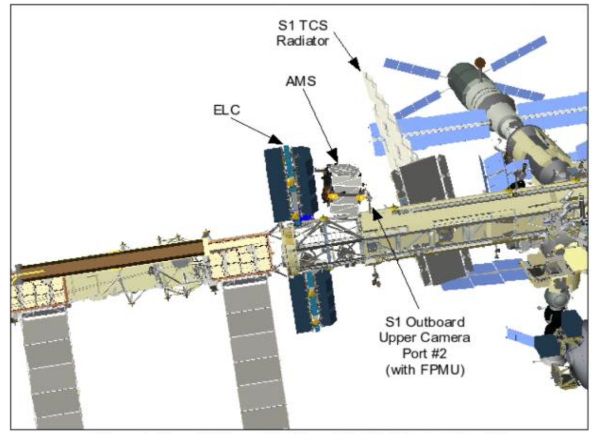


Figure 1: Overall View of AMS and the ELC Installed on S3
(Both Fully Berthed, No Misalignments)
View Looking ISS Aft, Port and Nadir

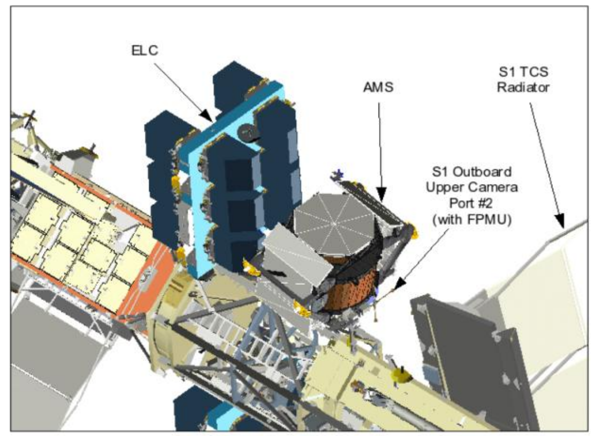


Figure 2: Overall View of AMS and the ELC Installed on S3
(Both Fully Berthed, No Misalignments)
View Looking ISS Aft, Starboard and Nadir

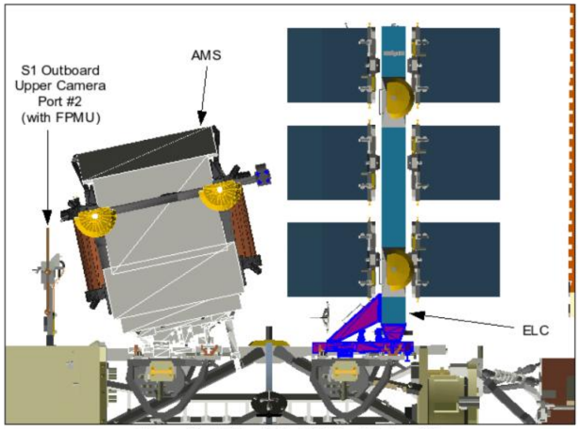


Figure 3: AMS and the ELC Installed on S3
(Both Fully Berthed, No Misalignments)
View Looking ISS Forward

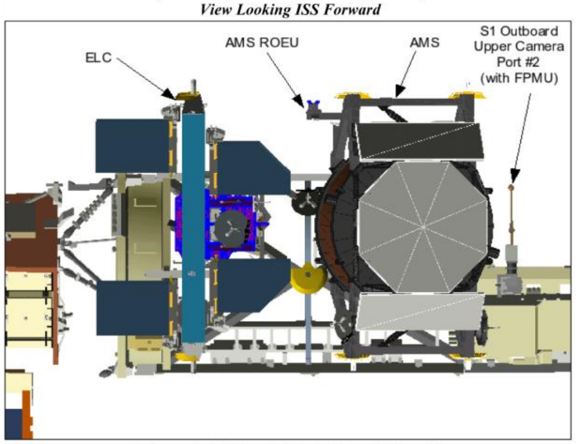


Figure 4: AMS and the ELC Installed on S3
(Both Fully Berthed, No Misalignments)
View Looking ISS Nadir
View Clipped for Clarity

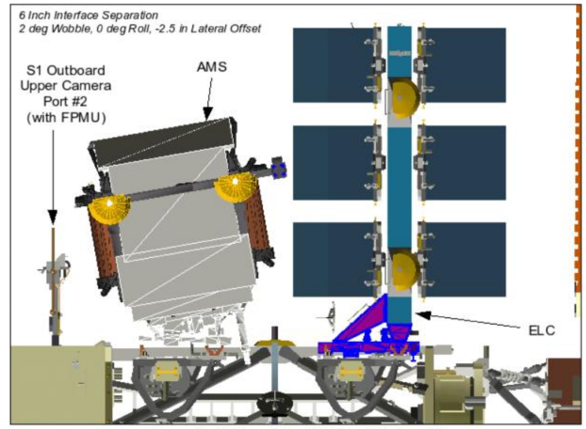


Figure 5: AMS and the ELC Installed on S3
(AMS Misaligned, ELC Fully Berthed with No Misalignments)
View Looking ISS Forward

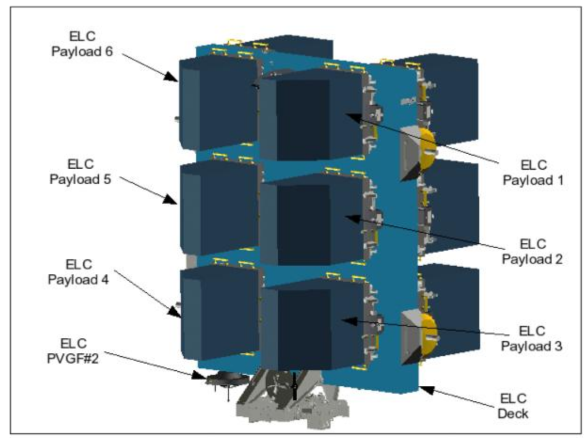


Figure 6: Orientation of ELC Payloads on ELC

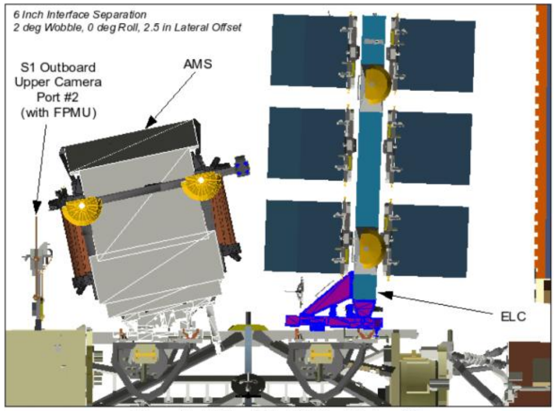


Figure 7: AMS and the ELC Installed on S3
(AMS Fully Berthed with No Misalignments, ELC Misaligned)
View Looking ISS Forward

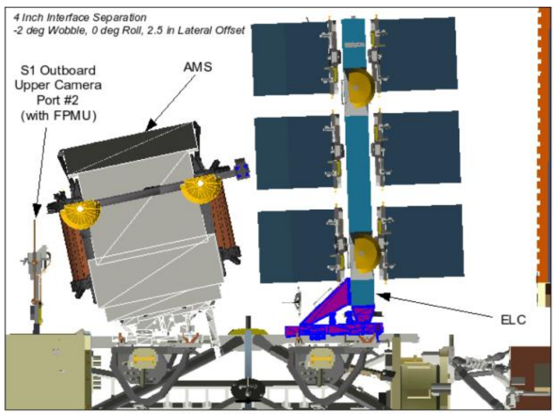


Figure 8: AMS and the ELC Installed on S3
(AMS Fully Berthed with No Misalignments, ELC Misaligned)
View Looking ISS Forward

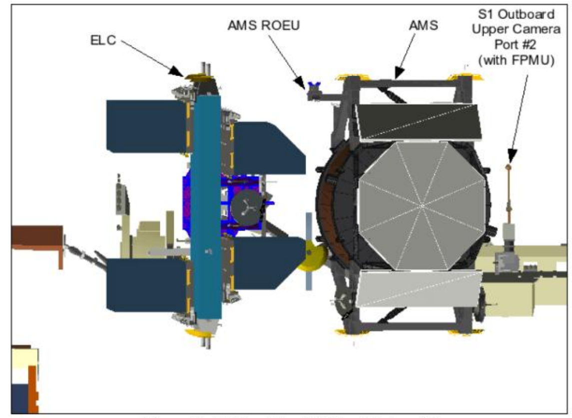


Figure 9: AMS and the ELC Installed on S3
(AMS Fully Berthed with No Misalignments, ELC Misaligned)
View Looking ISS Nadir
View Clipped for Clarity

PAYLOAD FLIGHT HAZARD REPORT				a. NO:	AMS-02-F12
b. PAYLOAD	Alpha Magnetic Spectrometer-02 (AMS-02)			c. PHASE:	III
d. SUBSYSTEM:	Electrical, Integration	e. HAZARD GROUP:	Injury/Illness, Damage to Hardware	f. DATE:	August 4, 2010
g. HAZARD TITLE:	Mate/Demate of Connectors			i. HAZARD CATEGORY:	CATASTROPHIC **X** CRITICAL
h. APPLICABLE SAFETY REQUIREMENTS:	NSTS 1700.7B, ISS Addendum: 200.1, 200.1b				
j. DESCRIPTION OF HAZARD:	The mating/demating of connectors associated with the exterior elements of the AMS-02 can result in the damage to integration hardware, payload hardware, the generation of molten debris, electrical shock and loss of system capabilities. The following are the connectors that will be mated/disconnected during the course of the AMS-02 Mission. ROEU, UMA, PVGF, AMS-02 EVA Connector.				
k. CAUSES *(list)*	1. Mate/Demate with power in connection. 2. Connector mismate. 3. Bent pin shorting				

o. APPROVAL	PAYLOAD ORGANIZATION	SSP/ISS
PHASE I		
PHASE II		
PHASE III		

PAYLOAD FLIGHT HAZARD REPORT	a. NO: AMS-02-F12
b. PAYLOAD Alpha Magnetic Spectrometer-02 (AMS-02)	c. PHASE: III

l. HAZARD CONTROL (CONTROL), m. SAFETY VERIFICATION METHODS (SVM), n. STATUS OF VERIFICATIONS (STATUS)	OPS CONTROL
1. CAUSE: Mate/Demate with power in connection.	
1.1 CONTROL: A contingency EVA operation is provided for in the AMS-02 design to be able to switch the routing of power to the AMS-02 to swap the internal AMS-02 buses between the two ISS supplies. To accomplish this EVA task and provide the required two upstream inhibits to preclude arcing/sparking during connector demate/mate power provided by Utility Rail S3 2B3A 3A (DDCU P1-3A) and Utility Rail S3 1A4B 4B (DDCU S1-4B) must be inhibited. Each of these power sources is routed through RPCMs to control power to the individual PAS locations. The power will be switched (on/off) at RPCM S3-3A-E(A2) and RPCM S3-4B-E (A9) (respective) to inhibit power availability to the AMS-02. The second inhibit will involve the remote retraction of the UMA connection to provide physical isolation of the AMS-02 from the ISS power sources. AMS-02 does not have the means of removing or limiting downstream loads to meet the low power option of MA2-98-170. 1.1.1 SVM: OCAD for demating UMA prior to EVA connector swap (Including power removal). (OCAD 67860) 1.1.2 SVM: <Deleted> 1.1.1 STATUS: Closed to SVTL 1.1.2 STATUS: <Deleted>	I
NOTE: Remote operation of program provided connectors (ROEU, SSRMS, UMA) will be controlled by the nominal operating procedures of the vehicles supporting the remote operations. Generically this involves isolating the power and then operating the remote connection. No EVA crew are involved with this nominal operation. In the event of remotely operated connectors failing either to mate or demate, EVA capability has been designed into the remotely operated devices to fulfill the automated operation. AMS-02 does not have the capability to reduce loads or eliminate the consumption of power to meet the low power option of MA2-98-170, thus the vehicle must provide additional inhibits to power to satisfy the requirements for EVA mate/demate of connectors for any contingency procedure where EVA operations on the automated connectors are performed.	
1.2 CONTROL: AMS-02 EVA Accessible connectors are an EVA compatible design, are of a scoop proof design and keyed to require a specific orientation for connection. The EVA connection has the “hot” side terminated in sockets and not pins. The EVA connectors used are compliant with NASA SSQ-21635, “General Specification For Connectors And Accessories, Electrical, Circular, Miniature, IVA/EVA Compatible, Space Quality”.	

PAYLOAD FLIGHT HAZARD REPORT	a. NO: AMS-02-F12
b. PAYLOAD Alpha Magnetic Spectrometer-02 (AMS-02)	c. PHASE: III

1.2.1 SVM: Review of design 1.2.2 SVM: Inspection of as built hardware 1.2.1 STATUS: Closed. ESCG Memorandum ESCG-4390-08-SP-MEMO-0022, “Mate/Demate of Connectors,” dated 11 June 2008. 1.2.2 STATUS: Closed to SVTL.	
1.3 CONTROL: AMS-02 EVA Connectors fully enclose the interconnecting pins and sockets prior to engagement. Engagement of the pins and sockets is externally controlled by use of EVA operated lever. 1.3.1 SVM: Review of design 1.3.2 SVM: Inspection of as built hardware 1.3.1 STATUS: Closed. ESCG Memorandum ESCG-4390-08-SP-MEMO-0022, “Mate/Demate of Connectors,” dated 11 June 2008. 1.3.2 STATUS: Closed. TPS 2A0720181, completed 4/21/2008 verifies proper mating and connector type.	
1.4 CONTROL: <Deleted. UPS Removed from AMS-02>	
1.5 CONTROL: Nominally, the SSRMS will demate power connections from the AMS-02 prior to engaging the UMA in order to preclude power (high) lines from one power source on the ISS to be interconnected with the output of another power source. In the event of the situation where the SSRMS has delivered the AMS-02 to the PAS location and the UMA is connected while the SSRMS is still connected, power from the UMA (or the SSRMS) will be switched off and a diode protection included in the AMS-02 circuitry will prevent power, originating from the UMA, from being present in the PVGF. NOTE: Control of SSRMS power supply through the arm is a standard GFE procedure as indicated in preceding NOTE (following Control 1.1). 1.5.1 SVM: Review of Design 1.5.2 SVM: Testing of PVGF blocking diodes 1.5.3 SVM: Requirement to physically separate SSRMS power path to the AMS-02 prior to engaging the UMA power connection to AMS-02 accepted by MOD through and OCAD. (OCAD 67861) 1.5.1 STATUS: Closed. ESCG Memorandum ESCG-4175-09-REENTES-MEMO-0024, "Isolation between the UMA and PVGF," dated May 4, 2009.	I

PAYLOAD FLIGHT HAZARD REPORT	a. NO: AMS-02-F12
b. PAYLOAD Alpha Magnetic Spectrometer-02 (AMS-02)	c. PHASE: III

1.5.2 STATUS: Closed to SVTL.

1.5.3 STATUS: Closed. OCAD Closure reported to AMS-02 Project on 6/4/2010 by JSC-DA8/B. O'Keeffe.

1.6 CONTROL: The power supplied specifically for the AMS-02 through Shuttle T-0 connection will be depowered prior to 48 hours before launch.

1.6.1 SVM: Review of OMRS for power shutdown procedure.

1.6.1 STATUS: Closed. OMRSD File II, Volume 2 (P507 – ISS-ULF6 Baseline), requirement # P507KC.020 requires procedure for powering off AMS-02.

2. CAUSE: Connector Mismate.

2.1 CONTROL: EVA connectors are keyed to only connect to compatible locations and in appropriate orientation. Each connector application uses different connectors with differing housing diameters and internal pin configurations. Attachment to hazard report provides technical detail of each connector application.

2.1.1 SVM: Review of design

2.1.2 SVM: Inspection of as built hardware

2.1.1 STATUS: Closed. ESCG Memorandum ESCG-4390-08-SP-MEMO-0022, "Mate/Demate of Connectors," dated 11 June 2008.

2.1.2 STATUS: Closed to SVTL.

3. CAUSE: Bent Pin Shorting

3.1 CONTROL: The pin assignments within the AMS-02 EVA connectors will be assigned such that a bent pin will not short power to return.

3.1.1 SVM: Bent Pin Analysis.

3.1.1 STATUS: Closed. ESCG Memorandum ESCG-4390-08-SP-MEMO-0022, "Mate/Demate of Connectors," dated 11 June 2008.

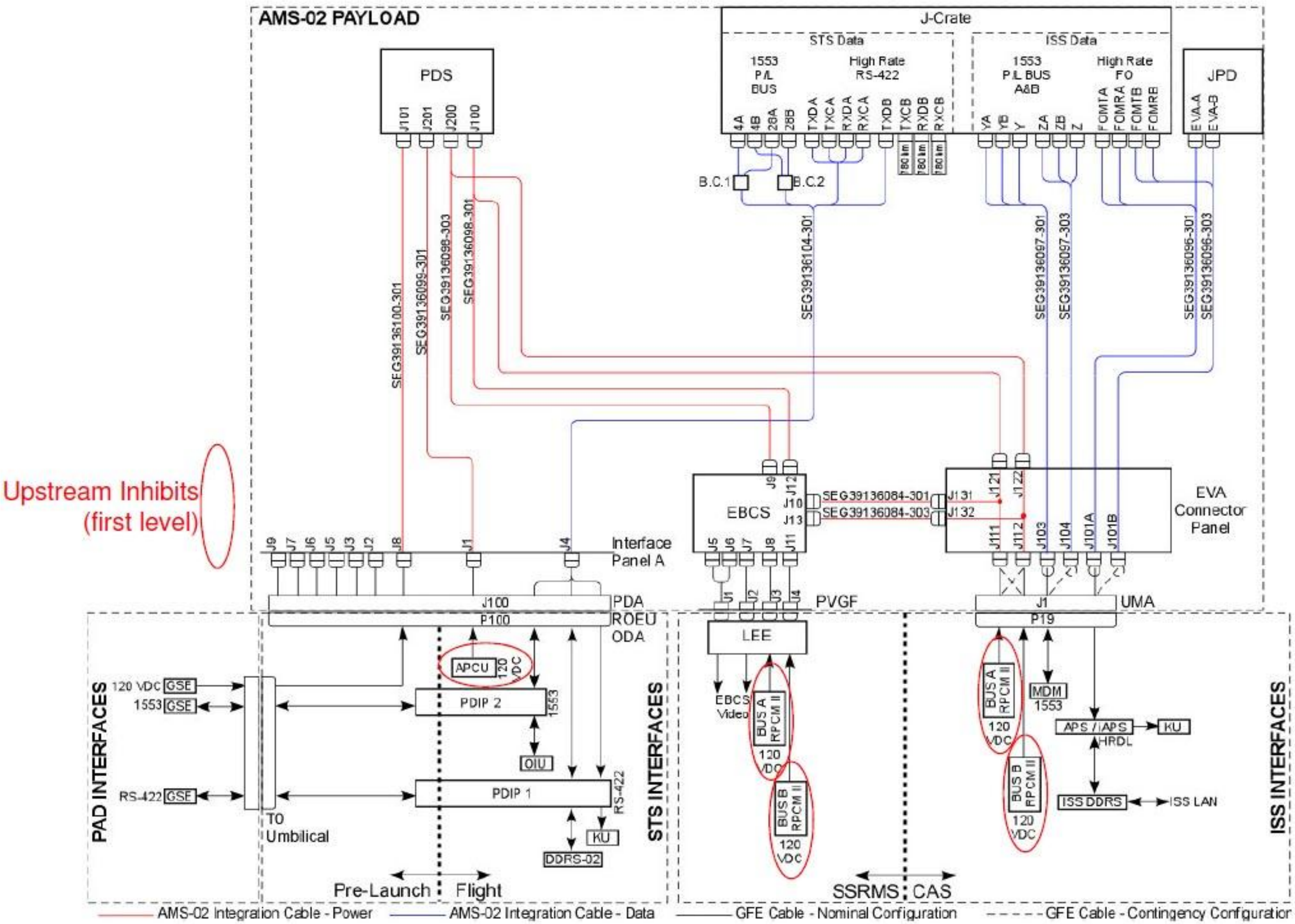
3.2 CONTROL: Any potential contact between pins/bent pins will only occur when connector shells have already mated, containing any products of arcing/shorting.

3.2.1 SVM: Review of connector design.

PAYLOAD FLIGHT HAZARD REPORT	a. NO: AMS-02-F12
b. PAYLOAD Alpha Magnetic Spectrometer-02 (AMS-02)	c. PHASE: III

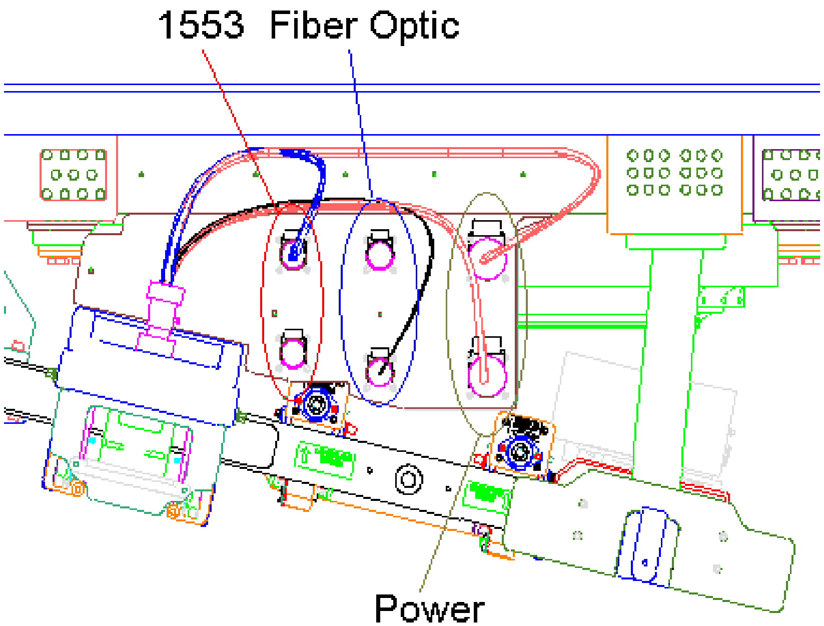
3.2.1 STATUS: Closed. ESCG Memorandum ESCG-4390-08-SP-MEMO-0022, "Mate/Demate of Connectors," dated 11 June 2008.	
Notes:	

ACRONYMS	
ACASS – Active Common Attach Site Simulator	PtP – Peak to Peak
AKA – Active Keel Assembly	PVGF – Power Video Grapple Fixture
AMS-02 – Alpha Magnetic Spectrometer - 02	QTY – Quantity
APS – Automated Payload Switch	RCV – Receive
BCS – Berthing Camera System	ROEU – Remotely Operated Electrical Umbilical
C&DH – Command and Data Handling	RPC – Remote Power Controller
DDCU - Direct Current-to-Direct Current Converter Unit	RPCM – Remote Power Control Module
DFMR – Design for Minimum Risk	SPDA – Secondary Power Distribution Assembly
EMU – Extravehicular Mobility Unit	SRMS – Shuttle Remote Manipulator System
EVA – Extravehicular Activity	SSRMS – Space Station Remote Manipulator System
HRDL – High Rate Data Link	SVM – Safety Verification Method
IVA – Interavehicular Activity	UMA – Umbilical Mating Assembly
MSWG – Mechanical Systems Working Group	UPS – Uninterruptible Power Supply
PAS – Payload Attach System, Payload Attach Site	VDC – Volts direct current
PRLA – Payload Retention Latch Assembly	XMT – Transmit


AMS-02 PAYLOAD
PDS
J101 J201 J200 J100
J-Crate
STS Data
1553 P/L BUS
High Rate RS-422
4A 4B 28A 28B TXDA TXCA RXDA RXCA TXDB TXCB RXDB RXCB
ISS Data
1553 P/L BUS A&B
High Rate FO
YA YB Y ZA ZB Z FOMTA FOMRA FOMTB FOMRB
JPD
EVA-A EVA-B
B.C.1
B.C.2
SEG39136100-301
SEG39136099-301
SEG39136098-303
SEG39136098-301
SEG39136104-301
SEG39136097-301
SEG39136097-303
SEG39136096-301
SEG39136096-303
Upstream Inhibits
(first level)
EBCS
J9 J12 J10 J13 J5 J6 J7 J8 J11
SEG39136084-301
SEG39136084-303
J131 J132
J121 J122 J111 J112 J103 J104 J101A J101B
EVA Connector Panel
J9 J7 J6 J5 J3 J2 J8 J1 J4
Interface Panel A
J100
P100
PDA
ROEU
ODA
J1 J2 J3 J4
PVGF
LEE
J1
P19
UMA
PAD INTERFACES
120 VDC GSE
1553 GSE
RS-422 GSE
T0 Umbilical
APCU
120 VDC
PDIP 2
1553
OIU
PDIP 1
RS-422
KU
DDRS-02
Pre-Launch
Flight
STS INTERFACES
EBCS Video
BUS A RPCM II
120 VDC
BUS B RPCM II
120 VDC
SSRMS
CAS
MDM 1553
APS / iAPS
KU
HRDL
ISS DDRS
ISS LAN
ISS INTERFACES
AMS-02 Integration Cable - Power
AMS-02 Integration Cable - Data
GFE Cable - Nominal Configuration
GFE Cable - Contingency Configuration

Connector	TYPE	Voltage	Max Current	Inhibit #1	Inhibit #2	Connector Type/Feature	EVA Automated
HIGH POWER CONNECTORS							
EVA Connector Power	AMS-02	120V DC (ISS)	~19 A	ISS RPC SPDA S3-1A4B, II 4B-E (A9), SPDA S3-3A, II03A-E(A2)	Demate UMA (Optional use of DDCU P1-3A and DDCU S1-4B)	NZGL06G2525LN 7SN	EVA
ROEU	GFE	120V DC (APCU)	~19 A	APCU OFF	APCU Power Source Off	GFE Provided	Auto/ EVA Capable
UMA	GFE	120V DC (ISS)	~19 A	ISS RPC SPDA S3-1A4B, II 4B-E (A9), SPDA S3-3A, II03A-E(A2)	*Vehicle Discretion as to location of second inhibit to power.*	GFE Provided	Auto/ EVA Capable
PVGF	GFE	120V DC (ISS)	~15 A	(depends on location on ISS)	*Vehicle Discretion as to location of second inhibit to power.*	GFE Provided	Auto/ EVA Capable
LOW POWER CONNECTORS							
EVA Connector Data – 1553 Talkback	AMS-02	14V PtP (1553) <=5 V DC	Very Small – Signal <<1 A	ISS RPC SPDA S3-1A4B, II 4B-E (A9), SPDA S3-3A, II03A-E(A2)		NZGL06G1515N35 PA-1	EVA
EVA Connector Fiber Optic/Talk Back	AMS-02	<=5 V DC	<<1 A	ISS RPC SPDA S3-1A4B, II 4B-E (A9), SPDA S3-3A, II03A-E(A2)		NZGL06G1717N13 PN	EVA

Highlighted elements are GFE hardware and controlled by the supporting vehicle programs.

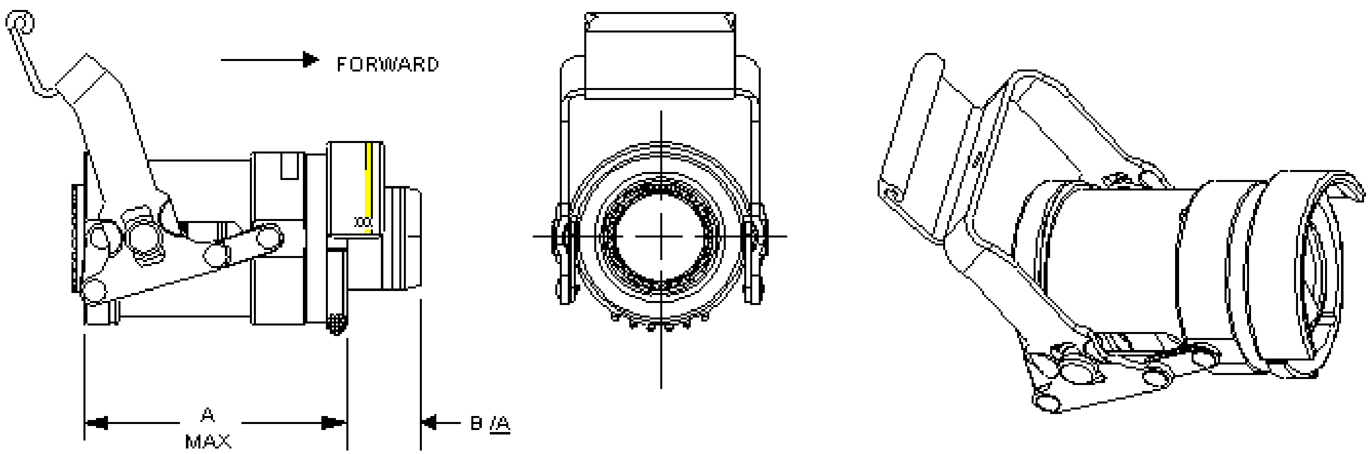


CABLE CONNECTORS

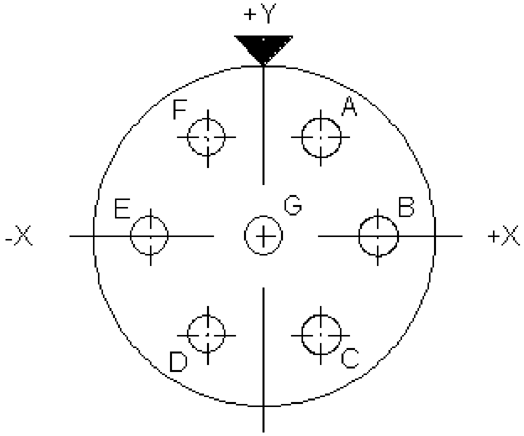
1553 – QTY: 1 EA P/N: NZGL06G1515N35PA-1
Fiber Optic – QTY: 1 EA P/N: NZGL06G1717N13PN
Power – QTY: 2 EA P/N: NZGL06G2525LN7SN
(Matching panel mounted connector halves Qty 2 for each)

From NASA Spec SSQ21635:

NZGL – NASA Zero-G Level Actuated
06 – Plug, Lever Actuated
G – Aluminum Shell, EMI Shielded, Environment Resisting
15, 17, 25 – Housing Size
15, 17, 25 – Insert Size
L – Size 25 Long Housing, (blank) – All other sizes
N – Electroless Nickel Finish
35, 13, 7 – Insert Arrangement
P – Pin, S- Socket
A, N – Polarization



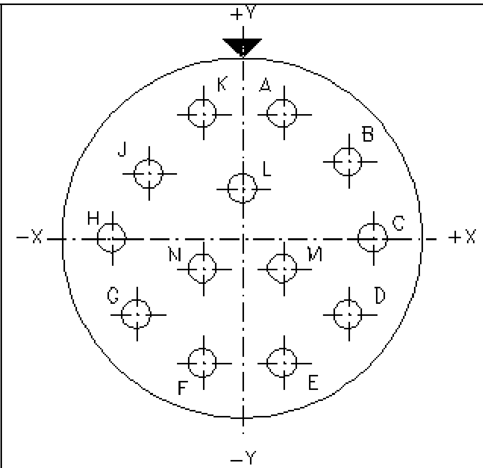
AMS-02 EVA Operable Connector



AMS-02 EVA CONNECTORS

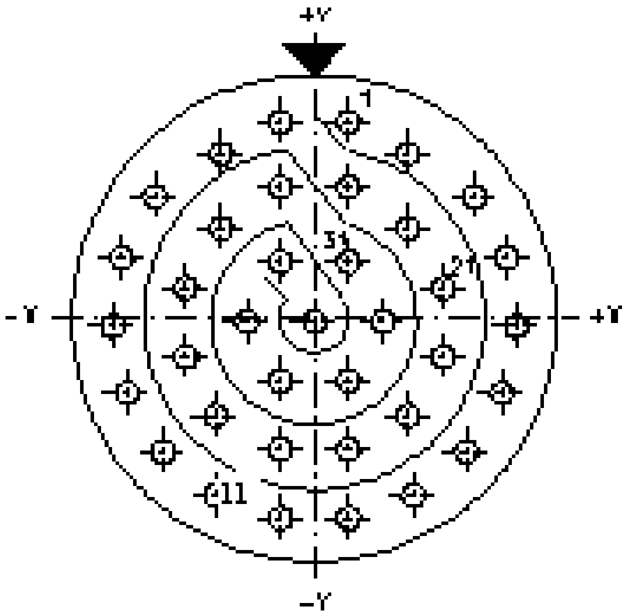
Power Connector Pinout (Socket Side View)
(8 gauge pins/sockets)

Pin/Socket	Assignment
A	Power 120 VDC (+)
C	Power Return
D	Ground



Fiber Optics Connector Pinout (Socket Side View)
(16 gauge pin/sockets)

Pin/Socket	Assignment
A	5.0 VDC Power
B	5.0 VDC Power
C	HRDL XMT TO APS
D	5.0 VDC Power Return
E	5.0 VDC Power Return
F	5.0 VDC Power Return
G	5.0 VDC Power Return
H	HRDL RCV FROM APS
K	5.0 VDC Power
J	5.0 VDC Power



Mil-Std-1553 Bus Connector (Socket Side View)
(22 gauge pin/sockets)

Pin/Socket	Assignment
1	1553 Bus A Hi
2	1553 Bus A Lo
3	AMS Address Bit 0
4	AMS Address Bit 0 Return
5	AMS Address Bit 1
6	AMS Address Bit 1 Return
7	AMS Address Bit 2
8	AMS Address Bit 2 Return
9	AMS Address Bit 3
10	AMS Address Bit 3 Return
11	AMS Address Bit 4
12	AMS Address Bit 4 Return
13	AMS Address Parity Bit
14	AMS Address Parity Bit Return
15	1553 Bus B Hi
16	1553 Bus B Lo
17 – 20	Unused
21	5 VDC Loop Back (22)
22	5 VDC Loop Back (21)
23	5 VDC Loop Back (24)
24	5 VDC Loop Back (23)
25	5 VDC Loop Back (26)
26	5 VDC Loop Back (25)
27	5 VDC Loop Back (28)
28	5 VDC Loop Back (27)
29 – 37	Unused

<table>
<tr><td colspan="3">PAYLOAD FLIGHT HAZARD REPORT</td><td>a. NO: AMS-02-F14</td></tr>
<tr><td>b. PAYLOAD</td><td colspan="2">Alpha Magnetic Spectrometer-02 (AMS-02)</td><td>c. PHASE: III</td></tr>
<tr><td>d. SUBSYSTEM:</td><td>Mechanical, Thermal, Electrical, Pressurized Systems</td><td>e. HAZARD GROUP: Injury/Illness.</td><td>f. DATE: August 4, 2010</td></tr>
<tr><td>g. HAZARD TITLE:</td><td colspan="2">EVA/EVR Hazards</td><td>i. HAZARD CATEGORY: CATASTROPHIC X
CRITICAL</td></tr>
<tr><td>h. APPLICABLE SAFETY REQUIREMENTS:</td><td colspan="3">NSTS 1700.7B, ISS Addendum, 200.1b, 200.3, 201.3, 217</td></tr>
<tr><td>j. DESCRIPTION OF HAZARD:</td><td colspan="3">The failure to design and construct the AMS-02 to be compatible with proximity to EVA translation paths and EVA activities can result in injury or death to the EVA crew. During EVR operations the AMS-02 has to be designed to avoid collision during SSRMS operations.

Note: EVR compatibility with magnetic field covered in AMS-02-F07</td></tr>
<tr><td>k. CAUSES

(list)</td><td colspan="2">1. Inadequate Access for EVA Tasks
2. Excessive Radiation
3. Sharp Edges/Corners
4. Thermal Extremes
5. Release of residual loads/forces applied</td><td>6. Excessive Loads/Effort From EVA Crew
7. Electric Shock/Molten Metal
8. Entrapment of EVA Crew
9. Improper Installation of EBCS
10. Protrusion Outside of PAS Payload Envelope
11. Improper Placement/Installation of Grapple Fixtures</td></tr>
</table>

o. APPROVAL	PAYLOAD ORGANIZATION	SSP/ISS
PHASE I		
PHASE II		
PHASE III		

PAYLOAD FLIGHT HAZARD REPORT	a. NO: AMS-02-F14
b. PAYLOAD Alpha Magnetic Spectrometer-02 (AMS-02)	c. PHASE: III

l. HAZARD CONTROL (CONTROL), m. SAFETY VERIFICATION METHODS (SVM), n. STATUS OF VERIFICATIONS (STATUS)	OPS CONTROL
1. CAUSE: Inadequate Access for EVA Tasks	
1.1 CONTROL: The AMS-02 has provided handholds/handrails in appropriate locations to support potential contingency EVAs. This includes EVAs associated with AMS-02 contingency re-routing of connections for power and communications, release of the PAS capture bar and AMS-02 GFE EVAs to the ROEU, the UMA and both grapple fixtures. A WIF interface is available for all EVA operations where tools are required except the FRGF and PVGF have also been approved for free float operations in addition to WIF socket use. These have waivers to SSP 57003 for free float operations. EVA access complies with the guidelines of JSC 28918 and NSTS 07700, Vol XIV, Appendix 7 for EVA accessibility. 1.1.1 SVM: Review of design. 1.1.2 SVM: Inspection of as built hardware. 1.1.3 SVM: Approval of EVA aid locations/Site Analysis by JSC/XA. 1.1.4 SVM: <Deleted> Removal of folding ROEU mechanism removes need for Free Float Operations. 1.1.1 STATUS: Closed. ESCG Memorandum ESCG-4410-09-MSDE-MEMO-0002, “AMS-02 EVA Worksites,” dated April 10, 2009 documents the review of the EVA worksites and tasks. 1.1.2 STATUS: Closed to SVTL. 1.1.3 STATUS: Closed. ESCG Memorandum ESCG-4410-09-MSDE-MEMO-0002, “AMS-02 EVA Worksites,” dated April 10, 2009 documents the review of the EVA worksites and tasks and the review and acceptance of these sites and tasks. 1.1.4 STATUS: <Deleted>	
1.2 CONTROL: All AMS-02 Operations involving the use of EVA tools, specifically the EVA release of the PAS, utilize standard EVA bolt interfaces to drive the ramp screws to release the PAS capture bar preload. These bolts are designed to interface with the EVA power tool. 1.2.1 SVM: Review of Design. 1.2.2 SVM: Tool Fit Check. 1.2.1 STATUS: Closed. ESCG Memorandum ESCG-4410-09-MSDE-MEMO-0001, "EVA Contingency Tool	

Requirements," dated May 7, 2009 1.2.2 STATUS: Closed. Boeing document BCP-s3-T037, "S3 Zenith Inboard PAS 2/AMS Passive PAS Fit Check, Preload and Release Mechanism Evaluation," dated February 26, 2003	
1.3 CONTROL: AMS-02 EVA mechanisms that the crew is to operate by hand are design to facilitate operations with the gloved hand. All EVA interfaces meet the requirements/intent of NASA-STD-3000, SSP 50005 for crew operability and access. 1.3.1 SVM: Review of Design. 1.3.2 SVM: Inspection of as built hardware. 1.3.3 SVM: Crew Inspection 1.3.1 STATUS: Closed. ESCG Memorandum ESCG-4295-09-CPAS-MEMO-0006, "AMS-02 EVA Access," dated October 8, 2009 1.3.2 STATUS: Closed to SVTL. 1.3.3 STATUS: Closed. Astronaut Crew Consensus Report for November 12-15, 2002 Columbus and AMS Development Test, Report File dated 12./11/2002	
2. CAUSE: Excessive Radiation	
NOTE: This hazard/cause is addressed in AMS-02-F07 for EMI and magnetic fields.for ionizing radiation is no longer applicable, all radiation sources have been removed.	
3. CAUSE: Sharp Edges/Corners	
3.1 CONTROL: The AMS-02 is designed to eliminate sharp edges, corners, protrusions and any mechanism that could be a pinch or scissor location. The AMS-02 meets the requirements of NSTS 07700, Vol XIV, Appendix 7 for all accessible surfaces and structures, with the exception of the two Star Tracker optical baffles, which by the nature of the optical properties of the baffle, has thin metal edges that do not comply with the rounding of edges. The Star Tracker baffles will be noted as "no touch areas". There has been no identified need for the EVA crew to operate in the immediate vicinity of the Star Tracker baffles. To access these thin sheet edges, the EVA crewmember would have to reach to the interior of the Star Tracker baffle. (Reference Page A14-34 for figure showing Star Tracker Location, "STAR TRACKER BAFFLE – EVA No Touch Area.") Note: Silver Teflon Tape was used to cover edges that were not properly finished in accordance with NSTS 07700 Vol XIV,	I, S

PAYLOAD FLIGHT HAZARD REPORT	a. NO: AMS-02-F14
b. PAYLOAD Alpha Magnetic Spectrometer-02 (AMS-02)	c. PHASE: III

Appendix 7.

3.1.1 SVM: Review of Design

3.1.2 SVM: Inspection of flight hardware (including swatch testing) for sharp edges, corners, etc.

3.1.3 SVM: Acceptance of EVA no touch area for Star Tracker baffles by MOD through an OCAD. (OCAD 67862)

3.1.1 STATUS: Closed. ESCG Memorandum ESCG-4295-09-CPAS-MEMO-0005, "AMS-02 Sharp Edge Review," dated October 8, 2009

3.1.2 STATUS: Closed to SVTL.

3.1.3 STATUS: Closed to SVTL.

4. CAUSE: Thermal Extremes

4.1 CONTROL: The AMS-02 Design precludes contact between an EVA crewmember and surfaces that exceed the thermal limits of 235°F to -180°F (112°C to -118°C) for incidental contact not to exceed 30 seconds in length. The AMS-02 design will minimize the continuous contact potential for EVA worksite beyond the requirement temperatures of 145°F to -45°F (63°C to -41°C). This has considered the required EVA translation paths while in the Orbiter Payload Bay, mounted on the ISS and for potential EVA work sites for contingency actions of Grapple Fixture release, ROEU mate/demate, PAS EVA disconnect, AMS-02 Power/Communications Cable Swap, etc. If unable to meet the numerical values of temperature as documented in SSP 57003, paragraph 3.11.5.14.1 and 3.11.5.14.2 for the incidental/continuous contact, heat transfer limits will be shown to be equivalently compliant with the alternate analysis method provided for in those requirements. A non-compliance report has been generated to ask for equivalent compliance to NSTS 1700.7B ISS Addendum paragraphs 200.3 and 217, AMS-02-NCR-001.

4.1.1 SVM: Thermal Analysis of EVA Work Sites and Translation Paths

4.1.2 SVM: Approval of AMS-02-NCR-001

4.1.1 STATUS: Closed. ESCG Memorandum ESCG-4470-07-TEAN-DOC-0033-B, "Alpha Magnetic Spectrometer (AMS-02) EVA Touch Temperature Evaluation," dated July 28, 2008. ESCG Memorandum ESCG-4175-REENTES-MEMO-0025, "Cryomagnet Dump Diode Accessibility," dated June 8, 2009 establishes Cryomagnet Dump Diode Inaccessible to EVA. ESCG-4470-10-TEAN-DOC-0097, "Re-evaluation of AMS-02 EVA Touch Temperatures," July 19, 2010

4.1.2 STATUS: Closed. AMS-02-NCR-001 "AMS-02 Payload EVA Touch Temperature," was approved as "Equivalent Safety" on January 6, 2009 by PSRP Chair.

4.2 CONTROL: Active thermal control devices will not be capable of heating AMS-02 components that are EVA accessible in exceedence of the EVA thermal limits for touch temperatures [235°F to -180°F (112°C to -118°C)]. Heaters have two thermal switches, one in the return leg and are monitored by the AMS-02 computer system and can be shut off if nominal working limits are exceeded. All of these limits are within the EVA thermal limits for touch temperature.

4.2.1 SVM: Review of Design

4.2.2 SVM: Inspection of as built hardware

4.2.3 SVM: Functional/workmanship testing of heater/thermal switch circuitry

4.2.4 SVM: Functional testing of thermal monitoring by avionics

4.2.5 SVM: Testing of software control of heaters.

4.2.1 STATUS: Closed. ESCG Memorandum ESCG-4470-09-TEAN-DOC-0181, "AMS-02 Active Thermal Devices and EVA Touch Temperature Limits," dated October 23, 2009. ESCG-4470-10-TEAN-DOC-0097, "Re-evaluation of AMS-02 EVA Touch Temperatures," July 19, 2010.

4.2.2 STATUS: Closed to SVTL.

4.2.3 STATUS: Closed. Thermal Vacuum Testing Report DEL037-UNIPC-20100603-is2.doc, "DEL037 TV TB Test Report," June 3, 2010, AMSTR-NLR-TR-080, "TTCS Condenser Heater Wire Test Report," February 2, 2010.

4.2.4 STATUS: Closed. Thermal Vacuum Testing Report DEL037-UNIPC-20100603-is2.doc, "DEL037 TV TB Test Report," June 3, 2010.

4.2.5 STATUS: Closed. Thermal Vacuum Testing Report DEL037-UNIPC-20100603-is2.doc, "DEL037 TV TB Test Report," June 3, 2010.

4.3 CONTROL: The AMS-02 is designed to position vent locations pressurized systems such that there will be no impingement of possible venting products, which could be extremely cold, upon EVA work sites and translation paths.

4.3.1 SVM: Review of Design of vents, vent locations and orientations.

4.3.2 SVM: Plume impingement assessment.

4.3.1 STATUS: Closed. ESCG Memorandum ESCG-4295-09-CPAS-MEMO-0014, "Review of AMS-02 Vent

Locations," dated November 13, 2009

4.3.2 STATUS: Closed. ESCG Memorandum ESCG-4295-09-CPAS-MEMO-0014, "Review of AMS-02 Vent Locations," dated November 13, 2009

5. CAUSE: Release of Residual Loads/Forces Applied

5.1 CONTROL: The potential EVA operation to move AMS-02 EVA connectors to restore communications paths or redirect power does not involve systems that involve stored mechanical energy.

5.1.1 SVM: The design of the EVA connectors, cable restraints and EVA panel will be reviewed for any mechanically stored energy.

5.1.1 STATUS: Closed. ESCG Memorandum ESCG-4175-09-REENTES-MEMO-0028, "AMS-02 EVA Cable Stored Energy," dated June 3, 2009

5.2 CONTROL: The EVA release mechanism for the PAS passive mechanism releases stored energy (5650 lb preload) by the operation of the two EVA operated release mechanisms, each using a screw driven ramp that slowly releases the tension of latched capture bar. Two mechanisms must be released fully to allow for the capture bar to clear interference brackets that preclude the attempts to extract the bar prior to full release of the preload. The SSRMS will be put into a limp mode to preclude a buildup of loads that could be released with the removal of the bar.

5.2.1 SVM: Review of Design.

5.2.2 SVM: Inspection of as built hardware.

5.2.3 SVM: Functional testing of EVA PAS Release Mechanism.

5.2.4 SVM: Review of Procedures associated with the EVA release of the AMS-02 PAS capture bar.

5.2.5 SVM: Acceptance of OCAD for EVA PAS Release(OCAD 67863)

5.2.1 STATUS: Closed. Memo ESCG-4390-06-SP-MEMO-0001, "Mechanical Design of the Payload Attach System (PAS)", dated 8 January, 2006 from AMS-02 Chief Engineer.

5.2.2 STATUS: Closed. Memo ESCG-4390-06-SP-MEMO-0003, "Quality Inspection of the Payload Attach System" dated 03 March 2006, from AMS-02 Chief Engineer Chris Tutt.

5.2.3 STATUS: Closed. Memo ESCG-4390-05-SP-MEMO-0012, "Functional Testing of the Payload Attach System" dated 28 December 2005, from AMS-02 Chief Engineer Chris Tutt.

I

PAYLOAD FLIGHT HAZARD REPORT	a. NO: AMS-02-F14
b. PAYLOAD Alpha Magnetic Spectrometer-02 (AMS-02)	c. PHASE: III

5.2.4 STATUS: Closed. Procedure “AMS-02 Passive PAS Assembly Capture Bar Release and Reinstallation Procedure,” reviewed October 6, 2009 by AMS-02 Jacobs Project Manager for appropriate steps and functionality. 5.2.5 STATUS: Closed. OCAD Closure reported to AMS-02 Project on 6/4/2010 by JSC-DA8/B. O’Keeffe.	
5.3 CONTROL: <Deleted> ROEU Bracket no longer folds 5.3.1 SVM: <Deleted> 5.3.1 STATUS: <Deleted>	
NOTE: The EVA tasks involving the release of grapple fixtures and other GFE hardware items are not covered under these assessments as the AMS-02 does not have any involvement in the design and operation of these EVA tasks.	
6. CAUSE: Excessive Loads/Effort from EVA Crew	
6.1 CONTROL: Mate/demating of EVA compatible connectors, operation of PAS passive mechanism for releasing stored energy and extraction of capture bar have all been assessed and established to be within EVA crew capabilities. 6.1.1 SVM: Ground testing of EVA interfaces. 6.1.1 STATUS: Closed. Functional Testing of PAS at thermal extremes documented in TPS 2A0720229 dated September 27, 2009 and TPS 2A0730116 dated January 18, 2008	
6.2 CONTROL: <DELETED> 6.2.1 SVM: <DELETED> 6.2.1 STATUS: <Deleted>	I
7. CAUSE: Electric Shock/Molten Metal	
NOTE: Electric Shock/Molten Metal for EVA crew (only electric shock potential for AMS-02) is addressed in AMS-02-F08.	
8. CAUSE: Entrapment of EVA Crew	
8.1 CONTROL: The design of the AMS-02 is such that all cables length and position are such that they will not snare or entangle EVA crew during EVA access to the AMS-02 or translation past or adjacent to the AMS-02. 8.1.1 SVM: Review of design.	

