Project Technical Requirements Specification for the Alpha Magnetic Spectrometer-02 (AMS-02) Payload Integration Hardware (PIH)

Engineering Directorate

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National Aeronautics and
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Lyndon B. Johnson Space Center
Houston, Texas 77058

PROJECT TECHNICAL REQUIREMENTS SPECIFICATION FOR THE ALPHA MAGNETIC SPECTROMETER-02 (AMS-02) PAYLOAD INTEGRATION HARDWARE (PIH)

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DOCUMENT CHANGE/REVISION LOG

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Basic	December, 2002	Initial release for baseline	All
A	August, 2004	Revised to incorporate comments from S&MA and to reflect transfer of the project from the Space and Life Sciences Directorate to the Engineering Directorate	All

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1. INTRODUCTION

In this Project Technical Requirements Specification (PTRS) "AMS" will refer to the total complement of activities, hardware, software, test, integration and operation of the Alpha Magnetic Spectrometer – 02 (AMS-02). The flight hardware is referred to as the "AMS Payload" and is comprised of two parts: the "AMS Experiment" provided by the International AMS Collaboration led by the Massachusetts Institute of Technology (MIT) and the "AMS Payload Integration Hardware (PIH)" provided by the Johnson Space Center (JSC) Engineering Directorate (EA) with the support of Lockheed Martin Space Operations (LMSO). This PTRS specifically covers the PIH provided by EA/LMSO.

The AMS Experiment is a state-of-the-art particle physics detector containing a large, cryogenic superfluid helium superconducting magnet (Cryomag) that is being designed, constructed, tested and operated by an international team organized under United States Department of Energy (DOE) sponsorship. The AMS Experiment will use the unique environment of space to advance knowledge of the universe and potentially lead to a clearer understanding of the universe's origin. Specifically, the science objectives of the AMS are to search for antimatter (anti-helium and anti-carbon) in space, to search for dark matter and dark energy (90% of the missing matter in the universe) and to study astrophysics (to understand Cosmic Ray propagation and confinement time in the Galaxy).

The AMS-02 is an unpressurized, full truss mounted payload that will utilize a Cryomag with planes of detectors above, inside and below the magnet. Electrically charged particles that pass through the magnetic field will curve. Charged particles made of matter will curve one way, and those of antimatter will curve the opposite way. The positions of the charged particles will be electronically recorded. Physicists will be able to study the trajectory of curvature and determine the charge of the particles from the direction of curvature. They will also be able to determine the mass of the particles from the amount of curvature. They will then be able to tell whether it was matter or antimatter.

1.1 PURPOSE AND SCOPE

This specification defines the technical requirements for the PIH delivered to the International Space Station (ISS) by the AMS-02 Project. The STS verification requirements for the AMS-02 Payload are contained in the Shuttle Orbiter/AMS-02 Cargo Element Interface Control Document, NSTS/AMS ICD-A-(TBD-1). The ISS verification requirements for the AMS-02

Payload are contained in the Alpha Magnetic Spectrometer (AMS–02) Attached Payload Hardware Interface Control Document (ICD), SSP 57213.

The following definitions differentiate between requirements and other statements.

- Shall: This is the only verb used for the binding requirements.
- Should/May: These verbs are used for stating non-mandatory goals.
- Will: This verb is used for stating facts or declaration of purpose.

1.2 RESPONSIBILITY AND CHANGE AUTHORITY

The PTRS establishes the overall project technical requirements for the AMS-02 elements that are the responsibility of EA and LMSO, and establishes safety requirements for all of the AMS-02 PIH elements.

The responsibility for assuring definition, control, implementation, and accomplishment of the activities identified in this document is vested with the EA/LMSO for all AMS-02 PIH and with the Massachusetts Institute of Technology (MIT) for the AMS Experiment.

1.2.1 NASA-JSC EA Responsibilities

EA/LMSO is responsible for providing all AMS payload integration activities consisting of flight and ground safety, analytical and physical integration, development of AMS payload integration hardware (PIH) [i.e. Unique Support Structure – 02 (USS-02), Cryomagnet Vacuum Case (VC), Digital Data Recording System – 02 (DDRS-02), etc.], development of AMS Payload software requirements, and AMS Payload hardware/software verification. In addition, EA/LMSO will provide Ground Support Equipment (GSE) and Ground Handling Equipment (GHE) to support ground processing for the USS-02, VC and DDRS-02. Table 1.2.1-1 details the flight hardware items that are the responsibility of EA/LMSO; Table 1.2.1-2 lists the flight hardware provided by NASA's Space Transportation System (STS) and ISS Programs that will be integrated by EA/LMSO; and Table 1.2.1-3 lists the GSE and GHE for which EA/LMSO is responsible.

All activities and deliverables will be performed in accordance with the AMS-02 Master Schedule, which is updated periodically by the EA. EA/LMSO is responsible for identifying to MIT all integration issues that may affect MIT responsibilities and will include a plan to resolve the issues.

TABLE 1.2.1-1 – EA/LMSO PROVIDED FLIGHT HARDWARE

ITEM	UNITS
Cryomagnet Vacuum Case (VC) (Flight Article)	1
Meteoroid and Orbital Debris (M/OD) shields	at least 2
Payload Attach System (PAS) (Passive Half)	1
EVA Interface Panel (Interface to UMA)	1
Interface Panel A (Interface to ROEU/PDA)	1
Cabling from interface panels to J-Crate and PDS	1
Digital Data Recording System (DDRS–02), associated software, and cabling/interface cards	1
Thermal Blankets	6
Unique Support Structure-02 (USS-02)	1
Brackets to interface the EBCS, FRGF, PVGF, ROEU/PDA, and UMA to the USS-02	1 Each

TABLE 1.2.1-2 – NASA STS/ISS PROVIDED FLIGHT HARDWARE

ITEM	UNITS
Electronic Berthing Camera System (EBCS) w/cables	1
EVA (Extravehicular Activity) Handrails	9
Flight Releasable Grapple Fixture (FRGF)	1
Portable Foot Restraints (PFR) Worksite Interface (WIF)	1
Power Video Grapple Fixture (PVGF) w/cables	1
Remotely Operated Electrical Umbilical/Payload Disconnect Assembly (ROEU/PDA) w/cables	1
Umbilical Mechanism Assembly (UMA) (Passive Half) w/cables	1
Worksite Interface Fixture (WIF)	1

TABLE 1.2.1-3 – EA/LMSO PROVIDED GSE AND GHE

ITEM	UNITS
VC Structural Test Article (STA) (NOTE: VC STA also serves as Flight Spare VC)	1
Primary Support Stand (PSS)	1
Lower USS Support Fixture	1
Primary Lifting Fixture	1
Multi-purpose Lifting Fixture	2
Intermediate Support Fixtures	4
USS-02 Assembly Fixture	1
Vacuum Case Test Fixture (VCTF)	1
Special Test Equipment (STE) for Structural Testing	Multiple
Neutral Buoyancy Laboratory (NBL) Mockup	1
VC/Magnet Shipping Fixture	2

EA/LMSO will convene and conduct a Preliminary Design Review (PDR) and a Critical Design Review (CDR) for the integration activities and hardware developed by the EA. EA/LMSO will support International Space Station Program (ISSP) and Space Shuttle Program (SSP) meetings and reviews as required to support the AMS integration process. The meetings and reviews will include, but are not limited to, the following:

- AMS Project Reviews
- Crew and Equipment Interface Test (CEIT)
- Cargo Integration Review (CIR)
- Payload Flight Safety Reviews (FSR)
- Payload Ground Safety Reviews (GSR)
- Flight Planning and Stowage Reviews (FPSR)
- Stage Operations Readiness Review (SORR)
- Verification Acceptance Review (VAR)

- Flight Operations Review (FOR)
- Flight Readiness Review (FRR)
- Space Shuttle Integrated Product Team (IPT) meetings
- Launch Package Manager's IPT meetings

1.2.2 Change Authority

This document is prepared to meet EA-WI-023, Project Management of GFE Flight Projects, paragraph 7.5.1.2. The responsibility for the development of this document lies with the Engineering Directorate. Change authority will be the AMS Configuration Control Board (CCB).

Configuration control will be initiated upon signature approval. EA will maintain configuration control of this document in accordance with JSC 27542, "Alpha Magnetic Spectrometer (AMS) Configuration Management Plan." All proposed changes to the PTRS shall be submitted by EA Change Request/Directive (CR/DIR) and jointly approved by the EA, LMSO and MIT.

2. APPLICABLE AND REFERENCE DOCUMENTS

2.1 APPLICABLE DOCUMENTS

The applicable document list can be found in the Project Plan for the AMS (JSC 27296) Appendix A.

2.2 ORDER OF PRECEDENCE

In the event of a conflict between the text of this specification and an applicable document cited in JSC 27296, the text of this specification takes precedence.

All specifications, standards, exhibits, drawings or other documents that are invoked as "applicable" in this specification are incorporated as cited. All documents that are referred to by an applicable document are considered to be for guidance and information only, with the exception of ICDs, which shall have their applicable documents considered to be incorporated as cited.

3. REQUIREMENTS

The AMS payload and collaboration are extremely complex. There are three main sets of requirements that must be met in order to certify the payload for flight. These sets include:

- NASA Developed Payload Integration Hardware (PIH) System Requirements and Integrated Payload Requirements
- AMS Payload Safety Requirements
- AMS Experiment Component Mission Assurance Requirements

The first set of requirements including the NASA Developed PIH System Requirements and Integrated Payload Requirements are fully defined in this PTRS. The verification of these requirements will be tracked via the PIH and Integrated Payload Verification Matrix found in the AMS-02 Master Verification Plan (MVP). These requirements are defined early in the project and are driven by the requirements for integration on the ISS and STS. The PIH requirements are also driven by the requirements of the experiment components. The PIH and any Integrated Payload requirements cannot be closed until all of the necessary analysis, testing or inspections have been performed. This matrix will be tracked until all items are closed prior to Certification of Flight Readiness (CoFR).