8.1.2 SVM: Inspection of as built hardware. 8.1.1 STATUS: Closed. ESCG Memorandum ESCG-4175-09-REENTES-MEMO-0041-A, "EVA Entrapment by AMS-02 Cables," dated July 26, 2010 8.1.2 STATUS: Closed to SVTL.	
8.2 CONTROL: Magnetic field is insufficient to entrap an EVA crew member by attraction of ferromagnetic materials in the EMU or EVA tools. 8.2.1 SVM: Magnetic Field Analysis 8.2.1 STATUS: Closed. Scientific Magnetics Memorandum AMS-302, "Force Estimates for ISS Equipment (Phase II Safety), Dated April 28, 2008. Note Permanent Magnet field approximately one-sixth of Cryomagnet field strength.	I
9. CAUSE: Improper Installation of EBCS	
9.1 CONTROL: The EBCS is installed and aligned to allow for proper alignment of the AMS-02 to the ISS PAS location during berthing operations per SSP 57003. Proper alignment of an operating EBCS provides visual cues for proper installation into the PAS location without unplanned contact. 9.1.1 SVM: Review of Design 9.1.2 SVM: Inspection of EBCS Installation on Flight hardware 9.1.3 SVM: Alignment testing of EBCS to PAS passive hardware mounted to AMS-02 (operational check) 9.1.1 STATUS: Closed. ESCG Memorandum ESCG-4410-09-MSDE-MEMO-0003, "EBCS Alignment," dated 04/17/09 9.1.2 STATUS: Closed to SVTL. 9.1.3 STATUS: Closed to SVTL.	
10. CAUSE: Protrusion Outside of PAS Payload Envelope	
10.1 CONTROL: AMS-02 has been designed to minimize the protrusions outside of the nominal define PAS site payload envelope per SSP 57003. AMS-02 has identified all locations where exceedences of the AMS-02 PAS site payload occur and confirmed that none of these protrusions will violated the installation envelope for an adjacent PAS site payload including worst case alignment in translation and rotation of that payload during installation.	

10.1.1 SVM: Review of Design

10.1.2 SVM: MAGIK analysis of installation clearances for adjacent payload.

10.1.3 SVM: ISS acceptance of SSP 57003 envelope exceedences.

10.1.1 STATUS: Closed. Review documented in ISS PIRN 57213-NA-0008, "AMS (Alpha Magnetic Spectrometer) – On-orbit Operations Envelope Exceedance," dated June 11, 2007, Approved 2/26/2009.

10.1.2 STATUS: Closed. Published MAGIK Analysis Action Item #1705 Report dated May 12, 2003, Published MAGIK Analysis Action Item #2172 Revision A dated February 27, 2007. MAGIK Analysis Action Item #2483 dated July 16, 2010.

10.1.3 STATUS: Closed to SVTL. To be closed with ISS PIRN # 57213-NA-0008

10.2 CONTROL: The AMS-02 ROEU fixture does not intrude into the adjacent payload envelope.

10.2.1 SVM: Review of Design

10.2.2 SVM: MAGIK analysis of installation clearances for adjacent payload.

10.2.3 SVM: ISS acceptance of SSP 57003 envelope exceendences.

10.2.1 STATUS: Closed. Review documented in ISS PIRN 57213-NA-0008, "AMS (Alpha Magnetic Spectrometer) – On-orbit Operations Envelope Exceedance," dated June 11, 2007, Approved 2/26/2009.

10.2.2 STATUS: Closed. Published MAGIK Analysis Action Item #1705 Report dated May 12, 2003, Published MAGIK Analysis Action Item #2172 Revision A dated February 27, 2007

10.2.3 STATUS: Closed. ISS PIRN 57213-NA-0008, "AMS (Alpha Magnetic Spectrometer) – On-orbit Operations Envelope Exceedance," dated June 11, 2007, Approved 2/26/2009.

11. CAUSE: Improper Placement/Installation of Grapple Fixtures

11.1 CONTROL: AMS-02 has placed the Flight Releasable Grapple Fixture and the Power Video Grapple Fixture on opposites sides of the AMS-02 structure to facilitate the hand off between the SRMS and SSRMS during AMS-02 installation operations.

11.1.1 SVM: Review of Design

11.1.2 SVM: MAGIK Analysis of robotic operations of removal from Orbiter Payload Bay, handoff and installation into PAS location.

PAYLOAD FLIGHT HAZARD REPORT	a. NO: AMS-02-F14
b. PAYLOAD Alpha Magnetic Spectrometer-02 (AMS-02)	c. PHASE: III

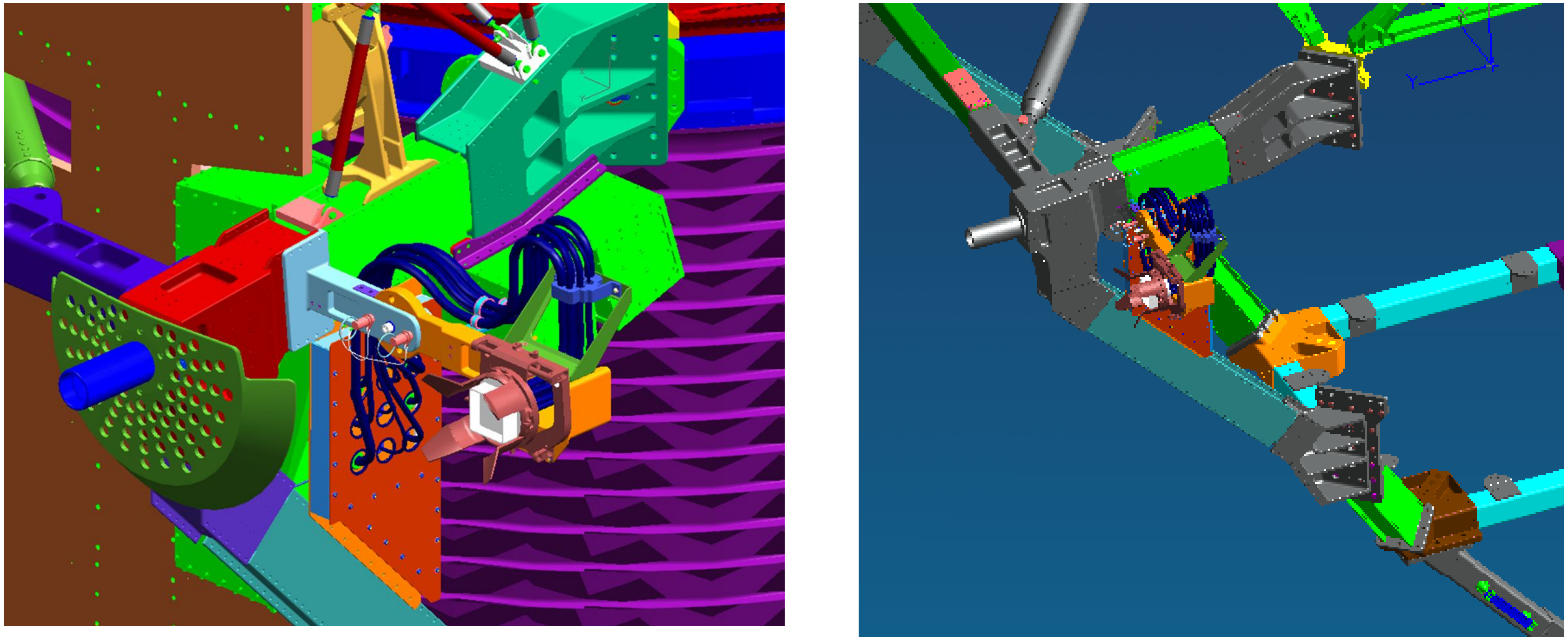
11.1.1 STATUS: Closed. ESCG Memorandum ESCG-4175-09-REENTES-MEMO-0056, "AMS-02 Grapple Fixtures," dated August 18, 2009

11.1.2 STATUS: Closed. Published MAGIK Analysis Action Item 2279 Revision A dated April 8, 2008. Published MAGIK Analysis Action Item 2483 dated July 15, 2010.

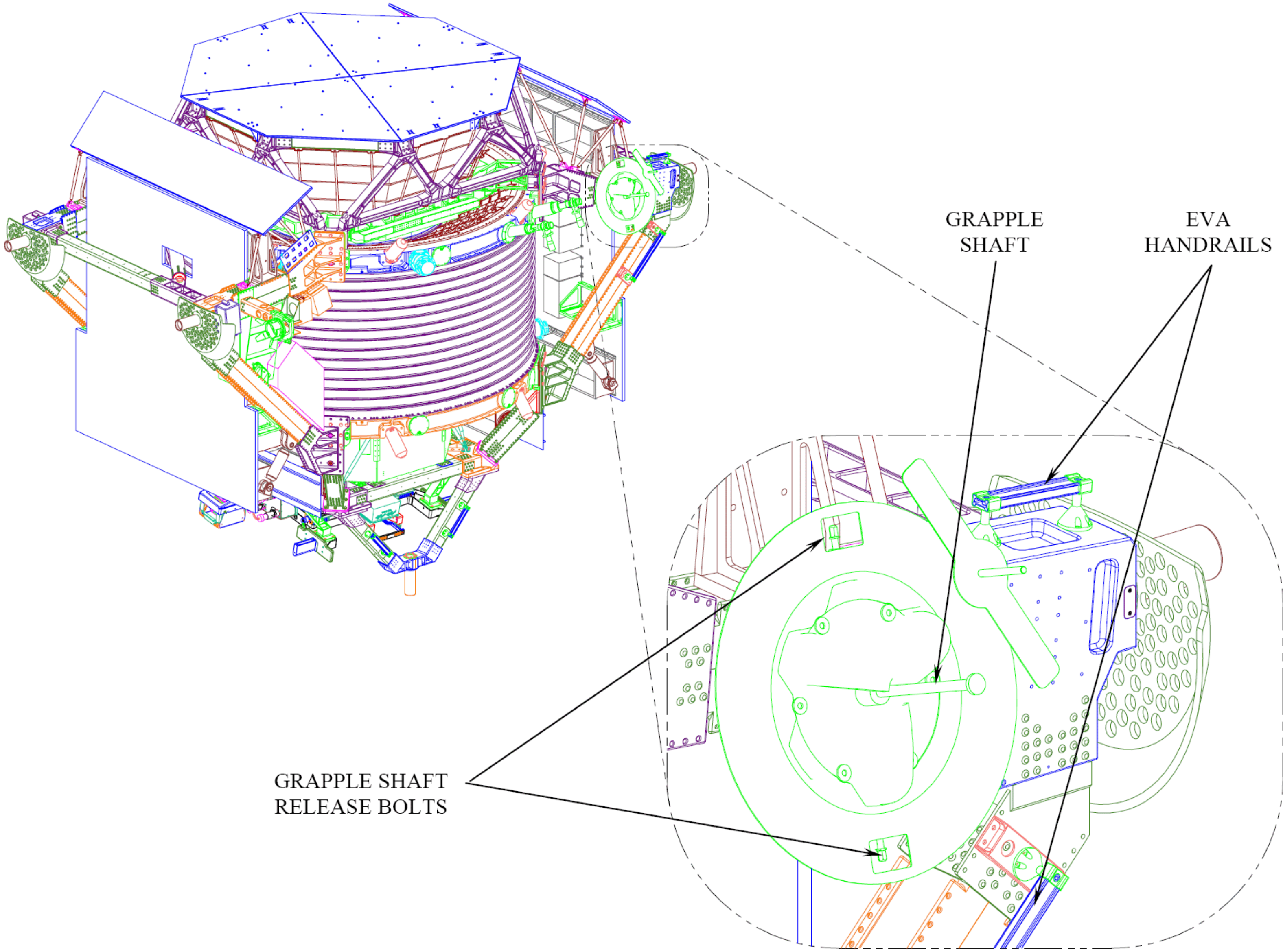
ACRONYMS	
°C – Degrees Centigrade (Celsius)	GFE – Government Furnished Equipment
°F – Degrees Fahrenheit	MAGIK – Manipulator Analysis Graphic and Interactive Kinematics (Team)
AMS-02 – Alpha Magnetic Spectrometer - 02	PAS – Payload Attach System, Payload Attach Site
ATA -	PVGF – Power Video Grapple Fixture
EVA – Extravehicular Activity	ROEU – Remotely Operated Electrical Umbilical
EVR – Extravehicular Robotic (activity)	SRMS – Shuttle Remote Manipulator System
EMU – Extravehicular Mobility Unit	SSRMS – Space Station Remote Manipulator System
EVA – Extravehicular Activity	SVM – Safety Verification Method
FRGF – Flight Releasable Grapple Fixture	WIF – Worksite Interface Fixture
EMI – Electromagnetic Interference	

SHUTTLE BASED EVAs

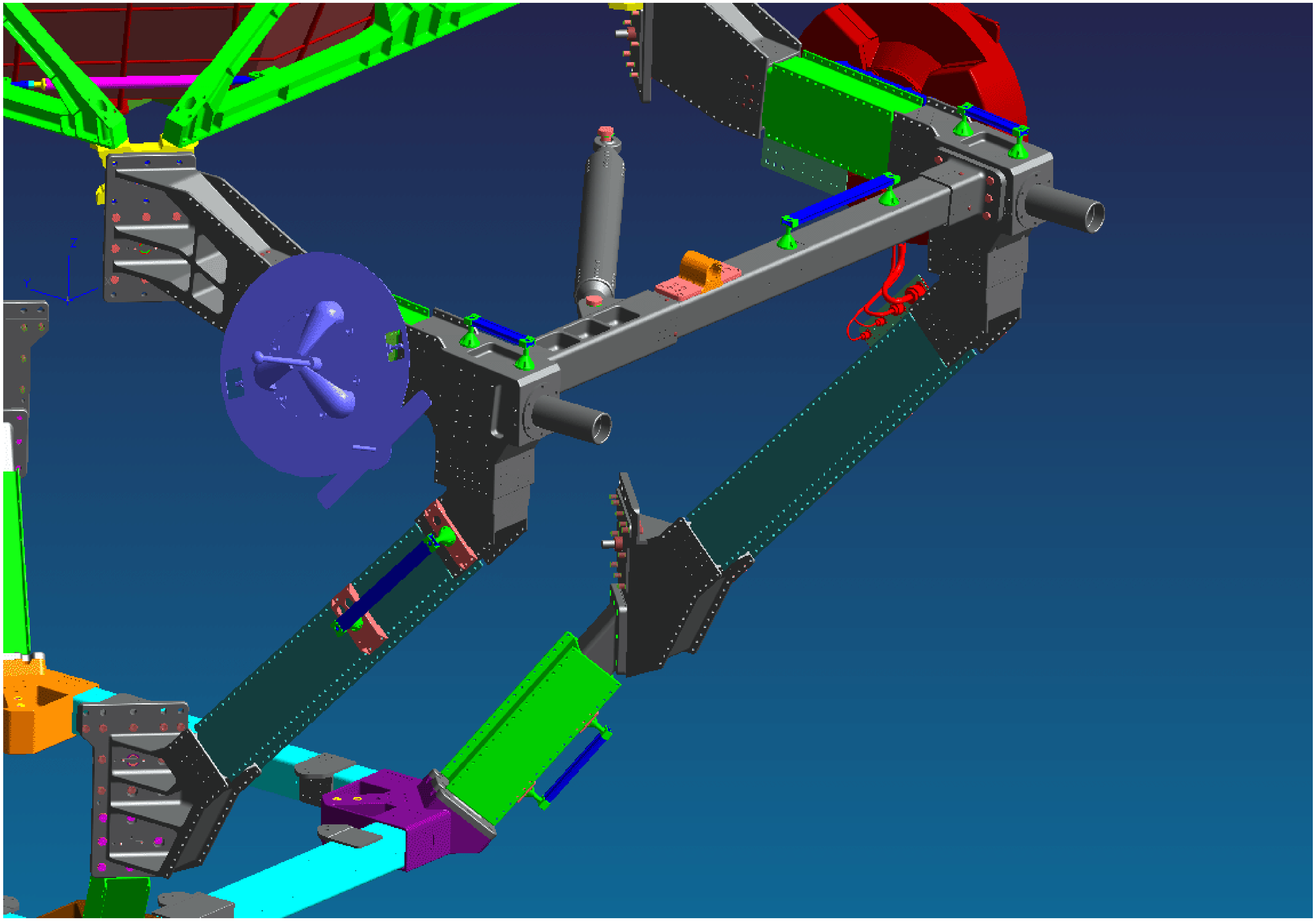
- ROEU Release/Mate
- FRGF Release
- PRLA Release/Closure



Potential EVA Work Site: Remotely Operated Electrical Umbilical (ROEU)



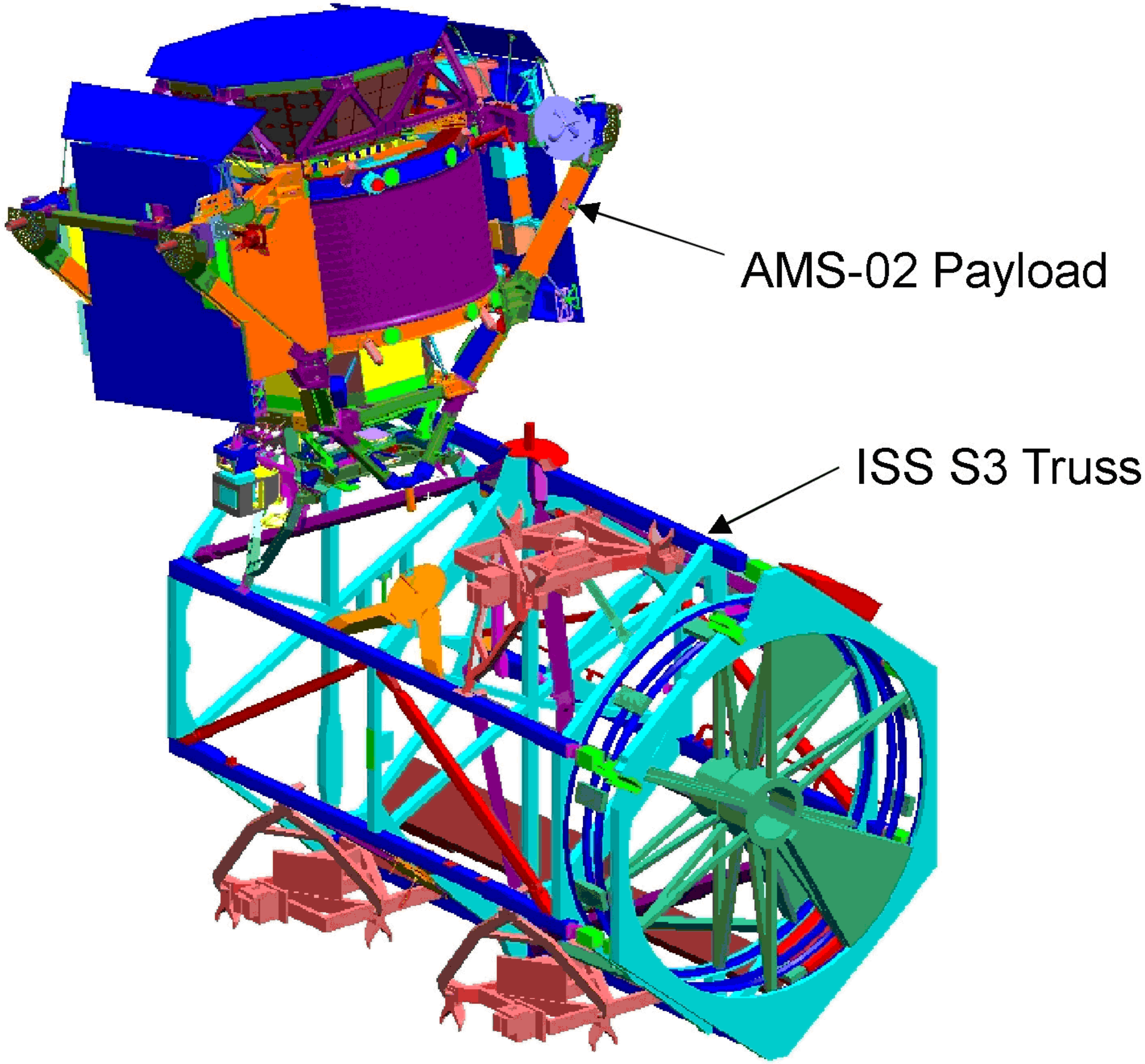
Potential EVA Work Site: Flight Releasable Grapple Fixture (FRGF)



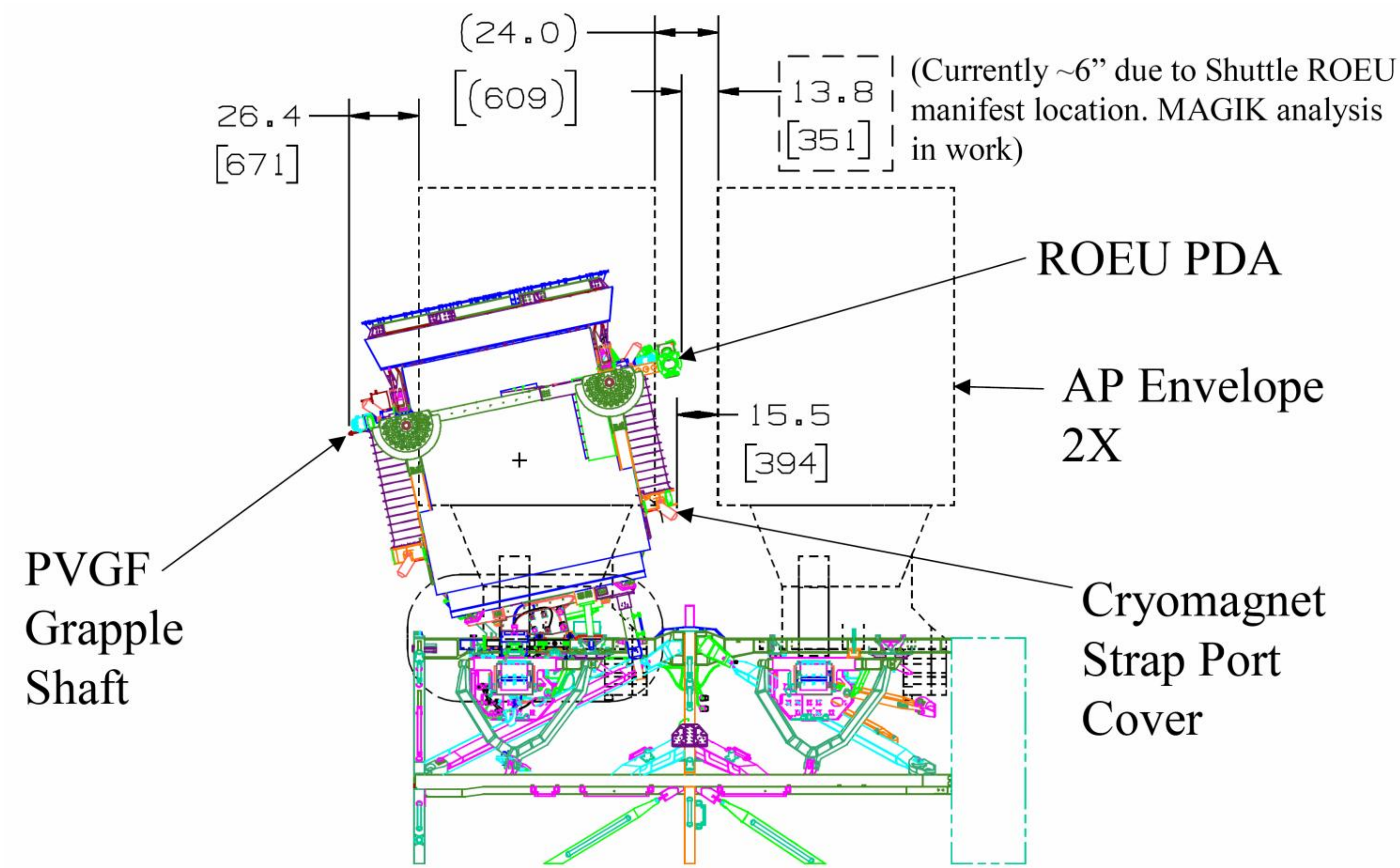
Handrails around FRGF

ISS BASED EVAs

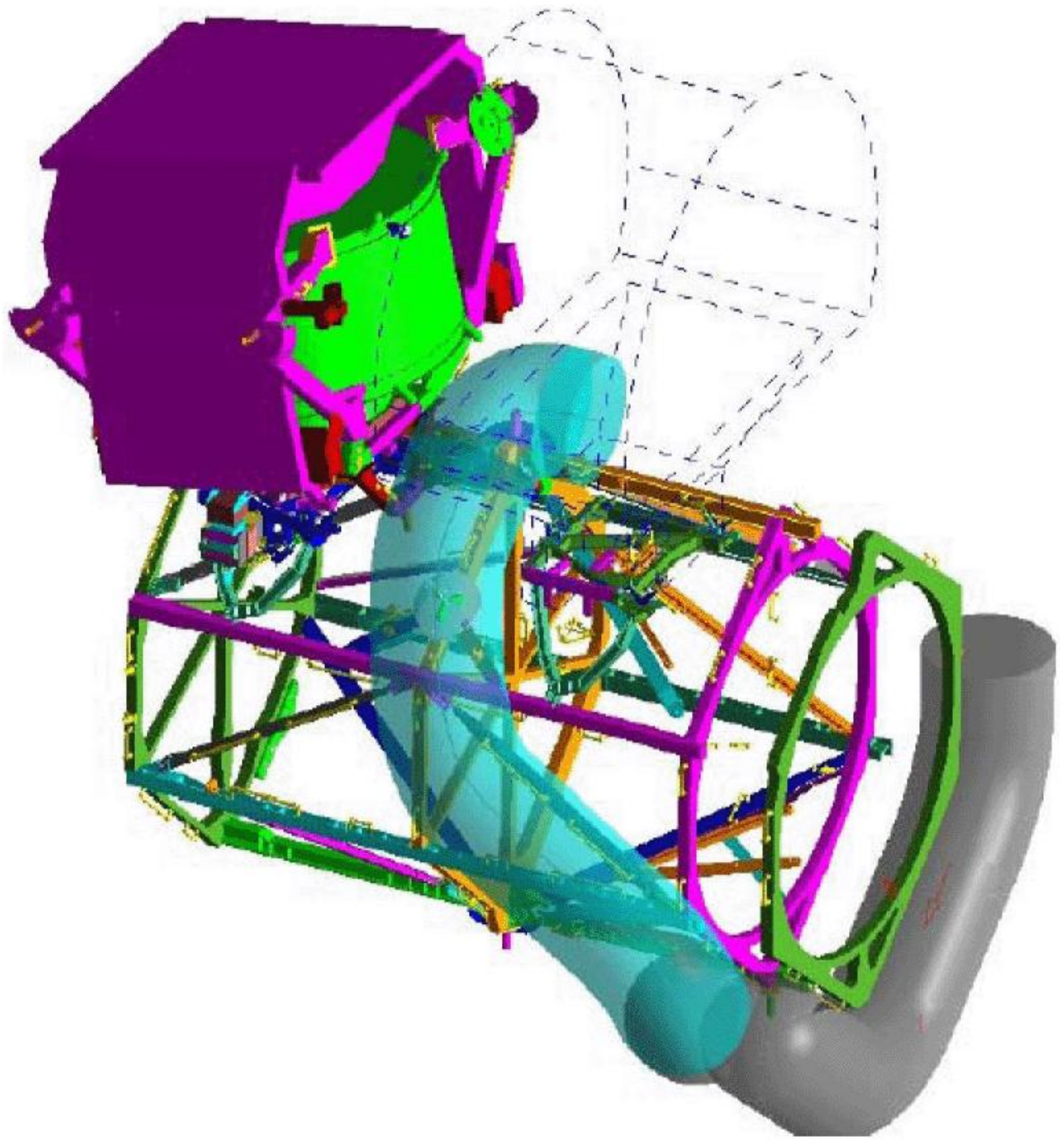
- General Translation Compatibility
- AMS-02 Passive PAS Release
- ISS UMA Release/Connect
- AMS-02 EVA Connector Swap
- ISS PVGF Release



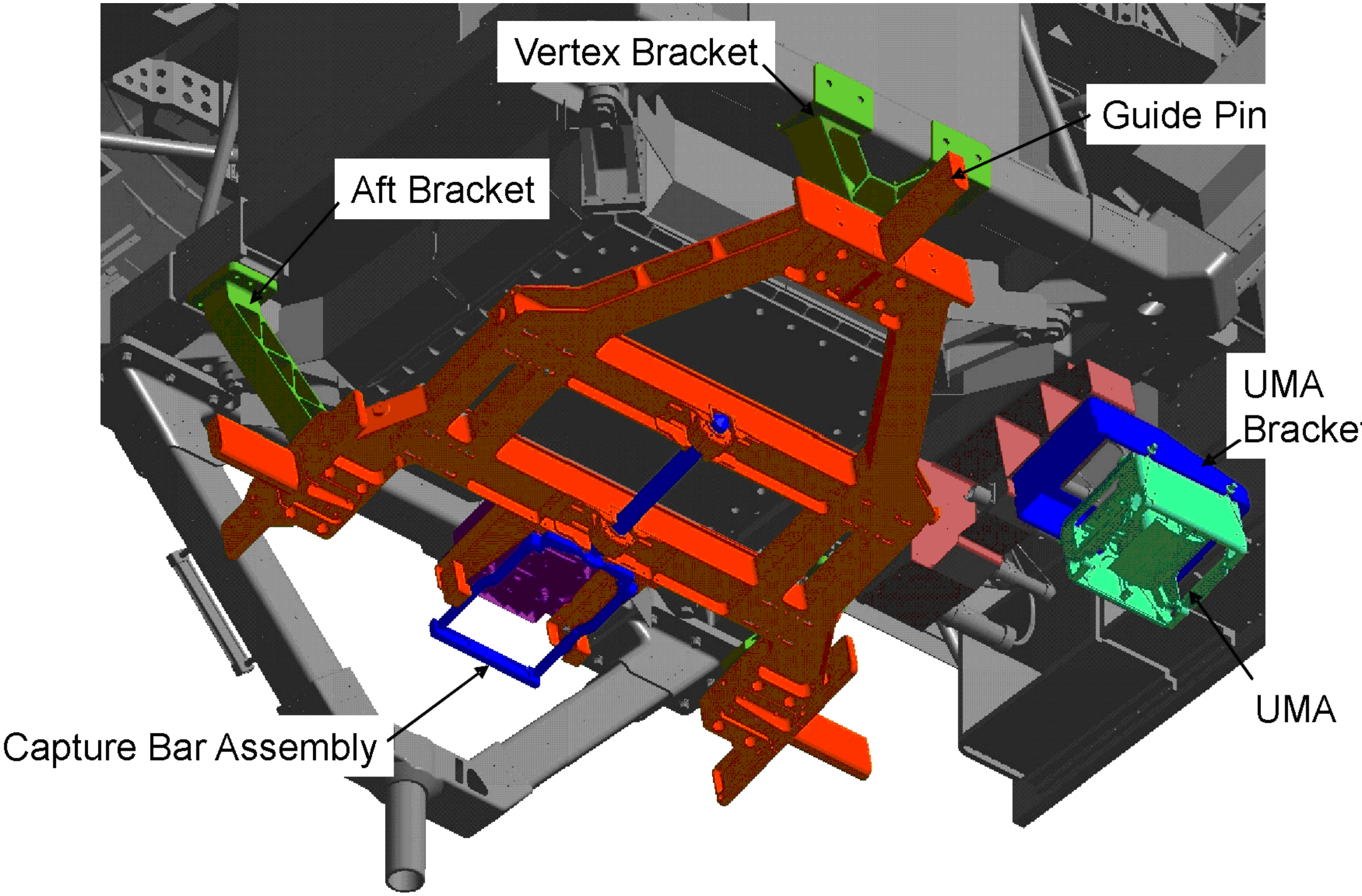
AMS-02 Location During Potential ISS Based EVAs



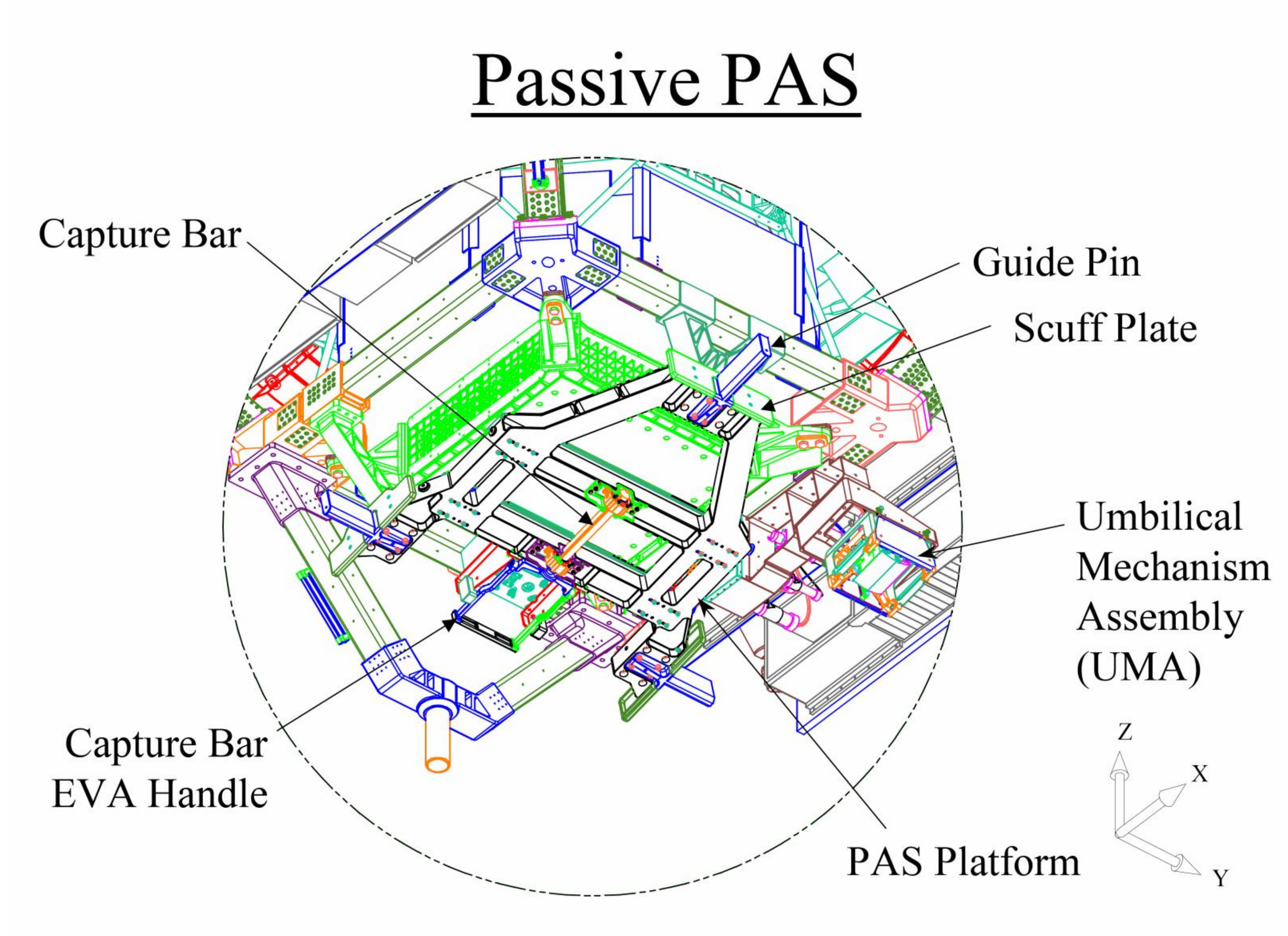
AMS-02 Location During Potential ISS Based EVAs



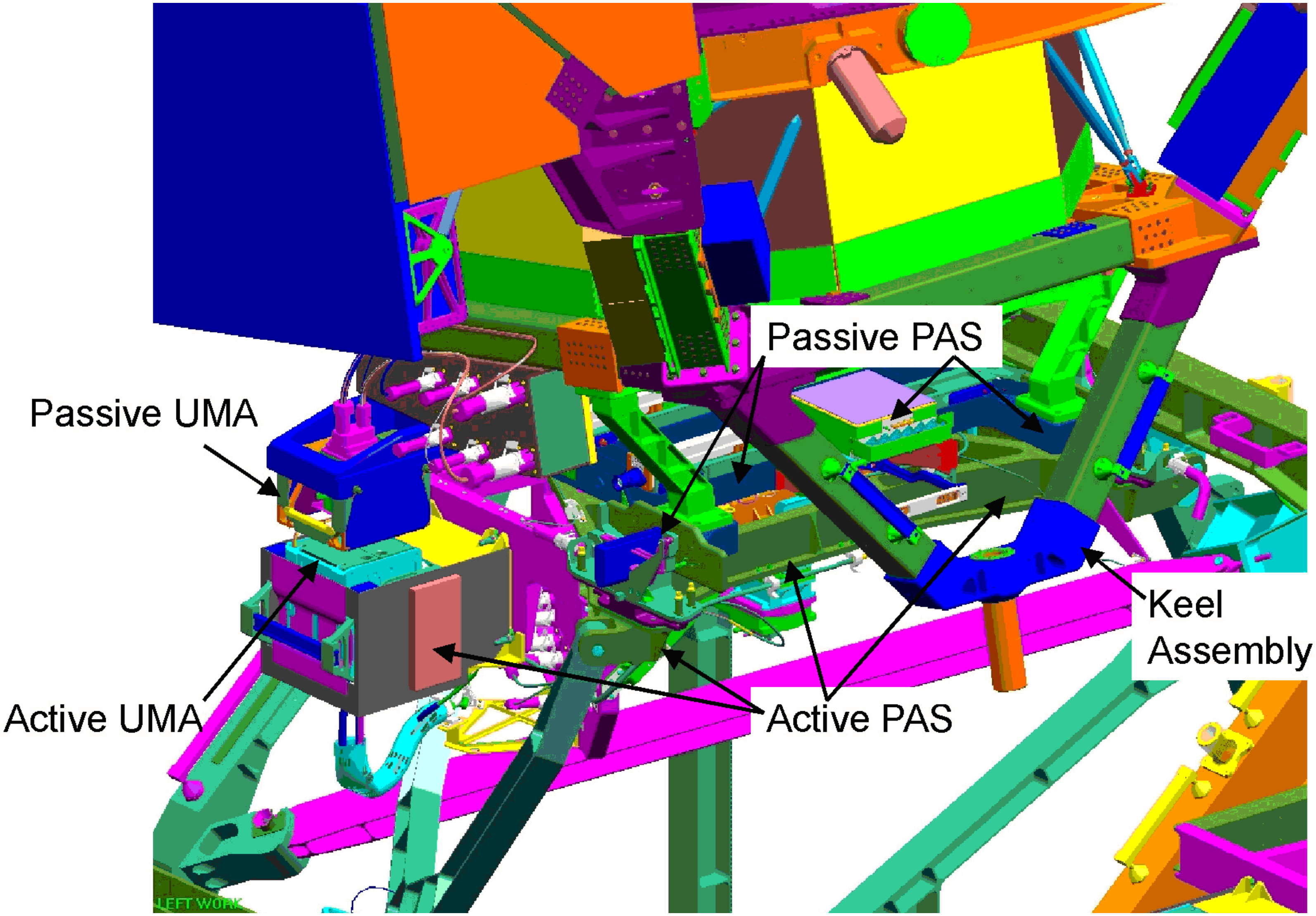
EVA Worksite Translation Analysis Results



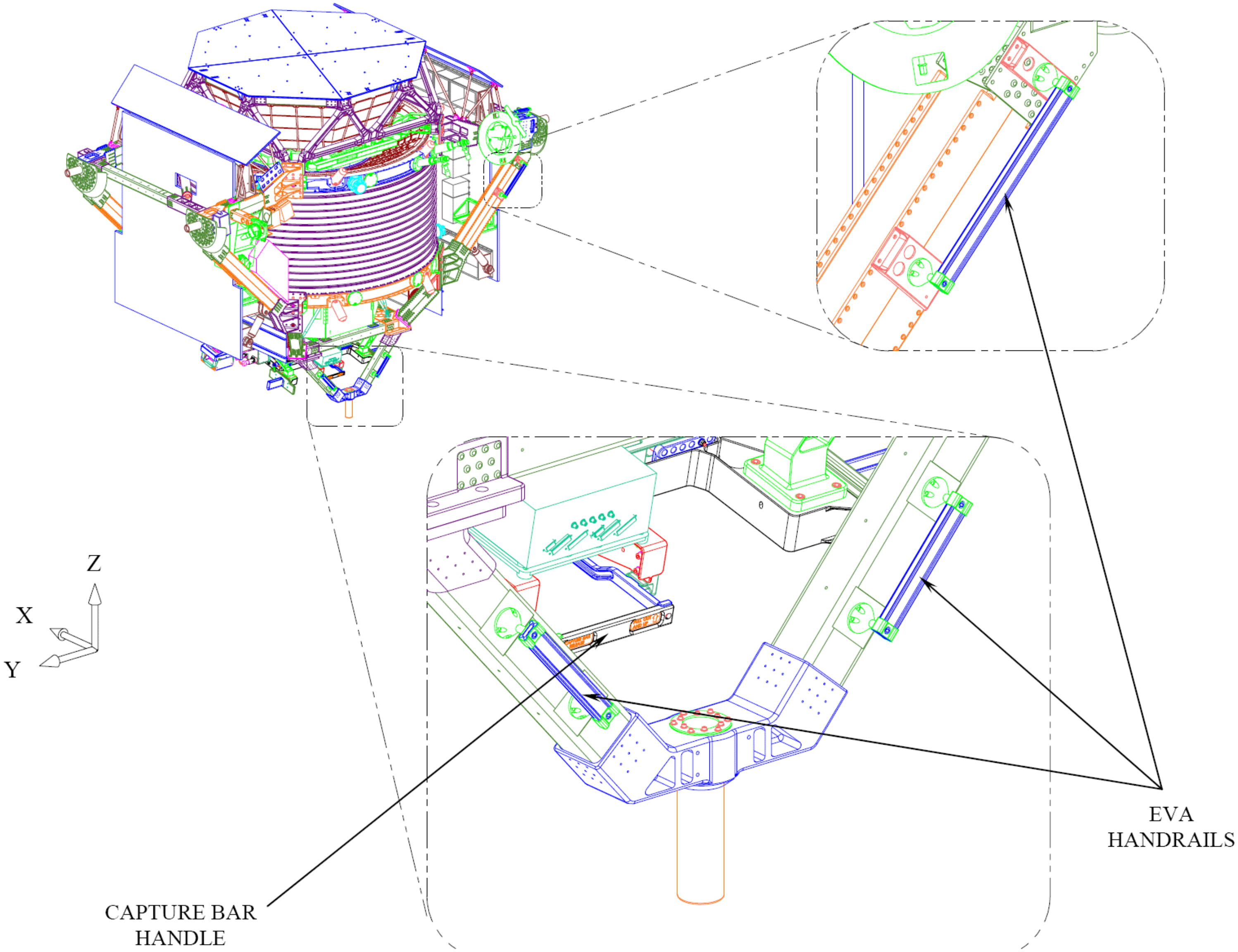
Potential EVA Work Site: Passive Payload Attach System (PAS)



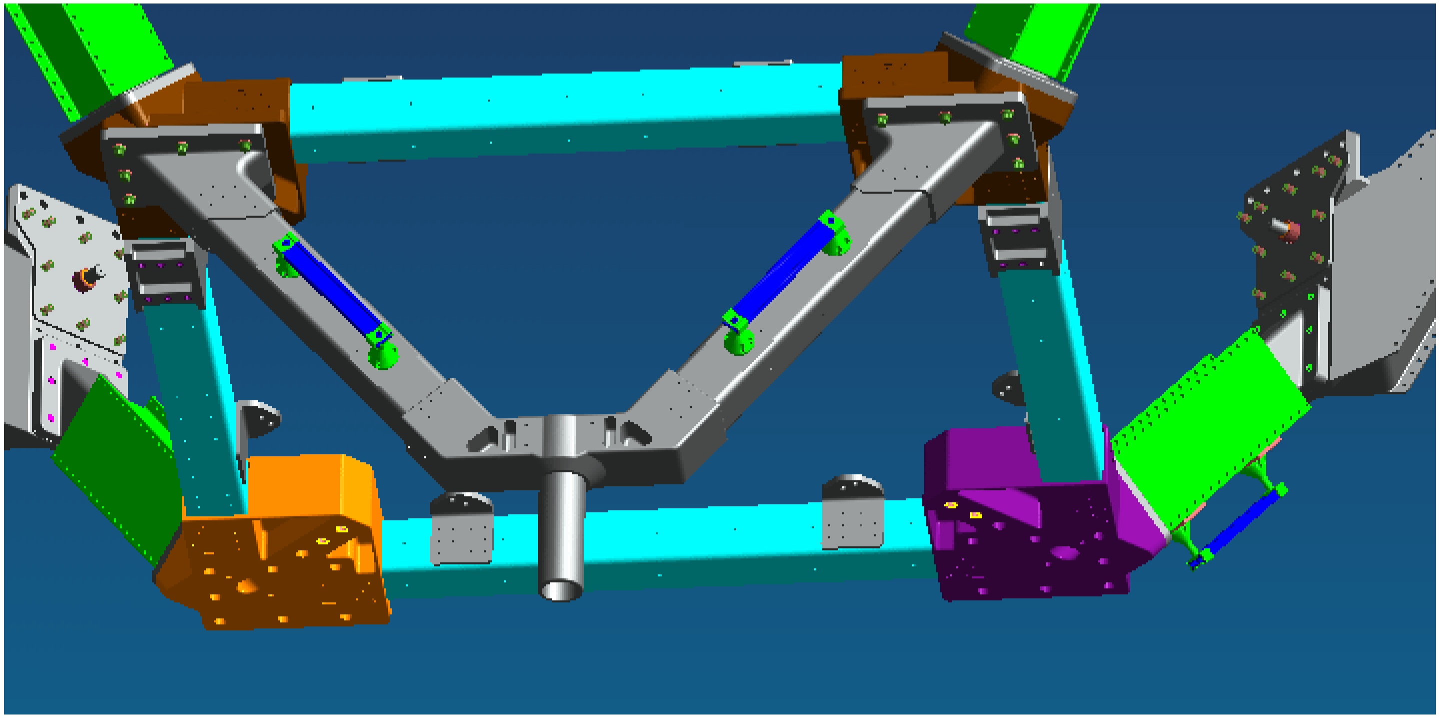
Potential EVA Work Site: AMS-02 Passive PAS



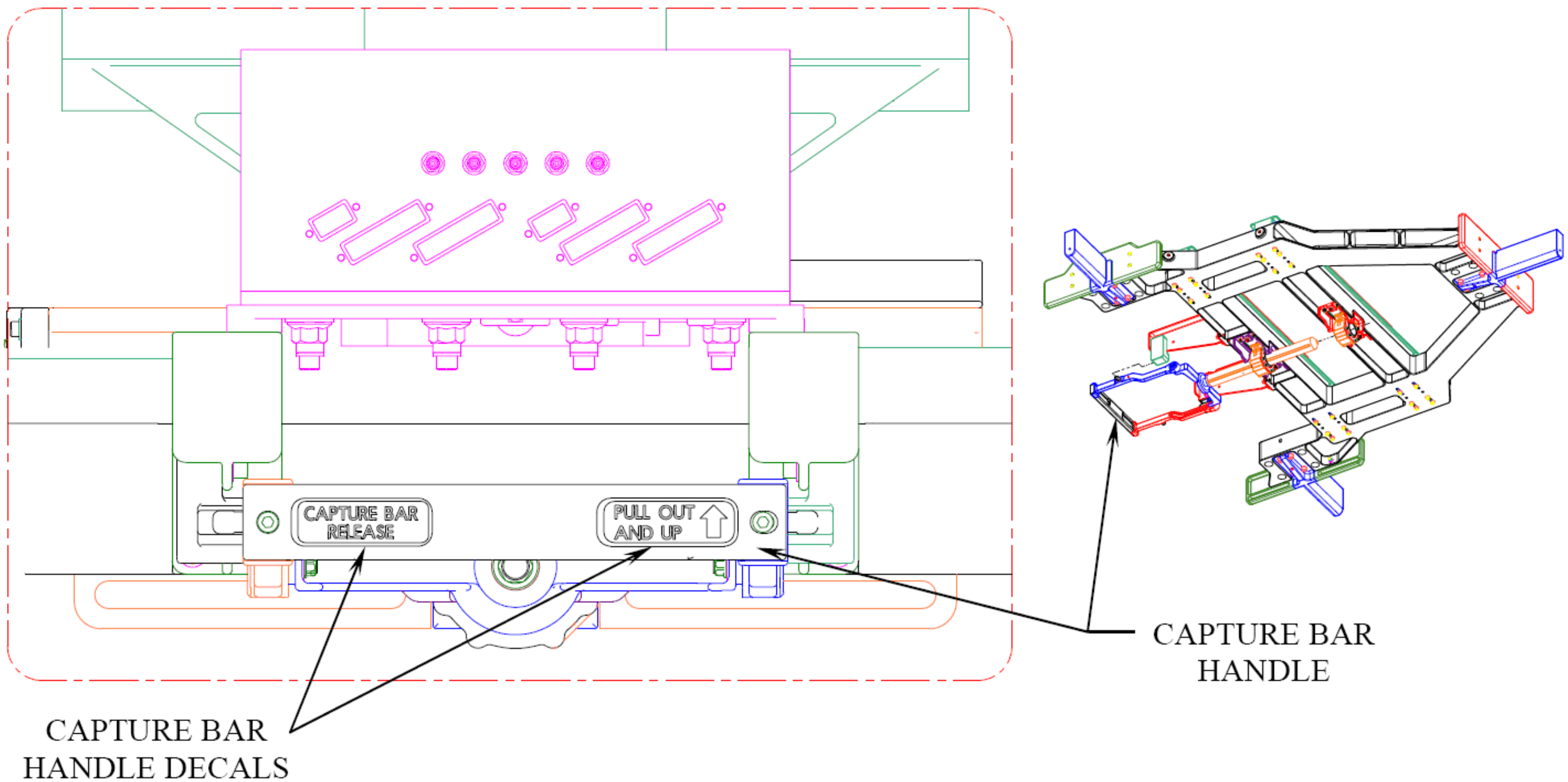
Potential EVA Work Site: AMS-02 Passive PAS, EVA Interface Panel and UMA



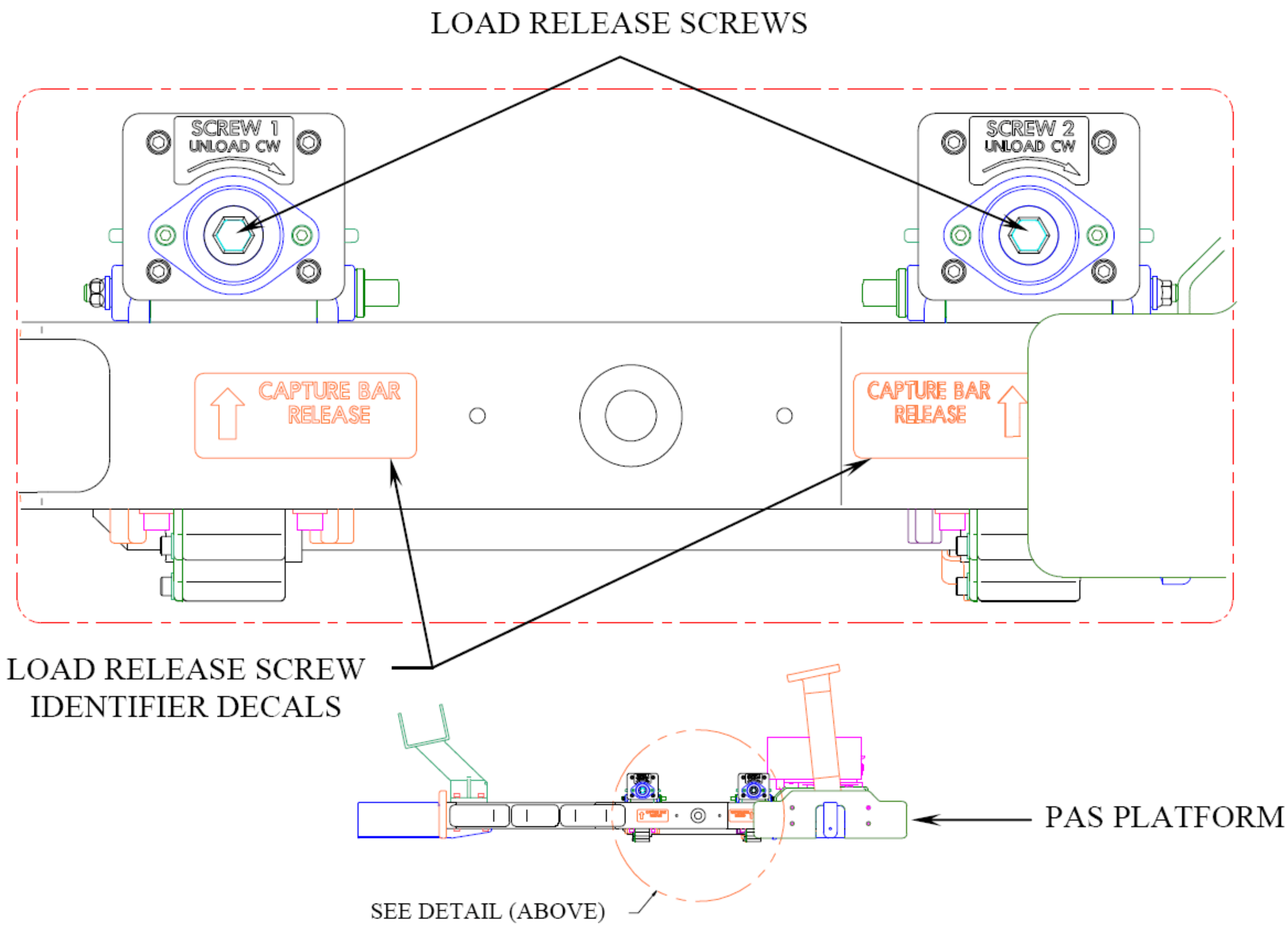
Potential EVA Work Site: AMS-02 Passive PAS



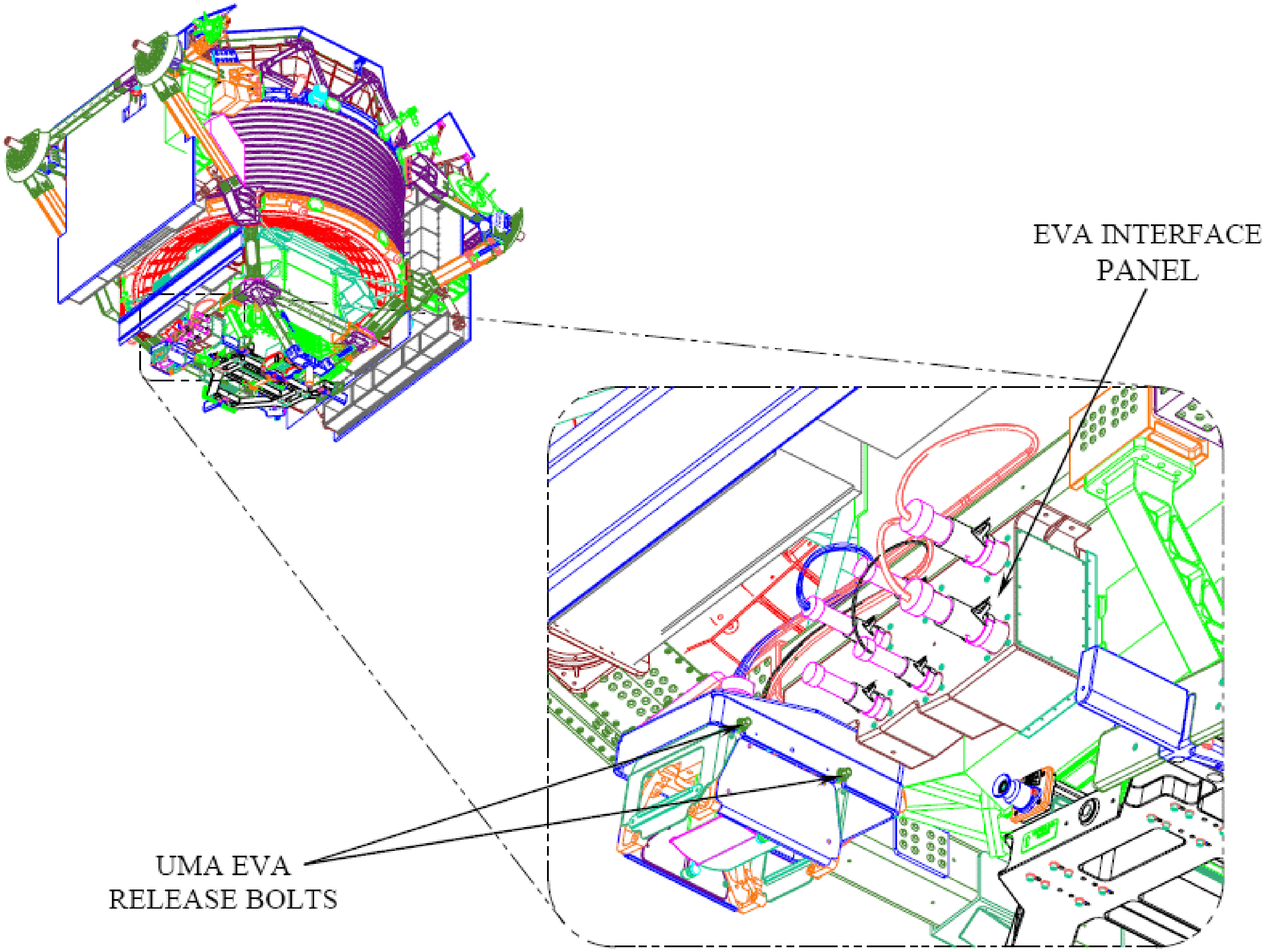
Keel Area Handrails



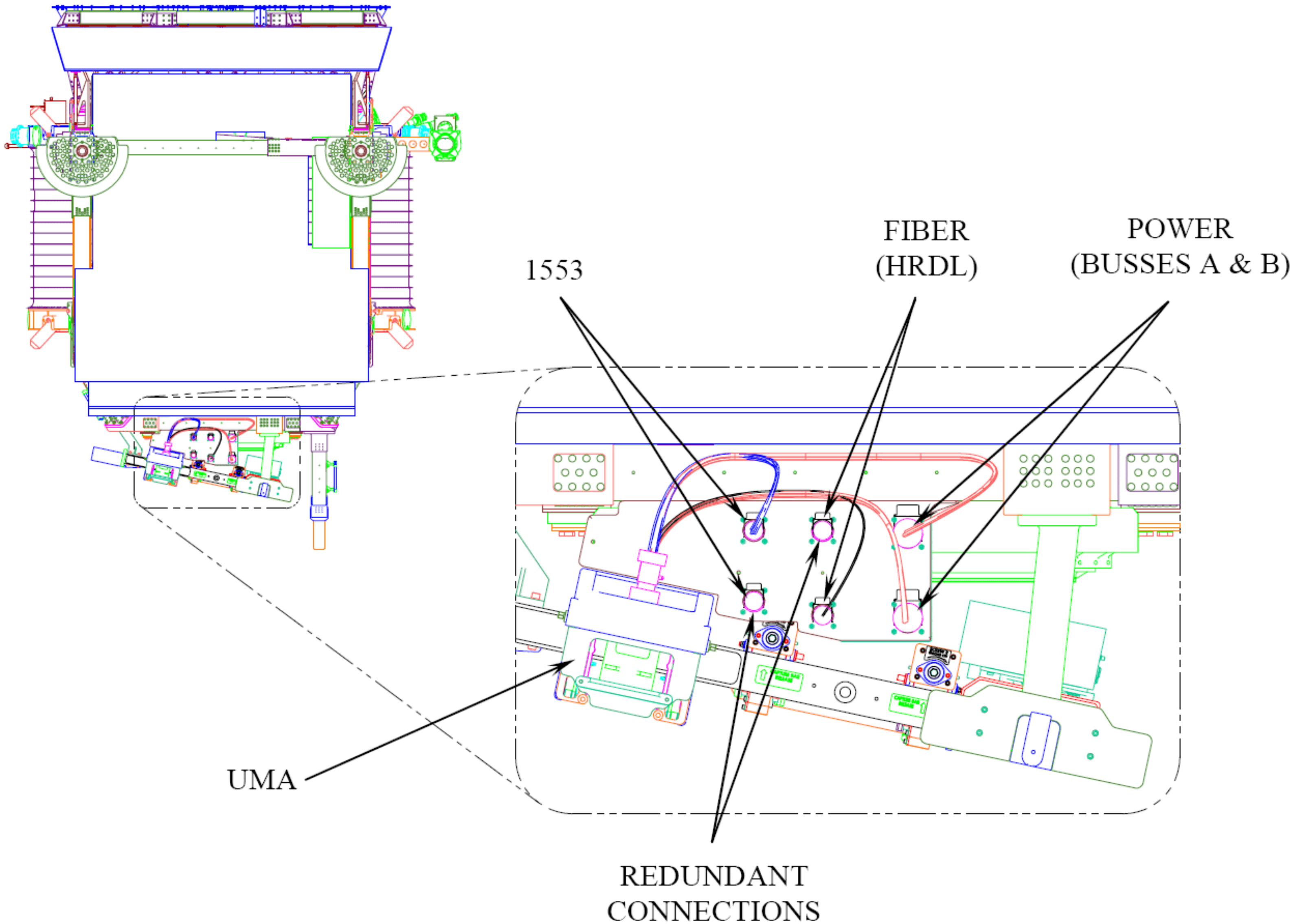
PAS Capture Bar Location



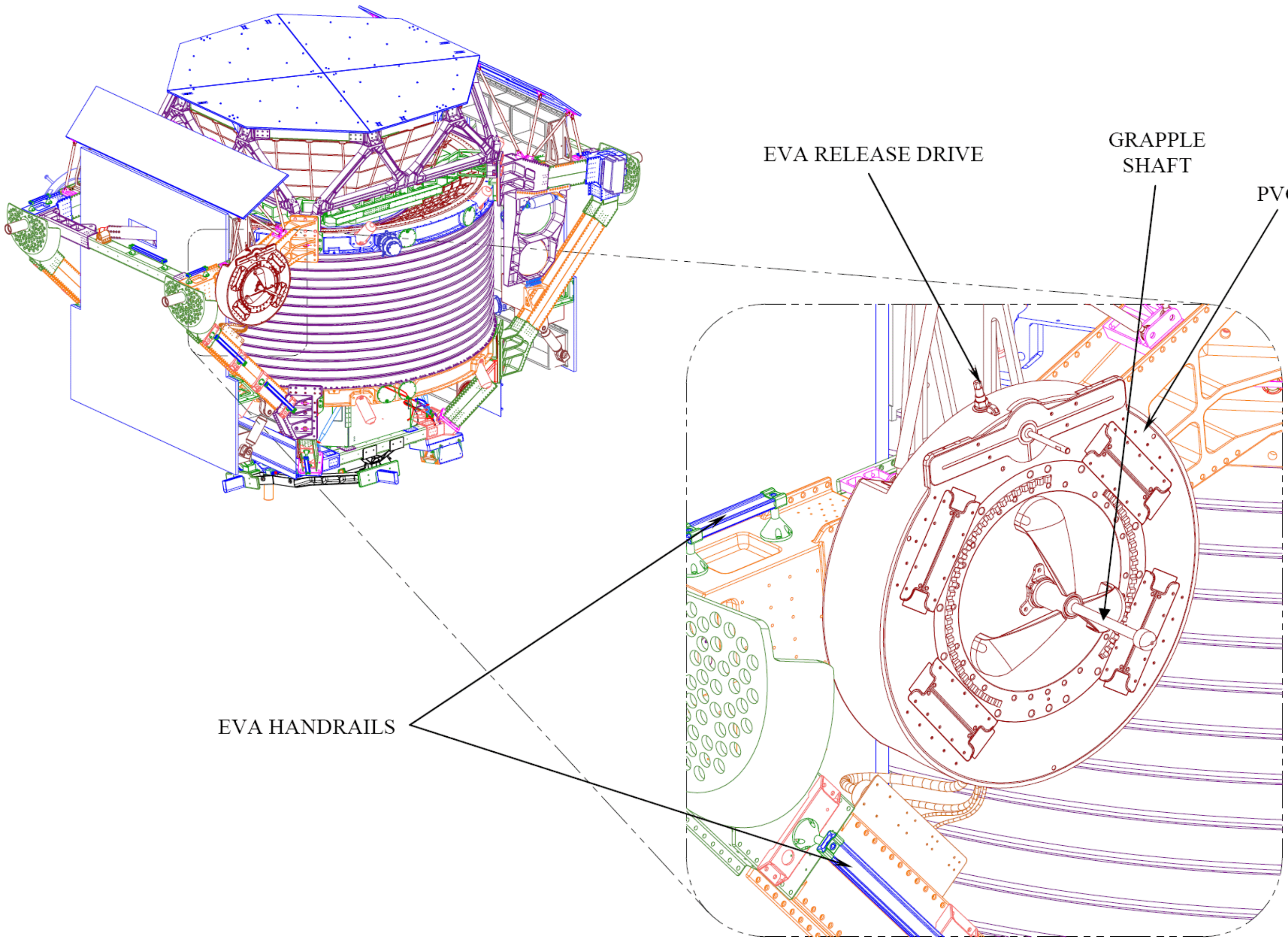
PAS EVA Interface Locations



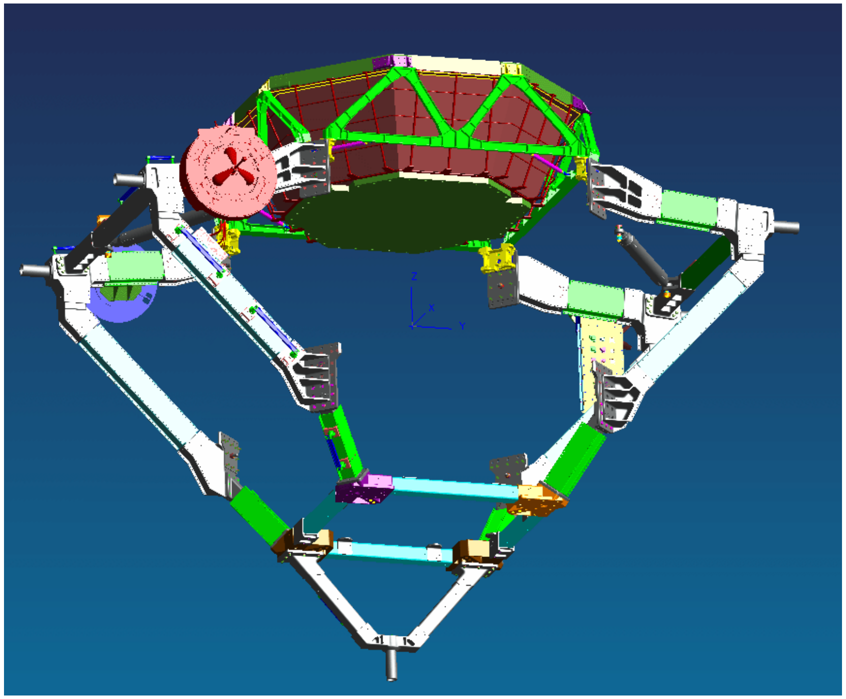
Potential EVA Worksite: AMS-02 EVA Panel, PAS EVA Release Location and UMA Release

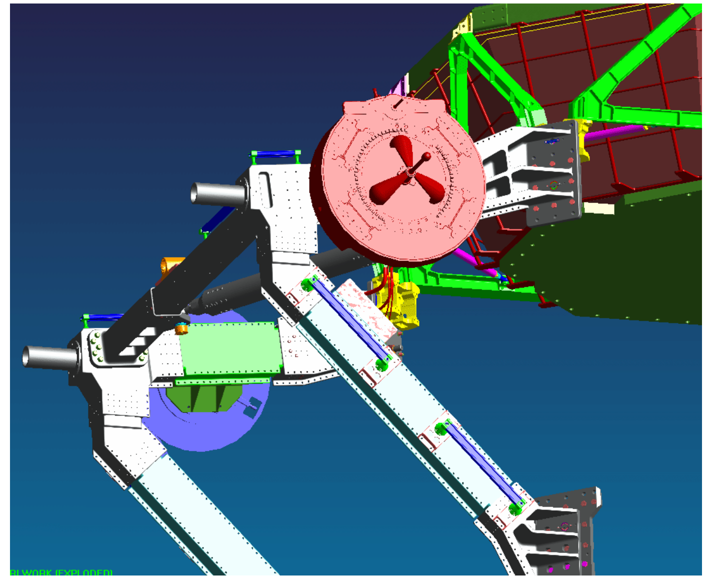


Potential EVA Work Site: AMS-02 Connector Panel and Passive UMA

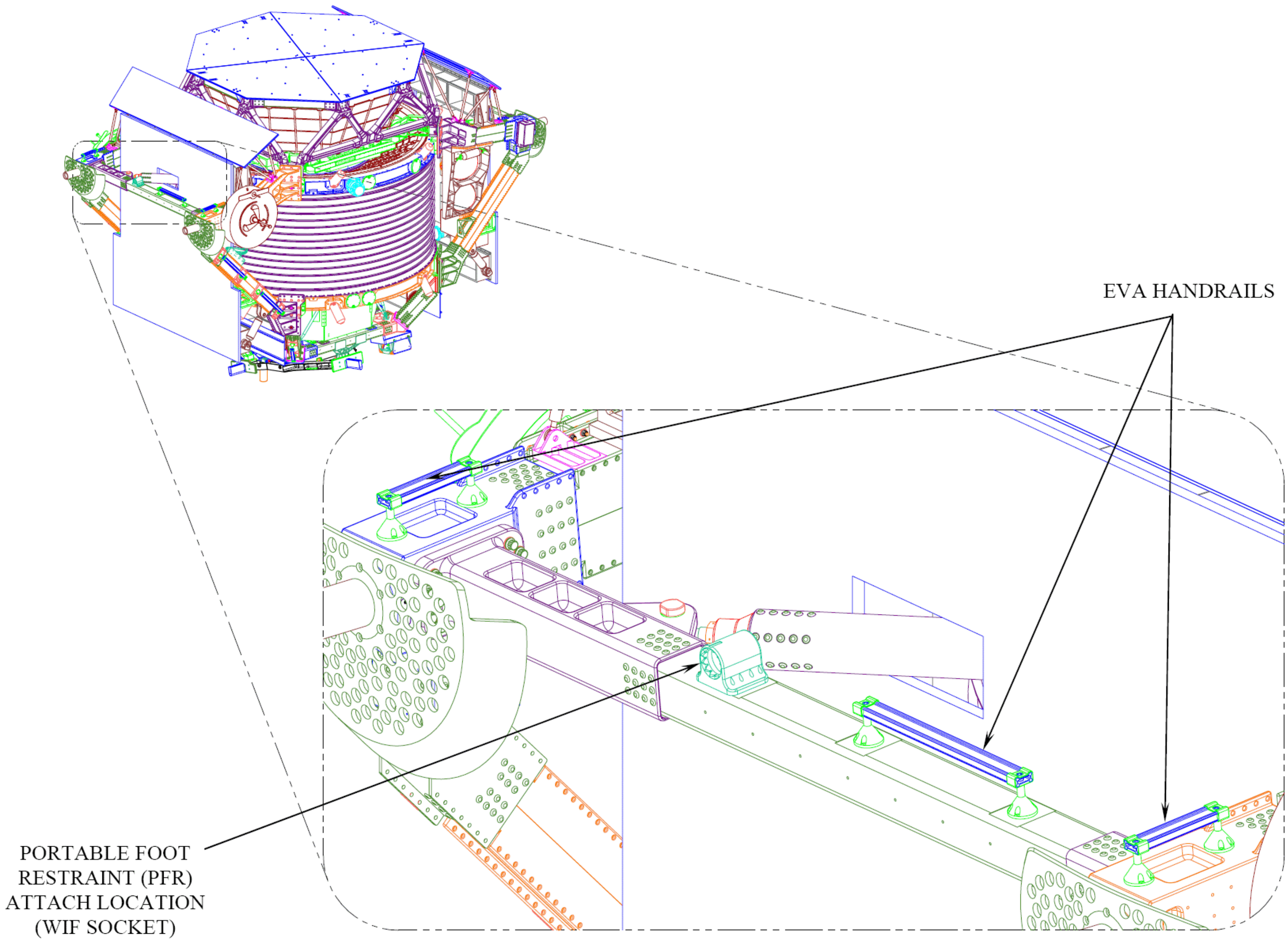


Potential EVA Work Site: Power Video Grapple Fixture (PVGF)

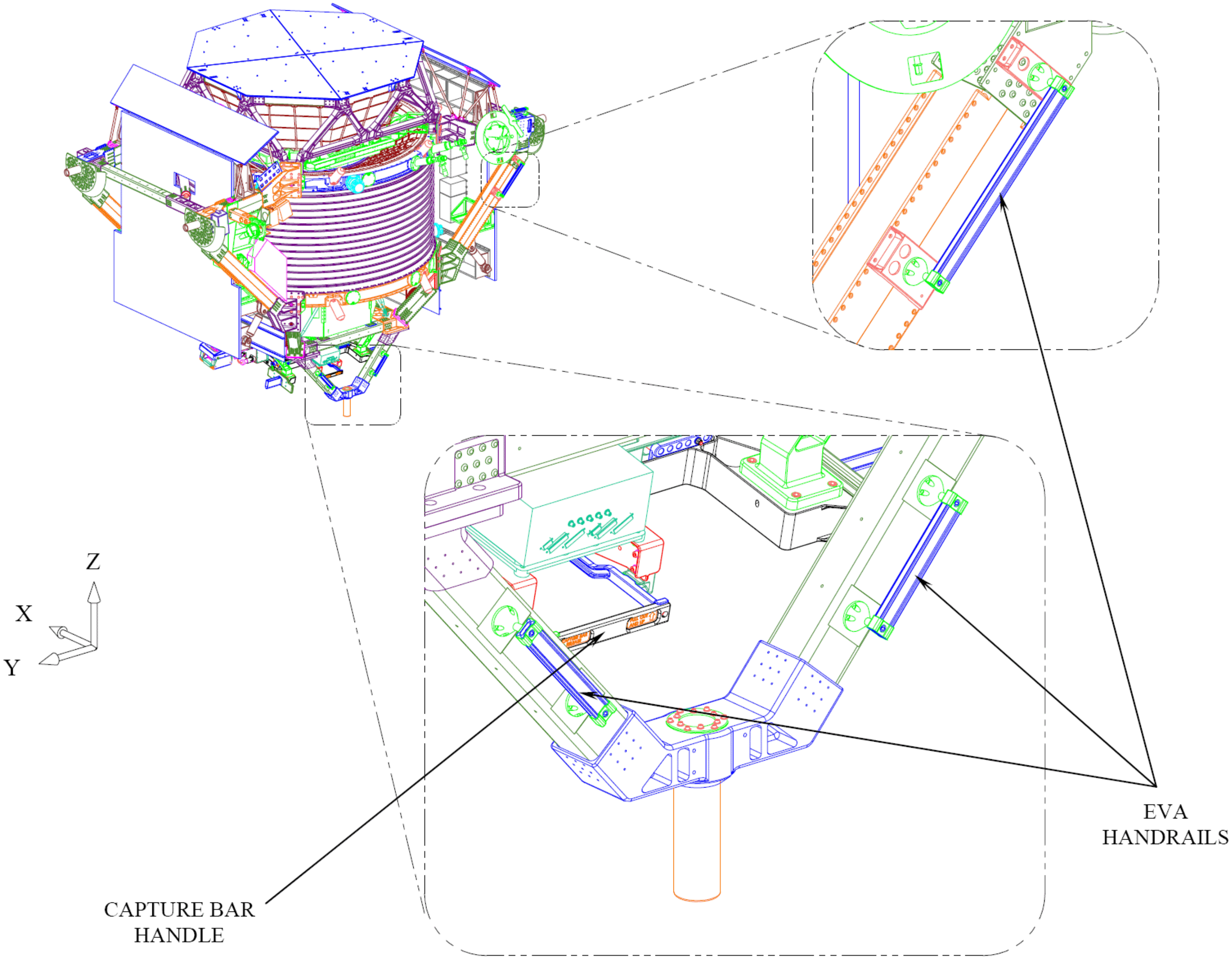




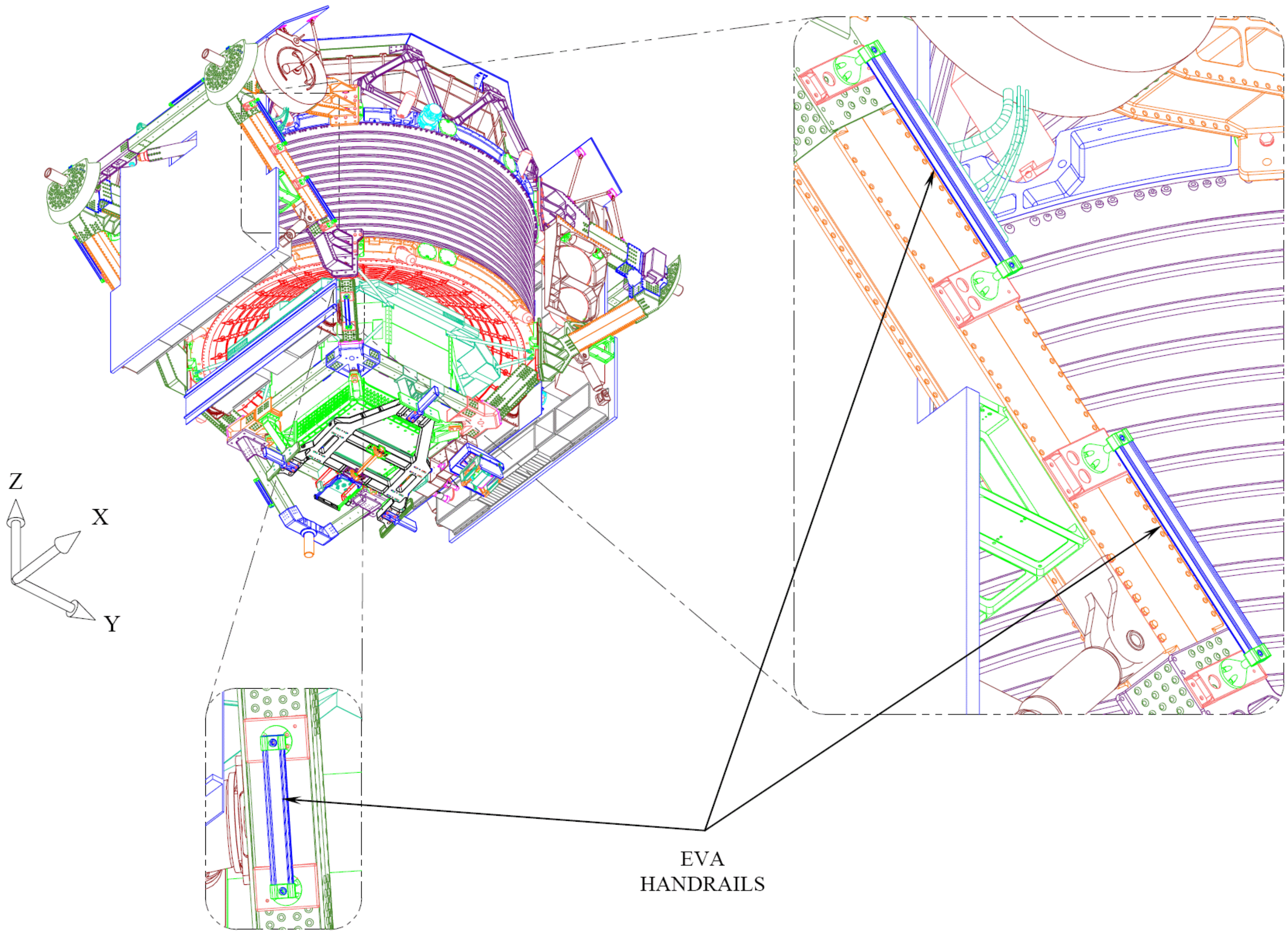
PVGF Area Handrails



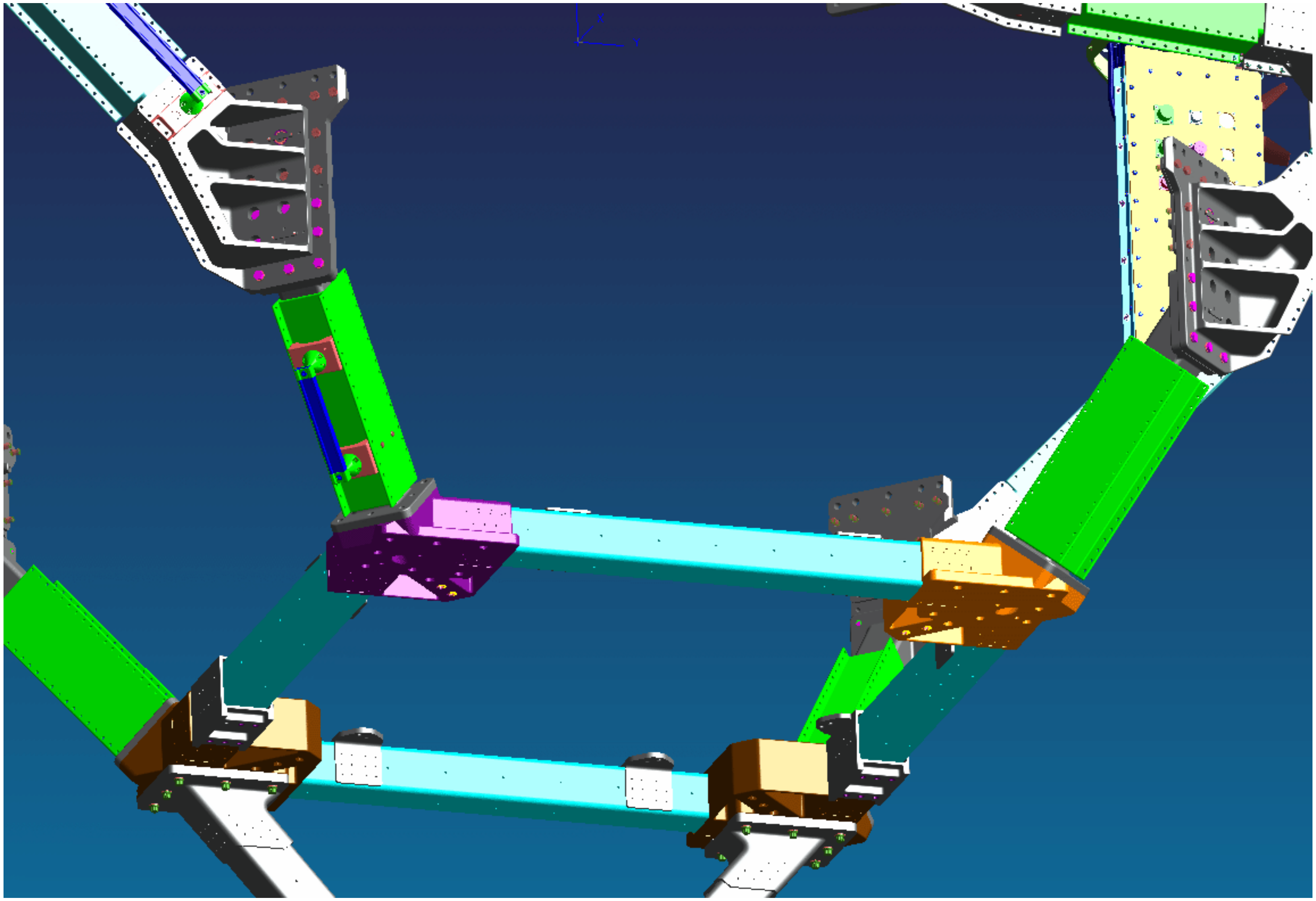
AMS-02 EVA TRANSLATION AID LOCATION



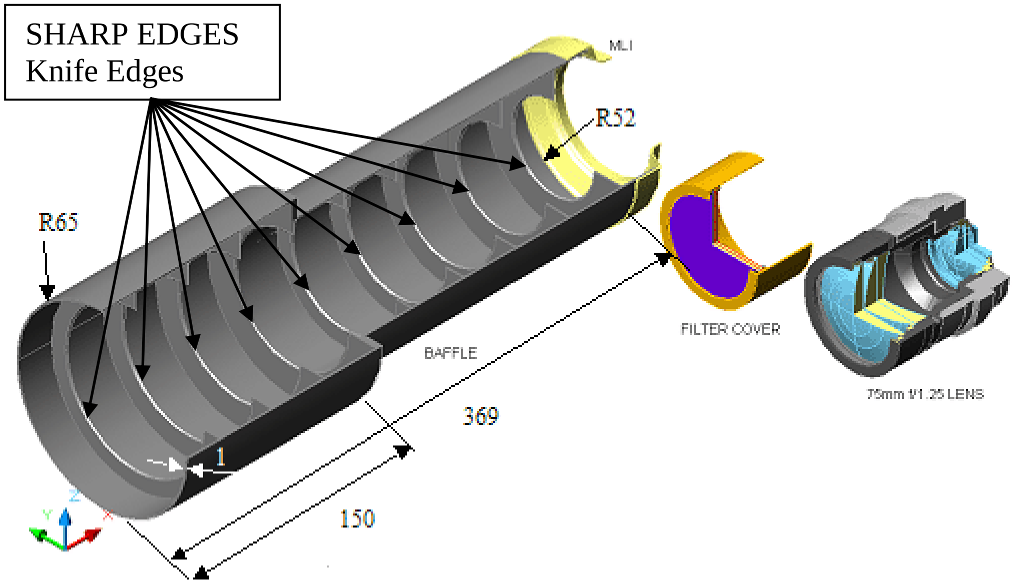
AMS-02 EVA TRANSLATION AID LOCATION



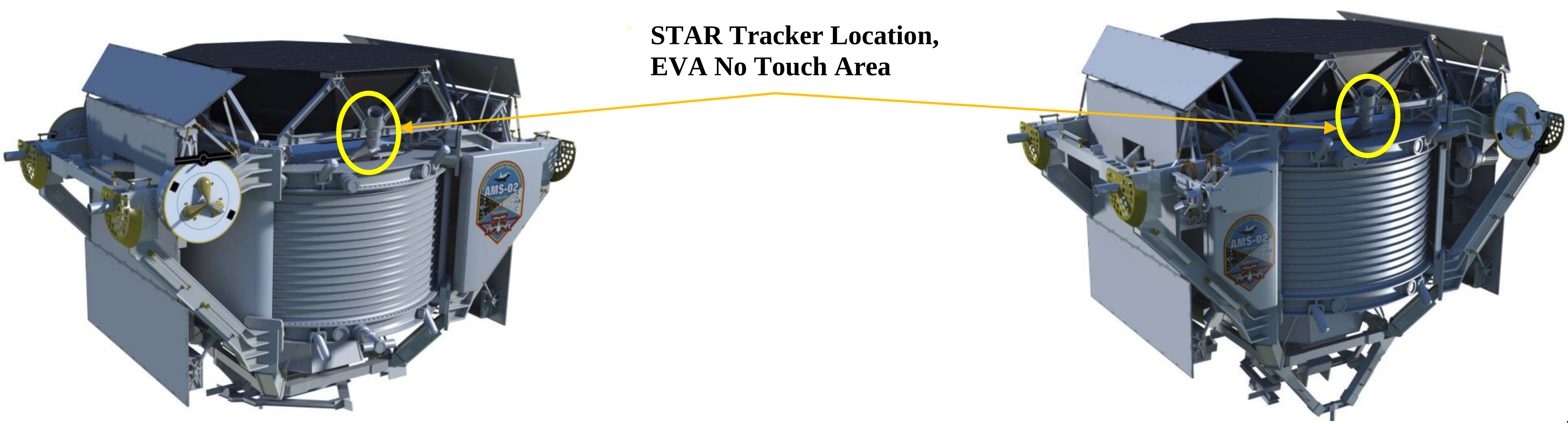
AMS-02 EVA TRANSLATION AID LOCATION



Lower USS-02 Handrail



STAR TRACKER BAFFLE – EVA No Touch Area



TO:	Bob Miley	(281) 244-4968
NASA Contact:	Cal Brogdon/OM7	(281) 244-7058
Analyst:	Alicia Mooty/MAGIK Team	(281) 483-8491
DATE:	February 27, 2007	
RE:	Misalignment Clearances Between AMS and ELC During Berthing, Revision A	
CC:	Michael Brown/Boeing, John Cook/Boeing, Trent Martin/EA, Chris Tutt/Jacobs, Paul Nemeth/Jacobs, Gene Cook/OZ, Vic Sanders/Boeing, Stacey Dries/Boeing, AJ Alfonzo/Boeing, Rodney Nabizadeh/OM, Paula Morris/ER, Larry Grissom/ER, Shakeel Razvi/OM, RS Library	
PAGES:	10	**Action Item: 2172, Revision A**

Abstract:

The MAGIK Robotic Analysis Team has completed an action to determine the clearances between the Alpha Magnetic Spectrometer – 02 (AMS) payload and the ExPRESS Logistics Carrier (ELC) during the berthing of AMS to the S3 Upper Inboard Payload Attach Site (PAS) and during the berthing of the ELC to the S3 Upper Outboard PAS.

It was determined that the clearances between AMS and the ELC are less than the required 24 inches of clearance, with a minimum clearance during AMS berthing operations of approximately 11 inches and **12** inches during ELC berthing. Note that certain misalignment cases produce contact between the S3 longeron and both the AMS and ELC guide pins.

Revision A updated the minimum clearances between the AMS and the ELC payloads for the ELC berthing to S3 (Part 2), resulting from additional analysis evaluating a 2 degree wobble of the ELC towards the AMS payload during berthing.

Assumptions:

- ISS Flight 19A configuration (based on SSCB Approved Assembly Sequence dated February 22, 2006) was used for the analysis.
- The AMS CAD model used in this analysis was created by the MAGIK Team from a high fidelity model received from the ISS CAD Modeling Team in May, 2003.
- The ELC CAD model used in this analysis was created by the MAGIK Team from a high fidelity model received from Rodney Nabizadeh in October, 2006.
- Pedigree information for pertinent models may be obtained from the MAGIK Team upon request.
- This analysis addresses clearance issues by measuring distances between 3D graphic models. Areas not addressed in this document - lighting, viewing, EVA/EVR tasks, thermal and/or pressure effects on elements, and dynamics - could have a significant influence on the measurements and overall feasibility.

- 3D graphical models used in this analysis are a result of the MAGIK Team's "best efforts" to obtain accurate models reflecting actual volumetric dimensions of the various ISS elements and/or create in the best possible manner an encompassing low fidelity model representative of the hardware and kinematically applicable to MAGIK analyses. Applicability is defined by the probability of interaction with the robotic arm(s), EVA on the arm, or a robotically moved hardware."Best efforts" include obtaining/creating models directly from the ISS CAD Modeling Team, the hardware designers, a 3rd party (a source other than the hardware designers), drawings/information from hardware designer or customer, or the ISS External Cargo Handbook (D684-11233-01). The MAGIK created models are lower fidelity, comparative to the source model, consisting of less detail. For applicable areas, the encompassing shape has a tolerance of +0.5/ -0.1 inch with respect to the source model; meaning the nearest source surface should be no greater than 0.5 inch from the surface on the encompassing shape. Non-applicable areas are modeled to tolerances of +1.5/ -0.1 inch.

Discussion and Results:

A berthing misalignment analysis was performed for two scenarios. Part 1 of this analysis looked at misalignments and resulting clearances for berthing the AMS payload to the S3 Upper Inboard PAS with an ELC on the adjacent S3 Upper Outboard PAS location. Part 2 analyzed the misalignments and clearances for berthing the ELC to the S3 Upper Outboard PAS with the AMS payload on the adjacent S3 Upper Inboard PAS. The misalignment cases evaluated are based on information provided by Michael Brown/Boeing - End to End Berthing Integration Team (EBIT) in MAGIK Action Item 2044.

Figure 1 - Figure 4 show the AMS payload and the ELC both installed on S3 (fully berthed with no misalignments). Table 1 summarizes the clearances between the AMS payload and the ELC payloads with both the AMS and ELC fully berthed with no misalignments and also at 2, 4 and 6 inch interface separation distances with no misalignments.

Table 1: Minimum Clearances Between AMS and ELC Payloads - No Misalignments

Interface Separation Distance (in)	Misalignment Case Wobble, Roll, Lateral Offset (deg, deg, in)	ELC Payload 1	ELC Payload 2	ELC Payload 3	ELC Payload 4	ELC Payload 5	ELC Payload 6
0	0, 0, 0	45	23	16	16	29	45
2	0, 0, 0	45	23	16	16	28	45
4	0, 0, 0	45	23	16	16	28	44
6	0, 0, 0,	43	23	16	16	28	43

The maximum misalignments used in the analysis (2 degrees wobble, 2.5 inches lateral offset, and 5.5 degrees roll) were provided by EBIT/Boeing. This analysis evaluated misalignment cases for separation distances of 2 inches, 4 inches and 6 inches.

Part 1

For Part 1, the AMS payload was misaligned to a set of cases and the clearances between the AMS payload and adjacent hardware, including ISS envelopes, was evaluated. Misalignments were applied about a point located at the center of the bottom of the AMS capture bar.

The minimum distances between the ELC payloads and AMS were found at an interface separation distance of 6 inches and a misalignment case of 2 degrees wobble, 0 degrees roll and -2.5 inches lateral offset, as illustrated in Figure 5. Figure 6 shows the orientation of the ELC payloads on the side adjacent to AMS when installed on S3. This produced the minimum clearance for all payloads simultaneously. The minimum clearances for this case, as well as additional cases producing the same minimum clearances, are noted in Table 2.

Table 2: Minimum Clearances Between AMS and ELC Payloads During AMS Berthing

Interface Separation Distance (in)	Misalignment Case Wobble, Roll, Lateral Offset (deg, deg, in)	ELC Payload 1	ELC Payload 2	ELC Payload 3	ELC Payload 4	ELC Payload 5	ELC Payload 6
6	2, 0, -2.5	**36**	**17**	**11**	**11**	**22**	**36**
6	2, 2, -1.5	37	**17**	12	13	24	38
4	2, 0, -2.5	37	**17**	**11**	**11**	23	37
4	2, 2, -1.5	37	**17**	12	13	24	38

Note that several of the cases analyzed produced contact (or clearances of less than an inch) between the AMS guide pin and the S3 longeron.

Clearances between AMS and the following ISS hardware (or envelopes) were also found to be less than the required 24 inches:

- -S1 Outboard Upper Camera Sweep Envelope (Camera Port (CP) 2)*
  - Minimum clearance = Contact
  - (Fully berthed with no misalignments and several other cases)
- -Floating Potential Measurement Unit (FPMU) installed at CP2*
  - Minimum clearance = 14 inches
  - (No misalignments – fully berthed and at 2 inch interface separation distance)
- -AMS to S1 Thermal Control System Radiator Sweep Envelope
  - Minimum clearance = 20 inches
  - (Fully berthed with no misalignments)
- -AMS to S1 Bulkhead
  - Minimum clearance = 16 inches
  - (Fully berthed with no misalignments and several other cases)
- -AMS to S3 Grapple Fixture
  - Minimum clearance = 18 inches
  - (Fully berthed with no misalignments and several other cases)

** CP2 should remain vacant if AMS is installed on the S3 Upper Inboard PAS according to the ISS Configuration Document, SSP 50504, Revision C.*

Part 2

For Part 2, the ELC was misaligned to a set of cases and the clearances between the ELC and adjacent hardware, including AMS and ISS envelopes, was evaluated. Misalignments were applied about a point located at the center of the bottom of the ELC capture bar. **Revision A added cases to evaluate a wobble of 2 degrees in the direction of the AMS payload.**

The minimum clearances between the ELC payloads and AMS, and their corresponding misalignment cases, are noted in Table 3. Figure 7 illustrates a misalignment case of 6 inch interface separation distance, 2 degrees wobble (away from AMS), 0 degrees roll and 2.5 inches lateral offset. Figure 8 and Figure 9 **illustrate a misalignment case of 4 inch interface separation distance, -2 degrees wobble (towards AMS), 0 degrees roll and 2.5 inches lateral offset.**

Table 3: Minimum Clearances Between AMS and ELC Payloads During AMS Berthing

Interface Separation Distance (in)	Misalignment Case Wobble, Roll, Lateral Offset (deg, deg, in)	ELC Payload 1	ELC Payload 2	ELC Payload 3	ELC Payload 4	ELC Payload 5	ELC Payload 6
0	0, 0, 0	**45**	**23**	16	16	28	**45**
2	0, 0, 0	46	**23**	16	16	29	46
2	2, 1, -0.5	53	27	18	17	**17**	52
4	0, 0, 0	47	**23**	16	16	29	47
4	2, 0, 2.5	50	24	**15**	**15**	30	50
4	2, 5.5, 0	55	29	20	**15**	30	51
4	2, -5.5, 0	51	24	**15**	20	35	55
4	2, 2, 1.5	52	26	17	**15**	30	51
4	2, -2, 1.5	51	24	**15**	17	32	52
6	0, 0, 0.	48	**23**	16	16	29	48
6	2, 0, 2.5	51	24	**15**	**15**	30	51
6	2, 5.5, 0	56	39	20	**15**	30	51
6	2, -5.5, 0	51	24	**15**	20	35	56
6	2, 2, 1.5	53	26	17	**15**	30	51
6	2, -2, 1.5	51	24	**15**	17	32	53
4	-2, 0, 2.5	**39**	17	**11**	**11**	**23**	**39**
4	-2, 5.5, 0	44	23	17	**11**	**23**	**39**
4	-2, -5.5, 0	**39**	**16**	**11**	17	28	44
4	-2, 2, 1.5	41	19	13	12	**23**	**39**
4	-2, -2, 1.5	**39**	17	12	13	24	41
6	-2, 0, 2.5	40	17	12	12	**23**	40
6	-2, 5.5, 0	45	23	17	**11**	**23**	40
6	-2, -5.5, 0	40	17	**11**	17	28	45
6	-2, 2, 1.5	**42**	19	13	12	**23**	40

Note that several of the cases analyzed produced contact (or clearances of less than an inch) between the ELC guide pin and the S3 longeron.