The second set of requirements is developed as part of the payload safety process. Because AMS is a payload, it must go through the Payload Safety Review Process. This includes phased reviews for both flight and ground safety. The Safety Data Packages that are developed to support these phased reviews include a complete description of the entire payload and identification of hazards in Hazard Reports. Safety requirements can be added to the payload during any of these reviews and are tracked via the Hazard Reports and the Safety Verification Matrix in the AMS-02 MVP. Any safety verification item that has not been closed by the Phase III safety review will be tracked on a verification tracking log until all items have been closed prior to CoFR.

The third set of requirements are defined by the AMS Experiment Component teams and are not the responsibility of the NASA AMS Project Office. NASA does have some insight into these requirements and will create a third verification matrix that will be tracked until all items are closed and prior to CoFR. The Experiment Component Mission Assurance Verification Matrix will be developed as a part of the AMS-02 MVP, but will be tracked by the AMS CCB. Keep in mind that the AMS experiment team has a vested interest in ensuring that their experiment functions as expected. Although the team does not use a traditional NASA approach to mission assurance, their methodology has successfully worked over many years on ground based experiments and on the AMS-01 mission on STS-91. The AMS experiment methodology includes numerous acceptance tests at the component and sub-system level. It includes functional testing at various subcomponent levels and at the fully integrated system level. It also includes functional tests during a full-up thermal vacuum test.

3.1 AMS-02 PIH SYSTEM DEFINITION

The AMS-02 payload integration hardware (PIH) provides the required structural, electrical, and C&DH interfaces between the components of the AMS-02 experiment and the STS for transfer to and from orbit, and the ISS during its on-orbit operational lifetime. The major AMS-02 PIH subsystems which are addressed in this PTRS are shown below. The AMS-02 PIH system and its interfaces with the STS, ISS and AMS Experiment are shown in Figure 3.1-1. This PTRS is meant to define the requirements for the middle section of this graphic. Graphic representations of the flight hardware (including both PIH and the experiment) are shown in Figures 3.1-2 thru 3.1-5. Figure 3.1-6 shows a flow chart of all of the hardware components that must come together to make up the entire AMS Payload. The chart includes the originating location of the hardware and denotes certification and verification testing points.

- Unique Support Structure-02
- Vacuum Case
- STS & ISS Integration Hardware
- Payload Attach System
- External Berthing Camera System
- Power Video Grapple Fixture
- Flight Releasable Grapple Fixture
- Handrails
- Worksite Interface Fixture
- Umbilical Mechanism Assembly & EVA Interface Panel
- Remotely Operated Electrical Umbilical & Interface Panel A
- Digital Data Recording System-02
- Micro Meteoroid and Orbital Debris Shields
- Thermal Blankets

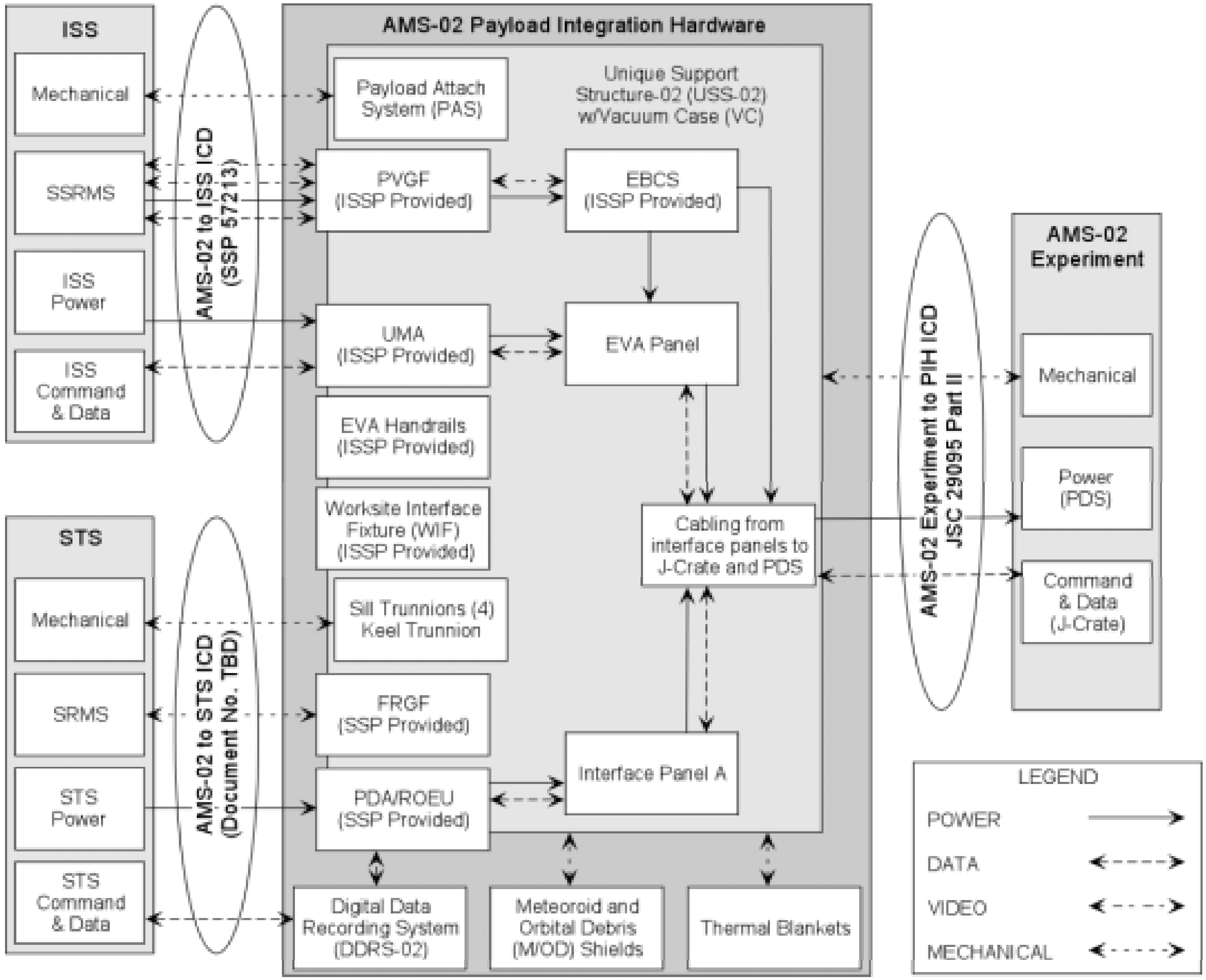

Figure 3.1-1 The AMS-02 System

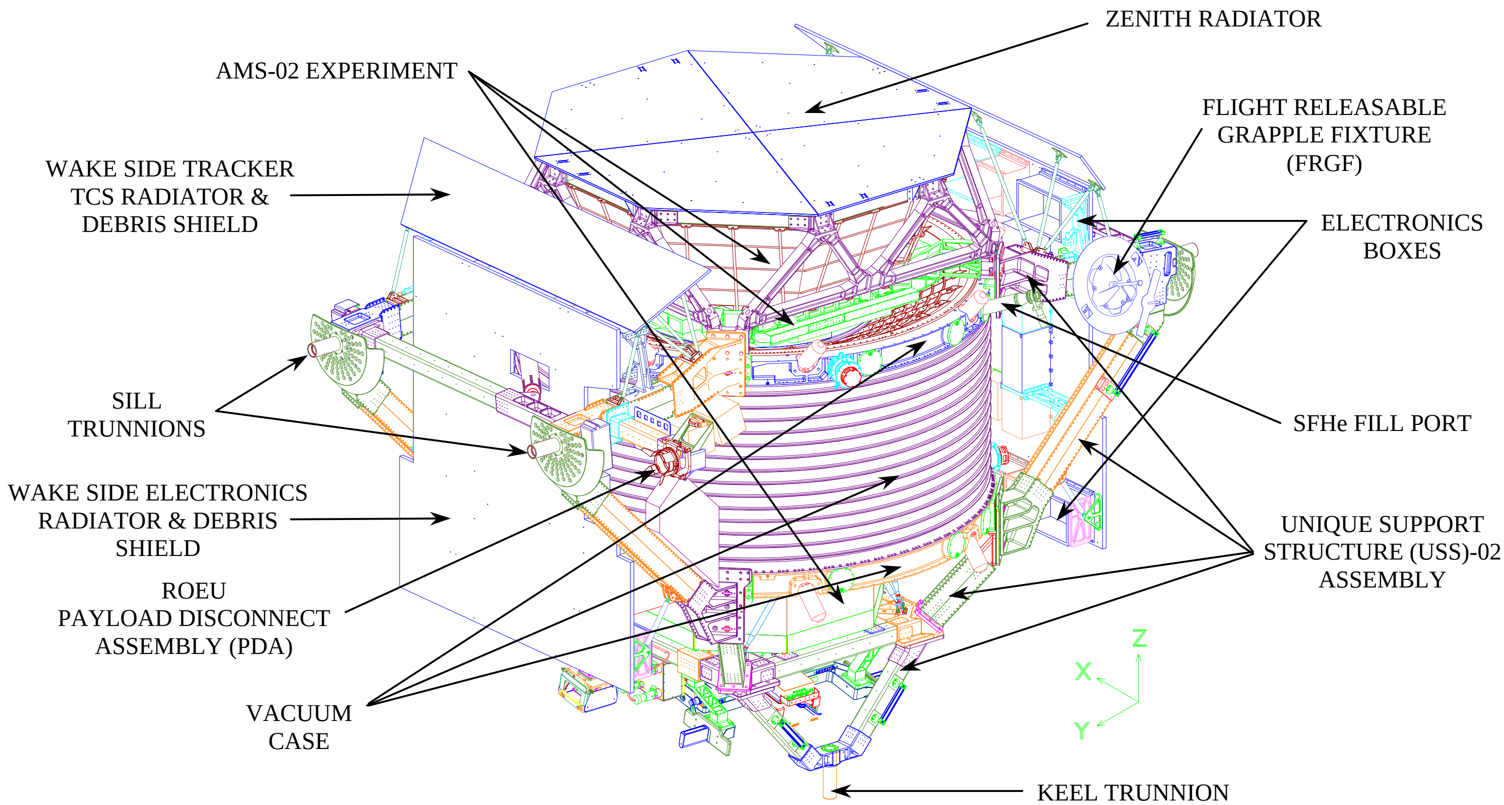

Figure 3.1-2 AMS-02 Payload Assembly (View 1 of 4)