Clearances between the ELC hardware and the following ISS hardware were also found to be less than the required 24 inches:

-ELC Power and Video Grapple Fixture (PVGF) #2 to S3
  Minimum clearance = 10 inches
  (Fully berthed with no misalignments)

-ELC Deck to S3
  Minimum clearance = 13 inches
  (Fully berthed with no misalignments)

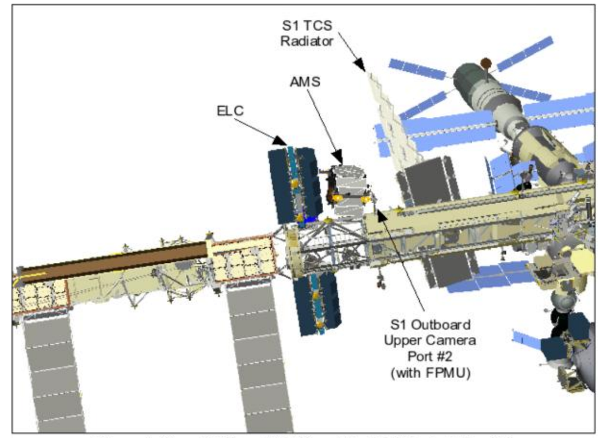


Figure 1: Overall View of AMS and the ELC Installed on S3
(Both Fully Berthed, No Misalignments)
View Looking ISS Aft, Port and Nadir

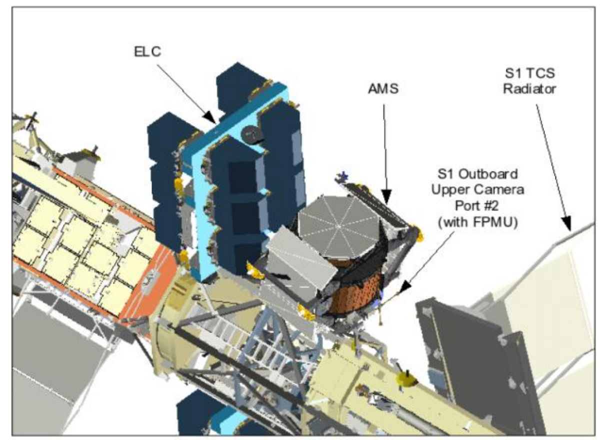


Figure 2: Overall View of AMS and the ELC Installed on S3
(Both Fully Berthed, No Misalignments)
View Looking ISS Aft, Starboard and Nadir

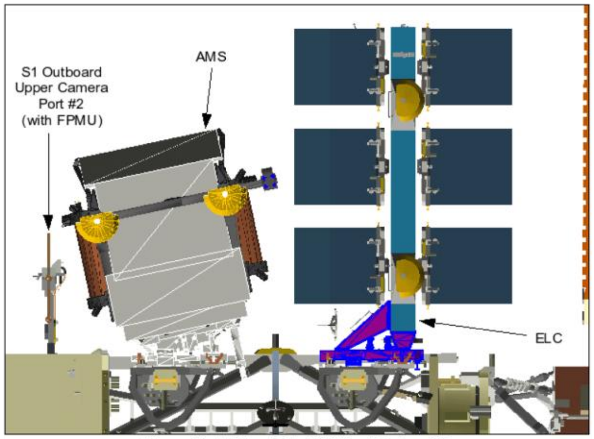


Figure 3: AMS and the ELC Installed on S3
(Both Fully Berthed, No Misalignments)
View Looking ISS Forward

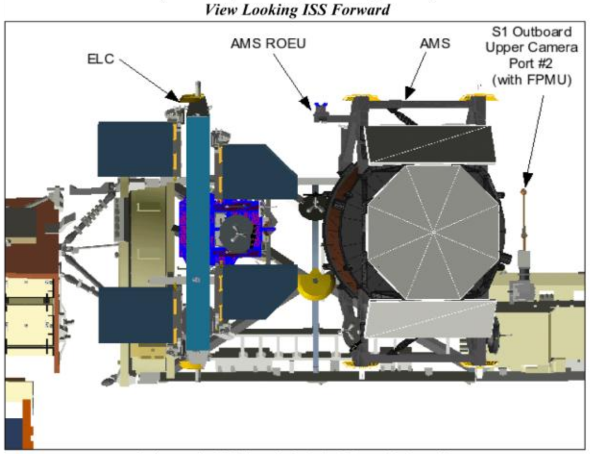


Figure 4: AMS and the ELC Installed on S3
(Both Fully Berthed, No Misalignments)
View Looking ISS Nadir
View Clipped for Clarity

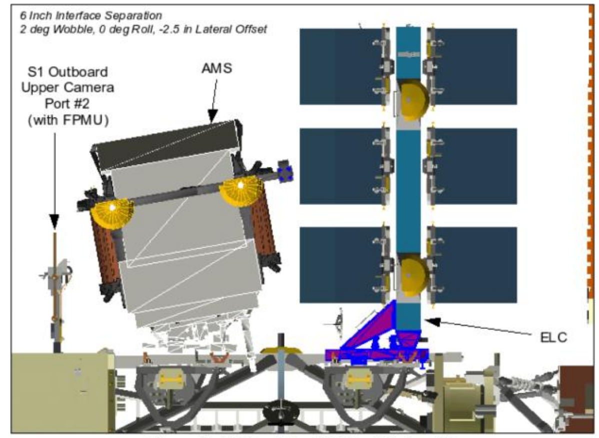


Figure 5: AMS and the ELC Installed on S3
(AMS Misaligned, ELC Fully Berthed with No Misalignments)
View Looking ISS Forward

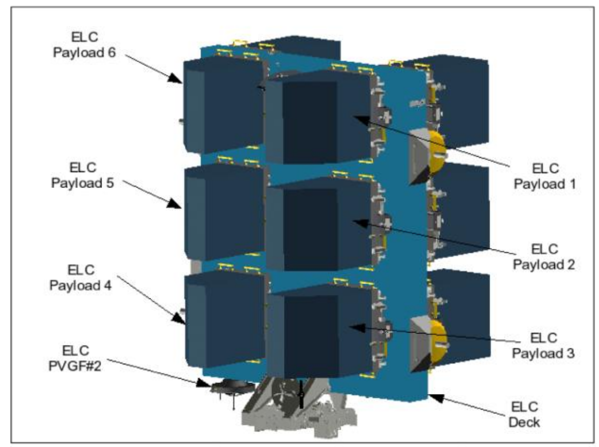


Figure 6: Orientation of ELC Payloads on ELC

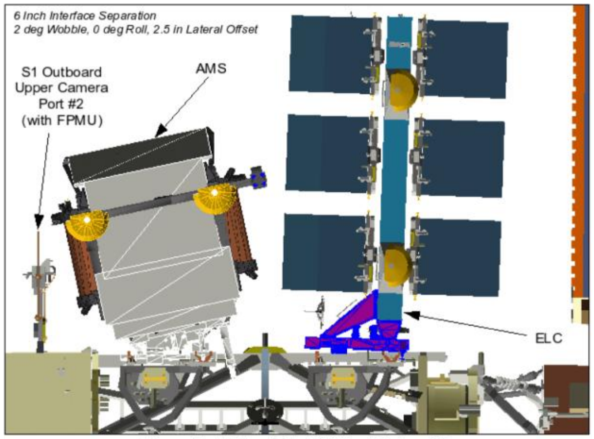


Figure 7: AMS and the ELC Installed on S3
(AMS Fully Berthed with No Misalignments, ELC Misaligned)
View Looking ISS Forward

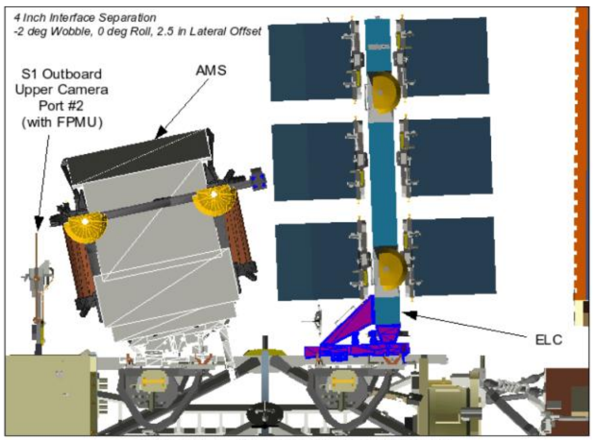


Figure 8: AMS and the ELC Installed on S3
(AMS Fully Berthed with No Misalignments, ELC Misaligned)
View Looking ISS Forward

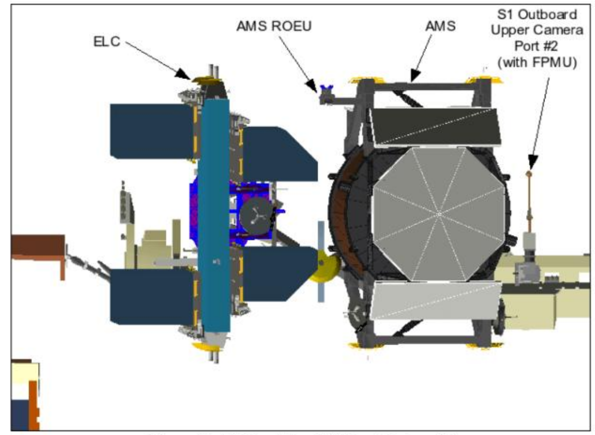


Figure 9: AMS and the ELC Installed on S3
(AMS Fully Berthed with No Misalignments, ELC Misaligned)
View Looking ISS Nadir
View Clipped for Clarity

Safety Noncompliance Report

Date: 12/10/08

NCR NUMBER: AMS-02-NCR-001

FLIGHT EFECTIVITY: non-flight specific EXPIRATION DATE: n/a

ORIGINATOR: *(Organization/Company)* JSC-EA3/AMS-02 Project Manager/Trent Martin

TITLE: AMS-02 Payload EVA Touch Temperature

END ITEM IDENTIFICATION: *(Include reference to applicable end item, subsystem, and/or component)*
Alpha Magnetic Spectrometer-02 (AMS-02) Payload

APPLICABLE REQUIREMENT:
NSTS 1700.7B ISS Addendum

217 Extravehicular Activity (EVA)

200.3 Environmental Compatibility. (See Note Below)

NOTE: Reference below for specific EVA contact temperature values consistent with NSTS 07700 Volume XIV, Appendix 7 and SSP 57003

SSP 57003, 3.11.5.14.1 INCIDENTAL CONTACT

For incidental contact, temperature shall be mintained within -180 to +235 degrees Fahrenheit or limited heat transfer rates as listed in Table 3.11.5.14.1-1 [per SSP 41162, paragraph 3.3.6.12.2.1]

SSP 57003, 3.11.5.14.2 UNLIMITED CONTACT

For unlimited contact, temperatures shall be maintained within -45 to +145 degrees F, or for designated EVA crew interfaces listed in Table 3.11.5.14.2-1, limit heat transfer rates as listed in table 3.11.5.14.1-1. [per SSP 41162, paragraph 3.3.6.12.2.2]

DESCRIPTION OF NONCOMPLIANCE: (Specify how the design or operation does not meet the safety requirements.)
A worst case thermal analysis of AMS payload shows a Debris Shield reaching -183 degrees F (violating Incidental contact temperatures and heat rates), a Flight Releasable Grapple Fixture (FRGF) reaching 258 degrees F (violating Unlimited contact temperature and heat rates) and an EVA Connector Panel reaching 174 degrees F (violating Unlimited contact temperature and heat rates). See attached memo.

REASON REQUIREMENT CANNOT BE FULFILLED:
Because of the induced thermal environment and hardware material, the hardware cannot remain within temperature limits or allowable heat rates for all ISS attitudes.

RATIONALE FOR ACCEPTANCE: (Define the design feature or procedure used to conclude that the noncompliance condition is safe. Attach applicable *support data, i.e. drawings, test reports, analyses, etc.)*
The hardware does meet the requirements of JSC 28918, "EVA Design Requirements and Consideration" for incidental contact and poses no risks to EVA suit or crewmember. Analysis of the EVA connector panel shows a high pressure grasp time of 4 minutes

JSC Form 542C (Rev September 13, 2007) (MS Word May 97) *and a 1-psi grasp time of 9.55 minutes. This should be ample time to perform the contigency EVA of swapping connectors. The connector panel does not need to be touched or held continuosly during this operation. Similarly, the FRGF shows high pressure grasp time of 2 minutes and 1-psi grasp time of 3.25 minutes. This should also be sufficient for the FRGF contigency EVA. All temperatures are enveloped by NCR-EVA-XA002.*

SIGNATURES			
SUBMITTED BY:			
AUTHOR			DATE
TRENT MARTIN			12/10/08
PROGRAM MANAGER OF SUBMITTING ORGANIZATION OR GFE PROJECT MANAGER			DATE
CONCURRENCE			
AFFECTED AIT/SPRT/FIT	DATE	FLIGHT EQUIPMENT SAFETY AND RELIABILTY REVIEW PANEL (FESRRP)	DATE
		Michael R. [signature]	1/6/2009
AFFECTED AIT/SPRT/FIT	DATE	SAFETY REVIEW PANEL (SRP/PSRP)	DATE
ISS S&MA PANEL	DATE	SHUTTLE S&MA PANEL	DATE
APPROVAL			
ISS CHIEF S&MA OFFICER	DATE	SHUTTLE CHIEF S&MA OFFICER	DATE
ISS INDEPENDENT TECHNICAL AUTHORITY	DATE	SHUTTLE INDEPENDENT TECHNICAL AUTHORITY	DATE
ISS PROGRAM MANAGER	DATE	SHUTTLE PROGRAM MANAGER	DATE

* Approved as Equivalent Safety.

JSC Form 542C (Rev September 13, 2007) (MS Word May 97)

GROUP
Engineering and Science Contract Group
2224 Bay Area Boulevard
Houston, Texas 77058

ESCG-4470-07-TEAN-DOC-0033-B
July 28, 2008

To:	J. C. Tutt	ESCG
Via:	**J. L. Cox**	**ESCG**
Reviewed by:	A. H. **Milliken**	**ESCG**
From:	E. L. Yagoda	ESCG
Revised by:	C. S. Clark	ESCG

Subject: **Alpha Magnetic Spectrometer (AMS-02) EVA Touch Temperature Evaluation**

Note: This document was revised to correct typos in a referenced document and transposed results in the Conclusions section.

1.0 Summary

This report presents an Extra Vehicular Activity (EVA) touch temperature evaluation of the Alpha Magnetic Spectrometer (AMS-02). EVA interfaces that were designed to be touched by the EVA Mobility Unit (EMU) include the handrails, the Flight Releasable Grapple Fixture (FRGF), the Power and Video Grapple Fixture (PVGF), the EVA connector panel, and the Remotely Operated Electrical Umbilical (ROEU). In addition to the EVA interfaces, an addition investigation was done in order to determine if any of the external portions of the payload that can be touched or bumped during EVA operations exceeds the incidental contact limits.

Craig S. Clark
Thermal and Environmental Analysis Section
Engineering and Science Contract Group

2.0 Introduction

The AMS-02 is a large external attached payload that will be mounted to the International Space Station (ISS) S3 truss payload attach site. There are no planned EVAs associated with the AMS-02 but there are several contingency EVAs while attached to the ISS that must be considered. Requirements for the AMS-02 are defined in SSP 57003 [1].

3.0 Environmental Survey

Extensive analysis has been performed to determine extreme temperatures for the AMS-02 while it is mounted to the ISS. Results were calculated considering the entire range of solar beta angles (-75 to +75°) as well as the range of possible ISS attitudes. These cases were further analyzed assuming extreme hot or cold natural environments.

This data was used to find temperature extremes for all EVA interfaces. For cold temperatures it was also assumed that the payload would be powered off with heaters disabled for 20 hours. The results of this survey are shown in Table 1. Note that only the hottest and coldest handrails are included.

Table 1: Environmental Survey Results

Component Description	Attitude	Beta Angle	Submodel	Node Number	Max/Min Temp °F	Results
Handrails	-15+25-15	b-75c	HANDRL	1033	-78.4	Cold
	+00-20-15	b+75h	HANDRL	1013	182.6	Hot
Grapple Fixture	+00+00+15	b+00c	FRGF3	8	-75.4	Cold
	+15+00+00	b-75h	FRGF3	3	258.3	Hot
Grapple Fixture	-15+00-15	b-75c	PVGF	7	-72.5	Cold
	+00-20-15	b+75h	PVGF	8	221.5	Hot
Connector Panel	-15-20-15	b+00c	USS02	53100	-6.7	Cold
	-15+00-15	b-75h	USS02	53100	173.6	Hot
ROEU Clevis	-15-20+15	b+75c	ROEU	10	-61.0	Cold
	-15+25+15	b-75h	ROEU	10	154.2	Hot
ROEU Mount Brkt	-15-20+15	b+75c	ROEU	20	-68.3	Cold
	-15+25+15	b-75h	ROEU	20	134.0	Hot
ROEU PDA	-15-20+15	b+75c	ROEU	50	-59.1	Cold
	-15+25+15	b-75h	ROEU	50	111.8	Hot
ROEU Pin	-15-20+15	b+75c	ROEU	102	-62.5	Cold
	-15+25+15	b-75h	ROEU	102	120.7	Hot

4.0 EVA Touch Temperature Evaluation

An EVA touch temperature evaluation was performed using the methods outlined in SSP 57003 [1]. This document dictates that for unlimited contact with designated crew interfaces, temperatures shall be maintained within -45 to +145°F or heat transfer rates be limited as specified in Table 2. For incidental contact, temperatures shall be maintained within -180 to +235°F or heat transfer rates be limited as specified in Table 2.

Table 2: Heat Transfer Rates [1]

Object Temperatures	Contact Duration (minutes)	Boundary Node Temperatures (°F)	Linear Conductor (BTU/hr.°F)	Maximum Avg Heat Rate (BTU/hr)
Hot Object	Unlimited	113	1.149	45.52 (2)
	Incidental (0.5 max)	113	1.444	176.2 (3)
Cold Object	Unlimited	-40	1.062	±132.7 (2)
	Incidental (0.5 max)	-40	1.478	±325.2 (3)

Notes:
(1) Positive denotes heat out of object, negative denotes heat into object.
(2) Averaged over 30 minutes of simulated contact.
(3) Averaged over 2 minutes of simulated contact.

If the touch temperature analysis fails to satisfy the above requirements, it is recommended that the EMU grasp limits outlined in JSC 28918 [2] be used to justify a waiver. This document dictates that for unlimited contact, EVA hardware temperatures shall be maintained between -80 to +150°F. If a particular component falls outside of these grasp limits, a heat rate analysis must be performed to ensure that the heat rate of any object does not exceed the maximum allowable average heat rates in Table 3. If any component fails to meet this criteria, grasp time limits are determined by the phase VI EMU glove palm limits which allow for a short duration grasp time for both “high pressure” and 1 PSI grasps [3]. Hardware that could be inadvertently touched by brushing or bumping during EVA shall be maintained within -244 to +320°F [2].

Table 3: 30 Minute Touch Temperature Heat Transfer Compliance [2]

Object Temperature (°F) Before Contact	Contact Duration (minutes)	Boundary Node Temperatures (°F)	Linear Conductance (BTU/hr·in^2·°F)	Maximum Avg Heat Rate (BTU/hr·in^2)
Greater Than 150	30	101	0.0033	0.205
Less Than -80	30	75	0.0033	-0.583

5.0 EVA Touch Temperature Results

Table 4 shows the results of the heat rate analysis for the method described in SSP 57003 [1]. All items passed this analysis with the exception of the FRGF and the EVA connector panel in the hot case. Table 5 shows that these two objects also fail the heat rate analysis of JSC 28918 [2]. The two right hand columns in Table 5 show the grasp times for these two items, per the phase VI EMU glove palm limits [3].

Table 4: Touch Temperature Results - Reference 1 Method

Component Description	Submodel	Node Number	Max/Min Temp °F	Unlimited Contact Analysis Required	Avg Heat Rate (BTU/hr)	Pass/Fail	Incidental Contact Analysis Required	Avg Heat Rate (BTU/hr)	Pass/Fail
Handrails	HANDRL	1033	-78.4	Yes	-53.5	P	No	NA	NA
	HANDRL	1013	182.6	Yes	41.6	P	No	NA	NA
Grapple Fixture	FRGF3	8	-75.4	Yes	-40.5	P	No	NA	NA
	FRGF3	3	258.3	Yes	46.9	F	Yes	163.6	P
Grapple Fixture	PVGF	7	-72.5	Yes	-40.5	P	No	NA	NA
	PVGF	8	221.5	Yes	34.3	P	No	NA	NA
Connector Panel	USS02	53100	-6.7	No	NA	NA	No	NA	NA
	USS02	53100	173.6	Yes	63.7	F	No	NA	NA
ROEU Clevis	ROEU	10	-61.0	Yes	-91.3	P	No	NA	NA
	ROEU	10	154.2	Yes	42.0	P	No	NA	NA
ROEU Mount Brkt	ROEU	20	-68.3	Yes	-101.2	P	No	NA	NA
	ROEU	20	134.0	No	NA	NA	No	NA	NA
ROEU PDA	ROEU	50	-59.1	Yes	-88.0	P	No	NA	NA
	ROEU	50	111.8	No	NA	NA	No	NA	NA
ROEU Pin	ROEU	102	-62.5	Yes	31.0	P	No	NA	NA
	ROEU	102	120.7	No	NA	NA	No	NA	NA

Table 5: Touch Temperature Results - Reference 2 & 3 Method

Component Description	Submodel	Node Number	Max/Min Temp °F	Contact Analysis Required	Avg Heat Rate (BTU/hr·in^2)	Pass/Fail	High PSI Grasp Time Limit (minutes)	1 PSI Grasp Time Limit (minutes)
Grapple Fixture	FRGF3	3	258.3	Yes	0.41	F	2.00	3.25
Connector Panel	USS02	53100	173.6	Yes	0.24	F	4.00	9.50

6.0 Incidental Touch Temperature Survey

A survey was done of all external surfaces (excluding soft goods) that can be inadvertently touched by brushing or bumping during an EVA operation. This survey was conducted for all surfaces at all attitudes and beta angles. The results of this survey indicated that a debris shield, node 60211, in the USS02 submodel reached a minimum temperature of -183°F. This temperature is outside the minimum incidental contact temperature stated in SSP 57003 [1] but is within the acceptable limits of those stated in JSC 28918 [2].

7.0 Conclusions

A touch temperature thermal evaluation of the AMS-02 was performed. EVA interfaces that were evaluated include the handrails, grapple fixtures, the EVA connector panel, and the ROEU. The results of this analysis showed that all the components passed touch temperature requirements as stated in SSP 57003 [1] with the exception of the EVA connector panel and the FRGF. Further analysis as described in References [2] and [3] result in an allowable high pressure and 1 PSI grasp times of 4.00 and 9.50 minutes respectively for the EVA connector panel. Similarly, the allowable high pressure and 1 PSI grasp times are 2.00 and 3.25 minutes respectively for the FRGF. The investigation to determine if any of the external portions of the hardware that can be touched or bumped during EVA operations exceeds the incidental contact limits revealed that the debris shield, reached a minimum temperature of -183°F. This temperature is outside the minimum incidental contact temperature stated in SSP 57003 [1] but is within the acceptable limits of those stated in JSC 28918 [2]. It is recommended that based on these results, a waiver be processed for these items.

References

1) "Attached Payload Interface Requirements Document", SSP 57003, Rev.C, NASA- Johnson Space Center, July 2006.
2) "EVA Design Requirements and Considerations", JSC 28918, NASA – Johnson Space Center, February 2005.
3) Bue, G., "EMU ISS EVA Thermal Environment Requirements for Certification", JSC 39117, NASA-JSC, May 2004.

DISTRIBUTION

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J. L. Cox	ESCG
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A. H. Milliken	ESCG
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Project Library	

PAYLOAD FLIGHT HAZARD REPORT				a. NO:	AMS-02-F16
b. PAYLOAD	Alpha Magnetic Spectrometer-02 (AMS-02)			c. PHASE:	III
d. SUBSYSTEM:	Optics, Materials	e. HAZARD GROUP:	Impact/Collision, contamination, Injury/Illness	f. DATE:	August 4, 2010
g. HAZARD TITLE:	Shatterable Material Release			i. HAZARD CATEGORY:	CATASTROPHIC **X** CRITICAL
h. APPLICABLE SAFETY REQUIREMENTS:	NSTS 1700.7, NSTS 1700.7B ISS Addendum, 200.3, 206, 209, 215				
j. DESCRIPTION OF HAZARD:	The breakage of glass or other frangible material can results in contamination/damage of space suits (EMU, Orlan) or the generation of debris of sufficient size to cause a released mass hazard.				
k. CAUSES *(list)*	1. Release of shatterable materials				

o. APPROVAL	PAYLOAD ORGANIZATION	SSP/ISS
PHASE I		
PHASE II		
PHASE III		

PAYLOAD FLIGHT HAZARD REPORT	a. NO: AMS-02-F16
b. PAYLOAD Alpha Magnetic Spectrometer-02 (AMS-02)	c. PHASE: III

l. HAZARD CONTROL (CONTROL), m. SAFETY VERIFICATION METHODS (SVM), n. STATUS OF VERIFICATIONS (STATUS)	OPS CONTROL
1. CAUSE: Shatterable Material Release	
1.1 CONTROL: The TOF and ACC Photomultiplier Tubes (PMT) are vacuum tubes, and have a reduced interior pressure. All photomultiplier tubes are sealed within PMT housings with potting used to protect the high voltage circuitry also preventing any potential broken glass from the rear of the assembly. The glass body of the PMT is covered with conductive paint and a protective coating that will protect and contain the glass in the event of a breakage. The glass front of the PMTs is covered with a polymer optical coupling/pad that will contain any fragments and preclude migration of glass. The PMTs are enclosed by an aluminum housing to additionally contain any fragments and preclude migration of fragments. Beyond the optical coupling/pad is the PMT support and the light guides that are sealed to the TOF PMT housing and within the housing for the ACC light guides. Additionally, an ACC PMT is sealed within a cover that is vented through a filter. 1.1.1 SVM: Review of Design. 1.1.2 SVM: Inspection of as built hardware. 1.1.3 SVM: Qualification of TOF & ACC PMT designs (vibration testing). 1.1.1 STATUS: Closed. ESCG Memorandum ESCG-4175-09-REENTES-MEMO-0016, “AMS-02 Photomultiplier Tube Safety Controls, “ dated April 3, 2009 1.1.2 STATUS: Closed. Review of LTOF, UTOF and ACC Acceptance Data Package by Jacobs AMS-02 Project Manager confirms inspections documented. Confirmed in email “PMT Review” sent October 6, 2009 From John C. Tutt to Leland D Hill. ADPs on file in AMS-02 Project Archive. 1.1.3 STATUS: Closed. ACC PMT Vibration Testing has been documented in the ACC ADP to validate PMT vibrational design compatibility. ADP Posted March 9, 2009 to AMS-02 Project Archive.	
1.2 CONTROL: The RICH and ECAL Photomultiplier Tubes (PMT) are vacuum tubes, and have a reduced interior pressure. All photomultiplier tubes are sealed within PMT housings with potting used to protect the high voltage circuitry and preventing any potential release from the rear of the assemblies. The glass body of the PMT is covered with conductive paint and a protective coating that will protect and contain the glass in the event of a breakage. The glass front of the PMTs is covered with a polymer optical coupling/pad that will contain any fragments. The ECAL front face is additionally optically sealed to the ECAL lead optical fiber sandwiches to preclude any release path. The RICH polymer optical coating is compressed by the light guides held in place with nylon wires.	

1.2.1 SVM: Review of Design.

1.2.2 SVM: Inspection of as built hardware.

1.2.3 SVM: Qualification of PMT designs (vibration testing).

1.2.1 STATUS: Closed. ESCG Memorandum ESCG-4175-09-REENTES-MEMO-0016, "AMS-02 Photomultiplier Tube Safety Controls, " dated April 3, 2009

1.2.2 STATUS: Closed. Review of RICH and ECAL ADP for certification of as built design by J. C. Tutt documented in email "RICH and ECAL ADPs," dated July 12, 2010.

1.2.3 STATUS: Closed. ECAL Vibration Testing conducted at SERMS in Terni ItalyNovember/December 2003, reported successful results to AMS-02 Collaboration on January 08, 2004 by Catherine Adloff.

1.3 CONTROL: All fiber optics cables (glass and polymer) are constructed to retain fibers within the cables and connectors by bonding the fibers or by sealing the end of the cables. Use of fiber optic cables are within the TAS and avionics integration hardware.

1.3.1 SVM: Review of Design.

1.3.2 SVM: Inspection of as built hardware.

1.3.1 STATUS: Closed. ESCG Memorandum ESCG-4175-09-REENTES-MEMO-0025, "Integration Cables Shatterable Materials Containment," dated May 4, 2009. "AMS-02 Tracker Alignment Control System (TAS)… response to information request #51…" From W. Wallraff, RWTH Aachen, November 30, 2004

1.3.2 STATUS: Close to SVTL. NOTE: ESCG Internal email summarizing review of ADPs for TAS, ECAL and ACC for proper design of the fiber optics cables. Email between John C. Tutt (AMS-02 ESCG Project Manager) and Leland D. Hill (AMS-02 Safety Engineer) October 8, 2009, titled "TAS ADP." ESCG Memorandum ESCG-4295-10-ADV SY-MEMO-0020, "TAS Inspection," dated July 15, 2010. ADPs in Project File. Verification open pending KSC integration fiber optic cables inspection after final installation.

1.4 CONTROL: The ACC fiber optic connectors must distribute the fibers (non-glass, non-frangible) to specific connector locations from the ACC panel cables ("Y" connector) and to the ACC PMT. The connectors utilize a free volume to route the individual fibers. This free volume is vented through filters to contain any possible broken fibers.

1.4.1 SVM: Review of Design.

1.4.2 SVM: Inspection of as built hardware.

1.4.1 STATUS: Closed. ESCG Memorandum ESCG-4175-09-REENTES-MEMO-0017, “Frangible Materials in the AMS-02 Detectors,” dated April 7, 2009.

1.4.2 STATUS: Closed. ACC Acceptance Data Package, Posted March 9, 2009 to AMS-02 Project ADP repository.

1.5 CONTROL: Fiber optics are used within the Tracker Laser Alignment System laser source boxes that are contained within the structure of the box and a simple sheath and the 50 micron sized box vents preclude the release of any possible generation of glass particulates that get by fiber optics covering.

1.5.1 SVM: Review of Design.

1.5.2 SVM: Inspection of as built hardware.

1.5.1 STATUS: Closed. ESCG Memorandum ESCG-4175-09-REENTES-MEMO-0017, “Frangible Materials in the AMS-02 Detectors,” dated April 7, 2009.

1.5.2 STATUS: Closed. TAS Acceptance Data Package, Sonia Natalie, October 8, 2009 and confirmation of final construction inspection by Prof. em. Dr. Klaus Luebelsmeyer, RWTH Aachen on 11/4/2009. ESCG Memorandum ESCG-4295-10-ADV SY-MEMO-0020, “TAS Inspection,” dated July 15, 2010

1.6 CONTROL: The Tracker Silicon Wafers are glued to a flexible metalized film that will retain fractured pieces. The film is Upilex which is supported (adhered to) on 5 mm Airex Foam. The foam is glued to a carbon fiber layer which is glued to the aluminum ladders that support the sensors as a whole. In addition, the light tight air vents have been fitted with a mesh screen to preclude the release of any particles.

1.6.1 SVM: Review of Design.

1.6.2 SVM: Inspection of as built hardware.

1.6.1 STATUS: Closed. ESCG Memorandum ESCG-4175-09-REENTES-MEMO-0017, “Frangible Materials in the AMS-02 Detectors,” dated April 7, 2009. ESCG Memorandum ESCG-4295-ADV SY-MEMO-0017, “New Tracker Planes on AMS-02,” dated July 12, 2010

1.6.2 STATUS: Closed. Installation of Tracker Silicon Wafers and light tight air vents visually confirmed by a designated verifier (DV), T. Martin on September 25, 2007 and documented in correspondence to Safety Engineer on that same date. Tracker Planes 1N and 6 visually confirmed by ESCG/P. Mott, DV, confirmed by email "Verification Activity Request", dated 7/26/2010

PAYLOAD FLIGHT HAZARD REPORT	a. NO: AMS-02-F16
b. PAYLOAD Alpha Magnetic Spectrometer-02 (AMS-02)	c. PHASE: III

1.7 CONTROL: The Laser Diodes and optics are mounted within the Tracker Laser Alignment System laser source boxes and are contained within the structure of the box. Fiber optics within the box are contained within jackets and are contained by structure of the enclosure in the event of breakage.

1.7.1 SVM: Review of Design.

1.7.2 SVM: Inspection of as built hardware.

1.7.1 STATUS: Closed. ESCG Memorandum ESCG-4175-09-REENTES-MEMO-0017, "Frangible Materials in the AMS-02 Detectors," dated April 7, 2009.

1.7.2 STATUS: Closed. TAS Acceptance Data Package, Sonia Natalie, October 8, 2009 and confirmation of final construction inspection by Prof. em. Dr. Klaus Luebelsmeyer, RWTH Aachen on 11/4/2009.

1.8 CONTROL: The ACC imbeds a polymer (non-glass, non-frangible) fiber optics in the BICRON BC 414 scintillator panels using optical cement (BC 600) to retain the fibers in place.

1.8.1 SVM: Review of Design.

1.8.2 SVM: Inspection of as built hardware.

1.8.1 STATUS: Closed. ESCG Memorandum ESCG-4175-09-REENTES-MEMO-0017, "Frangible Materials in the AMS-02 Detectors," dated April 7, 2009.

1.8.2 STATUS: Closed. ACC Acceptance Data Package, Posted March 9, 2009 to AMS-02 Project ADP repository.

1.9 CONTROL: The ECAL is constructed using layers of grooved lead (lead-antimony alloy) with doped polystyrene fibers (PolHiTech 0046) strands (non-glass, non-frangible) placed in the groves. The layers of lead and the fibers are assembled together using optical cement. The fibers are retained by the tight tolerance construction and adhesive.

1.9.1 SVM: Review of Design.

1.9.2 SVM: Inspection of as built hardware.

1.9.1 STATUS: Closed. ESCG Memorandum ESCG-4175-09-REENTES-MEMO-0017, "Frangible Materials in the AMS-02 Detectors," dated April 7, 2009.

1.9.2 STATUS: Closed. ECAL Acceptance Data Package, Posted March 9, 2009 to AMS-02 Project ADP repository.

PAYLOAD FLIGHT HAZARD REPORT	a. NO: AMS-02-F16
b. PAYLOAD Alpha Magnetic Spectrometer-02 (AMS-02)	c. PHASE: III

1.10 CONTROL: RICH aerogel and sodium fluoride blocks are adhered to the "upper" structure of the RICH, a volume which is vented through filters. The aerogel and sodium fluoride blocks are covered by a Plexiglas plane that is sealed to the block support structure. This volume is vented through filters to contain released particles.

1.10.1 SVM: Review of Design.

1.10.2 SVM: Inspection of as built hardware.

1.10.1 STATUS: Closed. ESCG Memorandum ESCG-4175-09-REENTES-MEMO-0017, "Frangible Materials in the AMS-02 Detectors," dated April 7, 2009.

1.10.2 STATUS: Closed. RICH ADP/ Ciemat Log Sheet/Historical Record for RICH Aerogel Assy, Assembly P/N 11-RICSYS-10.000 dated June 19, 2007

1.11 CONTROL: The construction of the Star Tracker Lenses and filters are provides vent paths around the optics to preclude pressure loading of the optical components. The lenses are secured using standard optics interfaces without glue or potting compounds. No optical component of the Star Tracker exceeds 0.25 pounds; the heaviest glass component is approximately 55 grams.

1.11.1 SVM: Star Tracker Lenses will be vibration tested to flight levels and inspected for damage.

1.11.2 SVM: Star Tracker Lenses will be pressure decay tested to confirm venting performance without damage or release.

1.11.3 SVM: Review of Design to confirm mass of optical components.

1.11.1 STATUS: Closed. Vibration Test Report, VIBRPT30_S0100R_24JAN2K6.doc, dated 26 January 2006, from Laboratorio per lo Studio degli Effetti delle Radiazioni sui Materiali per lo Spazio, confirms no damage to optics or released masses.

1.11.2 STATUS: Closed. Report AMIF/LETV/1/A, Issue 1, dated 23 October 2006 from Center for Advanced Research in Space Optics, documents the successful thermal vacuum testing of the lenses without damage or released masses.

1.11.3 STATUS: Closed. Communications from Paolo Trampus, Star Tracker Project, confirmed mass of optical components individually under 0.25 pounds. Email dated 31 March 2006 addressed to AMS-02 Safety Engineer Leland Hill, Titled "Safety Issue". File transmitted to AMS-02 Safety Verification Records.

1.12 CONTROL: The construction of the AMS-02 does not present any frangible material exposure to established EVA

PAYLOAD FLIGHT HAZARD REPORT	a. NO: AMS-02-F16
b. PAYLOAD Alpha Magnetic Spectrometer-02 (AMS-02)	c. PHASE: III

translation paths or work sites. Neither EVA Crew contact or EVA tool contact can result in the generation of frangible material debris.

1.12.1 SVM: Review of AMS-02 Design to confirm no frangible materials in EVA translation paths and around EVA work sites.

1.12.1 STATUS: Closed. ESCG Memorandum ESCG-4175-09-REENTES-MEMO-0043, "EVA Shatterable Material Release," dated July 1, 2009.

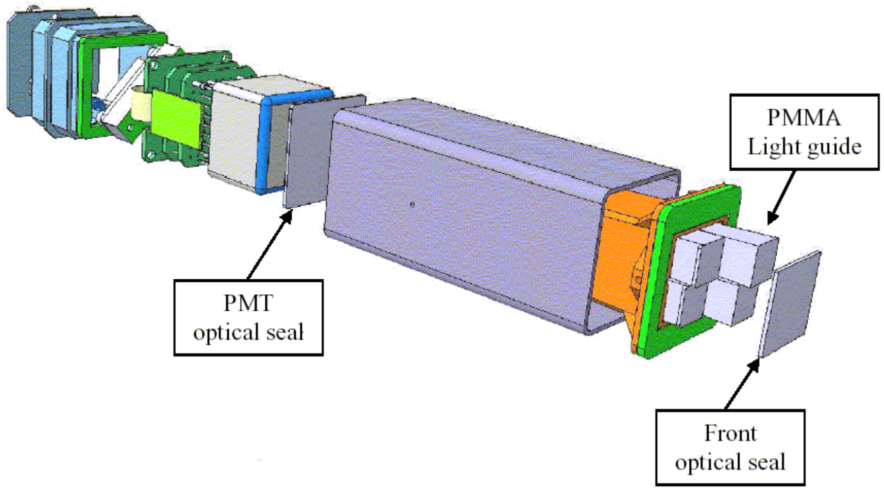
Notes:

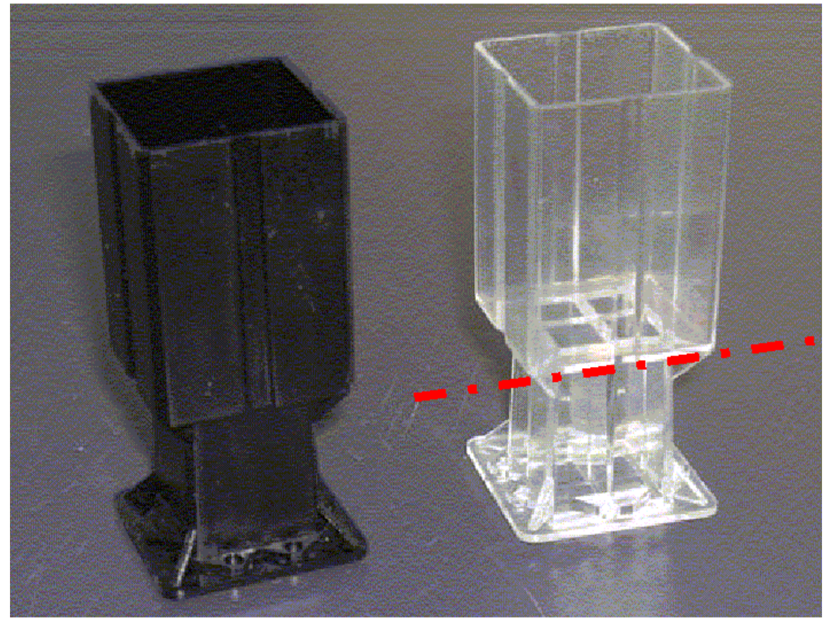
ACRONYMS	
°C – Degrees Centigrade (Celsius)	F – Fluoride
°F – Degrees Fahrenheit	Na – Sodium
ACC – Anti-Coincidence Counter	PFTE - Polytetrafluoroethylene
AMS-02 – Alpha Magnetic Spectrometer - 02	PMT – Photomultiplier Tube
CFRC – Carbon Fiber Reinforced Composite	RICH – Ring Imaging Cherenkov (detector)
ECAL – Electromagnetic Calorimeter	TOF – Time of Flight
EMU – Extravehicular Mobility Unit	UMA – Umbilical Mating Assembly
EVA – Extravehicular Activity	DV – Designated Verifier

Frangible Material Source	Application	Description	Control	
Photo Multiplier Tubes (PMT)	Electromagnet Calorimeter (ECAL)	Hamamatsu R7600-00-M04	Potted into PMT housing with glass front covered with optical coupling/pad.	Vibration testing of design. Thermo-Vacuum Testing
Photo Multiplier Tubes (PMT)	Ring Image Cherenkov Counter (RICH)	Hamamatsu R7600-00-M16	Potted into PMT housing with glass front covered with optical coupling/pad.	Vibration testing of design. Thermo-Vacuum Testing
Photo Multiplier Tubes (PMT)	Time of Flight (TOF) Upper and Lower Untis	Hamamatsu R5946	Potted into PMT housing with glass front covered with optical coupling/pad.	Vibration testing of design. Thermo-Vacuum Testing
Photo Multiplier Tubes (PMT)	Anti-Coincidence Counter (ACC)	Hamamatsu R5946	Potted into PMT housing with glass front covered contained by fiber optic connector that is vented through filter foam. Four PMT are enclosed within sealed volumes with filtered vents.	Vibration testing of design. Thermo-Vacuum Testing
Silicon Wafers	Tracker	Silicon wafers are bonded to metalized Upilex film which is bonded to 5 mm AIREX foam which is bonded to a carbon fiber layer and finally to a 5 mm aluminum ladder.	Silicon is adhered and retained to the Upilex film.	Vibration testing of design. Thermo-Vacuum Testing
Laser Tracker Optics	Tracker Alignment	Reflective interface to	Reflective surfaces are	Review of Design

Frangible Material Source	Application	Description	Control	
	System	take fiber optics laser energy and directing through Tracker	glued to housing.	Inspection of as built hardware Thermal-Vacuum Testing
Laser Diodes, Optics and Fiber Optics	Tracker Alignment System	Laser Diodes, Splitter, fiber optics	Laser Diodes, Optics and Fiber Optics are properly mounted and contained in laser source boxes contained by structure and 50 micronvent. Fibers are cladded and jacketed.	Review of Design Inspection of As-built hardware.
Fiber Optics Cable	Tracker Alignment System	Fiber optics that carry photons from sensitive sensors or avionics data.	Fiber optics utilizes standard fiber optic techniques of bonding fibers/sealing cables.	Thermo-Vacuum Testing
Fiber Optics Cable	UMA-EVA Connector			
Fiber Optics Cable	EVA Panel to Avionics box			
Avionics	Fiber Optics data cable			
Fiber Optics Cable	Anti- Coincidence Counter (ACC)	Fiber optics collect photons from collectors to PMT	Fibers are non-frangible polymer not glass. Contained in cables. Fibers in connectors are contained by connector housing and filters in housing vents.	Review of Design Inspection of as built hardware
ACC Sensor Fibers	Anti-Coincidence Counter (ACC)	Strands of fiber optic collect photons from energetic radiation passing through ACC.	Fibers are polymer and not glass and non frangible. Fibers are bonded into the ACC Scintillator Panels	Review of Design Inspection of as built hardware

Frangible Material Source	Application	Description	Control	
			(BICRON BC 414) with Optical cement (BC 600)	
ECAL Sensor Fibers	Electromagnet Calorimeter (ECAL)	Strands of fiber optic collect photons from energetic radiation passing through ECAL	Fibers are polymer fibers (doped polystyrene) contained within the lead layers of the ECAL. The lead has been machined to accept the fibers. Epoxy retains the fibers and layers in place.	Review of Design Inspection of as built hardware
Aerogel	Ring Image Cherenkov Counter (RICH)	Silica Aerogel	Aerogel is contained within RICH Structure and plexiglass cover. Structure is vented through filters and cover is sealed in place.	Review of Design Inspection of as built hardware
Crystalline	Sodium Fluoride Blocks	Solid NaF Crystal	NaF is contained within RiICH Structure and plexiglass cover. Structure is vented through filters and cover is sealed in place.	Review of Design Inspection of as built hardware
Optics (Lenses and Filters)	Star Tracker	Standard Optical components, lenses, filters.	Star Tracker optics are vented through mounting methodology and carry no appreciable pressure load.	Vibration testing of design. Thermo-Vacuum Testing



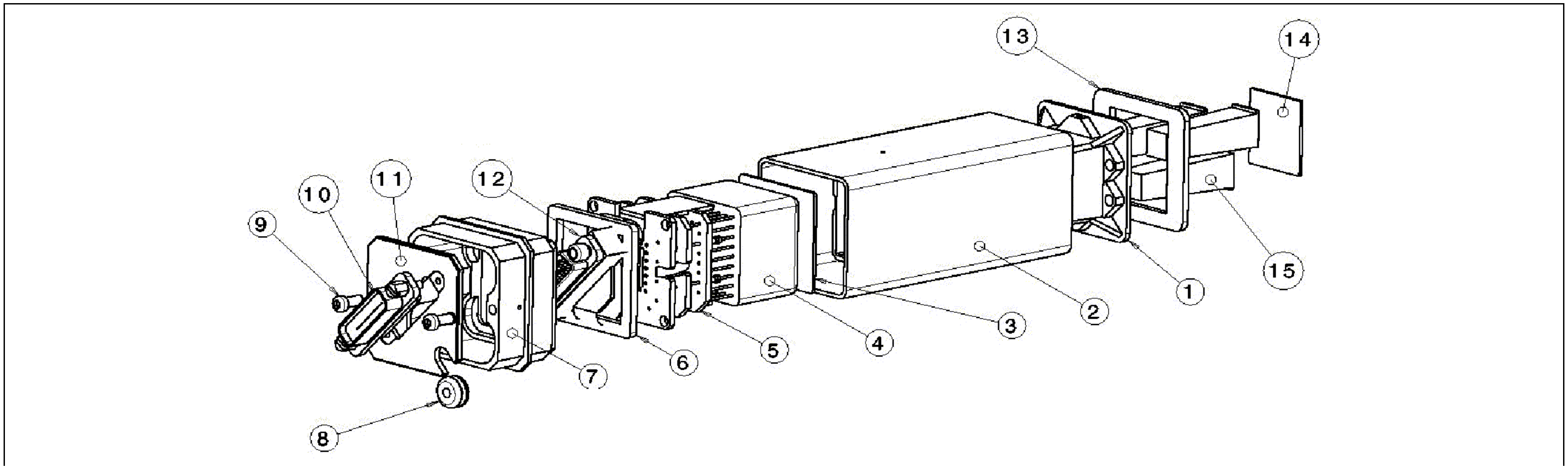


ECAL PMT Assembly

RICH is similar but uses a 4 x 4 light guide assembly and not 2 x 2 and no front optical seal.

ECAL Interior Housing Structure (dark flight, clear used for potting procedure)

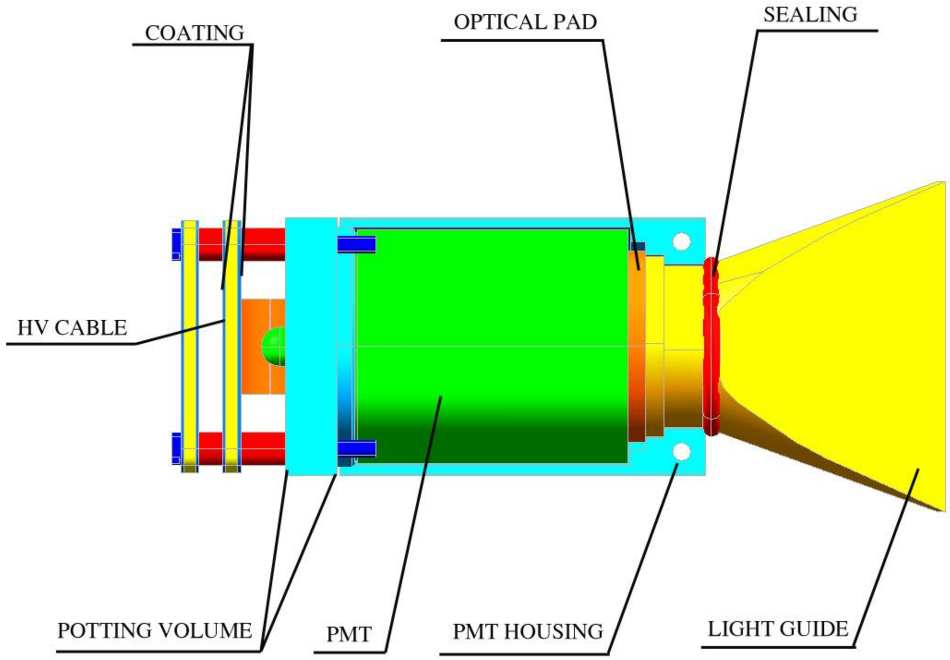
RICH uses a 4 x 4 light guide assembly and not the 2 x 2 assembly of the ECAL



Part number	Description	Material	Processing	Mass per unit (gr.)	Exposed Surface (cm^2)	Coating
1	PMT Box	Black Poly carbonat	Injection	14	0	No
2	Magnetic Shielding	Soft Iron	Bending / welding	68	-	Nickel platted
3	PMT optical coupling	DC 93-500	Moulding	0.3	0	No
4	Photomultiplier multi anodes	R5900U-00-M4	Hamamatsu process	24	0	No
5	Electronics divider + EFE	PCB + Potting DC93-500	-	15	0	DC 93-500
6	Back seal	Therm-a-gap A274	Cutting out	2	0	No
7	End cap	Al. 7075T7351	CNC Milling	9	-	Alodine 1200
8	Grommet	Black Silcone	Injection	0.4	0	No
9	M2.5 CHC Screw	Stainless steel 304	Standard	0.3		No
10	25 p Connector - EIB	GLENAIR M83513/03-D11N		8	0	
11	Connector plate	Al. 7075T7351	CNC Milling	4	-	Alodine 1200
12	25 p Connector - FEE	GLENAIR M83513/04-D11N		10	0	
13	Front seal + reflective foil	Therm-a-gap A274	Cutting out	8	0	No
14	Front optical coupling	DC 93-500	Moulding	0.3	0	No
15	Light guides	PMMA transparent	Injection	1.9	0	No

ECAL PMT Construction

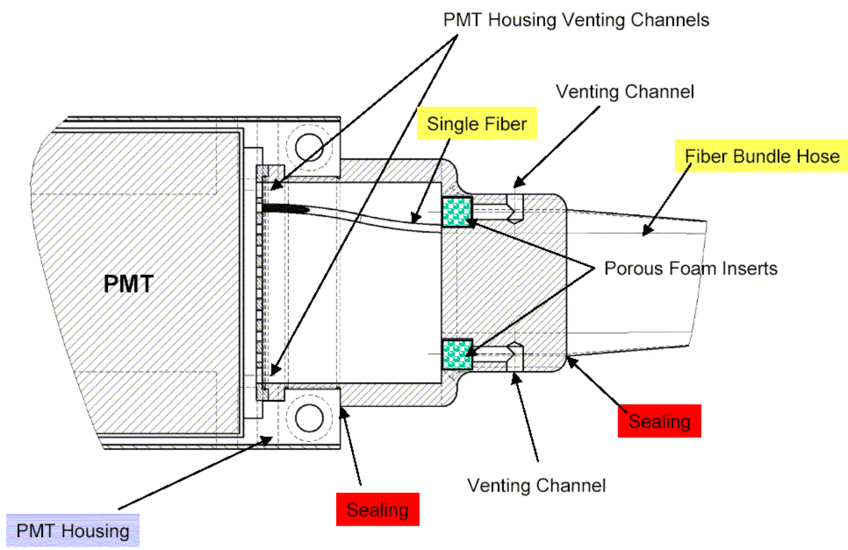
RICH construction similar but uses a 4 x 4 light guide assembly, Hamamatsu R5900U-00-M16 and no front optical seal



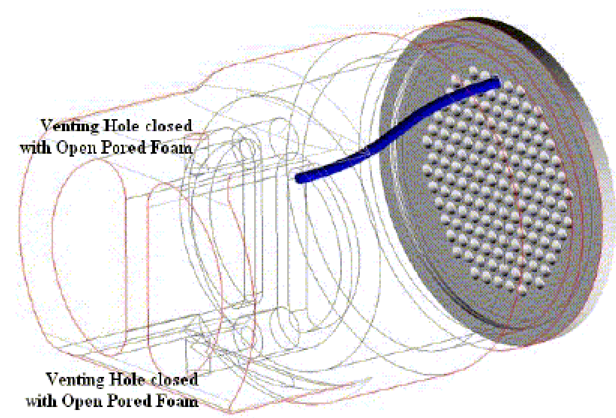
TOF Cross Section for PMT Glass Containment

ACC similar design except for Light Guide design and optical pad.

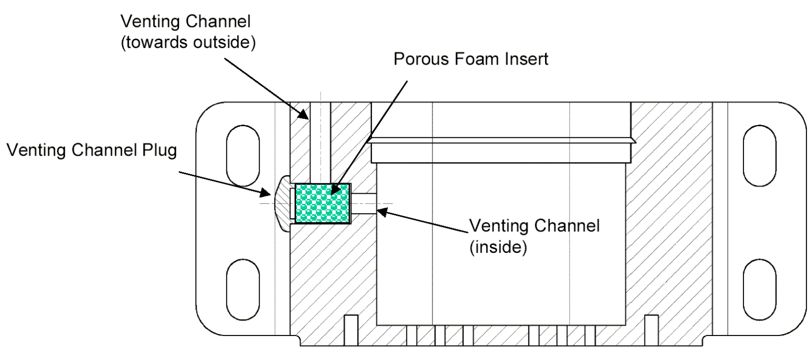
ACC Differences follow.



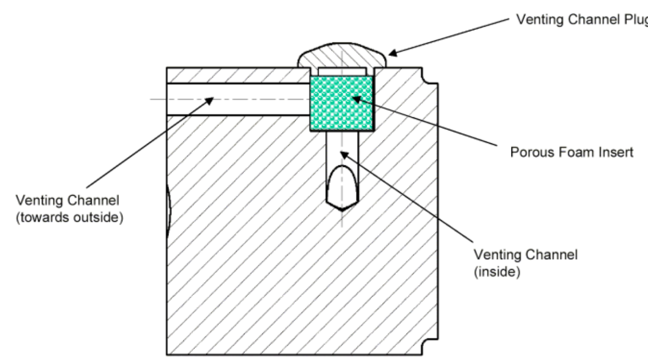
ACC PMT Construction Detail (Variance from TOF design)



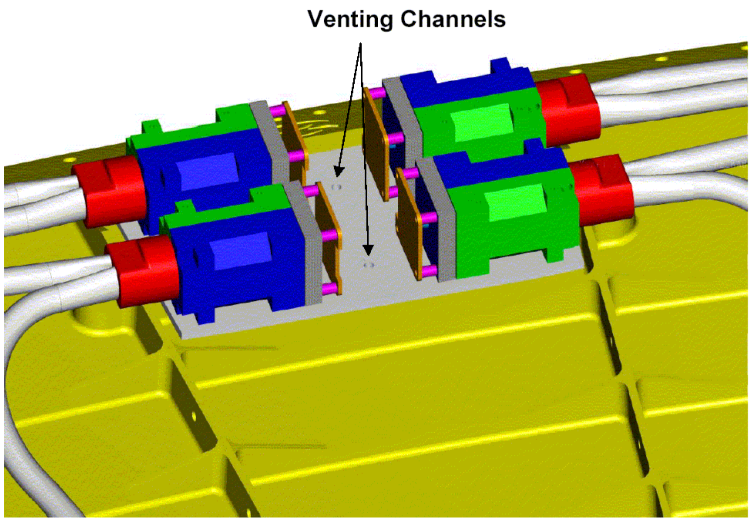
ACC PMT Fiber Routing and Vent Location



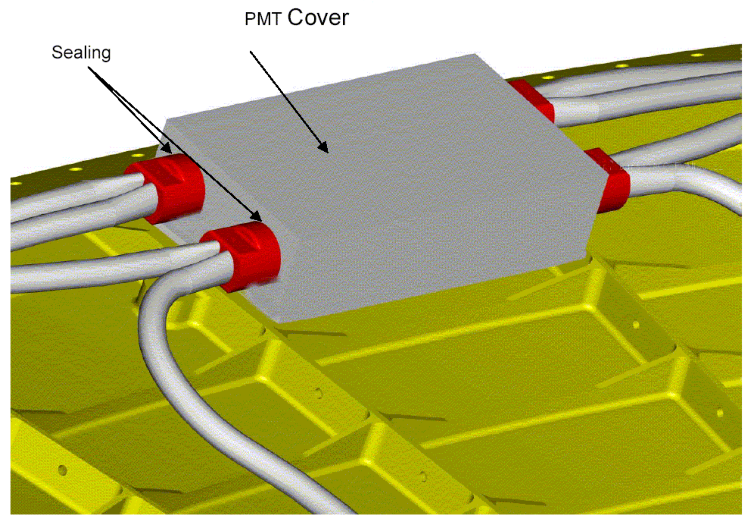
ACC PMT and Fiber Containment



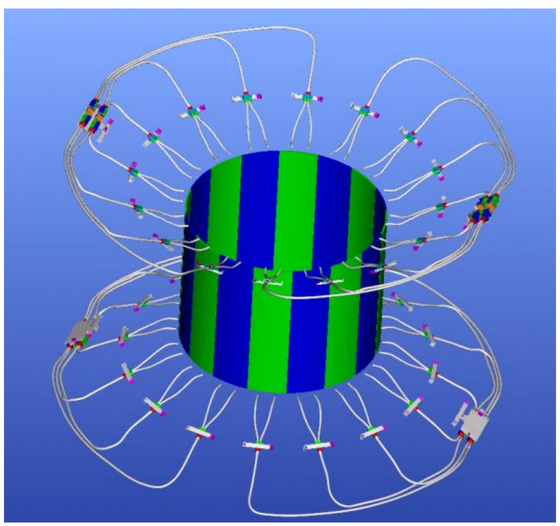
ACC Fiber “Y” Junction Connector Venting Detail



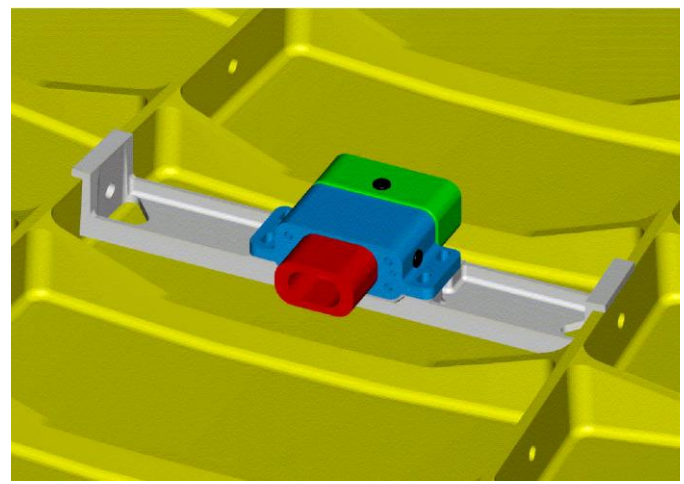
ACC PMT Mounting Enclosure (Cover Removed)



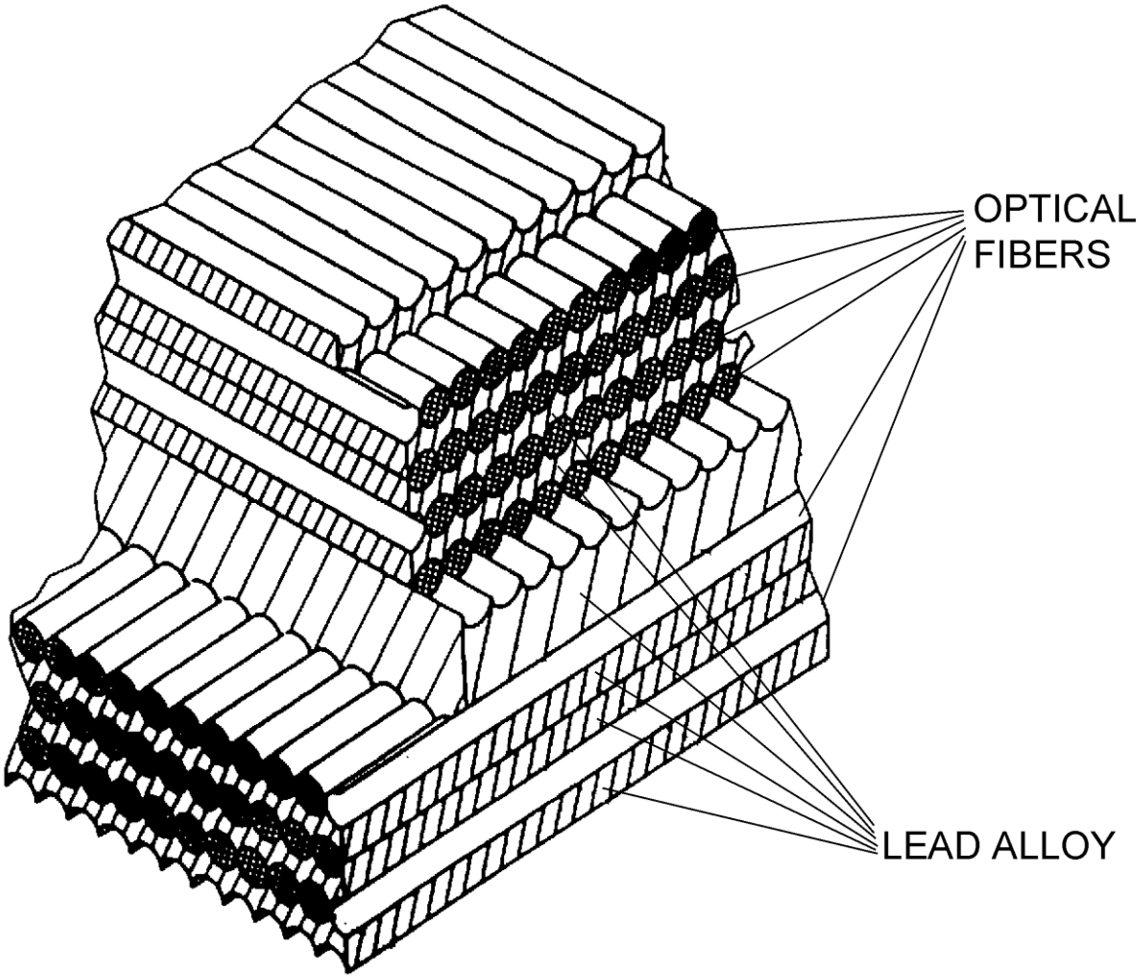
ACC PMT Mounting with Cover



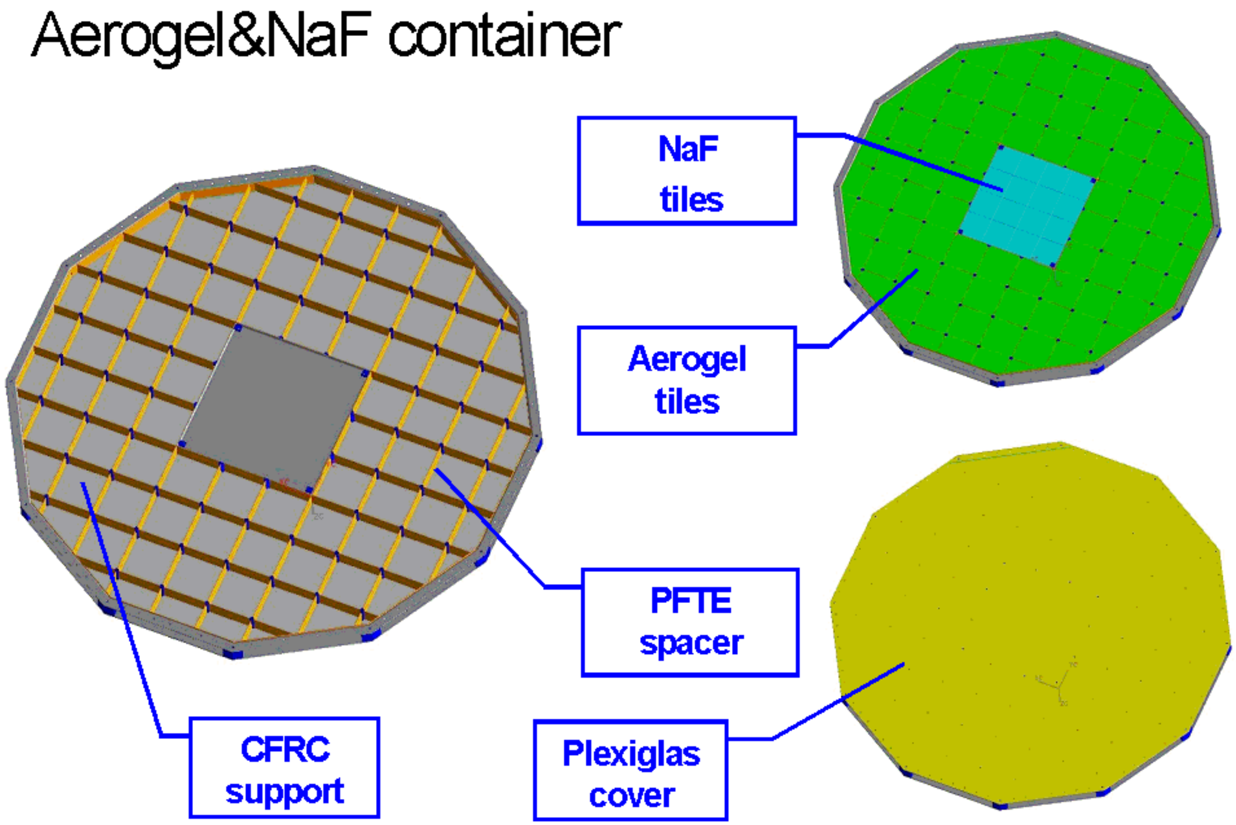
ACC Fiber Optics and PMT Layout



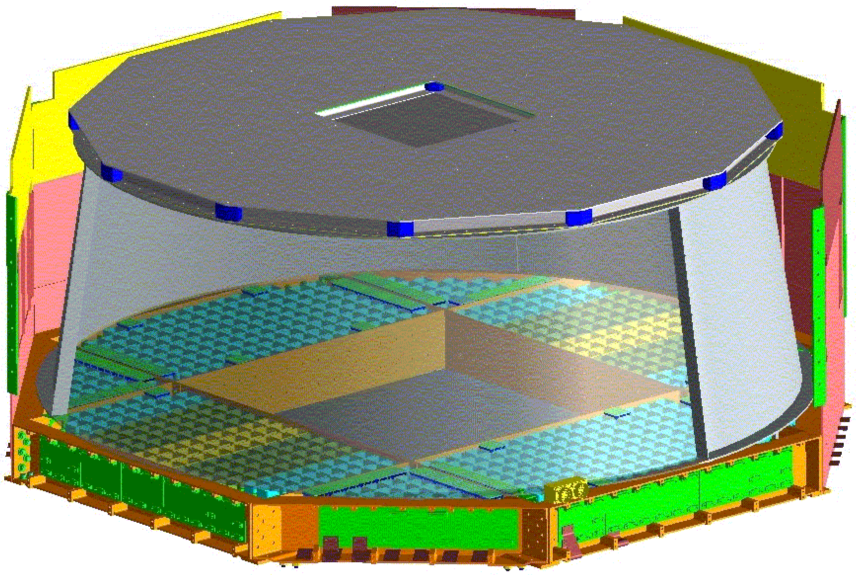
ACC Fiber Optics Coupler



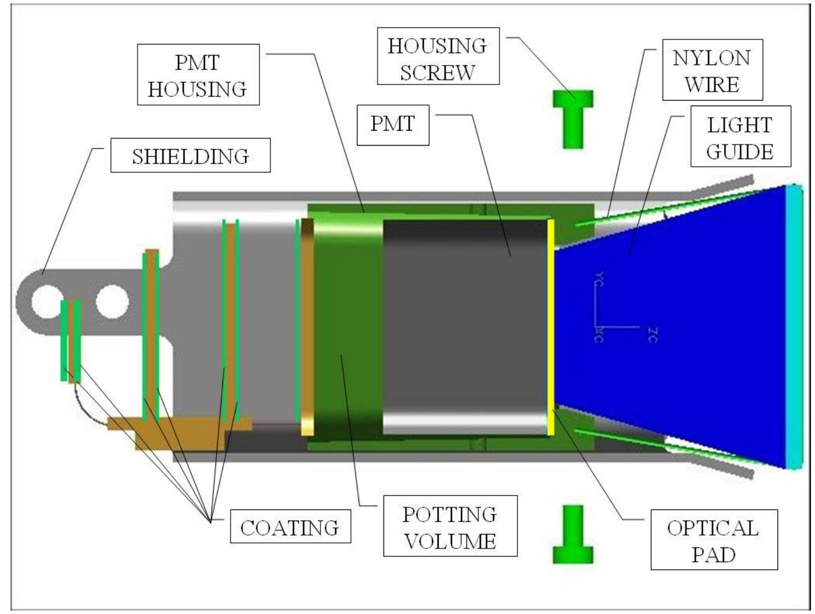
ECAL Lead-Fiber Sandwich



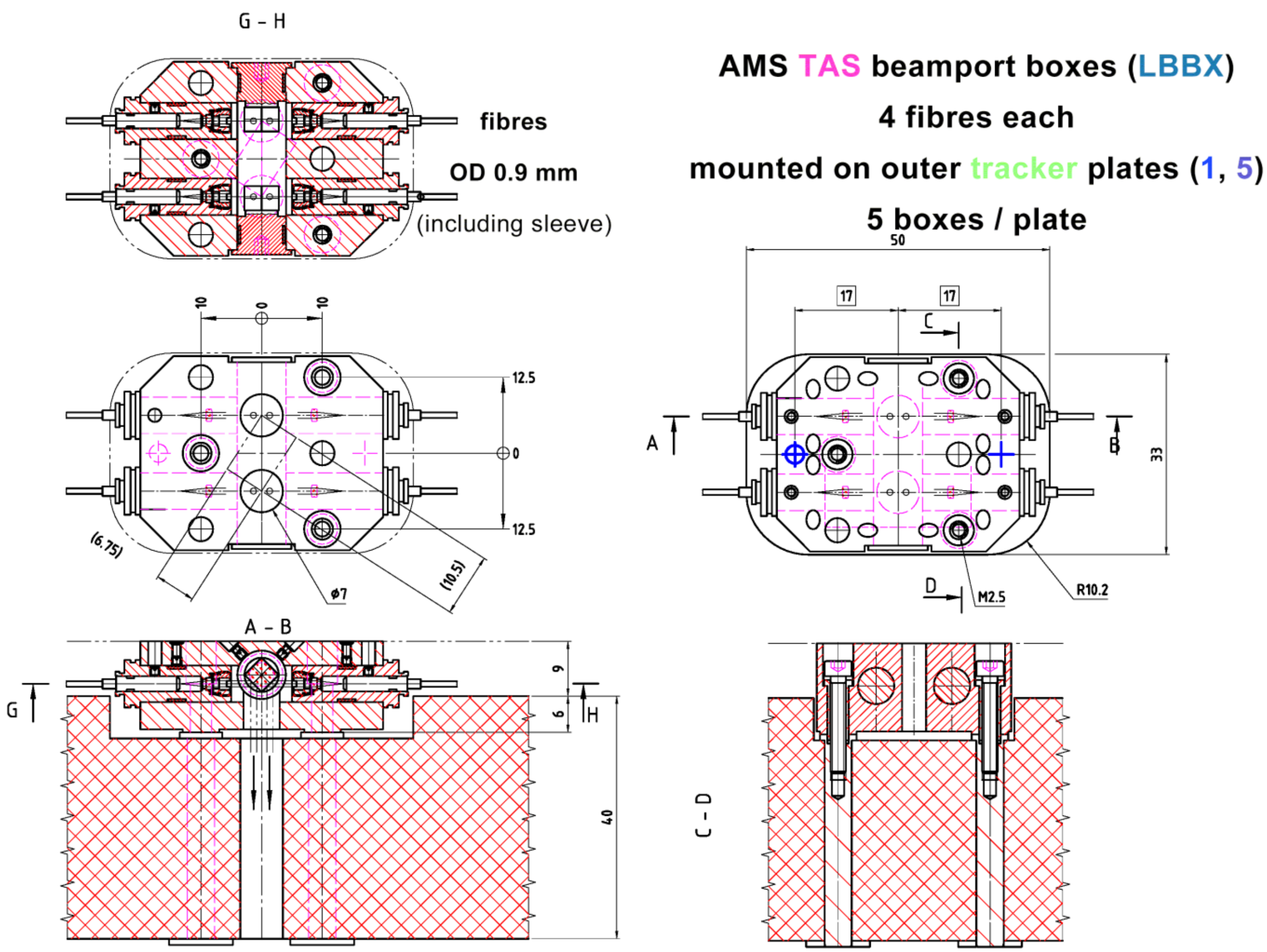
RICH Aerogel and NaF Containment



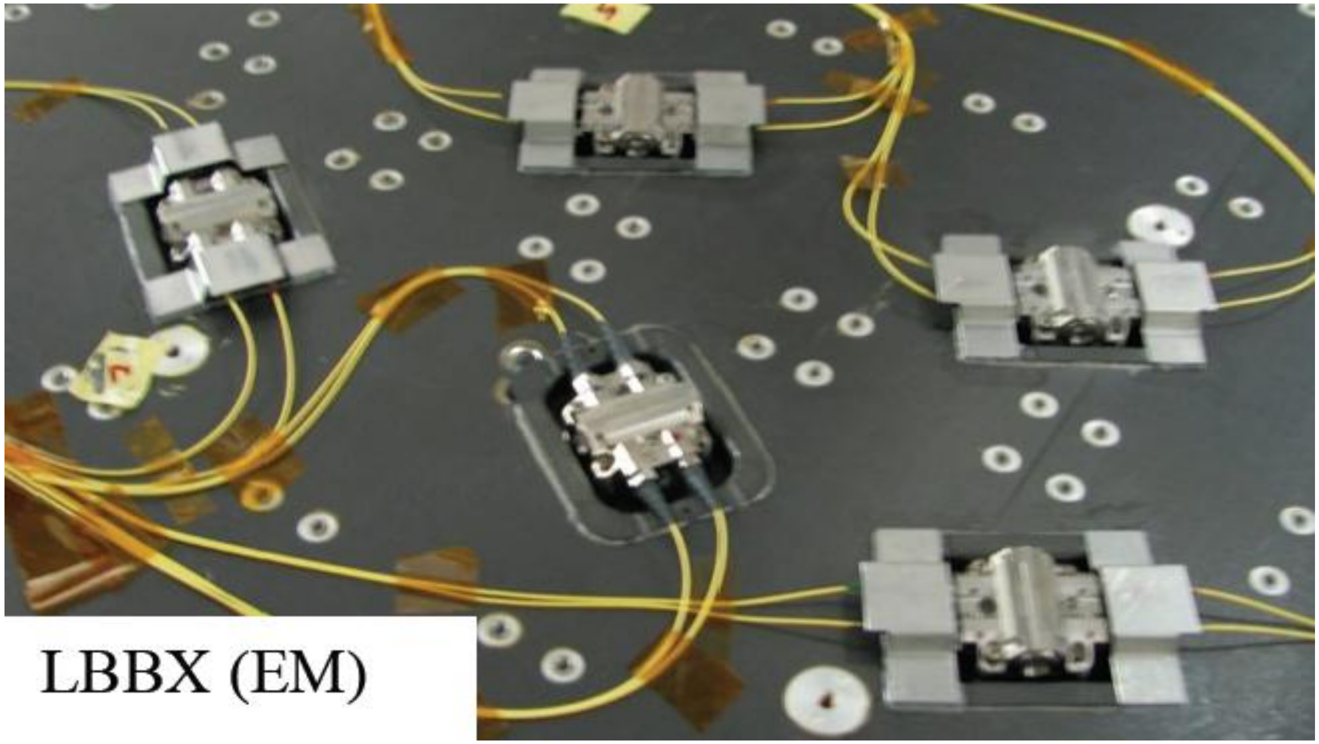
RICH Cutaway Diagram



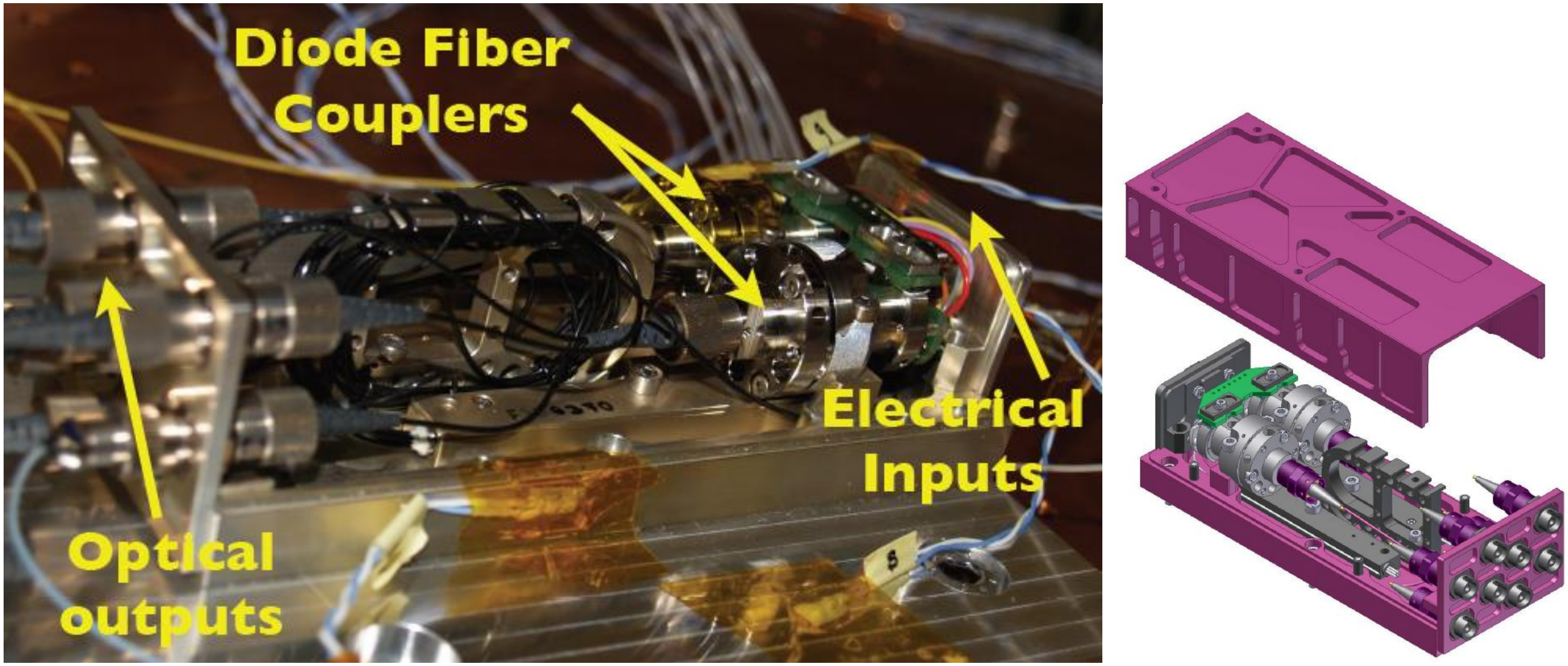
RICH PMT Construction



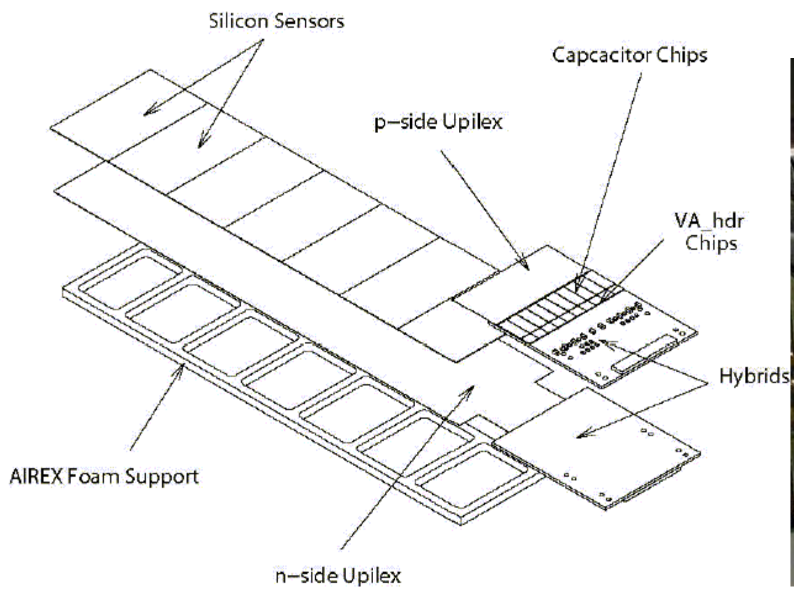
Tracker Laser Alignment System Beam Port Design



Mountd LBBX on Tracker Plane



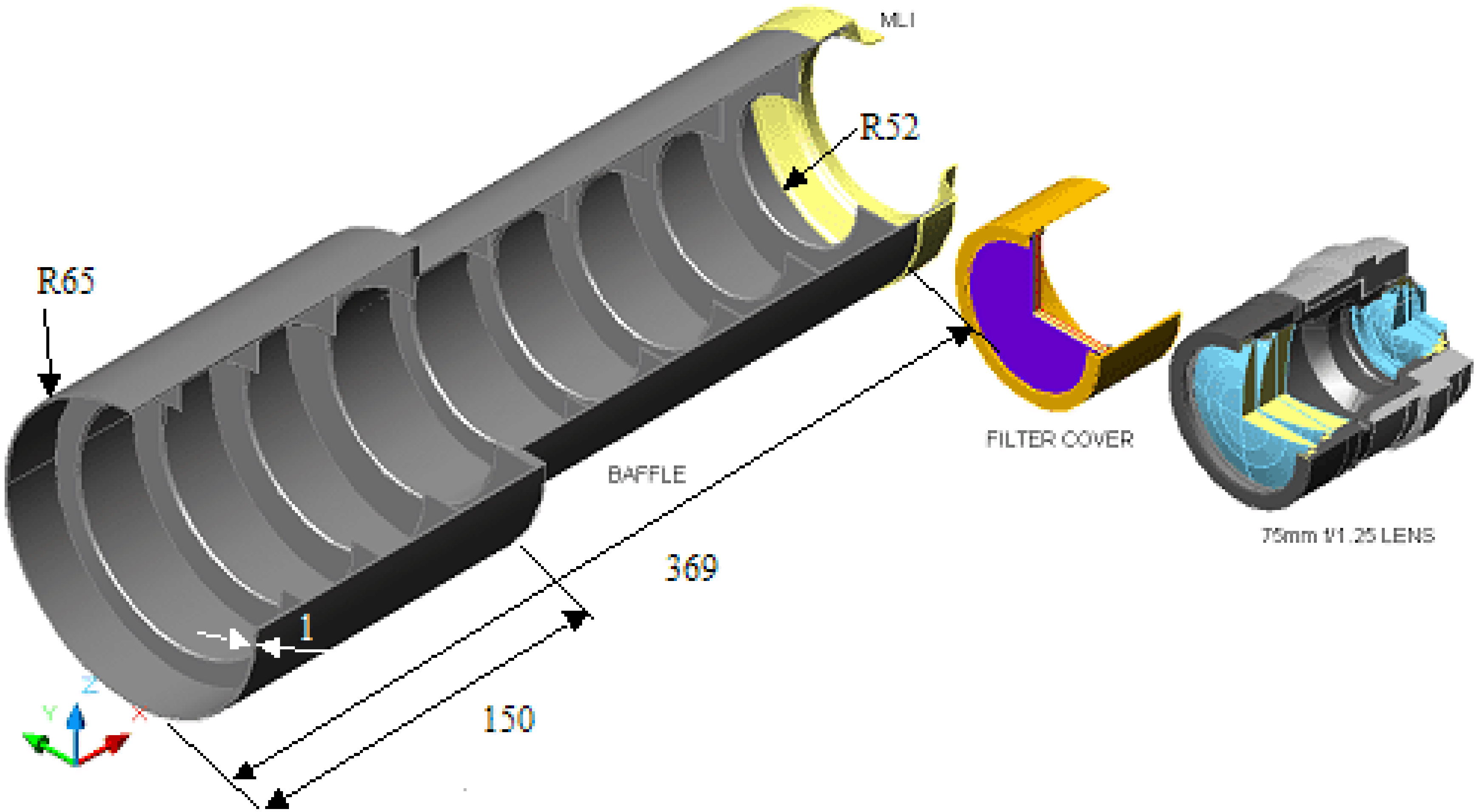
Tracker Alignment System Laser Fiber Coupler Box



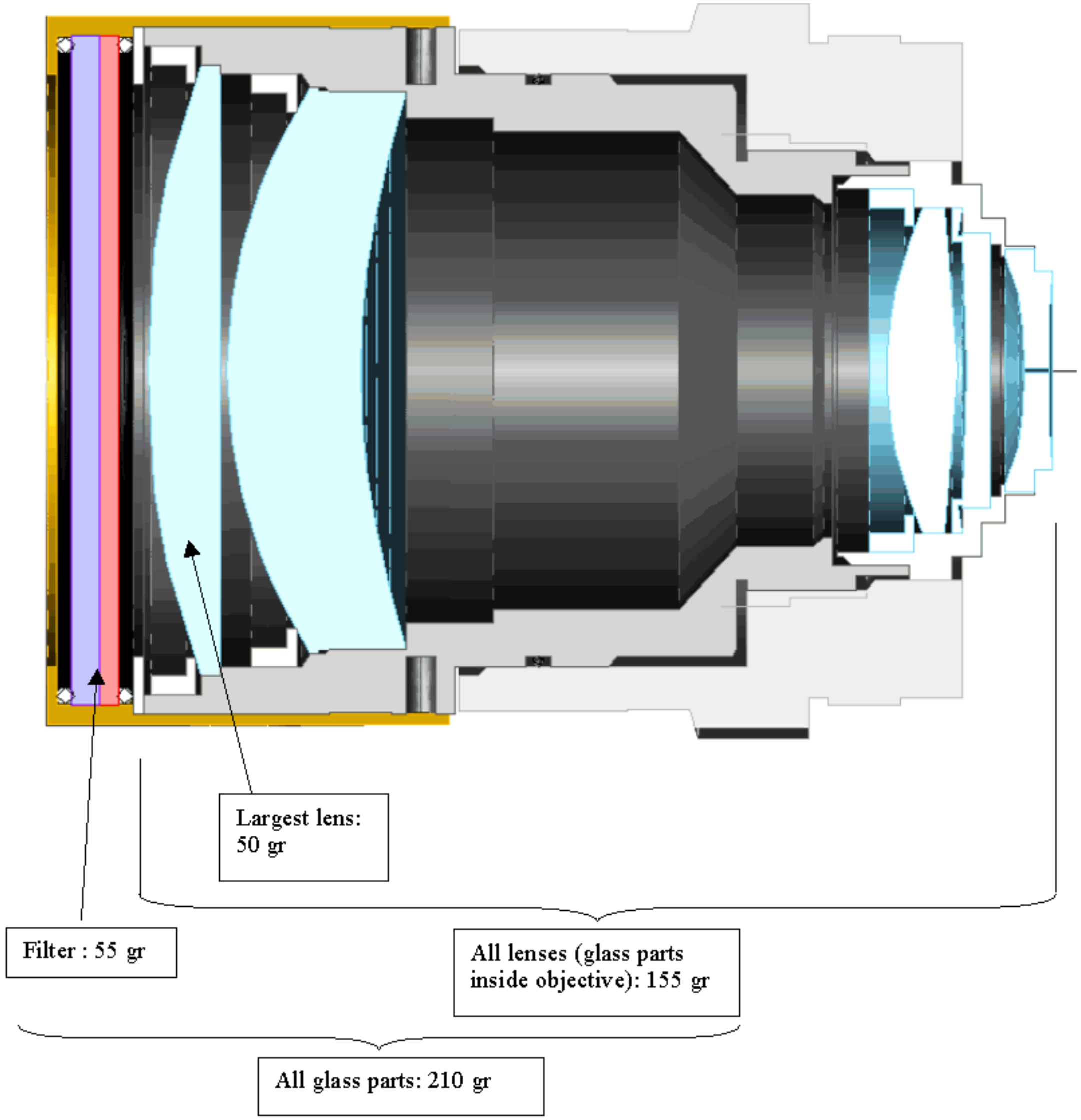
Tracker Ladder Components

Tracker Ladders Installed, fully wrapped in shielding.

SILICON TRACKER LADDER Construction



Star Tracker Optics



Significant Mass Characteristics of Star Tracker Optical Components

PAYLOAD FLIGHT HAZARD REPORT				a. NO:	AMS-02-F17
b. PAYLOAD	Alpha Magnetic Spectrometer-02 (AMS-02)			c. PHASE:	III
d. SUBSYSTEM:	Avionics	e. HAZARD GROUP:	Injury, Damage to critical systems	f. DATE:	January 21, 2011
g. HAZARD TITLE:	Electrical Power Distribution Damage			i. HAZARD CATEGORY:	CATASTROPHIC **X** CRITICAL
h. APPLICABLE SAFETY REQUIREMENTS:	NSTS 1700.7B and ISS Addendum: 201.3, 207, 213.1				
j. DESCRIPTION OF HAZARD:	Damage to electrical power distribution circuitry can lead to damage to shuttle and ISS wiring, loss of critical circuitry and loss of power source.				

k. CAUSES

(list)

1. Short circuit or load failures induce over-current condition in vehicle wiring.
2. Cross strapping of power sources damages vehicle circuitry.

o. APPROVAL	PAYLOAD ORGANIZATION	SSP/ISS
PHASE I		
PHASE II		
PHASE III		

PAYLOAD FLIGHT HAZARD REPORT		a. NO: AMS-02-F17
b. PAYLOAD Alpha Magnetic Spectrometer-02 (AMS-02)		c. PHASE: III
l. HAZARD CONTROL (CONTROL), m. SAFETY VERIFICATION METHODS (SVM), n. STATUS OF VERIFICATIONS (STATUS)	OPS CONTROL	
1. CAUSE: Short circuit or load failures induce over-current condition in vehicle wiring.		
1.1 CONTROL: Wire gauge and insulation for integration cabling have been selected to meet NSTS 1700.7B, "Safety Policy and Requirements For Payloads Using the Space Transportation System", NSTS 1700.7B ISS Addendum, "Safety Policy and Requirements For Payloads Using the International Space Station", and NASA Technical Memorandum #TM 102179, "Selection of Wires and Circuit Protection Devices for NSTS Orbiter Vehicle Payload Electrical Circuits" including proper wire bundle derating. 1.1.1 SVM: Review of Design 1.1.2 SVM: Inspection of As Built Design 1.1.1 STATUS: Closed. ESCG Memorandum ESCG-4175-09-REENTES-MEMO-0006, “Electrical Power Distribution System Review,” dated March 11, 2009. 1.1.2 STATUS: Closed to SVTL		
1.2 CONTROL: Circuit protection devices are sized to protect wiring and systems to meet NSTS 1700.7B, "Safety Policy and Requirements For Payloads Using the Space Transportation System", NSTS 1700.7B ISS Addendum, "Safety Policy and Requirements For Payloads Using the International Space Station", and NASA Technical Memorandum #TM 102179, "Selection of Wires and Circuit Protection Devices for NSTS Orbiter Vehicle Payload Electrical Circuits". AMS-02 will carefully select heater sizing and interfaces such that heaters that might possibly be powered during SSRMS operations does not exceed 16.2 amps. This full current draw is not anticipated as all heaters (with thermostatic control) would have to be activated at the same time. 1.2.1 SVM: Review of Design 1.2.2 SVM: Inspection of as built design 1.2.3 SVM: Testing/Analysis of current draw shows max current draw less than or equal to16.2 amps. 1.2.1 STATUS: Closed. ESCG Memorandum ESCG-4175-09-REENTES-MEMO-0006, “Electrical Power Distribution System Review,” dated March 11, 2009 and ESCG Memorandum ESCG-4295-10-CPAS-MEMO-0004, “AMS-02 Space Station Remote Manipulator System Wiring Protection,” dated March 2, 2010 1.2.2 STATUS: Closed. JSC TPS 2A1020253, “Fabricate AMS-02 PVGF Cable Assembly p/n SEG39136093-301		

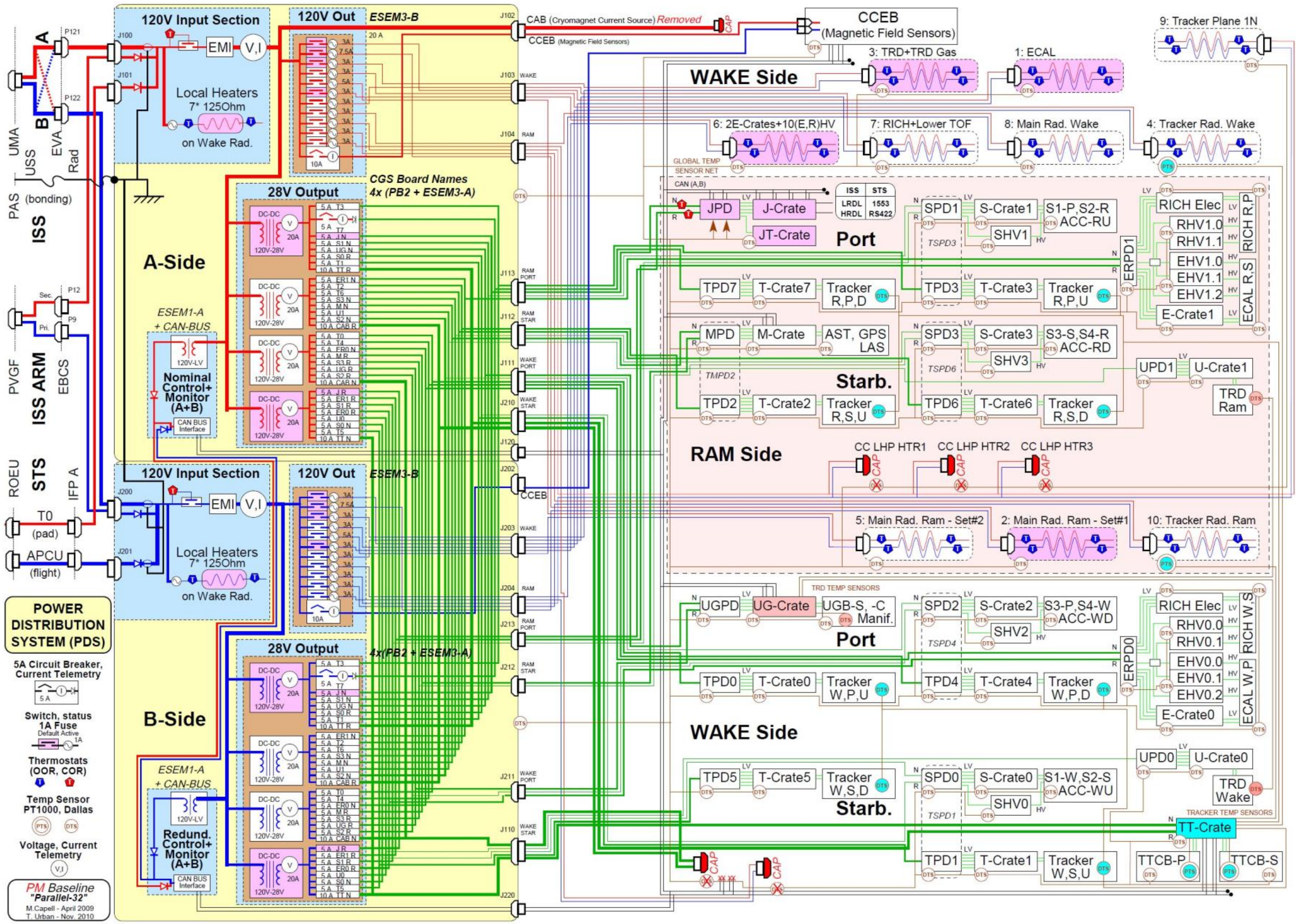
s/n 1001 (CI)," Closed October 1, 2010. AMS-02 ADP for Heaters and PDS Configuration on File in AMS-02 Project Office. 1.2.3 STATUS: Closed. ESCG-4295-10-ADV SY-MEMO-0040, "SSRMS Current Limits," dated September 20, 2010	
1.3 CONTROL: Wiring and connectors coming from the ISS, Orbiter APCU, T-0 and PVGF continue the wire rating of the supplying source to the location of circuit protection devices within the Power Distribution System. Failures within this system will not propagate and damage vehicle systems. 1.3.1 SVM: Review of design 1.3.2 SVM: Inspection of as build design 1.3.1 STATUS: Closed. ESCG Memorandum ESCG-4175-09-REENTES-MEMO-0006, "Electrical Power Distribution System Review," dated March 11, 2009. 1.3.2 STATUS: Closed.(PVGF) JSC TPS 2A1020253, Closed October 1, 2010. (UMA) JSC TPS 2A1020258, closed October 22, 2010, JSC TPS 2A1020259, closed October 22, 2010, JSC TPS, JSC TPS 2A0420007, Closed June 4, 2008, (ROEU) JSC TPS 2A1020272, Closed November 18, 2010	
2. CAUSE: Cross strapping of power sources damages vehicle circuitry.	
2.1 CONTROL: Diodes in the power supply circuit from the ROEU and from the ISS SSRMS preclude power from the ISS and the SSRMS from being present at the ROEU connector. Diodes also preclude ISS UMA supplied power from being present at the SSRMS grapple fixture connector. 2.1.1 SVM: Review of design for proper use of diode protection. 2.1.2 SVM: Inspection of as built hardware to assure proper installation of diode protection. 2.1.3 SVM: Testing of AMS-02 power interfaces to assure that diode protection is functioning. 2.1.1 STATUS: Closed. ESCG Memorandum ESCG 4175-09-REENTES-MEMO-0024, "Isolation between UMA and PVGF," dated May 4, 2009 2.1.2 STATUS: Closed. JSC TPS 2A1120002, "PDS Diode Verification Test of AMS-02 Payload at KSC SSPF," Closed January 18, 2011 2.1.3 STATUS: Closed. JSC TPS 2A1120002, "PDS Diode Verification Test of AMS-02 Payload at KSC SSPF,"	