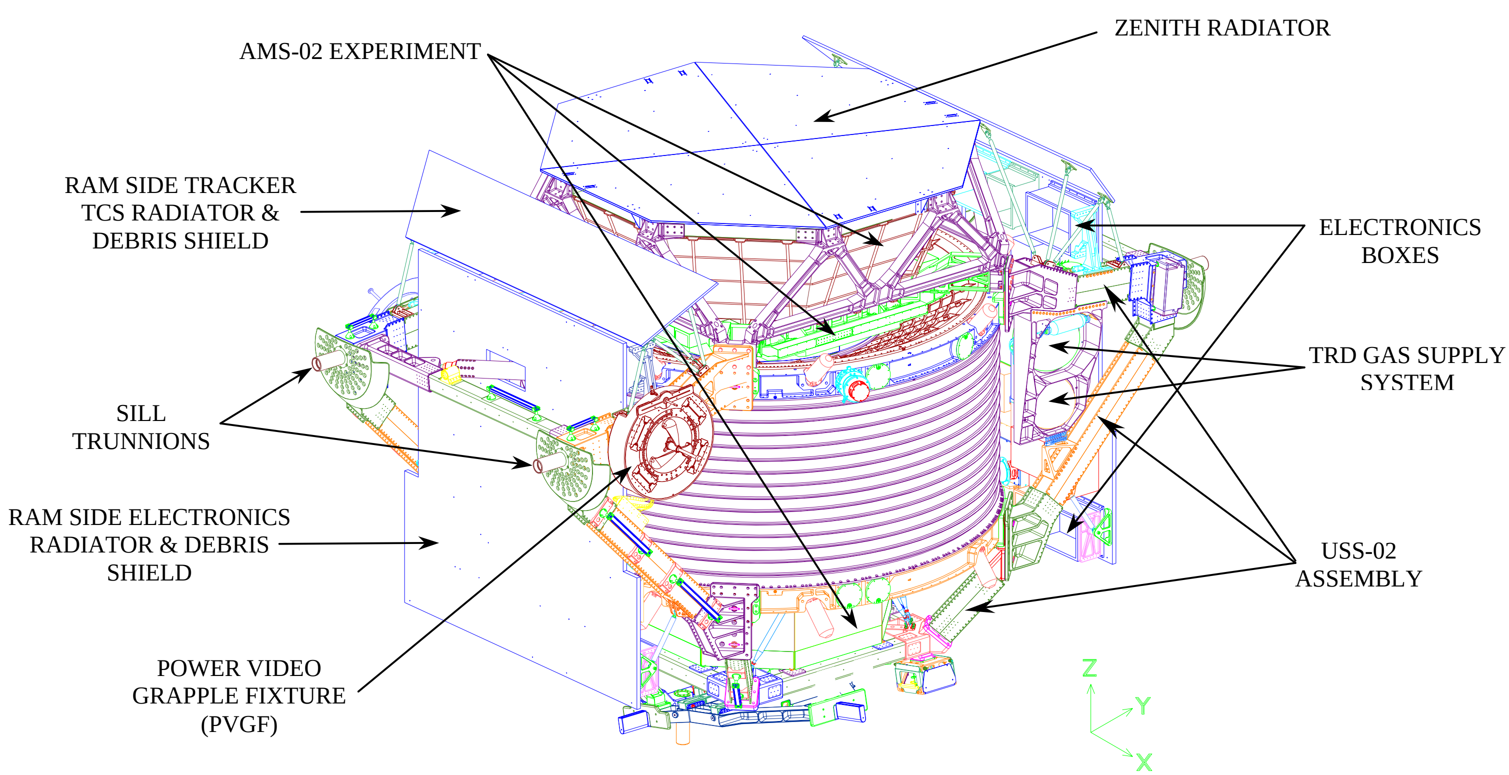

Figure 3.1-3 AMS-02 Payload Assembly (View 2 of 4)

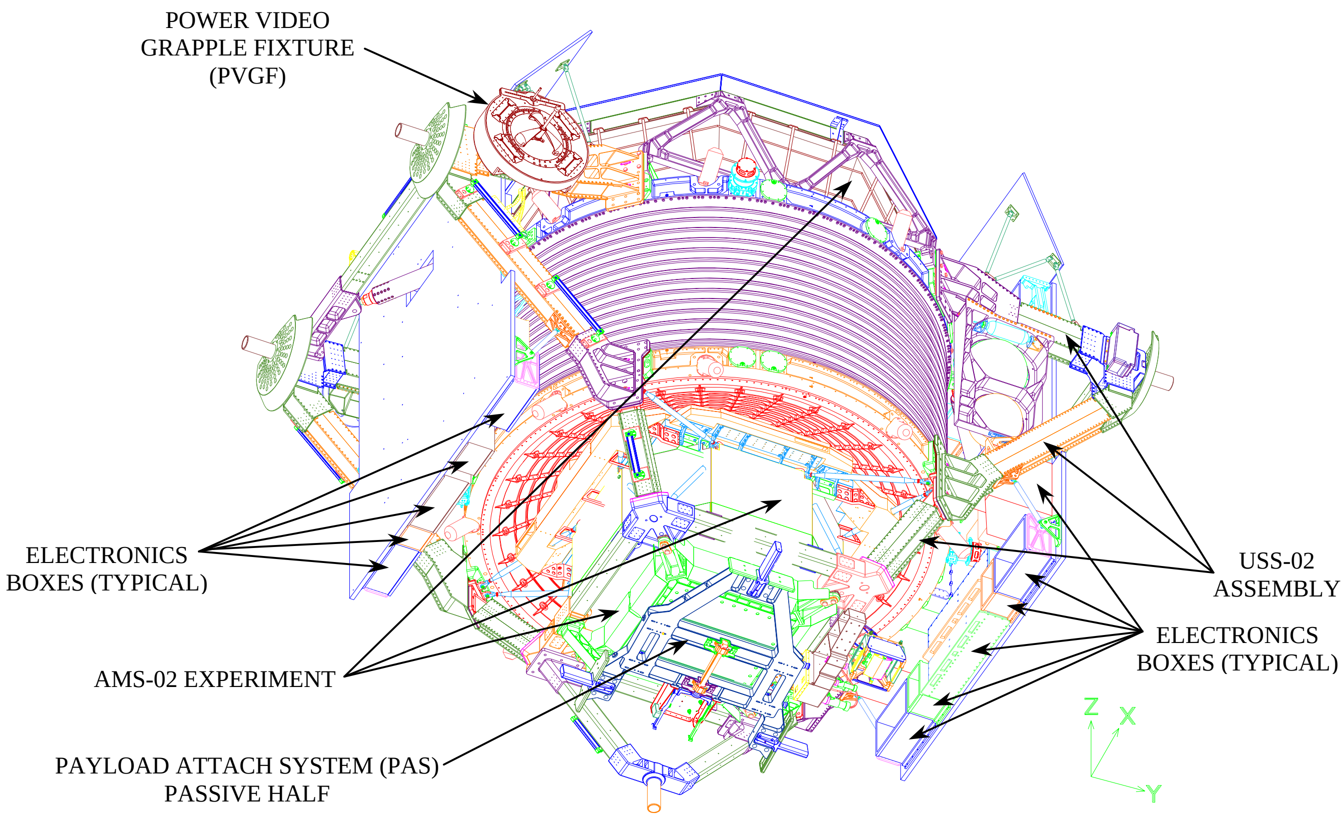

Figure 3.1-4 AMS-02 Payload Assembly (View 3 of 4)

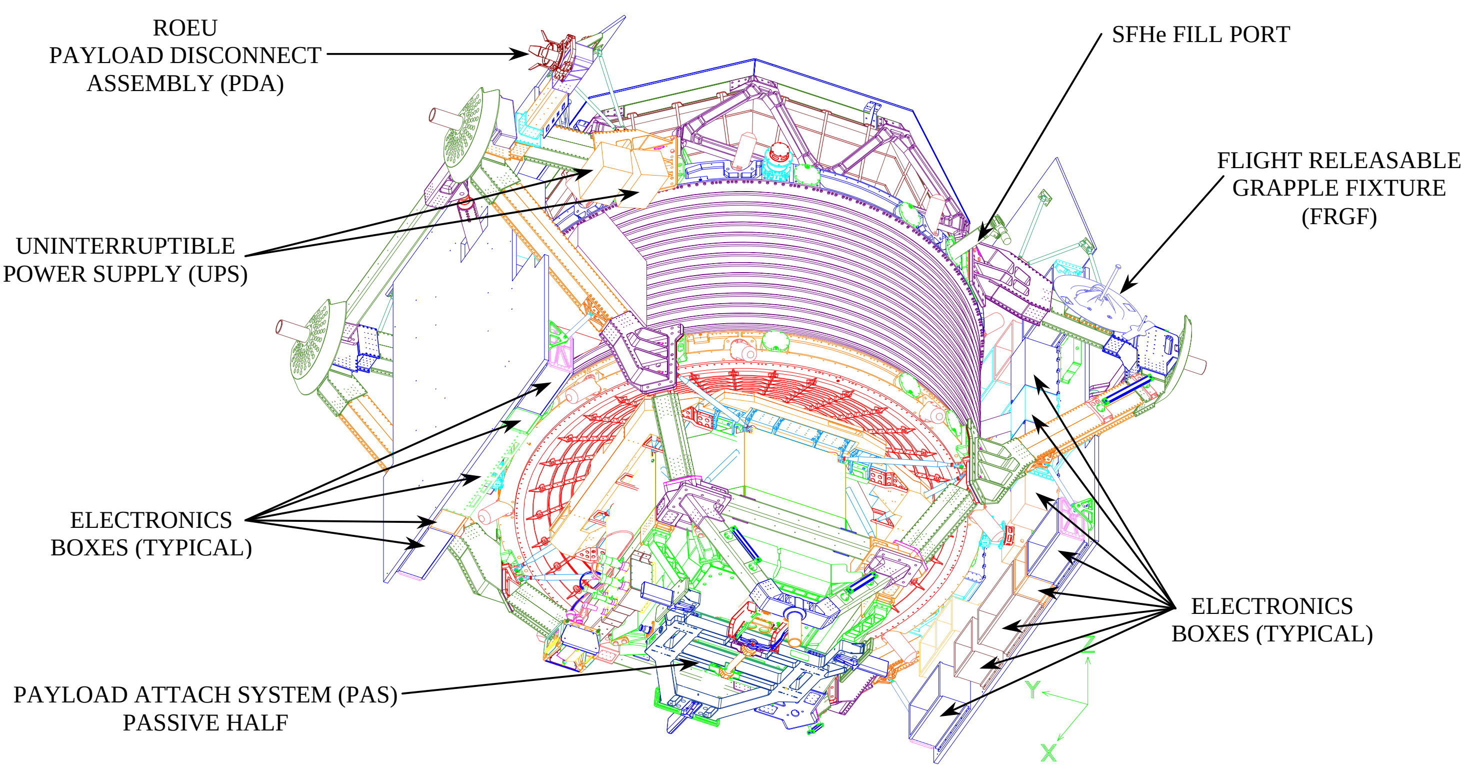

Figure 3.1-5 AMS-02 Payload Assembly (View 4 of 4)

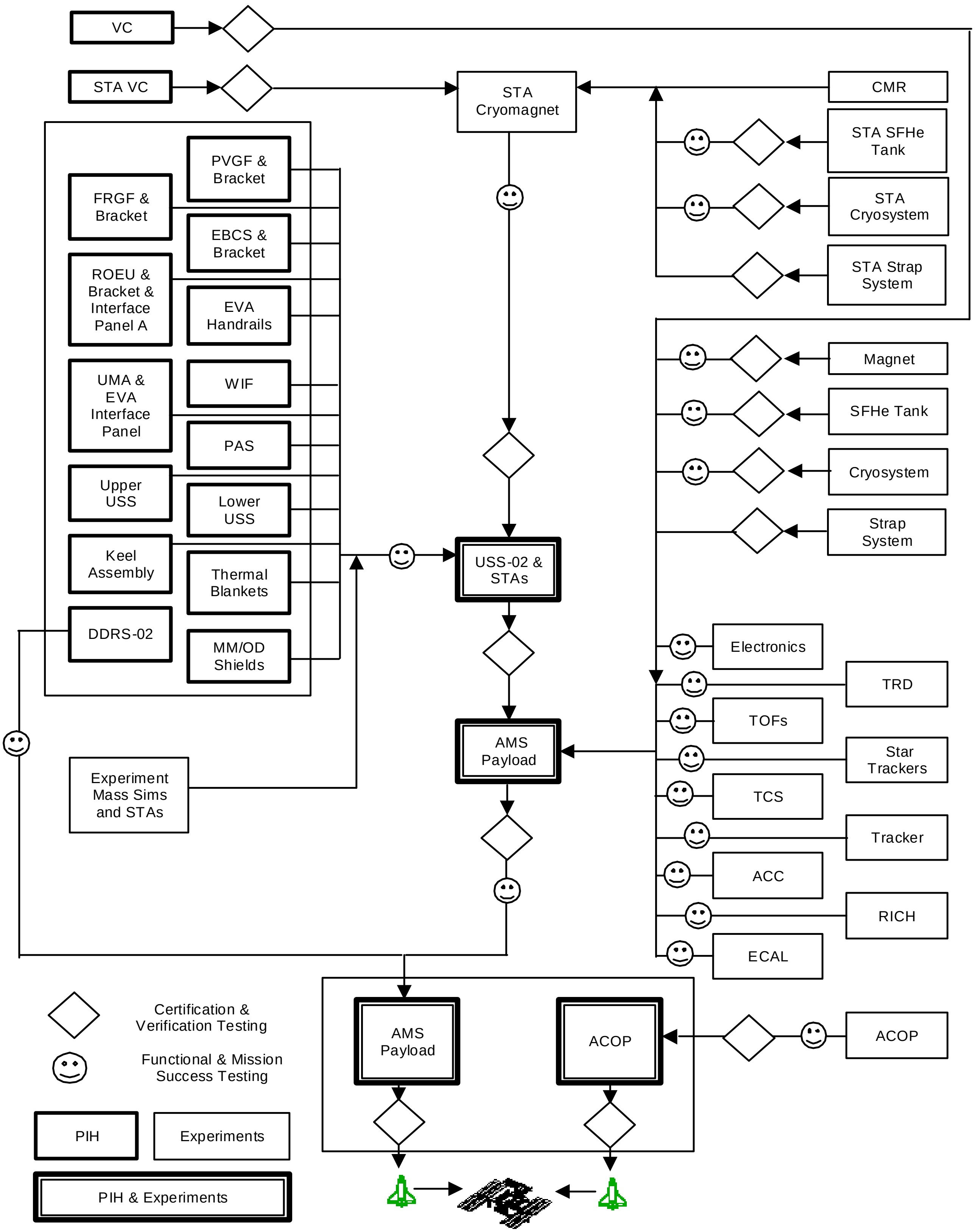

Figure 3.1-6 AMS-02 PIH and Experiment Hardware Flow & Testing Points

3.1.1 NASA Provided Payload Integration Hardware

3.1.1.1 Unique Support Structure-02 (USS-02)

The USS-02 is used to support the AMS-02 Cryomagnet and detectors and to interface the entire AMS-02 Experiment with the Space Shuttle Orbiter and ISS. The Vacuum Case is an integral part of the USS-02. The USS-02 is comprised of the following five subassemblies: (1) Upper USS-02 Assembly, (2) Vacuum Case Assembly, (3) Lower USS-02 Assembly, (4) Keel Assembly, and (5) passive Payload Attach System (PAS) Assembly/Umbilical Mechanism Assembly (UMA). The USS-02 mechanically attaches to the Space Shuttle Orbiter with four longeron trunnions and one keel trunnion. The AMS-02 payload mechanically attaches to the ISS via the PAS Assembly.

Several AMS-02 experiment components are mounted to the USS-02. These components include: the Transition Radiation Detector (TRD), Time of Flight Scintillator Counters (TOF), Ring Imaging Cherenkov Counter (RICH), Electromagnetic Calorimeter (ECAL), TRD gas supply system, Main Crates/Radiators, RICH electronics boxes, ECAL electronics boxes, Cryomagnet Avionics Box (CAB), Cryomag rectifiers, electrical cables and components of the Thermal Control System (TCS).

The Space Shuttle Program (SSP) provided hardware that will be attached to the USS-02 includes a Flight Releasable Grapple Fixture (FRGF) and a Remotely Operated Electrical Umbilical (ROEU) Payload Disconnect Assembly (PDA). The ISS Program provided hardware that will be attached to the USS-02 includes a Power Video Grapple Fixture (PVGF), a passive Umbilical Mechanism Assembly (UMA), an External Berthing Camera System (EBCS), a Worksite Interface Fixture (WIF), Side Mount, and nine (9) EVA Handrails.

3.1.1.2 Vacuum Case (VC)

The Vacuum Case (VC) houses the Superconducting Magnet, Superfluid Helium (SFHe) Tank, Cryocoolers, and a Cryogenic System. The VC provides primary structural support and works in conjunction with the USS-02 (See Figure 3.1.1.1-1). In addition, it serves as a vacuum vessel for the cryosystem and magnet, which is suspended inside the VC by sixteen support straps. The VC is 4.92 ft (1.5 m) high and has an outside diameter of is 9.1 ft (2.77 m). When fully assembled the VC and the enclosed magnet system weigh approximately 6200 lbs (2812 kg). Figure 3.1.1.1-2 illustrates the layout of the magnet and helium tank enclosed in the vacuum case.