PAYLOAD FLIGHT HAZARD REPORT	a. NO: AMS-02-F17
b. PAYLOAD Alpha Magnetic Spectrometer-02 (AMS-02)	c. PHASE: III

Closed January 18, 2011	
2.3 CONTROL: The two ISS power feeds are maintained within separate circuitry within the AMS-02 and are not “combined” until after the 120VDC power has been processed through independent DC to DC converters. There is no nominal path or component fault that will cause the two ISS power feeds to be interconnected. (See Control 2.4 for Exception) 2.3.1 SVM: Review of Design 2.3.2 SVM: Functional testing of AMS-02 for isolation between A and B buses at flight power interfaces. 2.3.1 STATUS: Closed. ESCG Memorandum ESCG-4175-09-REENTES-MEMO-0025, “Cross Strapping of Power Feeds,” dated August 18, 2009 2.3.2 STATUS: Closed to SVTL	
2.4 CONTROL: During robotic operation involving the AMS-02 while it is connected to the truss berthing location, the electrical source (RPCM) of the SSRMS and the electrical source (RPCM) of the UMA will be different, per SSP 57003 these two sources may not be interconnected. To avoid this condition the procedures for engaging the AMS-02’s power while on the truss will require a specific sequence that precludes the UMA to be connected when the PVGF is electrically connected to the SSRMS. The UMA must be demated prior to electrical mating of SSRMS LEE to PVGF and the PVGF must be electrically demated prior to UMA engagement for installation on the ISS. This separation of connectors will preclude any interconnection of the power sources. 2.4.1 SVM: Requirement to physically separate SSRMS power path to the AMS-02 prior to engaging the UMA power connection to AMS-02 accepted by MOD through an OCAD(OCAD 67911). 2.4.1 STATUS: Closed. Acceptance of OCAD transmitted by email from JSC-OCAD-Admin@mail.nasa.gov on June 3, 2010	I
Notes:	

ACRONYMS	
A – Amperes	ROEU – Remotely Operated Electrical Umbilical
ACC – Anticoincidence Counter	RP – Ram side port
AMS-02 – Alpha Magnetic Spectrometer - 02	RS – Rams side starboard
APCU – Auxiliary Power Control Unit	SFHe – Superfluid Helium
BMS – Battery Management System	SFHe – Superfluid Helium
CAB – Cryomagnet Avionics Box	SSRMS – Space Station Remote Manipulator System
CCEB – Cryocooler Electronics Box	Starb. – Starboard
CCS – Cyromagnet Current Source	SVM – Safety Verification Method
DC – Direct Current	TOF – Time of Flight
DC-DC – Direct Current to Direct Current (converter)	TRD – Transition Radiation Detector
DTS – Dallas Temperature Sensor	TTCB – TTCS Control Box
ECAL – Electromagnetic Calorimeter	TTCS – Tracker Thermal Control System
EMI – Electromagnetic Interference	UMA – Umbilical Mating/Mechanism Assembly
EVA – Extravehicular Activity	UPS – Uninterruptible Power Supply
HRDL – High Rate Data Link	USS – Unique Support Structure
LRDL – Low Rate Data Link	VC – Vacuum Case
Mainf – Manifold	VDC – Volts Direct Current
PAS – Payload Attach Site	W – Watt
PVGF – Power Video Grapple Fixture	WP – Wake side port
RICH – Ring Imaging Cherenkov (detector)	WS – Wake side starboard

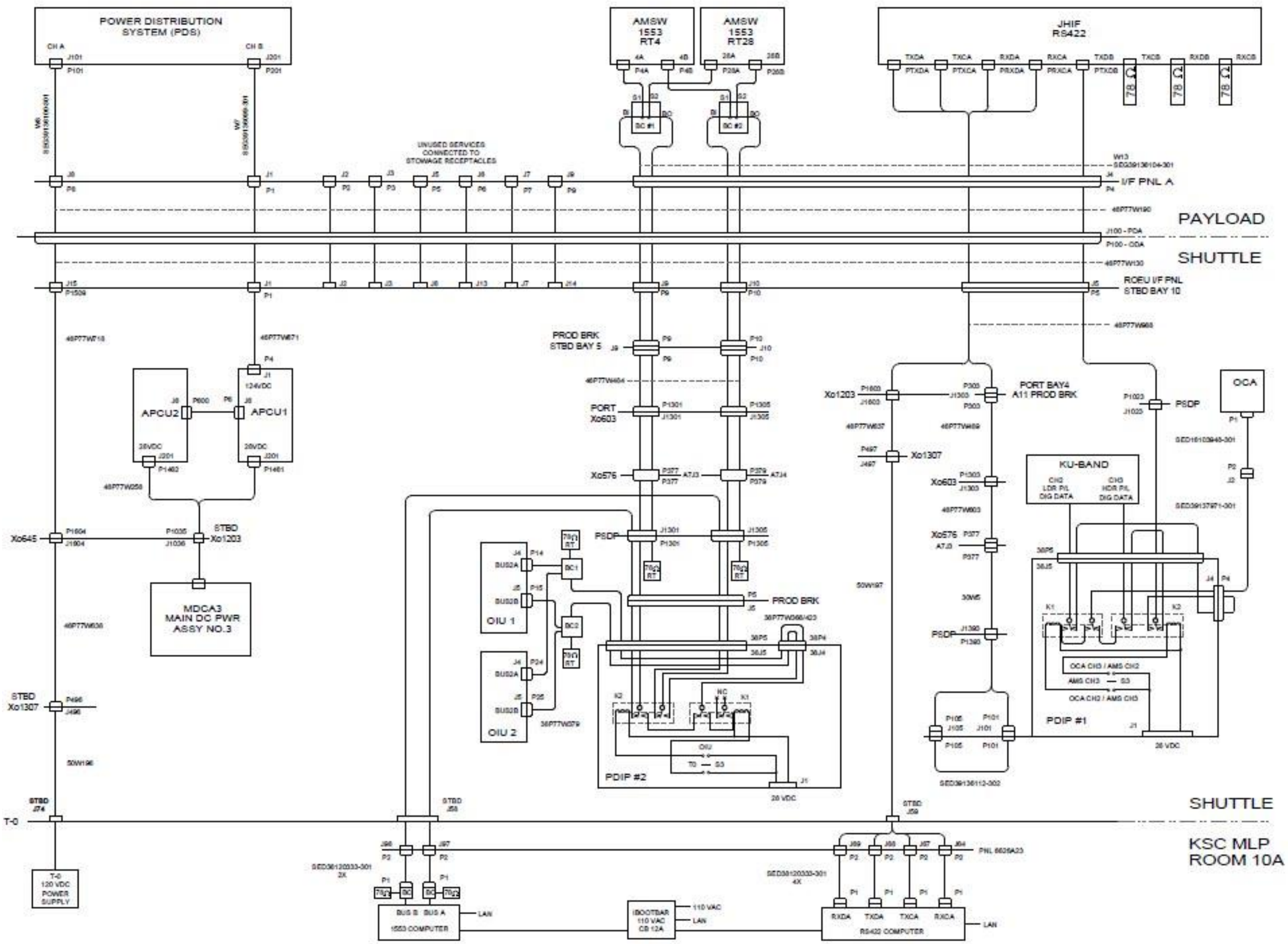
DECODING Electronic Boxes and Nomenclature:	
FIRST Character(s)	Following Designator
E - ECAL	PD – Power Distribution
J – Main Data Computers (MDC) and Command & Data Handling interfaces	HV – High Voltage
JT – Trigger and central data acquisition	Crate – Electronics box or crate
M – Monitoring	
R – RICH	Numerical designators follow.
S – Time of Flight (TOF) and Anti-Coincidence Counter (ACC)	
T – Tracker	
TT – Tracker Thermal	
U – Transition Radiation Detector (TRD)	
UG – TRD Gas	



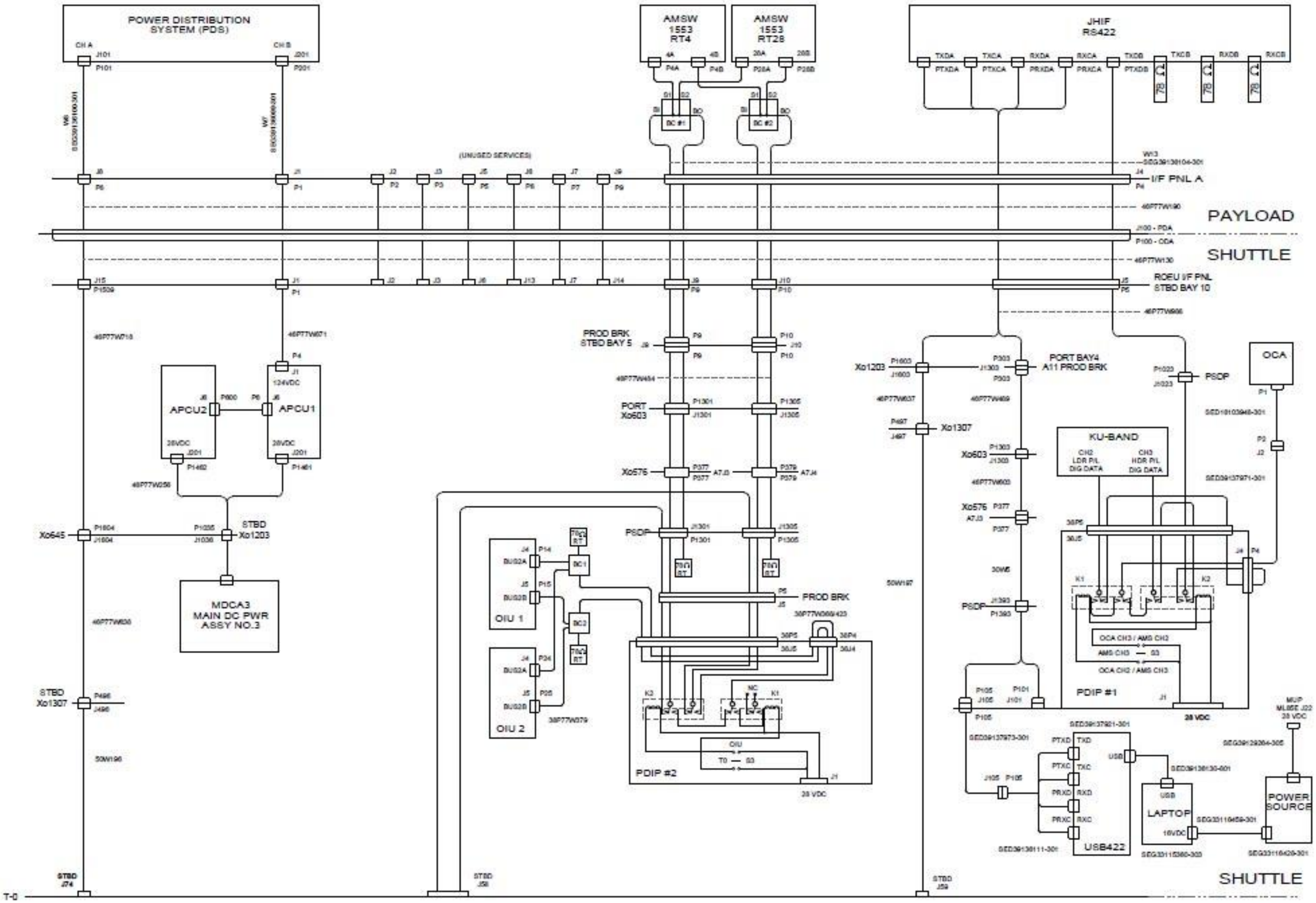
120V Input Section
120V Out
ESEM3-B
CAB (Cryomagnet Current Source) Removed
CCEB (Magnetic Field Sensors)
CCEB
(Magnetic Field Sensors)
9: Tracker Plane 1N
3: TRD+TRD Gas
1: ECAL
WAKE Side
EMI
V,I
Local Heaters
7* 125Ohm
on Wake Rad.
6: 2E-Crates+10(E,R)HV
7: RICH+Lower TOF
8: Main Rad. Wake
4: Tracker Rad. Wake
GLOBAL TEMP SENSOR NET
CAN (A,B)
UMA
USS
EVA
Rad
PAS
(bonding)
ISS
A-Side
28V Output
CGS Board Names
4x (PB2 + ESEM3-A)
DC-DC
120V-28V
JPD
J-Crate
JT-Crate
ISS
STS
LRDL
HRDL
1553
RS422
Port
SPD1
S-Crate1
S1-P,S2-R
ACC-RU
SHV1
TSPD3
RICH Elec
RHV1.0
RHV1.1
EHV1.0
EHV1.1
EHV1.2
E-Crate1
ERPD1
RICH R,P
ECAL R,S
TPD7
T-Crate7
Tracker R,P,D
TPD3
T-Crate3
Tracker R,P,U
ESEM1-A
+ CAN-BUS
120V-LV
Nominal Control+ Monitor (A+B)
CAN BUS Interface
MPD
M-Crate
AST, GPS LAS
TMPD2
SPD3
S-Crate3
S3-S,S4-R
ACC-RD
SHV3
TSPD6
UPD1
U-Crate1
TRD Ram
Starb.
TPD2
T-Crate2
Tracker R,S,U
TPD6
T-Crate6
Tracker R,S,D
PVGF
ISS ARM
EBCS
RAM Side
CC LHP HTR1
CC LHP HTR2
CC LHP HTR3
CAP
ROEU
STS
IFP A
T0
(pad)
APCU
(flight)
5: Main Rad. Ram - Set#2
2: Main Rad. Ram - Set#1
10: Tracker Rad. Ram
POWER DISTRIBUTION SYSTEM (PDS)
5A Circuit Breaker, Current Telemetry
Switch, status
1A Fuse
Default Active
Thermostats (OOR, COR)
Temp Sensor PT1000, Dallas
Voltage, Current Telemetry
PM Baseline
"Parallel-32"
M.Capell - April 2009
T. Urban - Nov. 2010
B-Side
TRD TEMP SENSORS
UGPD
UG-Crate
UGB-S, -C Manif.
SPD2
S-Crate2
S3-P,S4-W
ACC-WD
SHV2
TSPD4
RICH Elec
RHV0.0
RHV0.1
EHV0.0
EHV0.1
EHV0.2
E-Crate0
ERPD0
RICH W,S
ECAL W,P
TPD0
T-Crate0
Tracker W,P,U
TPD4
T-Crate4
Tracker W,P,D
UPD0
U-Crate0
TRD Wake
TPD5
T-Crate5
Tracker W,S,D
SPD0
S-Crate0
S1-W,S2-S
ACC-WU
SHV0
TSPD1
TRACKER TEMP SENSORS
TT-Crate
Redund. Control+ Monitor (A+B)
TPD1
T-Crate1
Tracker W,S,U
TTCB-P
TTCB-S

Vehicle Current Limitations and Circuit Protection

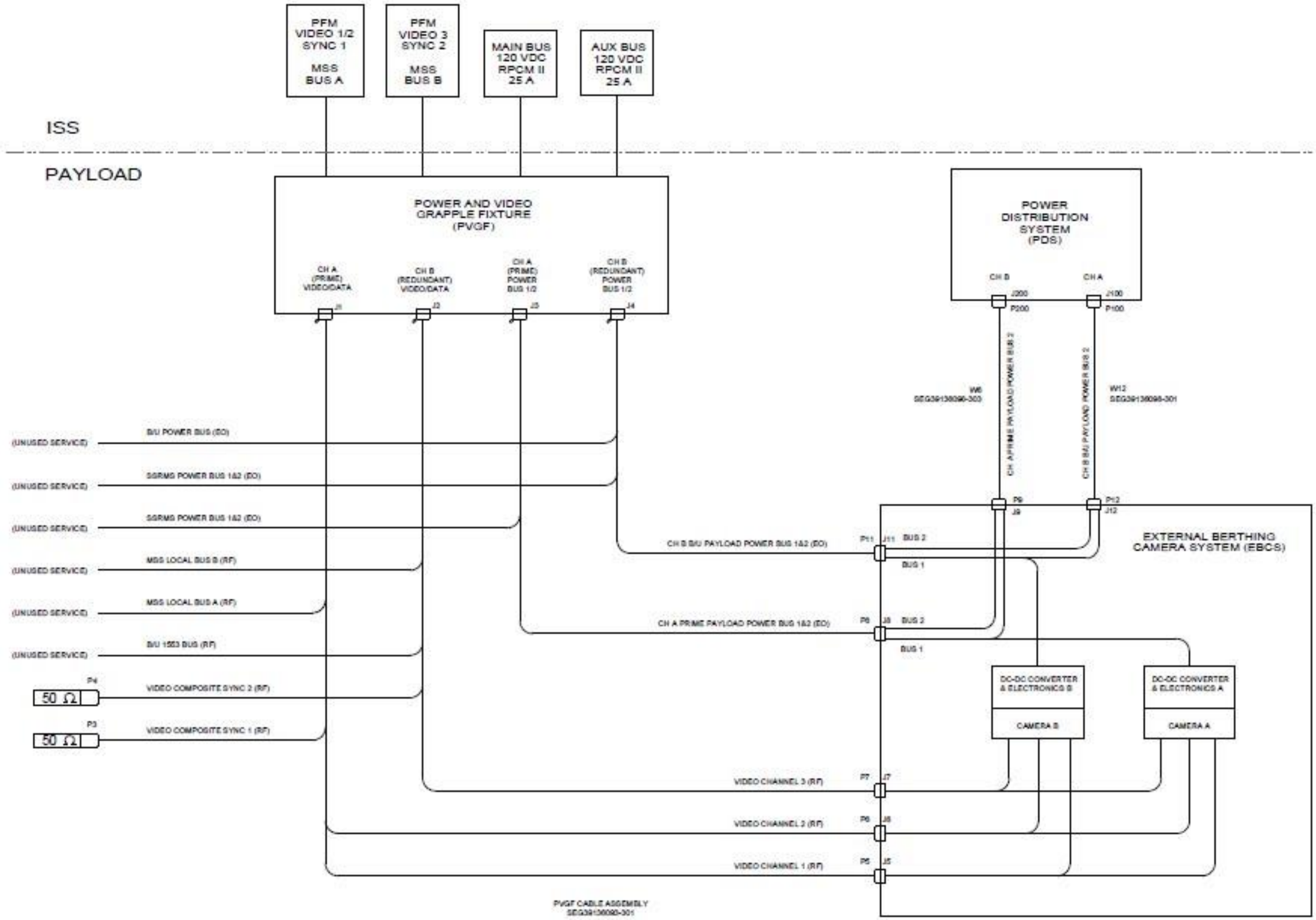
SOURCE	Wire/Cabling	Maximum Current Provided Nominally	Maximum Trip Current	Voltage
STS T0 Power	4 x AWG 12	14.7 A	27 A	120 VDC
STS APCU	3 x AWG 8	14.7 A	22 A	120 V
ITS S3 PAS 2	3 x AWG 8	25 A	27.5 A	120 V
PVGF	4 x AWG 12	16.7 A	27.5 A	120 V



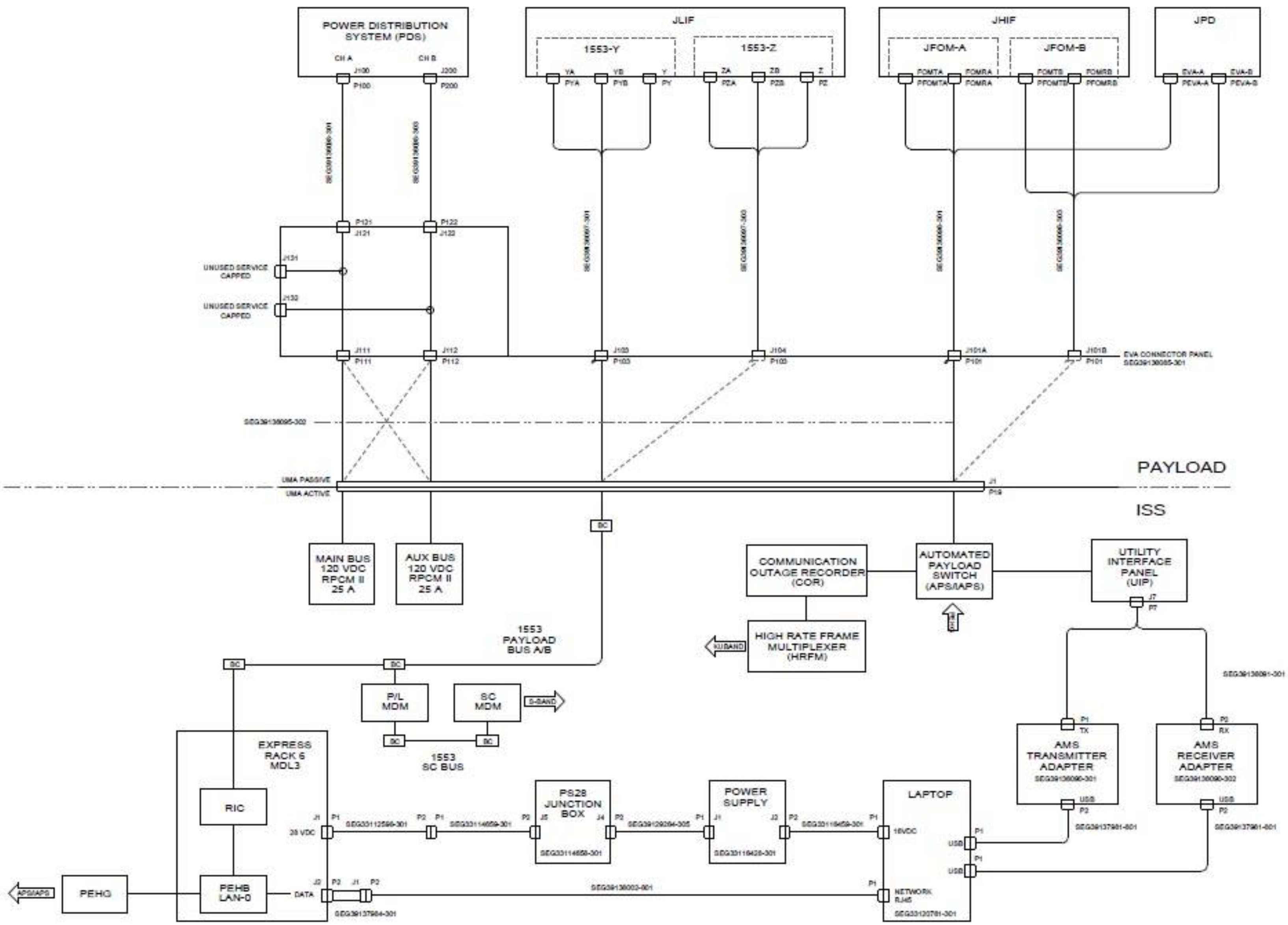
AMS-02 Interface Diagram to T-0 Line



AMS-02 Interface Diagram to STS



AMS-02 Interface Diagram to PVGF



AMS-02 Interface Diagram to ISS

AMS-02 Integration Cabling De-Rating Information
Cable numbers available on preceding schematics

Assembly Part Number	Component Part Number	Qty	Component Description	Specification / Supplier	EMC	V (max) Rating (VDC)	V (max) Applied (VDC)	V Ratio	V (Derating) Required	I (max) Rating (Amp)	I (max) Rating Bundle (Amp)	I (max) Applied (Amp)	I Ratio	I (Derating) Required	Notes
SEG39136099-301	MS3456L24-11SW	1 EA	Plug, Cable Mount, P201	MIL-C-5015	EO	200	124	0.62	1	-	-	-	-	-	Source: Two (2) APCU parallel config / 3600 W @ 124 VDC / Current Limited @ 22 A
	ME414-0234-7246	1 EA	Receptacle, Flange Mount, J1	ME414-0234		200	124	0.62	1	-	-	-	-	-	
	M22759/12-8-9	AR	8 AWG	MIL-W-22759/12		-	-	-	-	44	40.86	19.00	0.47	1	
SEG39136100-301	MS3456L24-11SW	1 EA	Plug, Cable Mount, P101	MIL-C-5015	EO	200	120	0.60	1	-	-	-	-	-	Source: 120 VDC KSC MPM Pwr Supply / Current Limited @ 25 A / Located in KSC MLP Room
	NB0E18-8SNT3	1 EA	Receptacle, Flange Mount, J8	40M39569		200	120	0.60	1	-	-	-	-	-	KSC Pad Ops only; NOT OPERATED IN FLIGHT.
	M27500-12RE2U00	AR	2 COND, 12 AWG	MIL-DTL-27500		-	-	-	-	25	20.54	19.00	0.93	1	
SEG39136104-301	5-0051-3-218	9 EA	Plug, Cable Mount, 450 Series, Twinax, P4A, P4B, P28A, P28B PTXDA, PTXCA, PRXDA, PRXCA, PTXDB	Trompeter	RF	900	30	0.03	1	-	-	-	-	-	1553 & RS422 Application
	NLS0T16-35S	1 EA	Receptacle, Flange Mount, J4	40M38277		200	30	0.15	1	-	-	-	-	-	
	NDBC-TFE-22-2SJ-75	AR	NASA Data Bus Cable, 2 COND, 22 AWG	SSQ21655		-	-	-	-	4.5	4.34	0.25	0.06	1	
	NDBC4B2ANH13849	AR	NASA Data Bus Coupler with NDBC stubs	SSQ21676											
SED39136111-301	NLS6GT12-35P	1 EA	Plug, Cable Mount, P105	40M38277	RF	200	5	0.03	1	-	-	-	-	-	RS422 Application
	5-0038-45	4 EA	Plug, Cable Mount, 70 Series, Twinax, PRXD, PRXC, PRTXD, PTXC	Trompeter		400	5	0.01	1	-	-	-	-	-	
	NDBC-TFE-22-2SJ-75	AR	NASA Data Bus Cable, 2 COND, 22 AWG	SSQ21655		-	-	-	-	4.5	4.34	0.25	0.06	1	
SED39136130-801	F3U133-03	1 EA	COTS USB 2.0 Cable, 3 FT	Belkin	RF										USB Application, COTS Cable wrapped in teflon tape
SED39136112-302	NLS6GT12-35P	2 EA	Plug, Cable Mount, P103, P105	40M38277	RF	200	5	0.03	1	-	-	-	-	-	RS422 Application
	M27500-22RE2S06	AR	2 COND, 22 AWG	MIL-DTL-27500		-	-	-	-	4.5	4.34	0.25	0.06	1	
SEG39136098-301, -303	MS3456L24-11S	2 EA	Plug, Cable Mount, P100, P200	MIL-C-5015	EO	200	120	0.6	1	-	-	-	-	-	Source: ISS Bus A/B / RPCM Type II / 120 VDC @ 25 A
	ME414-0235-7247	2 EA	Plug, Cable Mount, P121, P122	ME414-0235		200	120	0.6	1	-	-	-	-	-	Current Limited @ 27.5 A
	SCBM5W5M0000G	2 EA	Plug, SCBM Series, P9, P12, GFE EBCS	Positronic		300	120	0.4	1	-	-	-	-	-	
	M22759/12-8-9	AR	8 AWG	MIL-W-22759/12		-	-	-	-	44	40.86	25	0.61	1	
	M22759/12-12-9	AR	12 AWG	MIL-W-22759/12		-	-	-	-	25	23.21	16.5	0.71	1	
SEG39136097-301, -303	5-0051-3-218	4 EA	Plug, Cable Mount, PYA, PYB, PZA, PZB	Trompeter	RF	900	30	0.03	1	-	-	-	-	-	1553 Low Rate Data Application
	MWDM2L-21P-6J7-300B	2 EA	Plug, Cable Mount, PY, PZ	MIL-DTL-83513		600	5	0.01	1	-	-	-	-	-	Loopback Power Verification
	NZGL00T1515N35SA	2 EA	Receptacle, Wall Mount, NZGL Series, J103, J104	SSQ21635		200	30	0.15	1	-	-	-	-	-	
	NDBC-TFE-22-2SJ-75	AR	2 COND, 22 AWG	SSQ21655		-	-	-	-	4.5	4.34	0.25	0.06	1	
	M22759/33-26	AR	26 AWG, Pigtail included with Item # 40	MIL-W-22759/33		-	-	-	-	2.5	0.71	0.20	0.28	1	
SEG39136096-301, -303	FODT-PA1720BS	4 EA	Plug, Cable Mount, PFOMTA, PFOMTB, PFOMRA, PFOMRB	ITT CANNON	FO/ML	-	-	-	-	-	-	-	-	-	Fiber Optic High Rate Data Application
	MS27473E16F8P	2 EA	Plug, Cable Mount, PEVA-A, PEVA-B	MIL-C-38999		200	5	0.03	1	-	-	-	-	-	Loopback Power Verification
	NZGL00T1717N13SN	2 EA	Receptacle, Wall Mount, NZGL Series, J101A, J101B	SSQ21635		200	5	0.03	1	-	-	-	-	-	
	NFOC-2FFF-1GRP-1	AR	NASA Fiber Optic Cable	SSQ21634		-	-	-	-	-	-	-	-	-	
	M27500-16RE2N06	AR	2 COND, 16 AWG	MIL-DTL-27500		-	-	-	-	13	12.54	0.5	0.04	1	
SEG391360095-302	NZGL06G2525LN7SN	2 EA	Plug, Cable Mount, NZGL Series, P111, P112	SSQ21635	EO/RF/ ML/FO	200	120	0.60	1	-	-	-	-	-	UMA pigtail supplied by program office
	NZGL06G1515N35PA-1	1 EA	Plug, Cable Mount, NZGL Series, P103	SSQ21635		200	5	0.03	1	-	-	-	-	-	Source: ISS Bus A/B / RPCM Type II / 120 VDC @ 25 A
	NZGL06G1717N13PN	1 EA	Plug, Cable Mount, NZGL Series, P101	SSQ21635		200	5	0.03	1	-	-	-	-	-	Current Limited @ 27.5 A
	NSFW-SIL-8VB	AR	8 AWG, GFE UMA pigtail			-	-	-	-	44	40.86	25	0.61	1	Loopback Power Verification
	NGPC-ETF-22-2SJ	AR	22 AWG, GFE UMA pigtail			-	-	-	-	4.5	4.34	0.25	0.06	1	
	M22759/12-22-9	AR	22 AWG	MIL-W-22759/12		-	-	-	-	4.5	4.34	0.20	0.05	1	
	M22759/12-16-9	AR	16 AWG	MIL-W-22759/12		-	-	-	-	13	12.54	0.50	0.04	1	
	NDBC-TFE-22-2SJ-75	AR	NASA Data Bus Cable, 2 COND, 22 AWG, GFE UMA pigtail	SSQ21655		-	-	-	-	4.5	4.34	0.25	0.06	1	
	NFOC-2FFF-1GRP-1	AR	NASA Fiber Optic Cable, GFE UMA pigtail	SSQ21634		-	-	-	-	-	-	-	-	-	
SEG39136093-301	SCBM6W5F0000G	2 EA	Plug, Cable Mount, P8, P11, GFE EBCS	Positronic Industries	EO/RF	300	120	0.40	1	-	-	-	-	-	PVGF pigtail supplied by program office
	225609-4	3 EA	Plug, Cable Mount, P3, P4, P5, P6, P7, GFE EBCS	AMP Inc		750	2	0.003	1	-	-	-	-	-	
	142-0801-861	2 EA	Terminator, 50 ohms	Johnson Components		65	2	0.03	1	-	-	-	-	-	Terminate unused EBCS sync
	M27500-12RCU00	AR	2 COND, 12 AWG, PVGF pigtail	MIL-DTL-27500		-	-	-	-	25	24.11	16.70	0.69	1	
	PS267924-01	AR	COAX, RD316, PVGF pigtail			-	-	-	-	-	-	2	-	1	
SED39137971-301	NLS6GT12-35P	1 EA	Plug, P4	40M38277	RF	200	5	0.03	1	-	-	-	-	-	RS422 Application
	NLS7T12-35S	1 EA	Receptacle, J2	40M38277		200	5	0.03	1	-	-	-	-	-	
	NDBC-TFE-22-2SJ-75	AR	NASA Data Bus Cable, 2 COND, 22 AWG, GFE UMA pigtail	SSQ21655		-	-	-	-	4.5	4.34	0.25	0.06	1	
SED39137973-301	NLS6GT12-35P	1 EA	Plug, Cable Mount, P105	40M38277	RF	200	5	0.03	1	-	-	-	-	-	RS422 Application
	NLS7T12-35S	1 EA	Plug, Cable Mount, J105	40M38277		200	5	0.03	1	-	-	-	-	-	
	NDBC-TFE-22-2SJ-75	AR	NASA Data Bus Cable, 2 COND, 22 AWG	SSQ21655		-	-	-	-	4.5	4.34	0.001	0.00	1	
Miscellaneous Items	650BS012M22	2 EA	Stowage Connector	MIL-C-5015		-	-	-	-	-	-	-	-	-	Stow unused services
	650FS002M14	2 EA	Stowage Connector	MIL-C-38999		-	-	-	-	-	-	-	-	-	Stow unused services
	650DS001M16	1 EA	Stowage Connector	MS3115		-	-	-	-	-	-	-	-	-	Stow unused services
	650DS001M22	1 EA	Stowage Connector	MS3115		-	-	-	-	-	-	-	-	-	Stow unused services
	TNG451P-1-78	3 EA	78 Ohm Terminator	Trompeter		900	5	0.01	1	-	-	-	-	-	Terminate unused RS422 services

Engineering and Science Contract Group

2224 Bay Area Boulevard
Houston, Texas 77058

ESCG-4295-10-ADV SY-MEMO-0040
September 20, 2010

TO: Leland Hill

FROM: Chris Tutt

SUBJECT: SSRMS Current Limits

The Alpha Magnetic Spectrometer (AMS-02) has a requirement to verify that the maximum current AMS-02 drew on the SSRMS be less than 16.7A to protect the arm wiring. One of the verifications used to certify this was functional testing of the individual heater lines. This was intended to be done during the thermal vac test, but not all of the circuits had data recorded. As an alternative, the Project Office has reviewed the verification of the box-level components

There are basically three things that are powered while we are on the SSRMS:

1) The Power Distribution System (PDS) and its internal heaters
2) The AMS-02 main computer (J-Crate) and power supply
3) Four strings of heaters protecting various components within the experiment

The PDS was tested at the box level during its qualification program using simulated external loads and was shown to meet the 16.2A prediction. This verified item 1 directly and verified items 2 and 3 so long as the loads used matched the actual external hardware. Operational data from the last couple of years of running the system is sufficient to verify that the current draw at power on for the J-Crate is less than what the PDS developers assumed in their testing. For the third item, resistance values from the heater spec sheets match what the PDS developers used in their analysis.

This memo is submitted as formal closure of SVM 1.2.3 of HR #17.

FORM ESCG 002A-3 (04/13/2010)

PAYLOAD FLIGHT HAZARD REPORT			a. NO: AMS-02-F18
b. PAYLOAD	Alpha Magnetic Spectrometer-02 (AMS-02)		c. PHASE: III
d. SUBSYSTEM: All	e. HAZARD GROUP: Loss of Orbiter, Loss of ISS		f. DATE: August 4, 2010
g. HAZARD TITLE:	Rapid Safing/Payload Reconfiguration		i. HAZARD CATEGORY: CATASTROPHIC **X** CRITICAL
h. APPLICABLE SAFETY REQUIREMENTS:	NSTS 1700.7B and ISS Addendum, 202.4a, 202.4b, 202.4c (ISS only), 205		
j. DESCRIPTION OF HAZARD:	Operations or configurations of the AMS-02 may impede critical operations of the ISS or Orbiter. These include: Inability to close Orbiter Payload Bay Doors, Reconfiguration to that precludes ISS orbit boost or inability to return at end of life. The AMS-02 is complying with ICD requirements for Shuttle and ISS interfaces and is subject to integrated hazard analyses performed by the applicable Programs.		

k. CAUSES

(list)

1. Preclude closure of Payload Bay Doors/Orbiter Return
2. Configuration precludes ISS Operation such as reboost/EVA
3. AMS-02 Reconfiguration precludes safe return
4. Configuration requirement for planned ISS Service Loss

o. APPROVAL	PAYLOAD ORGANIZATION	SSP/ISS
PHASE I		
PHASE II		
PHASE III		

PAYLOAD FLIGHT HAZARD REPORT	a. NO: AMS-02-F18
b. PAYLOAD Alpha Magnetic Spectrometer-02 (AMS-02)	c. PHASE: III

l. HAZARD CONTROL (CONTROL), m. SAFETY VERIFICATION METHODS (SVM), n. STATUS OF VERIFICATIONS (STATUS)	OPS CONTROL
1. CAUSE: Preclude closure of Payload Bay Doors/Orbiter Return	
1.1 CONTROL: The AMS-02 design does not contain any mechanisms or structures that protrude through the Orbiter payload bay door dynamic envelope. Payload bay doors can be closed without physical constraint imposed by the AMS-02. 1.1.1 SVM: Review of AMS-02 Design. 1.1.2 SVM: Analysis of Dynamic Envelop intrusions. 1.1.1 STATUS: Closed. AMS-02 outer mold line model reviewed and all close clearance points identified through the process described in NSTS 37329 Appendix Q, Rev E, September 2006. 1.1.2 STATUS: Closed. DCLA analysis documented in ESCG-4460-09-LODY-MEMO-0272, “Design Coupled Loads Analysis for the Alpha Magnetic Spectrometer-02 (AMS-02),” dated September 1, 2009. Email from AMS-02 Project Engineer C. Lauritzen, March 8 2010, summarizes clearance assessment performed as part of the DCLA showed no intrusions into Orbiter Payload Bay Door Dynamic Envelope.	
1.2 CONTROL: The AMS-02 design does not require a specific configuration of AMS-02 systems (including ROEU connection) to safely return to the ground. 1.2.1 SVM: Review of Design. 1.2.1 STATUS: Closed. Memo ESCG-4390-06-SP-MEMO-0004 dated 06 March 2006 from AMS-02 Chief Engineer Chris Tutt. ESCG Memorandum ESCG-4295-ADV SY-MEMO-0019, “Rapid Safing Operations,” dated July 15, 2010.	
1.3 CONTROL: The AMS-02 does not need any special thermal conditioning of composite structures or other systems to allow for safe return. 1.3.1 SVM: Thermal Analysis to confirm thermal condition of structure under worst case conditions. 1.3.2 SVM: Structural Analysis to confirm adequate margin for thermal extremes of composite structures/systems. 1.3.1 STATUS: Closed. ESCG Memorandum ESCG-4175-09-REENTES-MEMO-0032, “Review of Stress Analysis of AMS-02 Composites,” dated June 4, 2009. ESCG Memorandum ESCG-4295-ADV SY-MEMO-0019, “Rapid Safing Operations,” dated July 15, 2010. 1.3.2 STATUS: Closed. ESCG Memorandum ESCG-4175-09-REENTES-MEMO-0032, “Review of Stress	

PAYLOAD FLIGHT HAZARD REPORT	a. NO: AMS-02-F18
b. PAYLOAD Alpha Magnetic Spectrometer-02 (AMS-02)	c. PHASE: III

Analysis of AMS-02 Composites," dated June 4, 2009. ESCG Memorandum ESCG-4295-ADV SY-MEMO-0019, "Rapid Safing Operations," dated July 15, 2010.	
1.4 <SKIPPED NUMBER>	
1.5 CONTROL: The AMS-02 is safe to return only with all four PRLAs and the Active Keel (latch) Assembly closed. 1.5.1 SVM: Structural Analysis to verify safe return with 4 of 4 PRLA and Keel Latch. 1.5.2 SVM: Formal acceptance of procedure requirement by MOD through and OCAD(OCAD 67910). 1.5.1 STATUS: Closed. ESCG-4005-05-AMS-0039, "Strength and Stability Assessment of the Alpha Magnetic Spectrometer-02 (AMS-02) Unique Support Structure (USS-02), Vacuum Case, Payload Attach System (PAS), and STS and ISS Integration Hardware," August 12, 2009 1.5.2 STATUS: Closed. Acceptance of OCAD transmitted by email from JSC-OCAD-Admin@mail.nasa.gov on June 3, 2010	S
NOTE: The AMS-02 is capable of clearing the payload bay by RMS and SSRMS operations or be resecured within the PRLAs and be safe for return within the required 1 hour and 35 minute time allotted per MA2-96-190 for a rapid undocking of the Orbiter from the ISS and return to Earth. ISS –STR-907 for rapid safing.	
2.0 CAUSE: Configuration precludes ISS Operation such as reboost/EVA	
2.1 CONTROL: The AMS-02 does not reconfigure its elements in such a manner that reduces the structural strength of the AMS-02 to handle worst-case ISS loads. (NOTE: The ability to sustain ISS/Orbiter loads safely is addressed AMS-02-F01) 2.1.1 SVM: Review of design. 2.1.2 SVM: AMS-02 Structural Analysis. 2.1.1 STATUS: Closed. ESCG MEMO ESCG4390-07-SP-MEMO-0019, "AMS-02 On-Orbit Configuration Changes", November 12, 2007 2.1.2 STATUS: Closed. ESCG-4005-05-AMS-0039, "Strength and Stability Assessment of the Alpha Magnetic Spectrometer-02 (AMS-02) Unique Support Structure (USS-02), Vacuum Case, Payload Attach System (PAS), and STS and ISS Integration Hardware," August 12, 2009	
2.2 CONTROL: The AMS-02 persistent magnetic field does not preclude translation of EVA crew, SPDM or MSBS down	

the truss past the AMS-02. EVA/EVR upon the AMS-02 itself are not impeded by the constant field of the AMS-02 magnet.

2.2.1 SVM: Review of design

2.2.2 SVM: <Deleted>

2.2.3 SVM: Magnetic Field Measurement and Analysis

2.2.1 STATUS: Closed. MAGIK Action Item 1808 demonstrating EVR capabilities and free path past AMS-02 along the MT rail with Cryomagnet (six times stronger field). Approved EMEP TIA 1133 dated May 14, 2010 addresses EVR compatibility.

2.2.2 STATUS: <Deleted>

2.2.3 STATUS: Closed. ESCG Memorandum ESCG-4295-10-ADV SY-MEMO-0013, “AMS Permanent Magnet Magnetic Field Correlation,” dated July 6, 2010

2.3 CONTROL: The AMS-02 design allows for the installation of the AMS-02 either in the Orbiter Payload Bay or upon a PAS site on the ISS Truss without specific reconfiguration of the AMS-02 hardware or avionics.

2.3.1 SVM: Review of Design.

2.3.2 SVM: Physical interface confirmation with Shuttle

2.3.3 SVM: Fit Check of hardware (ISS).

2.3.1 STATUS: Closed. ESCG Memorandums (3) indicate AMS-02 Compliance with ICD Interfaces without reconfigurations being required. ESCG-4390-06-SP-MEMO-0006, “USS-02 Trunnion Interfaces,” dated March 13, 2006, ESCG-4390-06-SP-MEMO-0001, “Mechanical Design of the Payload Attach System (PAS),” dated January 8, 2006, ESCG-4175-09-REENTES-MEMO-0019, “Review of AMS-02 ROEU Bracket Design,” dated April 24, 2009

2.3.2 STATUS: Closed to SVTL.

2.3.3 STATUS: Closed. Memo ESCG-4390-05-SP-MEMO-0012, “Functional Testing of the Payload Attach System” dated 28 December 2005, from AMS-02 Chief Engineer Chris Tutt.

3. CAUSE: AMS-02 Reconfiguration precludes safe return

3.1 CONTROL: The AMS-02 does not alter its configuration to preclude return at any time during the mission for an abort

return by the Orbiter 3.1.1 SVM: Review of Design 3.1.1 STATUS: Closed. ESCG Memorandum ESCG-4175-09-REENTES-MEMO-0022, “AMS-02 Potential Abort Landing Configurations,” dated April 28, 2009	
3.2 CONTROL: The AMS-02 Pressure systems do not require pressure stabilization of any pressurized tanks or components. 3.2.1 SVM: Review of Design. 3.2.2 SVM: Structural Verification Plan. 3.2.1 STATUS: Closed. ESCG Memorandum ESCG-4175-09-REENTES-MEMO-0022, “AMS-02 Potential Abort Landing Configurations,” dated April 28, 2009 3.2.2 STATUS: Closed. JSC 28792, Revision E, “Alpha Magnetic Spectrometer – 02 Structural Verification Plan for the Space Transportation System and the International Space Station,” dated September 2006.	
3.3 CONTROL: <Deleted>	
3.4 CONTROL: <Deleted>	
4 CAUSE: Configuration requirement for planned ISS Service Loss	
4.1 CONTROL: The AMS-02 does not require any configuration changes to support planned Loss of Services to ensure a safe configuration or condition of the AMS-02 hardware. The AMS-02 is designed to support planned and unexpected loss of ISS Services without causing a hazard to the ISS, the crew or other payloads. 4.1.1 SVM: Review of Design 4.1.1 STATUS: Closed. ESCG Memo ESCG-4390-07-SP-MEMO-0011, “Effect of Loss of Station Services on AMS-02”, dated 21 September, 2007.	
Notes:	

ACRONYMS	
AMS-02 – Alpha Magnetic Spectrometer	PAS – Payload Attach Site, Payload Attach System
DCLA – Design Coupled Loads Analysis	ROEU – Remotely Operated Electrical Umbilical
EVA – Extravehicular Activity	

PAYLOAD FLIGHT HAZARD REPORT				a. NO:	AMS-02-F20
b. PAYLOAD	Alpha Magnetic Spectrometer-02 (AMS-02)			c. PHASE:	III
d. SUBSYSTEM:	Tracker Alignment System	e. HAZARD GROUP:	Injury/Illness	f. DATE:	August 4, 2010
g. HAZARD TITLE:	Crew Exposure to Coherent Light			i. HAZARD CATEGORY:	CATASTROPHIC **X** CRITICAL
h. APPLICABLE SAFETY REQUIREMENTS:	NSTS 1700.7B and ISS Addendum, 200.1b, 212.3				
j. DESCRIPTION OF HAZARD:	Operation of the Laser for the Tracker Alignment System makes use of coherent light pulses. Should these irradiate the Crew, there is a potential for ocular damage.				
k. CAUSES *(list)*	1. Laser Power Output Exceeds Design Capability 2. Loss of Beam Path Containment and Integrity				

o. APPROVAL	PAYLOAD ORGANIZATION	SSP/ISS
PHASE I		
PHASE II		
PHASE III		

PAYLOAD FLIGHT HAZARD REPORT		a. NO: AMS-02-F20
b. PAYLOAD Alpha Magnetic Spectrometer-02 (AMS-02)		c. PHASE: III
l. HAZARD CONTROL (CONTROL), m. SAFETY VERIFICATION METHODS (SVM), n. STATUS OF VERIFICATIONS (STATUS)		OPS CONTROL
1. CAUSE: Laser Power Output Exceeds Design Capability		
1.1 CONTROL: The Tracker Alignment System (TAS) generates laser energy from ten independent laser diodes. Two diodes are contained within each of five Laser Fiber Coupler (LFCR) boxes. This energy is generated by Eagleyard EYP-RWL-1083 infrared (1083 nm) laser diodes with a maximum power output of 80 mW. Each laser diode will emit at a maximum 1 kHz interval with a maximum of 8 µs pulse duration when operating. Each laser diode's emissions are split into four output fibers, each with approximately one quarter of the total power output. The operation of the TAS consists of less than 1% of the AMS-02 operational time. The LFCR boxes are light tight and can not release any laser emissions with the exception of the fiber ports where laser emission are nominal design features. 1.1.1 SVM: Review of design. 1.1.2 SVM: Inspection of as-built hardware. 1.1.1 STATUS: Closed. ESCG Memo ESCG-4390-07-SP-MEMO-0007, "Review of TAS Design", August 14, 2007. 1.1.2 STATUS: Closed. AMS-02 Tracker Alignment System (TAS) ADP dated October 8, 2009		
2. CAUSE: Loss of Beam Path Containment and Integrity		
2.1 CONTROL: The connectors used by the TAS at the LFCR are FC-type and will not inadvertently release. The fiber optics cables are restrained. 2.1.1 SVM: Review of design. 2.1.2 SVM: Inspection of as built hardware. 2.1.1 STATUS: Closed. ESCG Memo ESCG-4390-07-SP-MEMO-0007, "Review of TAS Design", August 14, 2007. 2.1.2 STATUS: Closed. AMS-02 Tracker Alignment System (TAS) ADP dated October 8, 2009		

PAYLOAD FLIGHT HAZARD REPORT	a. NO: AMS-02-F20
b. PAYLOAD Alpha Magnetic Spectrometer-02 (AMS-02)	c. PHASE: III

2.2 CONTROL: The connectors to make fiber to fiber connections are clamped subminiature fiber connectors. The connectors are attached to Patch Panels at the rim of the tracker plate, restraining the fibers and connectors. 2.2.1 SVM: Review of Design 2.2.2 SVM: Inspection of as built hardware 2.2.1 STATUS: Closed. ESCG Memo ESCG-4390-07-SP-MEMO-0007, "Review of TAS Design", August 14, 2007. 2.2.2 STATUS: Closed. AMS-02 Tracker Alignment System (TAS) ADP dated October 8, 2009	
2.3 CONTROL: Fibers are fixed within the beamport boxes by use of standard fiber connectors to provide careful alignment with the optics of the beamport boxes. 2.3.1 SVM: Review of Design 2.3.2 SVM: Inspection of as built hardware 2.3.1 STATUS: Closed. ESCG Memo ESCG-4390-07-SP-MEMO-0007, "Review of TAS Design", August 14, 2007. 2.3.2 STATUS: Closed. AMS-02 Tracker Alignment System (TAS) ADP dated October 8, 2009. ESCG Memorandum ESCG-4295-10-ADV SY-MEMO-0020, "TAS Inspection," dated July 15, 2010.	
2.4 CONTROL: Fibers that interconnect the LFCR, patch panels and beamport boxes are Corning HI 1060RC type with cladding (0.08mm diameter) and jacket (diameter 0.165 mm). In addition the fibers are "armored" with Nylon (diameter 0.9 mm). Routed fibers are bundled in standard braided installation sleeves and fixed with tie wraps to cable fixation points. Cable routing considers the minimum bending radius of the individual fibers and bundled fibers, 20 mm and 40 mm respectively. 2.4.1 SVM: Review of Design 2.4.2 SVM: Inspection of as built hardware 2.4.1 STATUS: Closed. ESCG Memo ESCG-4390-07-SP-MEMO-0007, "Review of TAS Design", August 14, 2007. 2.4.2 STATUS: Closed. AMS-02 Tracker Alignment System (TAS) ADP dated October 8, 2009	

PAYLOAD FLIGHT HAZARD REPORT	a. NO: AMS-02-F20
b. PAYLOAD Alpha Magnetic Spectrometer-02 (AMS-02)	c. PHASE: III

2.5 CONTROL: Laser beams are emitted across the interior of the Tracker. The Tracker is designed to be light tight, and vent ports are specifically designed to preclude the entry and exit of light.