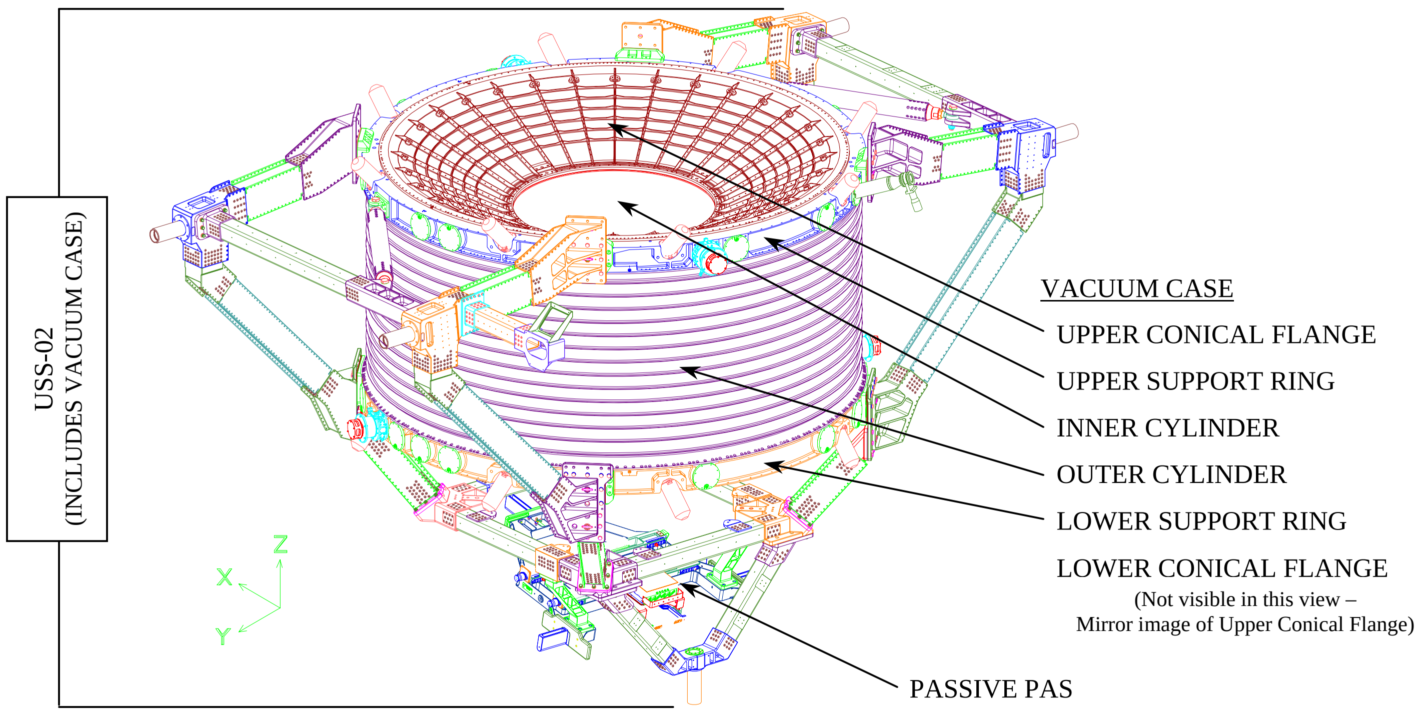

Figure 3.1.1.1-1 Unique Support Structure-02 (USS-02) with Passive Payload Attach System (PAS)

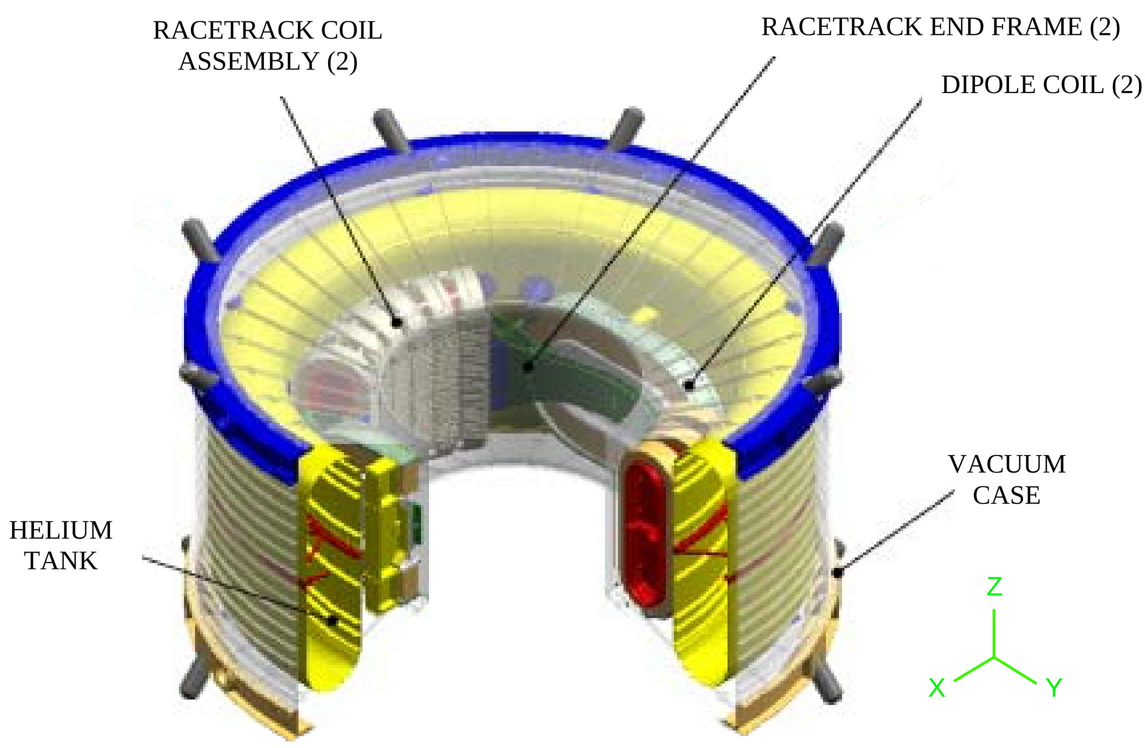

Figure 3.1.1.1-2 Vacuum Case with AMS-02 Superconducting Magnet and SFHe Tank (Rotated 90˚ from USS-02 in Figure 3.1.1.1-1 – Cut-away View)

3.1.1.3 STS & ISS Integration Hardware

3.1.1.3.1 Payload Attach System (PAS)

The passive PAS (Reference Figures 3.1-3 & 3.1-4) provides the mechanical interface between the AMS-02 Payload and the active PAS on the S3 Truss Segment of the ISS. The passive PAS is connected to the bottom of the Lower USS-02, aft of the keel trunnion (as the payload is oriented in the orbiter cargo bay). The PAS hardware on the AMS-02 consists primarily of three guide pins and a capture bar. It is designed to interface with the active PAS and react to the loads from the active PAS Capture Latch Assembly and Guide Vane Assemblies.

3.1.1.3.2 External Berthing Camera System (EBCS)

Interface brackets and integration drawings are required to structurally attach the EBCS, which is ISSP supplied hardware, to the PAS. The EBCS provides visual cues at the Robotics Work Station during AMS-02 berthing operations.

3.1.1.3.3 Power Video Grapple Fixture (PVGF)

Interface brackets and integration drawings are required to structurally attach the PVGF, which is ISSP supplied hardware, to the USS-02. The PVGF is the USS-02 interface to the Space Station Remote Manipulator System (SSRMS) and allows power to be provided to the EBCS and heaters on the payload, as well as providing a path for the video signal back to the Robotics Work Station.

3.1.1.3.4 Flight Releasable Grapple Fixture (FRGF)

Interface brackets and integration drawings are required to structurally attach the FRGF, which is SSP supplied hardware, to the USS-02. The FRGF is the USS-02 interface to the Shuttle Remote Manipulator System (SRMS). No power or video is available through this interface.

3.1.1.3.5 EVA Handrails

Interface brackets may be required to structurally attach the EVA handrails, which is ISSP supplied hardware, to the USS-02. The handrails may also be bolted directly to the USS-02. Integration drawings will be required. The EVA handrails are intended for use should an EVA be required in the area of the AMS-02 installed location.

3.1.1.3.5 Worksite Interface Fixture (WIF)

Interface brackets may be required to structurally attach the WIF, which is ISSP supplied hardware, to the USS-02. Integration drawings will be required.

3.1.1.3.7 Umbilical Mechanism Assembly (UMA) & EVA Interface Panel

Interface brackets are required to structurally attach the UMA, which is ISSP supplied hardware, to the USS-02. The EVA Interface Panel provides structural support for the UMA. It also provides electrical power and C&DH interfaces between the PIH and the AMS-02 payload when the payload is installed on the ISS. ISS power and C&DH are provided to the PIH via the Umbilical Mechanism Assembly (UMA). The EVA Interface Panel is located on the Lower USS-02 in proximity to the UMA passive half as shown in Figure 3.1.1.5-1. The panel provides ten connectors for the following: two LRDL interfaces (Y and Z, each with two busses A and B), two 120 Vdc ISS power inputs (A and B), four 120 Vdc bus outputs (A and B to the PDS and to the EBCS heaters) and two HRDL interfaces (A and B, each with transmit and receive).

3.1.1.3.8 Remotely Operated Electrical Umbilical (ROEU) & Interface Panel A

Interface brackets and integration drawings are required to structurally attach the ROEU, which is SSP supplied hardware, to the USS-02. Interface Panel A provides the electrical power and C&DH interfaces between the PIH and the AMS-02 payload when the payload is in the Shuttle payload bay. Power and C&DH are provided to the PIH via the ROEU (Orbiter side) through the PDA (PIH side). Interface Panel A is located on the Upper USS-02 adjacent to the PDA as shown in Figure 3.1.1.5-1. The panel provides six connectors for the following: GSE 120 Vdc power from the T-0 umbilical (for ground processing), 28 Vdc GSE power for operating the vent pump from the T-0 umbilical (for ground processing), 124 Vdc power from the Assembly Power Converter Units (APCUs) in the Shuttle, 28 Vdc ascent power, and two for Command and Data Handling (CD&H): one for Back-up Flight System (BFS) command and one for the RS422 and 1553 connections.

Interface cables will be provided to connect the power and C&DH feeds at the interface panels to the AMS-02 experiment. The data and interface electronics for the experiment will be housed in electronics crates on the outside of the USS-02 (see figures 3.1-2 and 3.1-4). The data and interface electronics will enable the connection of the experiment components to the ISS and STS data systems. The Power Distribution System (PDS) is mounted on the USS-02 near the passive UMA. The purpose of the PDS is to provide the power interface circuitry between the AMS-02 and the ISS and STS. The electronics crates and PDS are not a part of the PIH.

3.1.1.3.9 Digital Data Recording System (DDRS-02)

During the Shuttle portion of the mission, the AMS-02 will utilize an SSP-provided Payload General Support Computer (PGSC) with expansion chassis, replaceable hard-drives, internal Small Computer Systems Interface-II (SCSI-II), and a EA/LMSO supplied DIGI-board interface card to record AMS-02 High Rate data. The DDRS-02 will record data continuously during the AMS-02 operation on the Shuttle.

3.1.1.4 Micrometeoroid and Orbital Debris (MM/OD) Shielding

The MM/OD shielding provides protection for the pressure systems on the AMS-02 experiment including the TRD Gas System, TCS, and Warm Helium Supply. The shielding will be made from various components in different locations depending on the required shield thickness, shape and size. Much of the shielding will be thin aluminum plates, Nextel or Kevlar, with small standoffs from other AMS-02 experiment hardware.

In addition, the cryomagnet system on AMS-02 is considered a pressure system and is critical to mission success. Although a specific MM/OD shield will not be built, the Vacuum Case, multi-layer insulation (MLI), and Vapor Cooled Shields will be used to protect the pressure system from damage. The JSC Hypervelocity Impact Technology Facility has been and will continue to perform all of the analysis and testing for the M/OD requirements. Testing has been performed to ensure that the correct ballistic limit equations are used in the analysis.

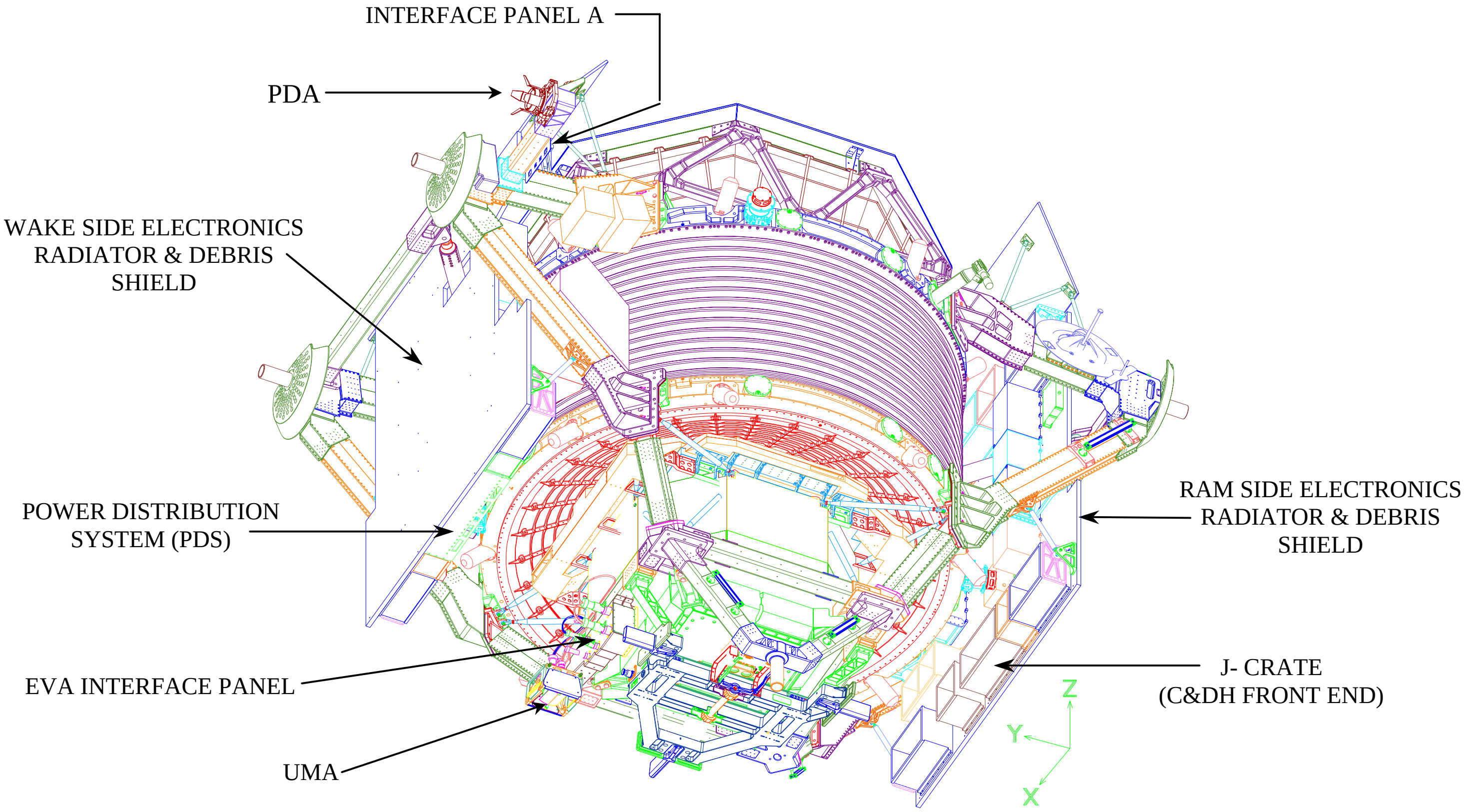

Figure 3.1.1.5-1 Location of Interface Panels and Front End Electronics Boxes

3.1.1.10 Thermal Blankets

Thermal blankets will be used in conjunction with the thermal control system (TCS) to protect AMS-02 components from temperature extremes. Standard NASA multi-layer insulation (MLI) will be used for fabrication of the thermal blankets. MLI will also be used in the cryogenic insulation system inside the Vacuum Case. Of the numerous thermal blankets defined in the the TCS ICD, EA/LMSO is responsible for the development and fabrication of four blankets on the Vacuum Case, one on the bottom of the ECAL just above the PAS, and one on the Uninterruptable Power Supply (UPS).

3.1.2 AMS-02 Interface Description

The Unique Support Structure-02 (USS-02) is used to support the AMS-02 Cryomagnet and detectors and to interface the entire AMS-02 Experiment with the Space Shuttle Orbiter and ISS. The USS-02 is comprised of the following five subassemblies: (1) Upper USS-02 Assembly, (2) Vacuum Case Assembly, (3) Lower USS-02 Assembly, (4) Keel Assembly, and (5) passive Payload Attach System (PAS) [including the Umbilical Mechanism Assembly (UMA)] (See Figure 3.1.2-1).