2.5.1 SVM: Review of Design

2.5.2 SVM: Inspection of As Built Hardware

2.5.1 STATUS: Closed. ESCG Memo ESCG-4390-07-SP-MEMO-0007, "Review of TAS Design", August 14, 2007.

2.5.2 STATUS: Closed. Installation of light tight air vents visually confirmed by a designated verifier (DV), T. Martin on September 25, 2007 and documented in correspondence to Safety Engineer on that same date.

2.6 CONTROL: The laser energy is carried from the LFCR boxes by fibers that interface with the LFCR by way of FC-type connectors. These fibers are routed from the M-structure mounted LFCR boxes to the rim of the outer tracker plate where there are subminiature fiber-fiber connectors. From these connectors the fibers are routed to the beam port boxes (positioned within the tracker at the "top" and "bottom" of the tracker. The connectors are securely held in place and should there be a release of a fiber, either through connector failure or fiber breakage, the NOHD for the laser energy has been established to be just under 2 inches. The fibers are routed under the MLI of the AMS-02 and are not exposed to the exterior environment.

2.6.1 SVM: Review of design.

2.6.2 SVM: Inspection of as-built hardware.

2.6.3 SVM: Laser Safety Analysis

2.6.1 STATUS: Closed. ESCG Memo ESCG-4390-07-SP-MEMO-0007, "Review of TAS Design", August 14, 2007.

2.6.2 STATUS: Closed. AMS-02 Tracker Alignment System (TAS) ADP dated October 8, 2009. ESCG Memorandum ESCG-4295-10-ADV SY-MEMO-0020, "TAS Inspection," dated July 15, 2010.

2.6.3 STATUS: Closed. Laser Safety Analysis Documented in ESCG Memo ESCG-4390-07-SP-MEMO-0002, "Safety Analysis of the TAS Laser", dated 23 June, 2007.

2.7 CONTROL: The modification of the AMS-02 to utilize the permanent magnet removed the need for half of the laser paths to the LBBXs, specifically those on the lower tracker plane. Half of the collective output of the LFCRs will be

PAYLOAD FLIGHT HAZARD REPORT	a. NO: AMS-02-F20
b. PAYLOAD Alpha Magnetic Spectrometer-02 (AMS-02)	c. PHASE: III

plugged with special blocking plugs on the LFCR output connector so that the laser energy never leaves the enclosed LFCR boxes. These plugs will connect as the standard fiber optic connections are made with a FC-type interface.

2.7.1 SVM: Review of blocking plug design

2.7.2 SVM: Inspection of plug installation

2.7.1 STATUS: Closed. Design modification reviewed by ESCG/L. Hill via email exchange, "Tracker Alignment System Changes," 4/23-6/10/2010 and confirmed in ESCG Memorandum ESCG-4295-10-ADV SY-MEMO-0020, "TAS Inspection," dated July 15, 2010.

2.7.2 STATUS: Closed. ESCG Memorandum ESCG-4295-10-ADV SY-MEMO-0020, "TAS Inspection," dated July 15, 2010.

NOTES:

ACRONYMS	
AMS-02 – Alpha Magnetic Spectrometer	MLI – Multilayer Insulation
ANSI – American National Standards Institute	mm – millimeter
CFC – Carbon Fiber Composite	mW – milliWatt
CW – Continuous Wave	nm – nanometer
Hz – Hertz	NOHD – Nominal Ocular Hazard Distance
LASER – Light Amplification by Stimulated Emission of Radiation	OD – Outer Diameter

ACRONYMS	
LBBX – Laser Beamport Boxes	Si – Silicon
LDDR – Laser Diode DriveR	TAS – Tracker Alignment System
LFCR – Laser Fiber (Fibre) Coupler	TRD – Transition Radiation Detector
LFIB – Laser Fibers (Fibres)	

System Feature	Control Type	Verification method
Laser light sources generated within five light tight boxes exterior to the Tracker, mounted to the M-Frame. Each box contains two lasers diodes that operate at: • 1043 nm • 1 kiloHertz pulse frequency • 8 microsecond maximum pulse duration. • 80mW continuous operation power (not an operations mode supported on AMS-02)	DESIGN	Review of Design Inspection of As Built Hardware
Software control of the laser diodes allows only two diodes to be firing simultaneously	Not Directly Relevant to Safety Controls	Safety Controls provide for control of continuosly powered lasers without threat, an operational mode that can not occur in the AMS-02 TAS Design
Within each laser source box, the emissions from the two laser diodes are split into four beams, each with approximately 20mW of power if the lasers were to be continuously powered. Each of these split beams is guided by a single fiber matched and bundled and taken to a FC-type connector. *Internal optics misalignment or fault results in no laser emission through fiber and contained beam.*	CONTAINMENT	Review of Design Inspection of As Built Hardware
Outside of the box fiber optics cables connected with a FC-type Connectors contain and direct the laser energy, with a single fiber per split beam. All fibers are routed the laser energy from each box to the interior of the Tracker. The fibers are split between the top and bottom of the Tracker and terminate at five beam ports. Each beam port takes the energy from four fibers and directs it along the central axis of the Tracker to illuminate the silicon sensors.	CONTAINMENT	Review of Design Inspection of As Built Hardware
Tracker volume is design to be light tight, including shielded vents that preclude exterior light from entering, or interior laser sources from exiting. Tracker Structure acts as beam stop if misalignment occurs.	CONTAINMENT	Review of Design
Rupture/breakage of fiber path. System is design to minimize the potential for breakage (clad, jacketed and armored fibers that are bundled within a sleeve). Routed under the MLI of the AMS-02. Should a broken fiber be exposed and allowed to emit, the NOHD has been established to be just under 2 inches.	DESIGN	Review of Design Inspection of As Built Hardware Laser Safety Analysis

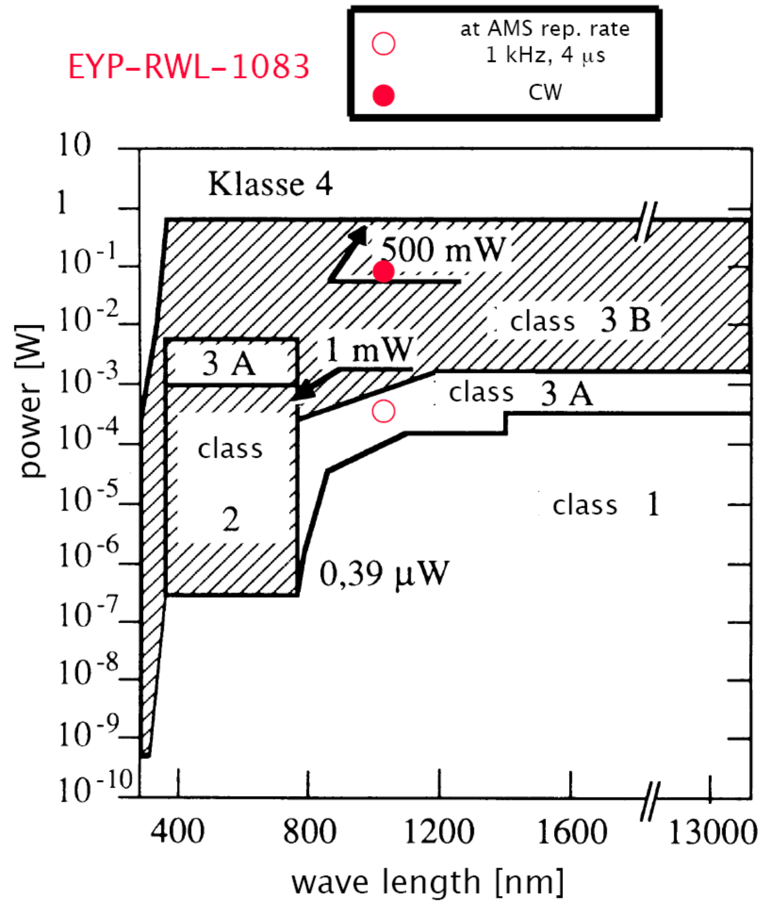
Ridge Waveguide Laser

GaAs Semiconductor Laser Diode

Characteristics at T_{amb} 25°C

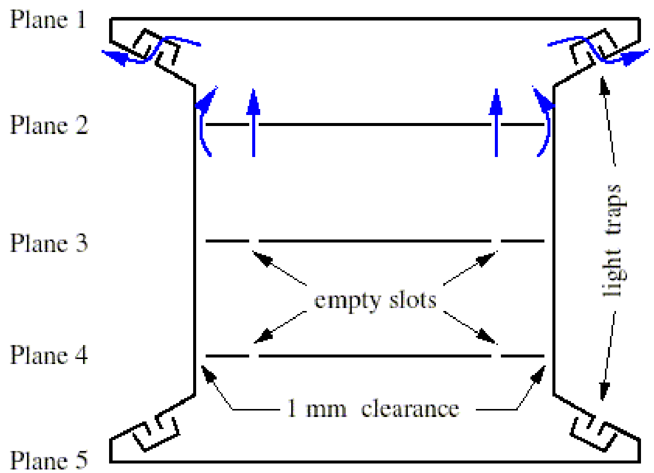
Parameter	Symbol	Unit	min	typ	max	Measurement Condition
Center Wavelength	λ_C	nm	1070	1080	1090	
Spectral Width (FWHM)	$\Delta\lambda$	nm			1	
Temp. Coeff. of Wavelength	TC_λ	nm / K		0,4		
Output Power	P_{opt}	mW		80		
Slope Efficiency	η_d	W / A	0,5	0,7		
Threshold Current	I_{th}	mA		20	30	
Operational Current @ 80 mW	I_{Op}	mA		100	130	
Cavity Length	l_C	µm		750		
Divergence parallel (FWHM)	$\Theta_{\|\|}$	°		10		
Divergence perpendicular (FWHM)	$\Theta_\perp$	°		40		
Polarization				TE		
Mode Structure				Fundamental Mode		

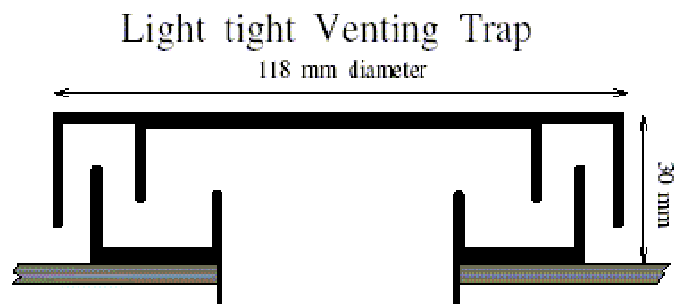
Laser Diode Specifications



Laser Diode Output Classification (CW and AMS-02 Operational)

GRAPHIC OF VENTING PATHS AND LIGHT TRAP OF AMS-02 Tracker Volume





Tracker Volume vents designed to preclude light passage

(Laser path down center of Silicon Sensor Planes, Filter mesh not shown in Tracker Vent Trap)

AMS-02 tracker alignment control system (TAS)

document for
phase II AMS Safety report
MS-word TAS_sysSaf_v2.1 181kB

v2.1 30-Jul-2005

in response to information request #51
of the Phase II action item list
(AMS-02_TIM_Safety_Act#B4F7E.xls)

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0 Document overview

1 Introduction

With the AMS-02 Si-Detector charged particle tracks are traced at 8 space points in a 1m^3 size B-field to an accuracy of better than 10µm in the most important axis perpendicular to the main component of the field.

The AMS tracker has to cope with a wide range of environmental conditions. Of major concern are the vibrations during the transport before deployment and the rapid periodic changes of the detector temperature due to solar radiation and cooling while in the shadow of Earth.

The Tracker Alignment Control System (TAS) provides optically generated signals in the 8 layers of the Si - Tracker, that mimic straight (infinite rigidity) tracks. It has been shown with AMS-01 [1, 2, 3], that these artificial straight tracks allow to follow up changes of the tracker geometry with a position (angular) accuracy of better than 5 µm (2 µrad).

The AMS approach to Si-tracker alignment control using IR laser beams fulfills the requirements of a space born experiment:

1 Light weight (3 kg)
2 Low power (<100mW peak, ca. 1mW averaged)
3 Proven as being safe in use both on ground and in space
4 Fast, autonomous and low overhead operation (< 1% of tracker running time)
5 Precision exceeding the tracker resolution (8µm) with a small number (<100) of laser shots

The particle tracker and the TAS use the same Si-sensors both for particle detection and alignment beam recording. The TAS can generate position control data within seconds at regular time intervals (4 – 6 / orbit), for example while the ISS flies into the shadow of Earth or coming back into the sunlight.

The realization of the TAS is based on:

1 The experience gained with AMS-01
2 A series of rigorous space qualification (thermal, vacuum, vibration) tests (most at the 1. Physikalisches Institut 1b, RWTH Aachen, Aachen, Germany)
3 The use of space flight compliant components
4 The application of documented space flight compliant working procedures at our manufacturer

2 TAS system components

After an overview of the system geometry (2.0) the description of the TAS starts with the beams (2.1) as they are used for alignment control. This is followed by the optical components (LBBX; 2.2) that deliver the beams into the tracker volume. Then the fibres (LFIB; 2.3) delivering the optical signal to the LBBX are described. We continue with the generation of the optical signal and its coupling into the fibres (LFCR, 2.4). We finish with an overview of the driving electronics (LDDR, 2.5).

2.0 *TAS geometry*

The AMS02 - tracker is equipped with 2 x 10 pairs of alignment control beams (altogether 40, see fig. 1). 2 pairs of alignment beams originate in each of the 5 beam port boxes (LBBX) on both of the outer tracker plates (#1 and #5). Both upward and downward going beams use the same roads defined by the anti-reflective areas on the Si and the cutouts in the ladder cladding (see fig.2).
TAS has 10 laser diodes mounted in pairs inside the Laser fibre couplers (LFCR). The optical output of one laser diode is split equally on four output fibres. The parameters of the driving signals are individually controlled for each diode. While operating in space no more than 2 diodes are operated concurrently.

2.1 *Laser beam parameters*

The wave length (lambda = 1082nm) of these beams has been chosen such as to penetrate all 8 Si detector layers of the tracker at once. At this wavelength only a small fraction (approx. 10% / 300 µm Si) of the generated photons are absorbed. The effective transparency of the Si (approx. 50%) is however dominated by the amount of the surface fraction not covered with Al (traces) for contacting the readout electrodes.

The beams are circular (radius <.7 mm) and have small divergence (ε < 1 mrad). The requirement on parallelism (ϕ < 5 mrad) is set by the diameter of the openings for the roads (7 mm) in the Si ladder shields and the ladder mounting precision.
As we have LBBX on both ends of the roads these are terminated and no IR radiation can directly escape from the tracker volume (for electrical reasons the tracker volume is designed for light tightness such that no scattered IR beams can exit the volume). From layer to layer The signal I_0 is attenuated by a factor of 2 due to the optical properties of the Si, i.e. after 8 layers the remaining intensity will be $4\ 10^{-3}\ I_0$.
Connected to the driver circuit (LDDR) the lasers can only be pulsed. With the best possible control of all coupling losses the maximum pulse energy per beam (at the LBBX output port) will be 30 nJ. Judging by the experience from recent laboratory tests we expect to run at 8 nJ or less. The Si response is strongly temperature dependent. In consequence we will adjust the diode pulse current at low ambient temperature such that the signal remains sufficient for analysis. Repetition rates are limited by the capacity of the tracker readout system to 1 kHz.

2.2 *Laser beam port boxes* (LBBX's)

The beams enter the tracker volume through the bottom of the beam port boxes LBBX's (see fig. 3) mounted on the outer face of the two outer tracker support plates (see fig. 4). Four (2x2) optical fibres connect to each LBBX. The divergent fibre outputs are collimated by projection optics (parallel to the tracker endplate surface) at each of the 4 input ports. The beams are redirected perpendicularly into the tracker volume by the mirrored surfaces of the 2 quadrilateral prisms at the center of the LBBX (see fig. 3). It is mandatory that the beams remain inside a cylindrical tube of 6 mm diameter and 1 m length centered on each of the output ports.
LBBX bodies are made from standard Aluminum (AlSi1MgMn - AW 6082). Lens- and mirror - holders are fabricated from "German Silver" Cu Ni12 Zn24 (Ns 6512). The manufacturer will provide documentation about the materials used for the lenses and the mirrors (typical transverse dimensions 3mm, typical mass 100mg).
LBBX are fixed into a recess (see fig. 3/4) with 3 M2.5 screws to the upper / lower flange of the tracker (for details see tracker drawings). The weight of a LBBX (without fibres connected) is <40g.

2.3 *Laser fibres* (LFIB's)

The fibres do run from the LBBX's (see fig. 3) to the rim of the tracker plate at (x=0, y= -700), where they are held in small patchpanels (LFIB-P4) holding subminiaturized fibre connectors (see fig. 5 < 5g /connection). At the upper tracker plate (#1) connecting fibres run directly from this transition point to the Laser Fibre Couplers (LFCR). These will have to be installed after tracker insertion into the magnet bore (and TCCS preparations) and before the mounting of the upper ToF-TRD assembly. At the lower tracker plate (#5) the connecting fibres have to be in place before tracker and ACC insertion.
Fibres are of the Corning HI 1060RC type with cladding (diameter 0.08 mm) and jacket (diameter 0.165 mm). They are "armed" with Nylon (diameter 0.9 mm). Beside the subminiature connection at the tracker flange rim we use standard fibre connectors (FC). Vendor specific details will be provided by our manufacturer. For routing fibres (4 – 8) will be bundled in standard braided installation sleeves and fixed with tie wraps to cable fixation points (see fig. 6). The bending radius for individual fibres / fibrebundles must exceed 20 mm / 40 mm. At their LFCR end the LFIB's pass through the MLI enclosure of the TRD.

2.4 *Laser fibre couplers* (LFCR's)

There are 5 Laser fibre couplers (fig. 7) mounted as a block against the lower x=0,-y node of the TRD M-structure (see fig. 6). Each coupler houses 2 diode coupling units and 2 4-fold splitters. The total weight of the 5 couplers is < 1500g. The fixation scheme (4 bolts M3 / LFCR) has been checked by Aachen engineering (report available).
LFCR bodies are made from standard Aluminum (AlSi1MgMn - AW 6082). Lens- and mirror - holders are fabricated from "German Silver" Cu Ni12 Zn24 (Ns 6512). The manufacturer will provide documentation about the materials used for the lenses (typical transverse dimensions 6mm, typical mass 750mg).
All glass parts are enclosed (coupling optics). The fibres including the splitters are cladded and jacketed as all our fibres.

The are several venting pathways (gaps in covers, optical connectors, etc.). During the vacuum test (Aachen, spring 2005) venting speeds will be tested (Vol. < 200 cm^3).

2.4.1 Laser diodes

We use Eagleyard EYP-RWL-1083 Laser diodes with 80mW max. output power. The diodes are mounted in a standard windowed TO-9 package. The driving current is limited to 100mA at typically 2 Volt. This Laser belongs to category 3b (a detailed account of safety aspects is given in section 3).

2.4.2 Diode fibre coupling optics

The coupling optics (fig. 9) adapts the (rotationally asymmetric) diode emission pattern to the acceptance of the signal transporting fibre (core diameter 6.0 µm). In addition to a perfect optics design a reliably adjustable diode position is essential for achieving high (>60%) coupling efficiency. Furthermore optical back-termination is required for preventing diode damage through back-reflection in the fibres. The AMS-02 design by Schäfter & Kirchhoff is derived from the design successfully used with AMS-01 (see appendix 5.2). Besides of intensive tests in Aachen the current design has been used with other (ESA) ISS experiments.

2.4.3 Fibre splitters

The fibre splitters provide a highly stable equipartitioning of the optical output power of a single Laser diode into 4 outputs. The splitters are delicate in handling. Therefore they have been incorporated into the LFCR. Both input and output lines of the splitters are coiled up (see cylindrical part in the center of fig. 7) and fixed to the body of the LFCR

2.4.4 Optical output connectors

The splitters end in FC type optical feedthroughs (fig. 8/9). There will be fibres (LFIB) connected to each of the 8 output connectors.
The maximum output energy per connector per pulse will be 55 nJ (in order to be able to deliver 32 nJ in spite of the unavoidable coupling losses between the LFCR output and the LBBX output).

2.4.5 Electrical input connectors

The switched diode driving current comes come from the laser diode driver (LDDR, fig.10) housed in the M-crate. The connector will use the standard d-sub 9 format

2.5 *Laser Diode Drivers* (LDDR's)

The Laser diodes are driven from a pulsed current source specifically designed to suppress spikes in the driving current. The pulse width can be set in steps of 0.5 µs from 0.5 µs to 8.0 µs. Rise/fall time are typically 60 ns. The output current (<200 mA) can be set with 8 bit resolution. All Control is through the USCM's via the M-crate backplane. The development of the LDDR [4] is approaching the construction of a set qualification modules (see fig.10). The M-crate houses 5 LDDR's (2 current sources each) serving the 5 LFCR's. The output cables run from the front panels of the LDDR's to the LFCR's mounted on the M-structure carrying the TRD. These cables have to pass the MLI of the TRD.

A.20-13

3 *The IR radiation levels*

3.1. TAS laser power basics

1. The LFCR diode *EYP-RWL-1083* operated at the maximum(tracker DAQ) LDDR setting delivers an average power of

$$P_{avg} = P_{CW} \bullet \text{duty factor}$$

$$= 80 \bullet 10^{-3}\,W \bullet 8 \bullet 10^{-3}\ (4 \bullet 10^{-3}) = 400\ (200)\ \mu W$$

duty factor_{max} = rep rate • pulse length = $1000\ s^{-1} \bullet 8\ 10^{-6}\ s = 8 \bullet 10^{-3}$
(duty factor_{DAQ} = rep rate • pulse length = $1000\ s^{-1} \bullet 4\ 10^{-6}\ s = 4 \bullet 10^{-3}$)

max. pulse energy at diode window:

$$w_{pulse} = P_{avg} / \text{rep rate} = 400\ nJ$$

max. pulse energy at a single LBBX output (1 laser diode feeds 4 beams on different LBBX):

$$w_{beam} = w_{pulse} \bullet \eta_{coupler} \bullet \eta_{splitter} / 4 \bullet \eta_{FC} \bullet \eta_{FC} \bullet \eta_{LBBX}$$
$$= 400\ nJ \bullet 0.6 \bullet 0.9/4 \bullet 0.85 \bullet 0.85 \bullet 0.8 = 31.2\ nJ$$

with η_i being the transfer efficiency at the various transitions in the light transport system (FC connector, LBBX beamport, etc.., these values can be achieved with careful adjustments, but they are somewhat smaller than the theoretical limits)

In ANSI Z136.1-2000 the power limits for a class 3b laser (see tables A1, A2 from that document) are defined as follows (see tables 1, 2):

a) P_{CW} ($1.05\mu m < \lambda < 1.40\mu m$) $\leq$ $125 \bullet 10^{-3}$ W
b) P_{avg} ($1.05\mu m < \lambda < 1.15\mu m$) $\leq$ $500 \bullet 10^{-3}$ W
c) w_{pulse} ($1.05\mu m < \lambda < 1.4\mu m$) $\leq$ $125 \bullet 10^{-3}$ J

Hence the design safety factor of TAS at the beamport (LBBX) output is :

d) $w_{pulse}^{\ limit} / w_{beam}$ = $125 \bullet 10^{-3}/31.2 \bullet 10^{-9} = 4 \bullet 10^{6}$

2. general position measurement related laser power aspects:

The pulse length for alignment runs in space will be adapted to the tracker readout integration time (3 – 4µs) hence shorter than the maximum possible (8 µs) from the LDDR. For example the generation of a 22 mip equivalent signal in the AMS Si plane 1(8) (farthest from the LBBX on plate 5 (1)) requires an energy of approximately 15 nJ out of the beamport. Since the laser beam is ca. 1.4 mm in diameter the maximum signal strip then receives approximately 2.5(5) mips on the y (x) side.
Far above the read out noise the position measurement precision is proportional to the square root of the product of the pulse energy w_{pulse} and the number of pulses $\mathbf{n_p}$. In consequence the alignment pulse energy can be traded with the number of pulses $\mathbf{n_p}$ observed.

3.2. **M**aximum **P**ermissible **E**xposure data

(adapted from ANSI Z136.1,
see example 11 in appendix B3 of the 2000 edition as well as
examples 4, 19 in the appendix of the 1993 edition)

1. (see ANSI Z.136.1-2000, tables 5a, 6; figs 4, 8a,
for **1083nm** pulses of ≤ **4µs** duration with **1 kHz** rep. rate ,
the **AMS02** case)

(repetitive pulse limit Eq. B10)
MPE / Pulse $= n^{-1/4} \bullet 5 \bullet C_C \bullet 10^{-6}\ J / cm^2$
$= \mathbf{0.5\ \mu J / cm^2}$

(1). n $= f \bullet T = 1000\ s^{-1} \bullet 10\ s = 10^4$
(2). C_C = 1 (see table 6)

2. **MPE(cumulative)** = n • MPE/pulse
$= \mathbf{5\ mJ / cm^2}$

3. average radiance = MPE(cumulative)/T
$= 0.5\ mW / cm^2$

4. estimated **N**ominal **H**azard **Z**ones
(**N**ominal **O**cular **H**azard **D**istance, minimum distance for safe working)

(1). direct viewing

(a). at a LBBX output
(see fig. 1,
ε_{LBBX} = 1mrad divergence, a_{LBBX} = 1.4 mm diameter)
$r_{NOHD} = [(1.27 \bullet w_{beam} / (\mathbf{MPE / Pulse}) - a_{LBBX}^2)^{1/2}] / \varepsilon_{LBBX}$
$= [(1.27 \bullet 0.031\ \mu J / (\mathbf{0.5}\mu J/cm^2) - 0.14^2)^{1/2}] / 10^{-3}$
$= 2.43\ m$

(b). from an open LFCR output (or broken LFIB)
(see fibre specs,
ε_{LFIB} = 0.15 rad divergence, a_{LFIB} = 0.006 mm diameter)
$r_{NOHD} = [(1.27 \bullet w_{pulse} / (\mathbf{MPE / Pulse}) - a_{LFIB}^2)^{1/2}] / \varepsilon_{LFIB}$
$= [(1.27 \bullet 0.4\ \mu J \bullet 0.6 \bullet 0.9/4 / (\mathbf{0.5}\mu J/cm^2) - 0.0006^2)^{1/2}] / 0.15$
$= 2.5\ cm$

(c). at the diode window
(see fig 1 and diode specs,
ε_{diode} = 0.5 rad divergence, a_{diode} = 0.020 mm diameter)
$r_{NOHD} = [(1.27 \bullet w_{pulse} / (\mathbf{MPE / Pulse}) - a_{diode}^2)^{1/2}] / \varepsilon_{diode}$
$= [(1.27 \bullet 0.4\ \mu J / (\mathbf{0.5}\mu J/cm^2) - 0.002^2)^{1/2}] / 0.5$
$= 2.0\ cm$

3.3. Summary Maximum Permissible Exposure data

The data shown in the preceding subsections do clearly demonstrate that AMS TAS power levels are far below the limiting levels imposed by ANSI Z.136.1 (see 3.1.1.d).
The TAS IR radiation is completely contained under all conceivable circumstances. The system is designed such that it is gracefully degrading even in cases were sub-components are destroyed (broken fibres etc.) during handling in the shuttle or on ISS.
Furthermore TAS is generally active for only 1% of the AMS data-taking.
The highest power densities occur in the tracker volume itself (see 3.2.4.1.a), which is a closed light tight inaccessible sub-volume of the AMS-02 experiment. At these small direct viewing power levels we have not evaluated the indirect (i.e. reflected) intensities.
Each of the LBBX that deliver the IR beams is controlled separately and its output is monitored by the signals from the Si-detectors, so the proper function of this component is permanently checked.
Due to the optical properties of our fibres there is no risk in case of a fibre rupture beyond the limits of a tiny keep out zone (see 3.2.4.1.b) with radius $r_{NOHD} \approx$ 1inch.

References

1 J. Vandenhirtz et al. Space flight experience with the AMS infrared tracker alignment system, Proceedings of the 27th International Cosmic Ray Conference, (ICRC2001), Hamburg , Germany, 2001, Vol.5, session OG, pp 2197-2200 (paper icc 1574) (http://www.copernicus.org/icrc/papers/icc1574_p.pdf)

2 W. Wallraff et al. The AMS Infrared Tracker Alignment Sytem – From STS91 to ISS, 7th International Conferenceon Advanced Technology and Particle Physics, (ICATPP-7), Villa Olmo Como Italy 2001, M. Barone et al. (Eds.), World Scientific, Singapore 2002, ISBN 981-238-180-5. pp. 149-153 (http://nss2000.mi.infn.it/Manuscript/5_tracking/Wallraff.pdf)

3 J. Vandenhirtz, Ein Infrarot Laser Positions-Kontroll-System für das AMS Experiment, 2001 PhD thesis, RWTH-Aachen (http://sylvester.bth.rwth-aachen.de/dissertationen/2002/137/02_137.pdf)

4 A. Gross, AMSII Laser Driver, LDDR v: 4.0, Sep.2004 RWTH-Aachen 1. Physikalisches Institut 1b, electronics development (gross@physik.rwth-aachen.de)

4 *Figures*

Figure Captions

Fig. 1 AMS-02 Tracker Alignment System, basic components, see text for details.
a) LFCR laser fibre couplers (5, mounted on the TDR M-frame).
Each coupler holds 2 diodes for 8 fibres. Diodes are driven by pulsed current sources on the LDDR boards located in the M-crate
b) LFIB fibers carry the optical signals (40) to the beamport boxes LBBX (5 on the upper(# 1), 5 on the lower tracker plate (# 5).
The 20 laser beams from above use the same roads as those from below.
For simplicity only part of the Si sensors are shown.
c) Surface micrograph of an AMS AR (antireflective) Si sensors at the Laser impact point.
The improved transparency due to the coating makes the implantations inside the Si visible..

Fig. 2 Laser beam roads superimposed on the the tracker Si-ladders of the two lowermost tracker plates

Fig. 3 Beam port box LBBX basic design (Al), shown are:
a) Cut through the beamport channels in the outer tracker plate (lower left). Fibres arrive parallel to the plate surface and end with a ferule clamped into a german silver sleeve that holds the projection optics. The IR beams are redirected into the tracker volume by quadrilateral prisms mounted into the side walls of the LBBX (the rotation angle of the prism can be adjusted).
b) Center left: LBBX seen from below (side towards the tracker plate). The beam holes are 10.5(6.75) mm apart in x(y). At most 1 of the 2 beams in each channel is fired in one run.
c) Upper left : cut through the LBX at the level of the incoming fibres.
d) Cut through 2 of the 3 fixation channels (lower right). The cut out in the carbon fibre sheets of the tracker plate is sealed with a CFC pocket piece ("baignoire", see fig. 4)
e) Center right: view of the LBBX from above. The inner dimensions of the "baignoire" are indicated. LBBX carry alignment marks for survey.

Fig. 4 beam port box LBBX prototype onto tracker plate simulator with "baignoire" glued into the surface cutout.

Fig. 5 View of the Vacuum Container (VC) together with the M structure of the TRD. Also indicated are the upper frames of the electronics crates (not up to date, for orientation purposes only).
The 5 LDDR's (Laser diode drivers) are located in the M-crate. The electrical output lines (10) run to the 5 LFCR's grouped together at the lower x=0, -y node of the TRD. From there 40 LFIB's (optical fibres) are strung to the outer plates of the tracker at x=0, -y location. The 20 fibres serving the lower tracker are run in between the ACC and the VC.

Fig.6 Subminiature fibre fibre connection (to be mounted at the rim of the outer tracker plate)

Fig.7 Laser fibre coupler (LFCR) box with 2 electro optical systems: view from above (b, lower part), view from the side (a, upper part), for more details and further views see fig 8. Fibres and splitters are shown in red. Optical outputs via FC connectors are seen on the right, electrical control signals are delivered from the left. For details see text.

Fig. 8 LFCR, detailed views, for example: fixation holes to rails on the M-structure, lower panel center.

Fig. 9 Diode fibre coupler over all dimensions and interface surfaces, on the right: Laser diode in TO-9 housing, on the left: angled fibre output (for minimizing back reflections), lens fixations and adjustment elements not shown. IR rays in red.

5 *Appendices* (file KSC&LASSAF_AMS1a.pdf)

In order to help engineers unfamiliar with AMS Laser use in understanding the background of IR Laser use at AMS-02 we have joined 2 of the essential documents exchanged between the collaboration and NASA in 1997/8

5.1 NASA Laser use authorization for AMS-01 (pages KSC1 – KSC3) , issued Feb. 18 1998 at KSC 15 weeks before STS-91 lift-off.

5.2 AMS-01 Laser system description,

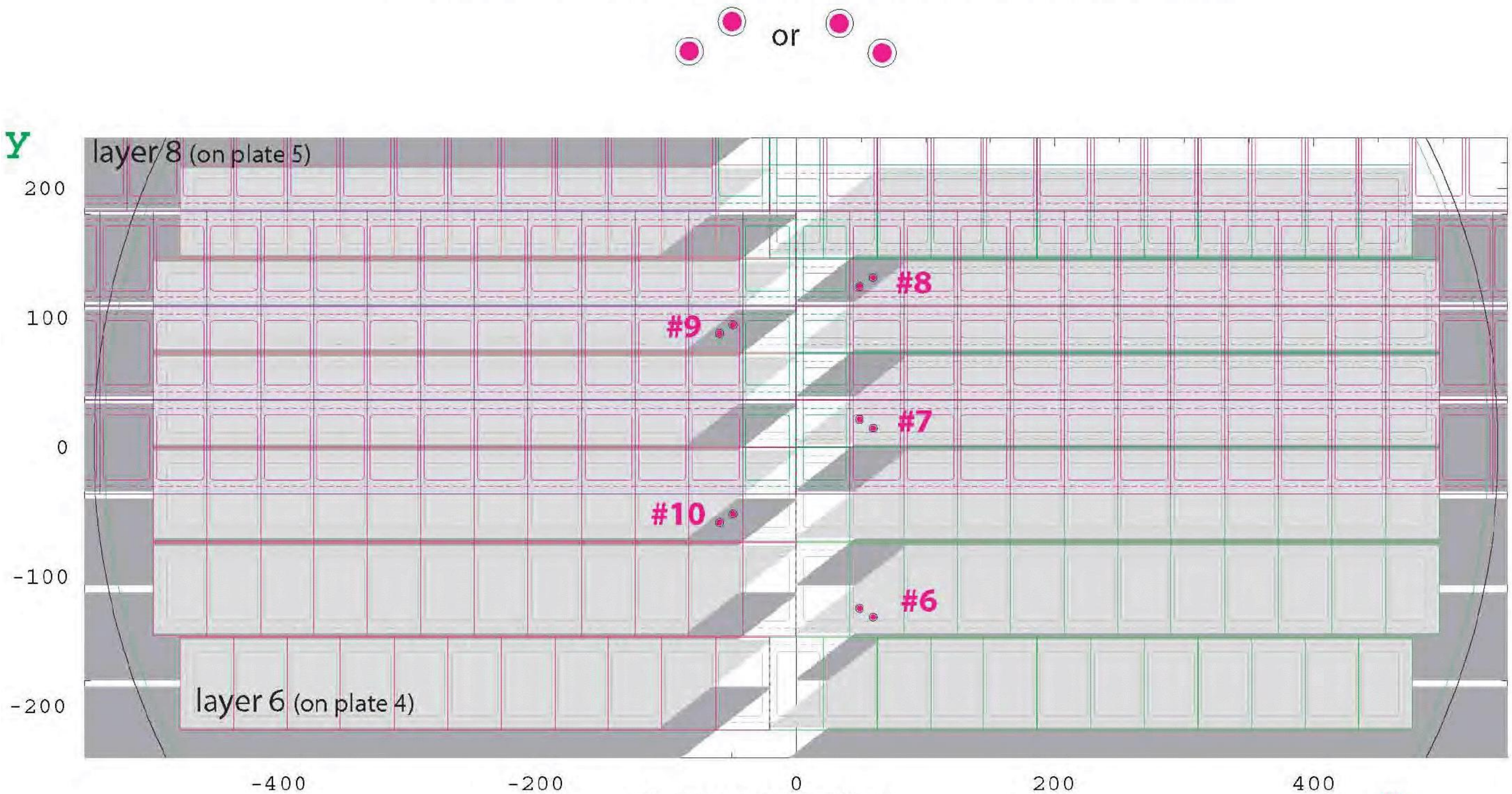
outline of laser based procedures,
ground support equipment for work at KSC,
authorization requests for potential Laser operators,

dated Sep. 4 1997, submitted 17 weeks after feasibility had been proven and 6 weeks before AMS-01 TAS was installed at ETH Zürich (pages AMS01_1 – AMS01_28)

Figures not republished with new assessment to ANSI Z 136.1 (2000) Previously published figures referenced.

Those figures are provided in the following pages

Si Geometry AMS-02 with
alignment rays fired from **beamports LBBX #n**



Si upward facing
ladders **layer 8** (stiffeners for y>0, K7 Kapton for center 7 rows)
seen through **layer 6** (K5 Kapton for center 6 rows)

from SnsrsTiling_20.2.nb by ww @ MacOS 1 macwall1 3/7/01 09:41

W. Wallraff AMS RWTH-AAchen

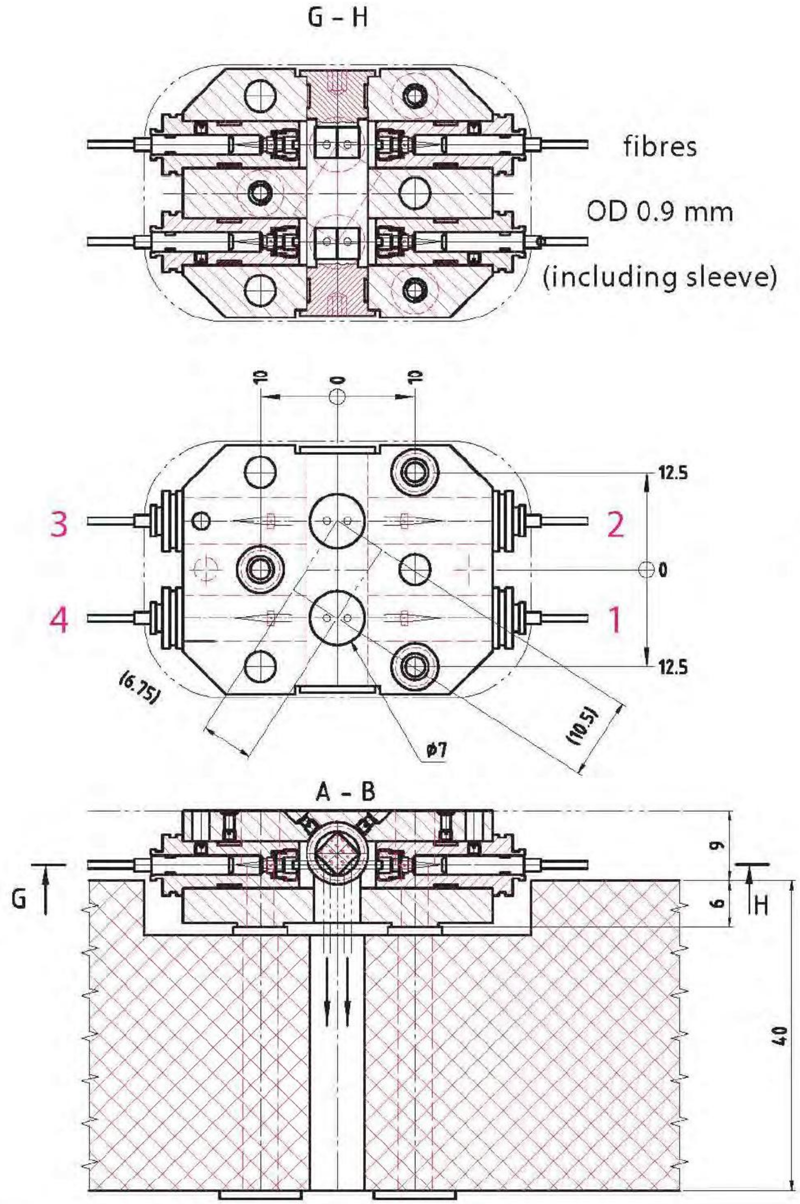
2004-12-05

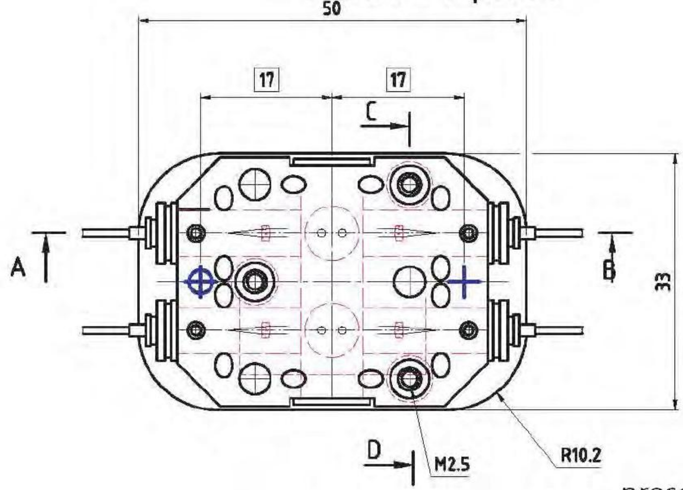
AMS TAS beamport boxes

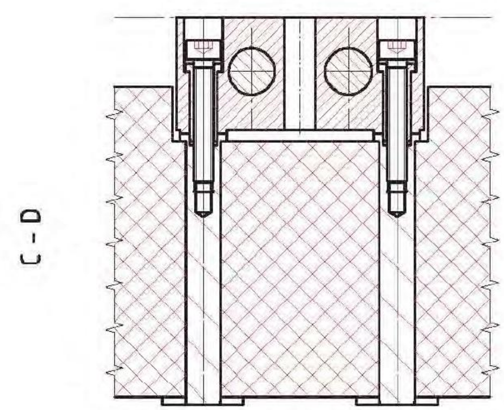
4 fibres each

mounted on outer tracker plates (1, 5)

5 boxes / plate







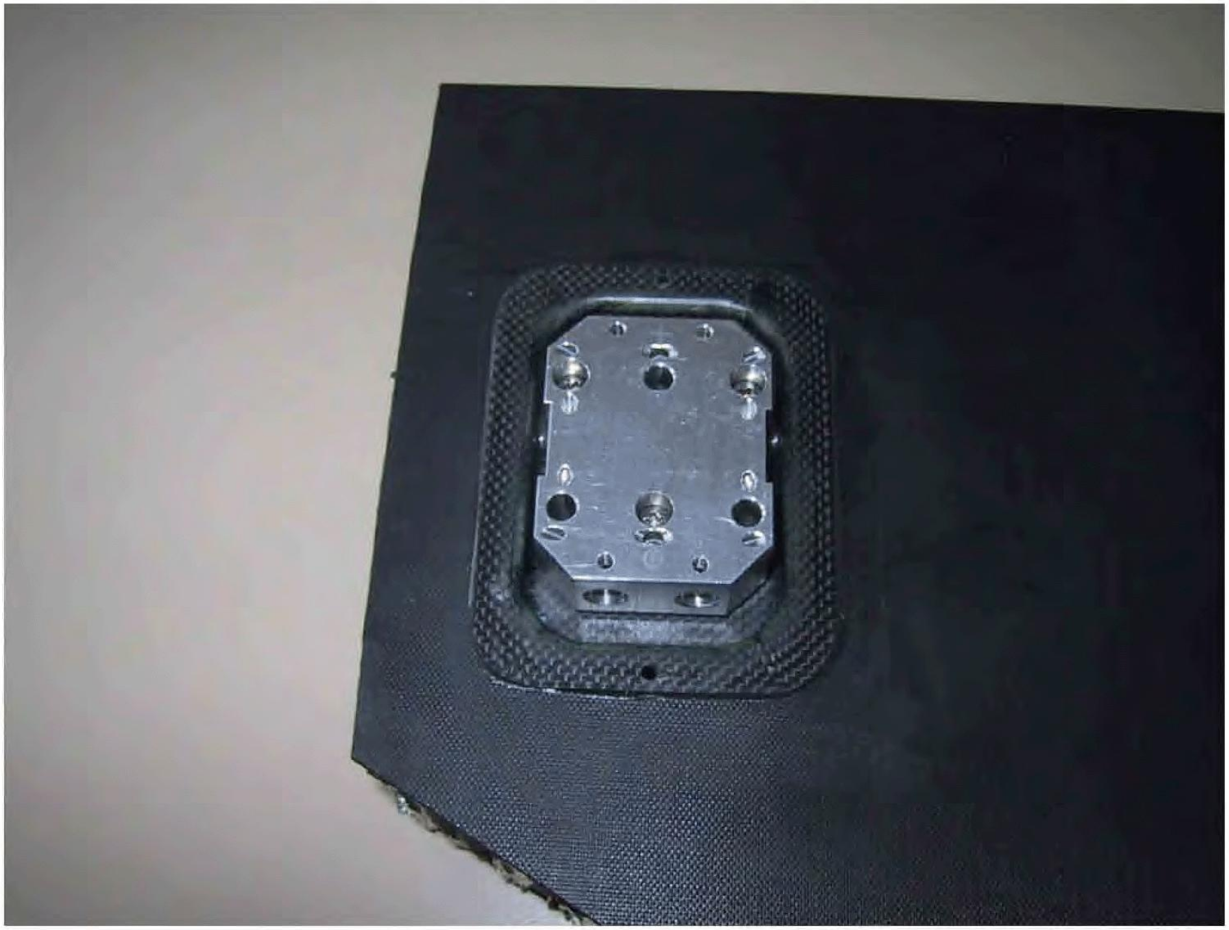
preseries (QMII)
of flight boxes
will be delivered
before Jan 31, 2005

trial mounting and
optics test on plate 1
at GVA planned

W. Wallraff AMS RWTH-AAchen

2004-12-05

Beamport box (without optics) mounted in a CFC pocket in plate 1 (specimen)