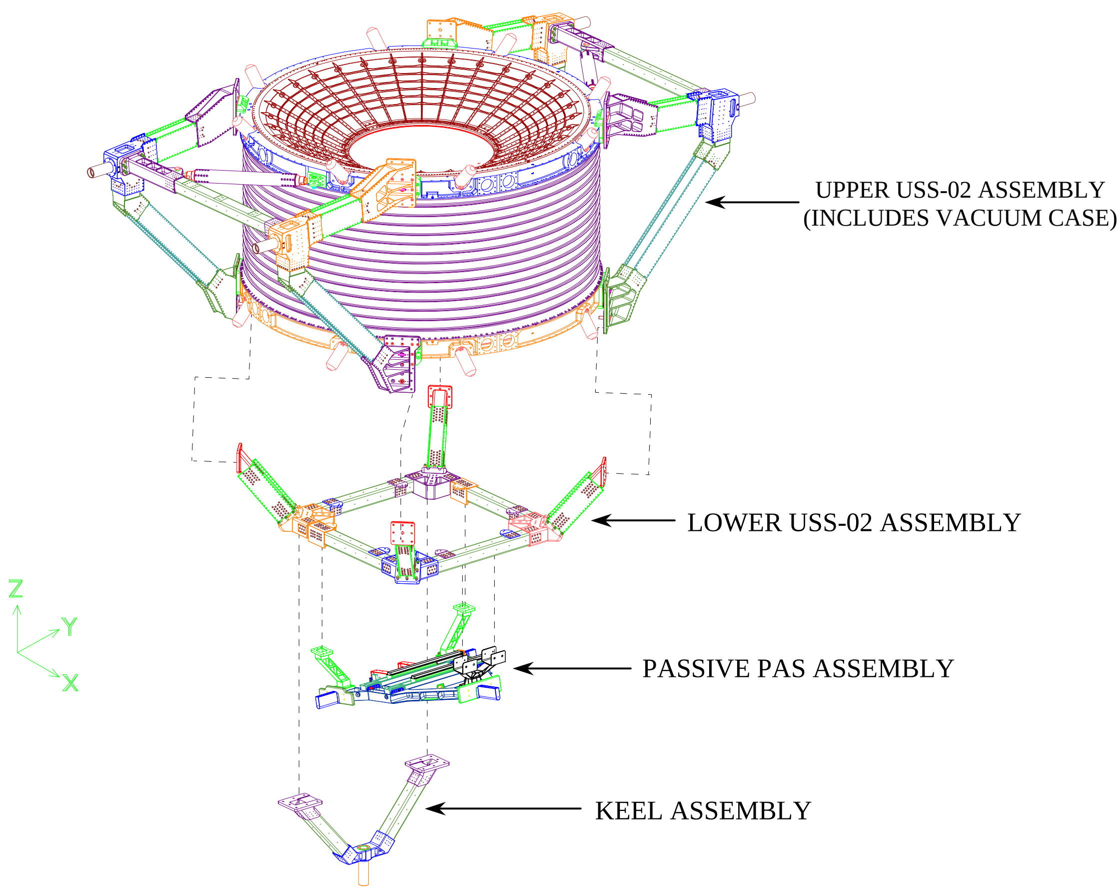

Figure 3.1.2-1 USS-02 Exploded View

3.1.2.1 STS Interfaces

The USS-02 attaches to the Space Shuttle Orbiter in the payload bay with four longeron trunnions and one keel trunnion. SSP provided hardware that will be attached to the USS-02 includes a FRGF and a ROEU PDA (See Figure 3.1.2.1-1). Figure 3.1.2.1-2 shows a cross-section of the AMS-02 Payload in the cargo bay of the Orbiter.

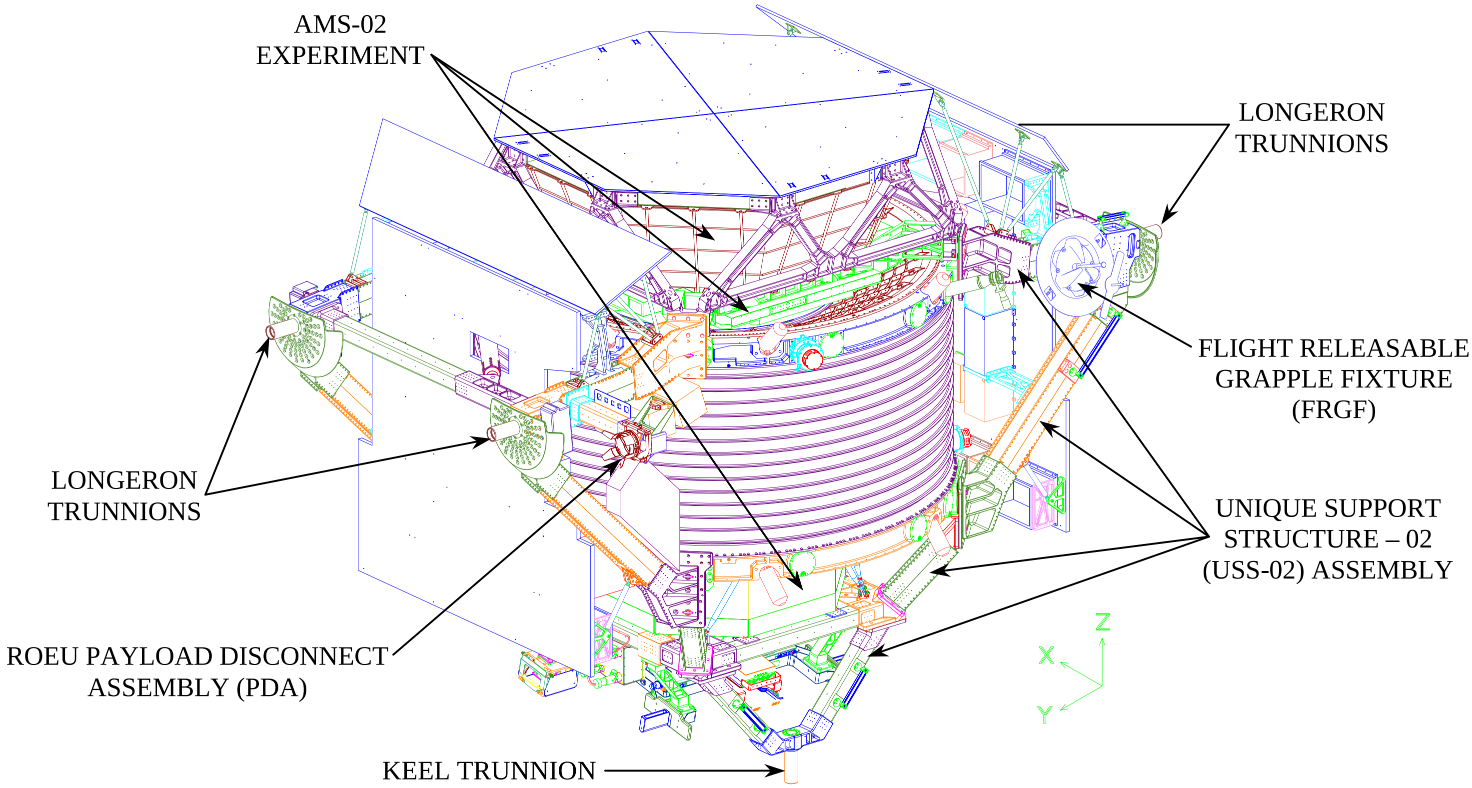

Figure 3.1.2.1-1 AMS-02 Payload STS Interfaces

Cabling will be provided to interface the DDRS-02 to a Payload Data Interface Panel (PDIP) in the Shuttle Aft Flight Deck to interface with the AMS-02 via a bi-directional RS-422 connection. (See Figure 3.1.2.1-3 for a schematic of the STS avionics interfaces.) This data will be recorded continuously during the AMS-02 operation on the Shuttle. A separate RS-422 connection from the AMS-02 via the PDIP, will allow for downlink of this data via the Ku-Band, as scheduling permits.

During ground operations on the Shuttle, the cabling for the DDRS-02 will be looped-back to the PDIP to allow for transmission of the data through the T-0 umbilical.

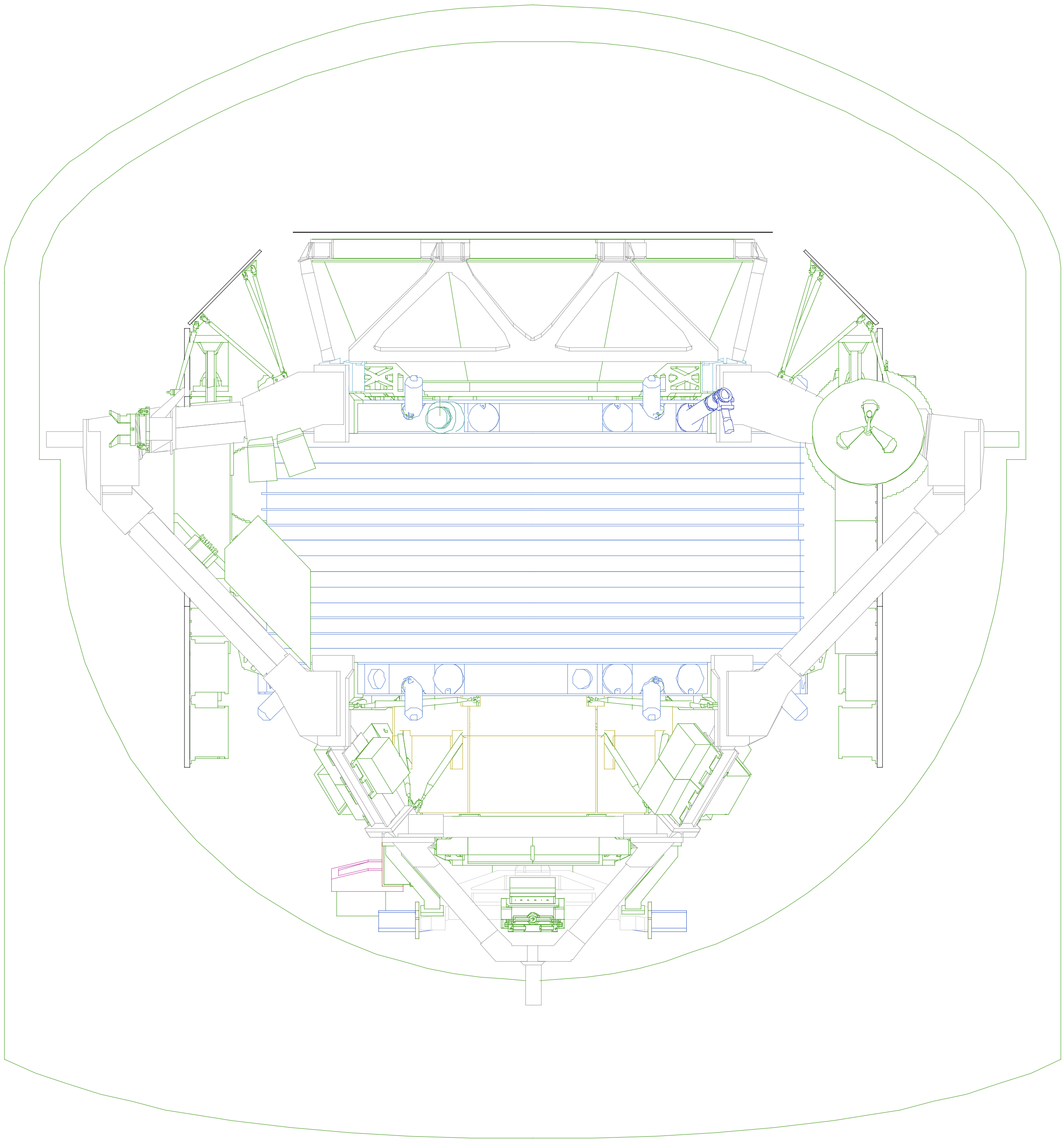

Figure 3.1.2.1-2 The AMS-02 in the Shuttle Payload Bay (From the Forward Bulkhead, Looking Aft)