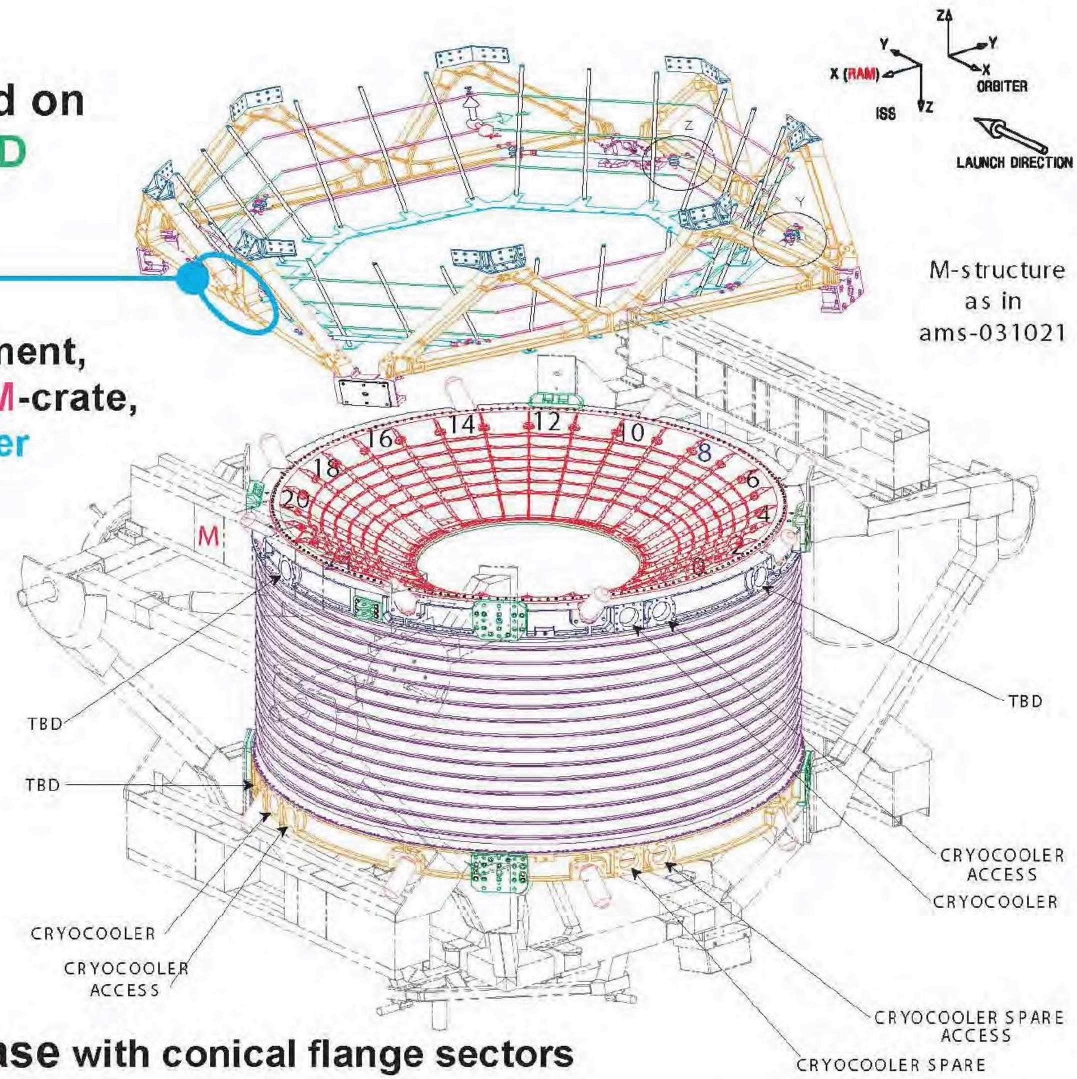


W. Wallraff AMS RWTH-AAchen

2004-12-05

TAS LFCR's will be mounted on the lower -y beam of the TRD M-structure (inside MLI):

well stabilized thermal environment, reasonably close to LDDR's in M-crate, not too difficult access to tracker plate 1(5)



Vacuum Case with conical flange sectors

used for ACC PMT's

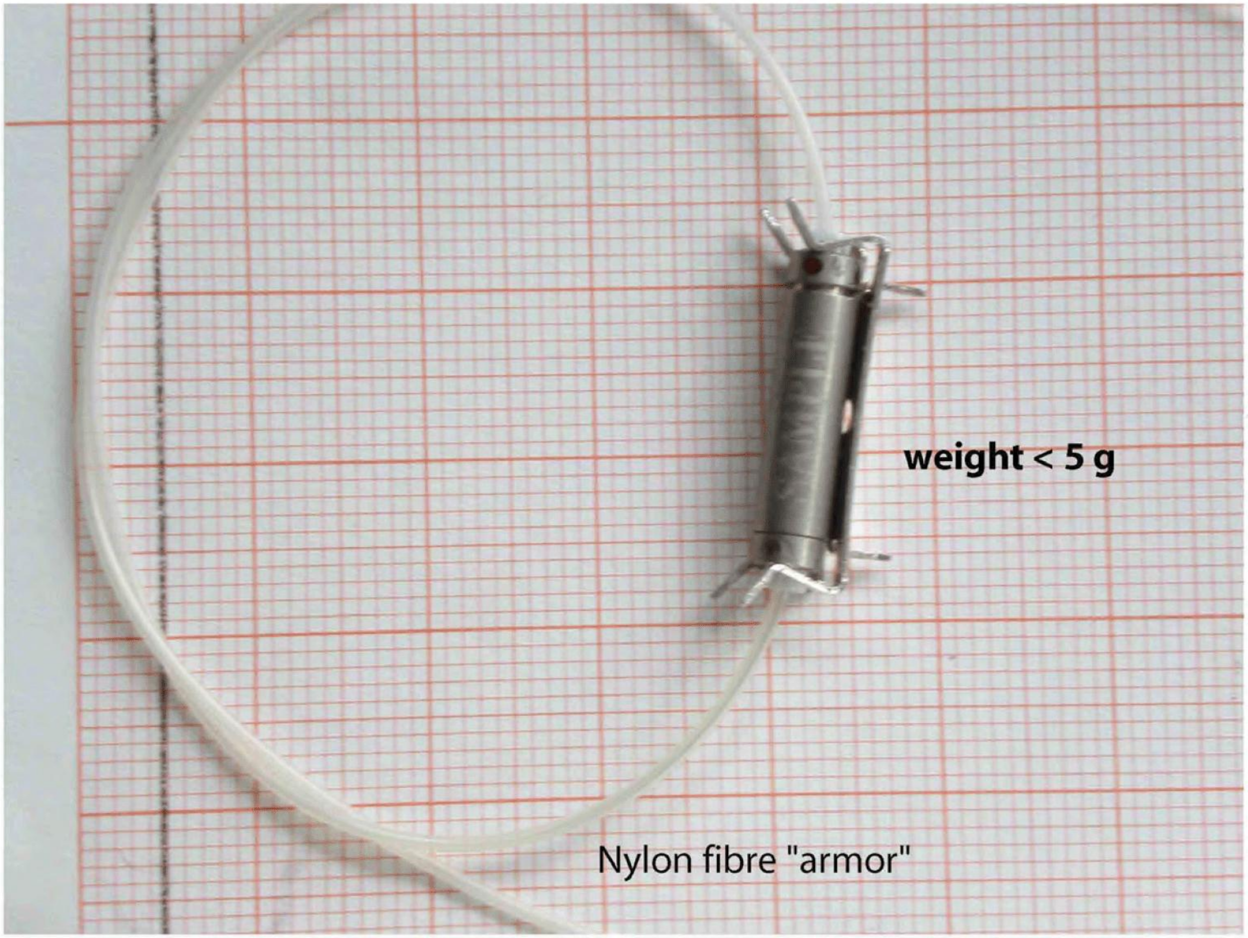
VC Port locations -Back ISO View

W. Wallraff AMS RWTH-AAchen

2004-12-05

AMS TAS LFIB's

subminiature fibre to **fibre connector**
with **0.5 μm positioning accuracy** at the **fibre joint**



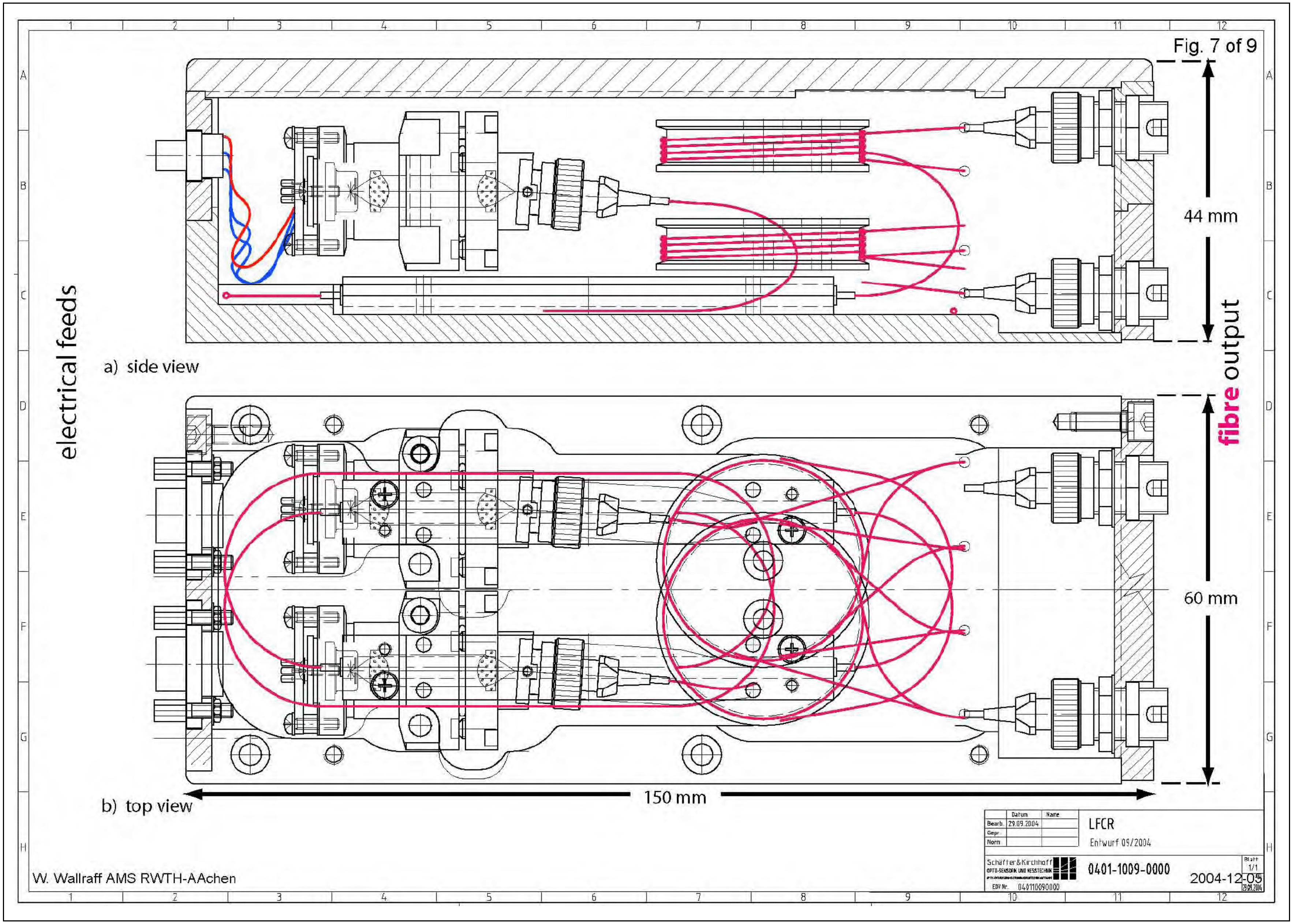
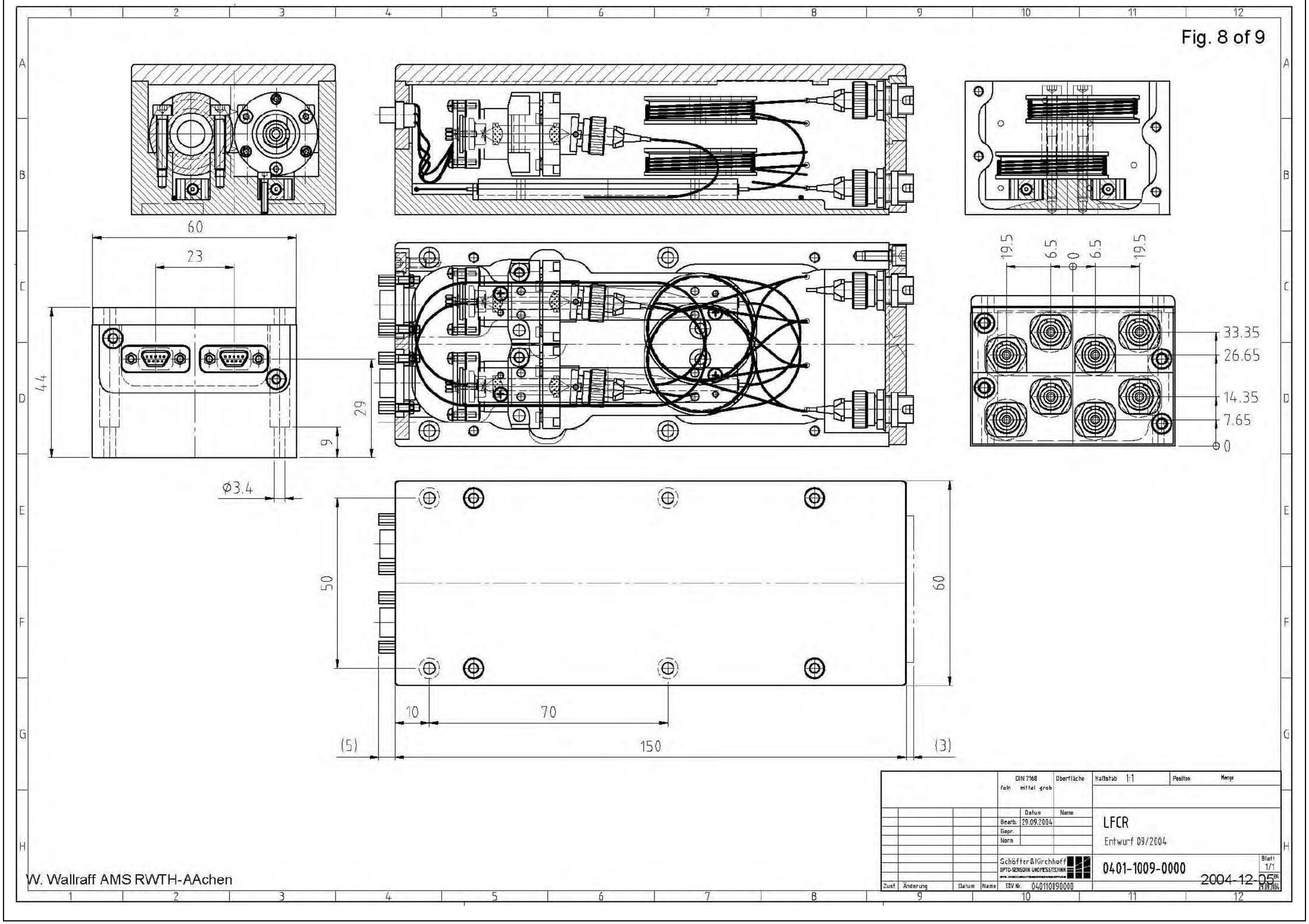
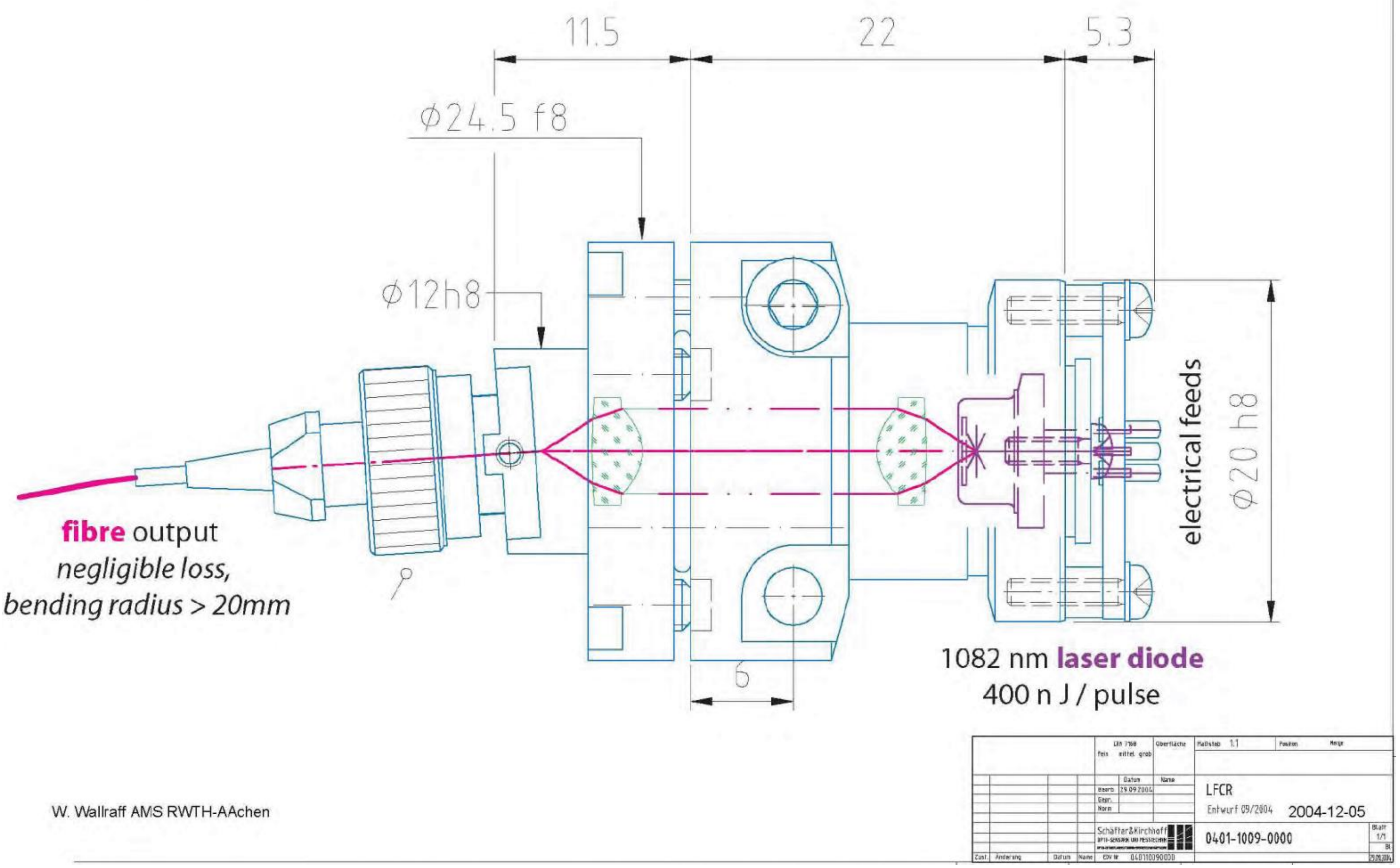


Fig. 7 of 9
electrical feeds
a) side view
44 mm
fibre output
60 mm
b) top view
150 mm
W. Wallraff AMS RWTH-AAchen
Datum
Name
Bearb.
29.09.2004
Gepr.
Norm
LFCR
Entwurf 09/2004
Schäfter+Kirchhoff
0401-1009-0000
2004-12-05
Blatt
1/1


60
23
44
29
9
Ø3.4
19.5
6.5
0
6.5
19.5
33.35
26.65
14.35
7.65
0
50
60
10
70
(5)
150
(3)
DIN 7168
fein mittel grob
Oberfläche
Maßstab 1:1
Position
Menge
Datum
Name
Bearb. 29.09.2004
Gepr.
Norm
LFCR
Entwurf 09/2004
Schäfter&Kirchhoff
OPTO-SENSORIK UND MESSTECHNIK
0401-1009-0000
Blatt 1/1
Zust. Änderung Datum Name
EDV Nr. 040110090000
2004-12-05
W. Wallraff AMS RWTH-AAchen

LFCR electro optical components

dimensions mm



W. Wallraff AMS RWTH-AAchen

FLIGHT PAYLOAD STANDARDIZED HAZARD CONTROL REPORT

A. NUMBER	B. PHASE	C. DATE
STD- AMS-02-F02	Phase III	August 4, 2010

D. PAYLOAD, DTO, DSO or RME *(Include Part Number(s), if applicable)*	HAZARD TITLE	E. VEHICLE
Alpha Magnetic Spectrometer (AMS-02) Orbiter Interior Elements– See Attached List	STANDARD HAZARDS	Shuttle

F. DESCRIPTION OF HAZARD:	G. HAZARD CONTROLS: *(complies with)*	H. APP.	I. VERIFICATION METHOD, REFERENCE, AND STATUS:
1. Structural Failure *(payloads must comply with the listed requirements for all phases of flight)* *Note: Locker and Soft Stowage items only.*	Designed to meet the standard modular locker stowage requirements of NSTS 21000-IDD-MDK or equivalent IDD ______ .	☒	1.1.1. SVM: Review for compliance with Middeck ICD 1.1.1 STATUS: Closed. ESCG Memorandum ESCG-4295-10-CPAS-MEMO-0002, "DDRS-02 Hazard Controls," dated February 2, 2010
2. Structural Failure of Sealed Containers **Note 1: Only sealed containers made of conventional metal (metal alloy) can use the 1230 form. Sealed containers made of unconventional metals or non-metallic materials shall be documented on Unique Hazard Reports.** **Note 2: The 1230 form is not applicable for "sealed container"(s) employed in levels of containment control of hazardous fluid.**	Sealed containers must meet the criteria of NASA-STD-5003, Para. 4.2.2.4.2.3a, contain a substance which is not a hazard if released, be made of conventional metals (e.g. Al, inconel, monel, steel or titanium), contain less than 14,240 foot-pounds (19,130 Joules) of stored energy due to pressure, and have a maximum delta pressure of 1.5 atm.	☐	**N/A**. – No Sealed Containers used as structure (No Sealed Containers for any purpose)

APPROVAL	PAYLOAD ORGANIZATION	SSP/ISS
PHASE I		
PHASE II		
PHASE III		

FLIGHT PAYLOAD STANDARDIZED HAZARD CONTROL REPORT		A. NUMBER STD- AMS-02-F02	B. PHASE Phase III	C. DATE August 4, 2010
D. PAYLOAD, DTO, DSO or RME *(Include Part Number(s), if applicable)* Alpha Magnetic Spectrometer (AMS-02) Orbiter Interior Elements– See Attached List		**HAZARD TITLE** STANDARD HAZARDS	**E. VEHICLE** Shuttle	

F. DESCRIPTION OF HAZARD:	G. HAZARD CONTROLS: *(complies with)*	H. APP.	I. VERIFICATION METHOD, REFERENCE, AND STATUS:
3. Structural Failure of Vented Containers	For intentionally vented containers, vents are sized to maintain a 1.4 factor of safety for Shuttle or a 1.5 factor of safety for Station with respect to pressure loads. Meets all of the applicable pressure rates defined for one or more of the following.		**N/A**. – No confined volumes in hardware design.
	a) Shuttle payload bay – ICD 2-19001, Para. 10.6.1	☐	
	b) Station environment – SSP 52005, paragraph 4.3 or equivalent payload specific ICD ______.	☐	
	c) Station PFE discharge – SSP 57000, Para. 3.1.1.4K, or equivalent payload specific ICD ______.	☐	
	d) Shuttle Middeck – NSTS 21000-IDD-MDK, Section 6.1.	☐	
4. Sharp Edges, Corners, and/or Protrusions.	Meets the **intent** of one or more of the following:		4.a.1 SVM: Inspection of payload provided flight hardware for sharp edges, corners and protrusions. 4.a.1 STATUS: Closed. ESCG Memorandum ESCG-4295-10-CPAS-MEMO-0002, “DDRS-02 Hazard Controls,” dated February 2, 2010
	a) NASA-STD-3000 / SSP 50005	☒	
	b) SLP 2104	☐	
	c) NSTS 07700 Vol. XIV App. 7 (EVA hardware)	☐	
	d) NSTS 07700 Vol. XIV App. 9 (IVA hardware) / SSP 57000	☐	
	e) SSP 41163, Para. 3.3.6.12.3 (EVA), Para. 3.3.6.12.4 (IVA).	☐	

JSC Form 1230 (Rev December 20, 2004) (MS Word July 1, 1996)

<table>
<tr><td colspan="2" rowspan="2">FLIGHT PAYLOAD STANDARDIZED HAZARD CONTROL REPORT</td><td colspan="2">A. NUMBER
STD- AMS-02-F02</td><td>B. PHASE
Phase III</td><td>C. DATE
August 4, 2010</td></tr>
<tr><td colspan="4"></td></tr>
<tr><td colspan="2">D. PAYLOAD, DTO, DSO or RME (Include Part Number(s), if applicable)
Alpha Magnetic Spectrometer (AMS-02) Orbiter Interior Elements–
See Attached List</td><td colspan="2">HAZARD TITLE
STANDARD HAZARDS</td><td colspan="2">E. VEHICLE
Shuttle</td></tr>
<tr><td>F. DESCRIPTION OF HAZARD:</td><td>G. HAZARD CONTROLS: (complies with)</td><td>H. APP.</td><td colspan="3">I. VERIFICATION METHOD, REFERENCE, AND STATUS:</td></tr>
<tr><td>5. Shatterable Material Release</td><td>a) All materials are contained.

b) Optical glass (i.e. lenses, filters, etc.) components of crew cabin experiment hardware that are non-stressed (no delta pressure) and have passed both a vibration test at flight levels and a post-test visual inspection.

c) Payload bay hardware shatterable material components that weigh less than 0.25 lb and are non-stressed (no delta pressure) or non-structural.</td><td>☐

☐

☐</td><td colspan="3">N/A. No Identified Shatterable Materials</td></tr>
<tr><td>6. Flammable Materials</td><td>a) A-rated materials selected from MAPTIS, or

b) Flammability assessment per NSTS 22648</td><td>☐

☒</td><td colspan="3">6.b.1 SVM: Review of design for appropriate use of non-flammable materials.
6.b.2 SVM: Review and approval of flammability assessment by JSC/ES4.
6.b.1 STATUS: Closed. ESCG Memorandum ESCG-4390-08-SP-MEMO-0021 RevA, “IVA Offgassing and Flammability,” dated February 17, 2009
6.b.2 STATUS: Closed. JSC Materials and Fracture Control Certification MATL-09-036, "Alpha Magnetic Spectrometer (AMS-02) Data Interface Hardware," Approved 3/25/2009</td></tr>
<tr><td>7. Materials Offgassing</td><td>Offgassing tests of assembled article per NASA-STD-6001 (previously published as NHB 8060.1C).</td><td>☐</td><td colspan="3">Reference Hazard Report AMS-02-F02</td></tr>
<tr><td>8. Nonionizing Radiation

8.1 Non-transmitters</td><td>Meets all that apply:

a) Pass ICD-2-19001, 10.7.3.2.2 / SSP 30238 EMI compatibility testing, or

b) NSTS/USA approved analysis ICD Section 20, or

c) ISS/EMEP approved TIA

d) Meets SSP 41163, Para. 3.3.6.6 and SSP 50094, Para. 3.4.</td><td>

☒

☐

☐

☐</td><td colspan="3">8.1.a.1 SVM: EMI testing results reviewed and approved by JSC/EV4
8.1.a.1 STATUS: Closed. Test Reports EV5-09-EMC-010R, “Test Report Electromagnetic Interference (EMI) of the Engineering Evaluation For The Alpha Magnetic Spectrometer (AMS-02) – USB422 Assembly,” dated August 25, 2009 and Universita’ Degli Studi Di Perugia Polo Scientifico E Didattico Di Terni, Facolta di Ingegneria, Laboratorio di Caratterizzazione Electromagnetica Test Report No. 099, AMS02 Digital Data Recording System USB – RS422 Interface, April 12, 2007. Approved by EV/Scully, EV/Tarditi</td></tr>
</table>

FLIGHT PAYLOAD STANDARDIZED HAZARD CONTROL REPORT	A. NUMBER	B. PHASE	C. DATE
	STD- AMS-02-F02	Phase III	August 4, 2010

D. PAYLOAD, DTO, DSO or RME *(Include Part Number(s), if applicable)*	HAZARD TITLE	E. VEHICLE
Alpha Magnetic Spectrometer (AMS-02) Orbiter Interior Elements– See Attached List	STANDARD HAZARDS	Shuttle

F. DESCRIPTION OF HAZARD:	G. HAZARD CONTROLS: *(complies with)*	H. APP.	I. VERIFICATION METHOD, REFERENCE, AND STATUS:
8.2 Lasers **NOTE: Lasers operating at class levels 3b and 4, meeting ANSI Z136.1, shall be documented on Unique Hazard Reports.**	Meet ANSI Z136.1-2000 for class 1, 2, or 3a Lasers (as measured at the source).	☐	**N/A.** Internal elements of AMS-02 do not generate coherent light.
9.1 Alkaline cells and batteries made of alkaline cells, connected in series or in parallel, up to 12 V and with up to 60 Watt-hours capacity, no potential charging source and cells are not in a gas-tight compartment.	Cells and batteries pass acceptance tests that include loaded and open circuit voltage measurements, visual examination, and leakage check under vacuum (e.g. 6 hours at 0.1 psia).	☐	**N/A.** AMS-02 Interior elements utilize no batteries. Submission of EP-Form-03(including the form's approved reference number) for EP5 approval Information to be included on the EP5 reviewed/approved Form-03: application and protective circuit schematics
9.2 Primary button cells such as Li-(CF)x, Li-iodine, LiV_2O_5, $LiMnO_2$, Ag-Zn and rechargeable button cells such as LiV_2O_5, Li-ion, Ni-Cd, Ni-MH, Ag-Zn cells or batteries, which have a capacity of 300 mAh or less and no more than 3 cells per common circuit, and cells are not in a gas-tight compartment.	Cells and batteries pass acceptance tests that include loaded and open circuit voltage measurements, visual examination, and leakage check under vacuum (e.g. 6 hours at 0.1 psia). Note: Above acceptance testing for button cells in Section 9.2 which are soldered to a circuit board in commercial equipment (not applicable to those button cells in a spring-loaded clip) is limited to a functional check of the equipment utilizing the subject battery.	☐ ☐ ☐	**N/A.** AMS-02 Interior elements utilize no batteries. Submission of EP-Form-03(including the form's approved reference number) for EP5 approval Information to be included on the EP5 reviewed/approved Form-03:: application and protective circuitry.
9.3 COTS NiMH, NiCd and Ag/Zn cells and batteries for IVA use up to 20 V and 60 Wh	Cells and batteries purchased in one lot; pass acceptance tests that include loaded and open circuit voltage measurements, visual examination, leakage check under vacuum (e.g 6 hours at 0.1psia) and vibration to workmanship levels with functional checks which include charge/discharge cycles for rechargeable batteries.	☐	**N/A.** AMS-02 Interior elements utilize no batteries. Submission of EP5 Form-03(including the form's approved reference number) for approval Information to be included on the EP5 reviewed/approved Form-03: manufacturer's specification, battery protective features and charger schematics

FLIGHT PAYLOAD STANDARDIZED HAZARD CONTROL REPORT	A. NUMBER STD- AMS-02-F02	B. PHASE Phase III	C. DATE August 4, 2010
D. PAYLOAD, DTO, DSO or RME *(Include Part Number(s), if applicable)* Alpha Magnetic Spectrometer (AMS-02) Orbiter Interior Elements– See Attached List	**HAZARD TITLE** STANDARD HAZARDS	**E. VEHICLE** Shuttle	

F. DESCRIPTION OF HAZARD:	G. HAZARD CONTROLS: *(complies with)*	H. APP.	I. VERIFICATION METHOD, REFERENCE, AND STATUS:
9.4 COTS Li-ion batteries up to 10 V and 60 Wh for IVA use	Batteries and charger shall be from a single lot; shall show one-fault tolerance at battery level and shall pass acceptance tests that include loaded and open circuit voltage measurements, visual examination, leakage check under vacuum (e.g 6 hours at 0.1psia) and vibration to environment or double the workmanship level, whichever is higher; and functional checks which include charge/discharge cycles.	☐	**N/A.** AMS-02 Interior elements utilize no batteries. Submission of EP-Form-03(including the form's approved reference number) for EP5 approval. Information to be included on the EP5 reviewed/approved Form-03: battery protective features and charger features Note: For hardware using batteries, and/or chargers additional levels of control shall be provided by the hardware .
10. Touch Temperature	a) Within IVA touch temperature range of –18 Degrees C. (0 Degrees F.) and 49 Degrees C. (120 Degrees F.) and satisfies the intentional contact constraints of letter MA2-95-048 (if applicable). b) Meets EVA touch temperature criteria of NSTS 07700 Vol. XIV App. 7.	☒ ☐	10.a.1 SVM: Review of design to confirm low power application with electronic components are inaccessible to the crew. 10.a.2 SVM: Thermal Analysis to confirm that interface will not Exceed Touch Temperature Limits. 10.a.1 STATUS: Closed. Memo ESCG-4470-08-TEAN-DOC-0210, "Touch Temperature Analysis for Alpha Magnetic Spectrometer (AMS-02) Digital Data Recording System (DDRS)", dated January 14, 2008 documents power consumption and enclosure. 10.a.2 STATUS: Closed. Memo ESCG-4470-08-TEAN-DOC-0210, "Touch Temperature Analysis for Alpha Magnetic Spectrometer (AMS-02) Digital Data Recording System (DDRS)", dated January 14, 2008, documents touch temperature analysis compliance.
11. Electrical Power Distribution	a) Shuttle-powered payloads – Meets all circuit protection requirements of Letter TA-92-038. b) Station-powered payloads – Meets station interface circuit protection requirements of SSP 57000 and payload circuit protection requirements of Letter TA-92-038.	☒ ☐	11.a.1 SVM: Review of Design 11.a.1 STATUS: Closed. ESCG Memorandum ESCG-4175-09-REENTES-MEMO-0055, "Circuit Protection on DDRS-02," dated August 12, 2009 Note: The USB422 makes its interface is with the PGSC/NGLS and is not directly interfaced with the Shuttle power systems.
12. Ignition of Flammable Atmospheres in Payload Bay	All ignition sources in the Payload bay, for launch and landing, are controlled as required in Letter NS2/81-MO82, and MLI grounded per ICD 2-19001.	☐	**N/A.** Hardware addressed in this hazard report is within the crew habitable environment and not exposed to a flammable atmosphere in the Shuttle Payload Bay
13. Rotating Equipment	Rotating equipment meets criteria of NASA-STD-5003 for obvious containment.	☐	**N/A.** AMS-02 Internal hardware does not utilize any rotating equipment.

FLIGHT PAYLOAD STANDARDIZED HAZARD CONTROL REPORT		A. NUMBER STD- AMS-02-F02	B. PHASE Phase III	C. DATE August 4, 2010
D. PAYLOAD, DTO, DSO or RME *(Include Part Number(s), if applicable)* Alpha Magnetic Spectrometer (AMS-02) Orbiter Interior Elements– See Attached List		**HAZARD TITLE** STANDARD HAZARDS		**E. VEHICLE** Shuttle

F. DESCRIPTION OF HAZARD:	G. HAZARD CONTROLS: *(complies with)*	H. APP.	I. VERIFICATION METHOD, REFERENCE, AND STATUS:
14. Mating/demating powered connectors	a) Meets the low power criteria of letter MA2-99-170 or,	☒	14.a.1 SVM: Review of Design. 14.a.1 STATUS: Closed. ESCG Memorandum ESCG-4175-09-REENTES-MEMO-0055, "Circuit Protection on DDRS-02," dated August 12, 2009
	b) Meets the paragraph 1 criteria of letter MA2-99-170 (e.g., IVA and open circuit voltage no greater than 32 volts).	☐	
15. Contingency Return and Rapid Safing	Shuttle Environment: a) If middeck payload – can be stowed within 50 min. (see paragraph 3 of letter MA2-96-190).	☒	15a.1 SVM: Rapid Safing Assessment to establish that the PGSC and data cables can be stowed within 50 minutes. 15.a.1 STATUS: Closed. A. M. Vaughan/DO5 concurrence with AMS-02 assessment documented in ESCG Memorandum ESCG-4390-08-SP-MEMO-0011 Rev A., "AMS-02 Digital Data Recording Systems -02 (DDRS-02) Rapid Safing" that stowage of PGSC and DDRS-02 cabling will occur in approximately six minutes.
	b) If SPACEHAB transfer item – can establish a safe for return configuration within 3 min. (see paragraph 5 of letter MA2-96-190).	☐	
	Station Environment: c) Payload design does not impede emergency IVA egress to the remaining adjacent pressurized volumes.	☐	
16. Release of Mercury from bulbs into crew habitable environment.	a) Mercury vapor bulbs contain less than 30 mg of Mercury per bulb, and	☐	**N/A**. AMS-02 internal hardware elements do not utilize mercury containing bulbs.
	b) No more than one bulb could break due to a single failure.	☐	

Alpha Magnetic Spectrometer –02 (AMS-02) Orbiter Interior Hardware Elements:

- DDRS-02 Assembly P/N SED39136116-301
    - USB422 Assembly P/N SED39137921-301
    - USB422 to PDIP Cables P/N SED 3939136111-301
    - COTS USB A-B cable, wrapped in Teflon tape (connects USB422 to PGSC/NGLS) P/N SED39136130-801
    - Extension Cable P/N 39137973-301

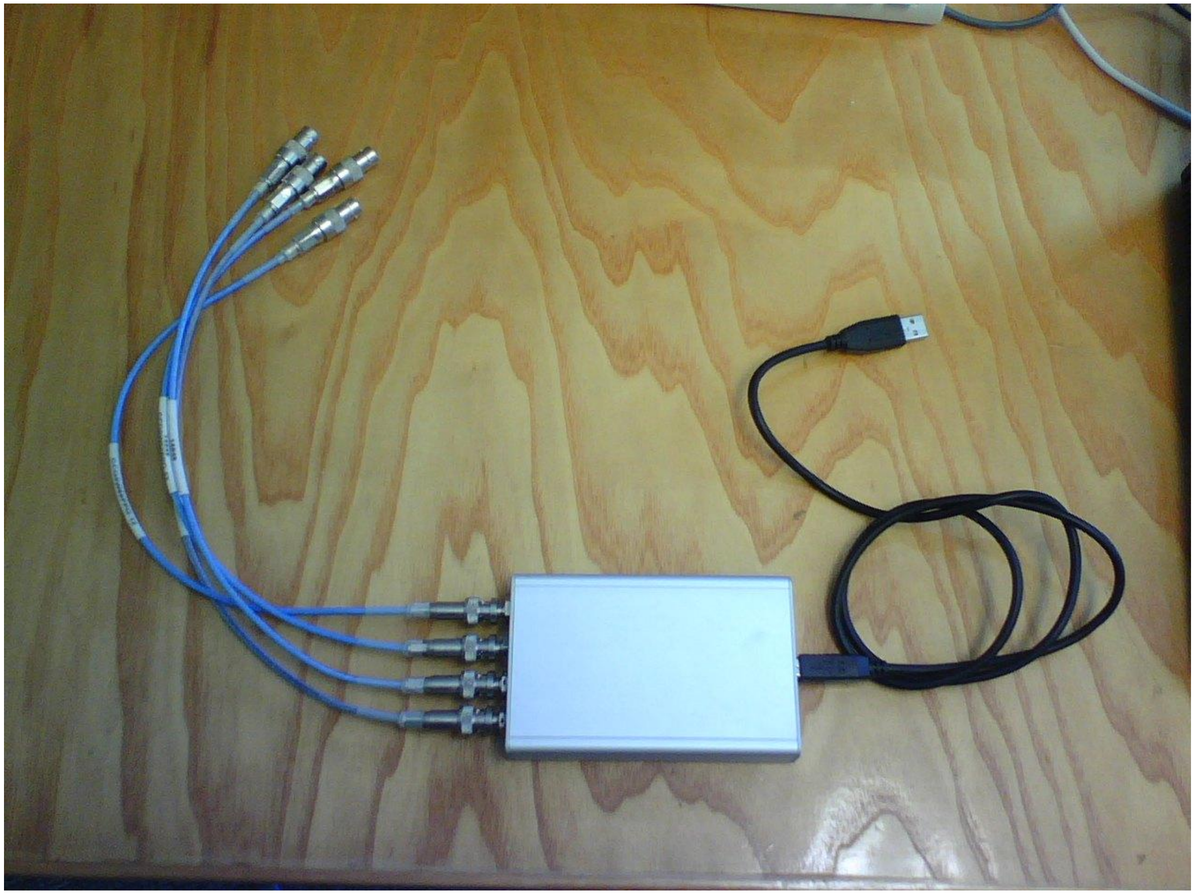
      NOTE:
        - *Payload General Support Equipment (PGSC)/ Next Generation Laptop System (NGLS)*, **not considered in STD-AMS-02-02, GFE is being used in accordance with its GFE certification.**
        - *Spare Hard Disk (GFE) for PGSC/NGLS*, **not considered in STD-AMS-02-02, GFE is being used in accordance with its GFE certification.**

- Other Hardware
    - Cable SED 39136112-302 – PDIP J101 to J105 Patch Cable – Patches RS422 to T0 umbilical for GSE monitoring and control of the AMS-02 prior to launch.

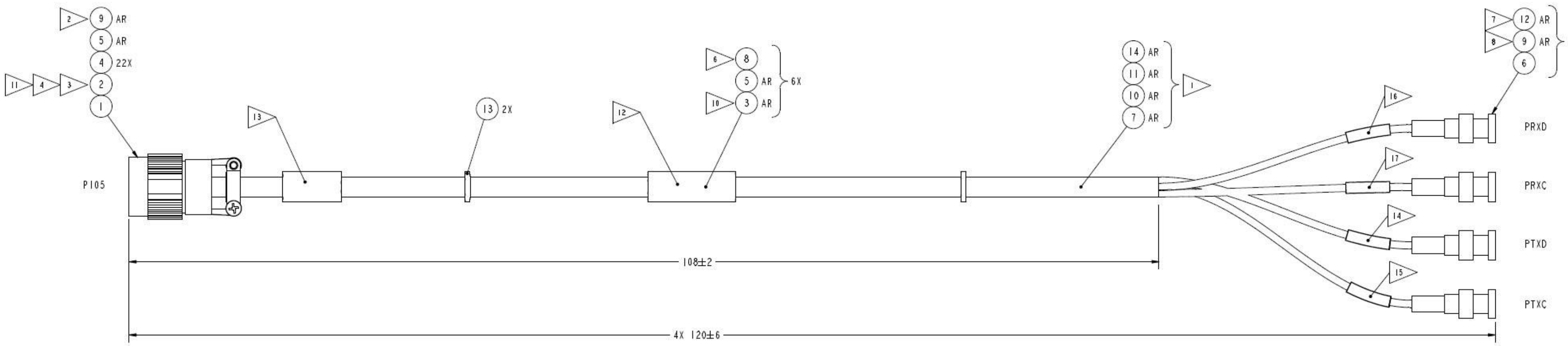
About USB422

The USB422 interface provides inline conversion of RS422 synchronous serial signals to a USB 2.0 interface. The unit is powered by the USB 5.0 volt bus provided power and draws less the 0.5 amp. USB422 is a single PCB based on a Cypress FX2 chip and a gate array. This card will be hand conformal coated with Dow Corning 3140 or equivalent.

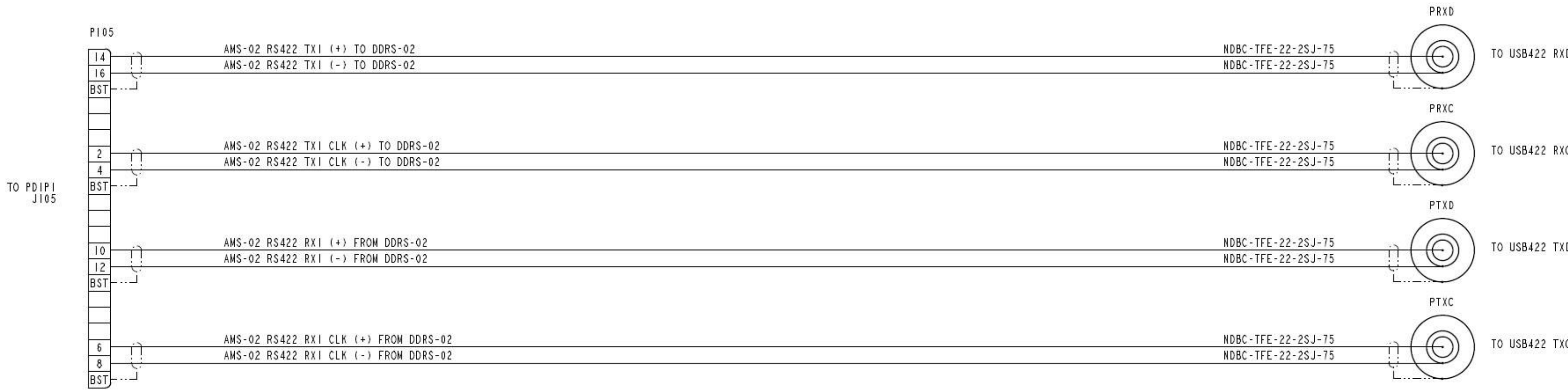
USB422 is housed in a rugged aluminum enclosure with Twinax style connections on one end and a commercial USB cable Teflon wrapped on the other. The USB cable plugs into the NGLS USB connection and is strain relieved by a Velcro strap to the power connection cable (TBC).



Picture is representation of USB422 and Non-Flight cables



-301



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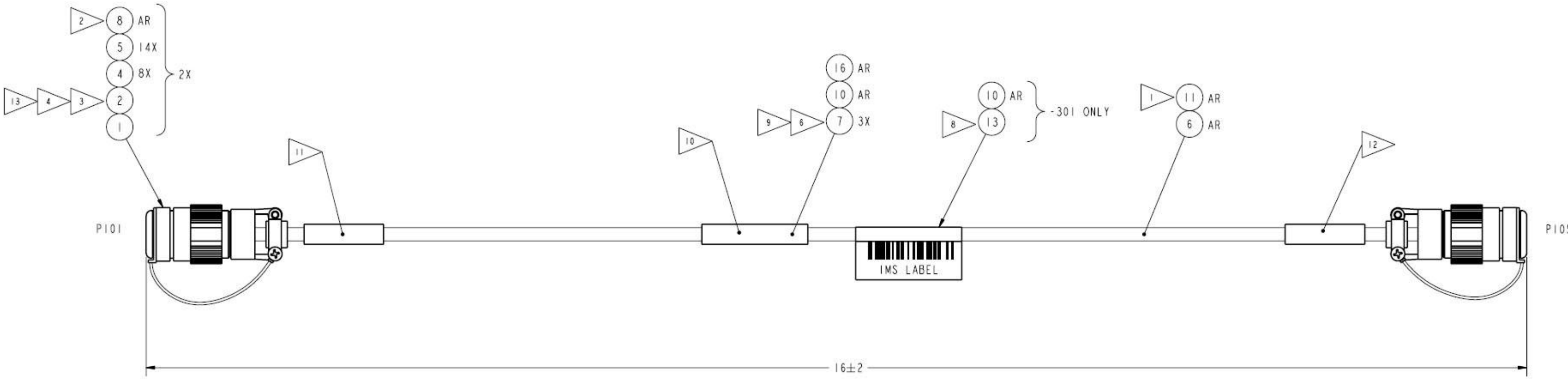
WIRING SCHEMATIC

DDRS-02 – Cable RS422 to PDIP (P/N SED 3939136111)



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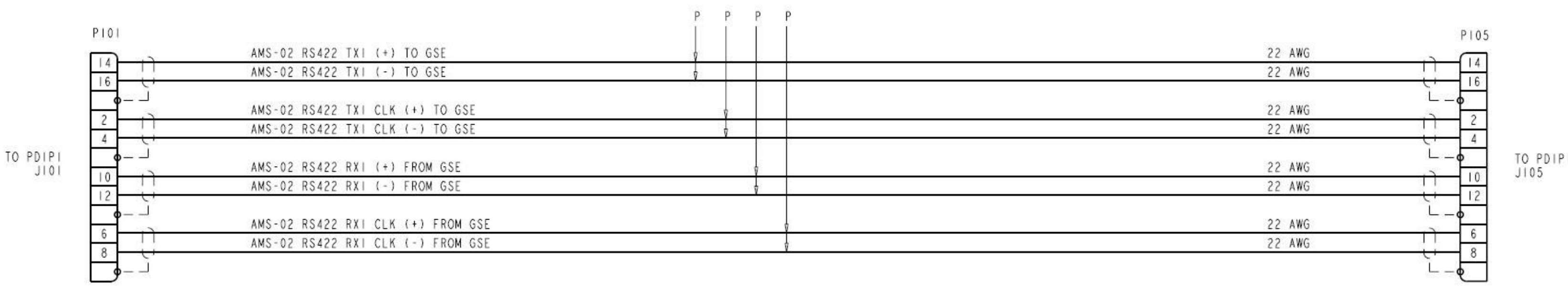

WIRING SCHEMATIC 5

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PDIP J101 to J105 Patch Cable Schematic P/N SED39136112