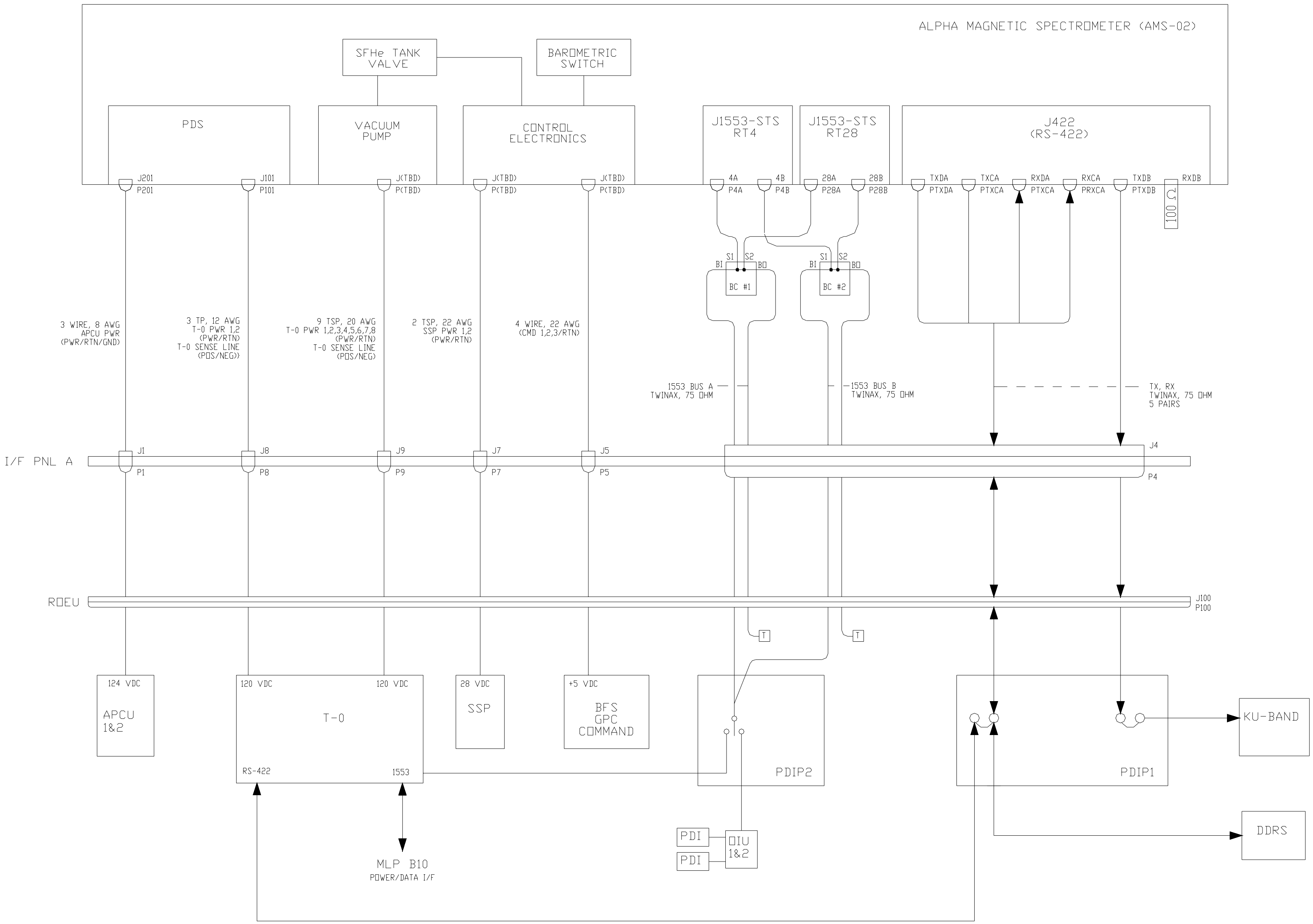

Figure 3.1.2.1-3   AMS-02/Pad and STS Avionics Interfaces Diagram

3.1.2.2 ISS Interfaces

The AMS-02 payload attaches to the ISS via the PAS. The PAS hardware on the AMS-02 is the passive half and consists of the PAS platform, three guide vanes with scuff plates, and an EVA releasable capture bar. The ISS Program provided hardware that will be attached to the USS-02 includes a PVGF and a passive UMA. An ISS Program-provided EBCS will be mounted on the PAS. (See Figure 3.1.2.2-1)

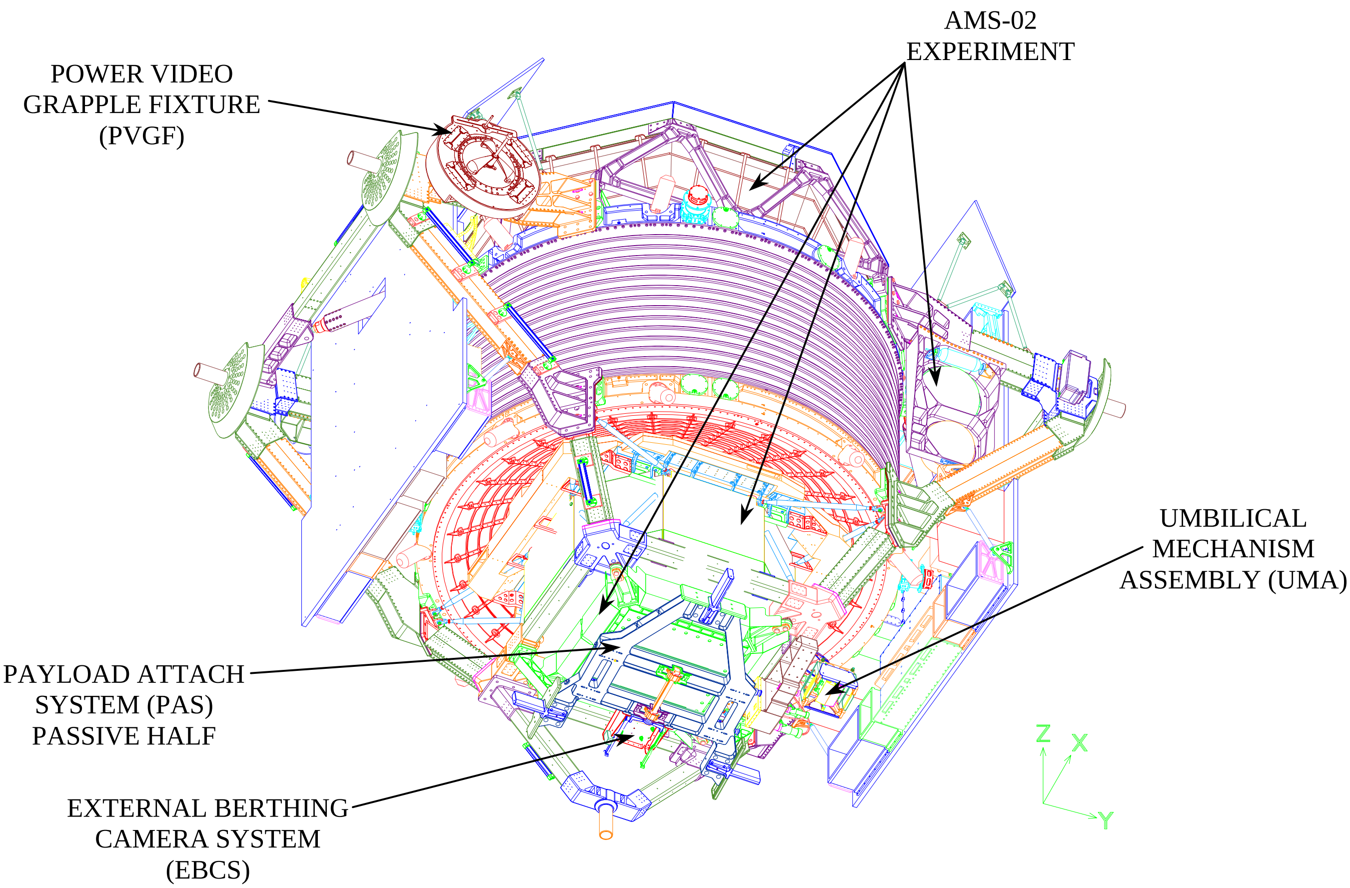

Figure 3.1.2.2-1 AMS-02 Payload ISS Interfaces

The passive PAS is being designed, built and integrated with the payload by EA/LMSO. The passive PAS is the AMS-02 interface to the active PAS on the S3 Integrated Truss Segment (ITS) of ISS. It is designed to sit in the active PAS and react to the loads from the active PAS Capture Latch Assembly. (See Figure 3.1.2.2-2) The center axis of the AMS-02 Payload is canted 12 degrees inboard to provide maximum clearance for the envelope of the adjoining payload and reduce infringement on the AMS field-of-view by the ISS photovoltaic arrays.

The data and interface electronics for the AMS-02 experiment will be housed in electronics crates on the outside of the Unique Support Structure-02 (USS-02). The data and interface electronics will enable the connection of the AMS-02 experiment to the ISS and STS data systems.

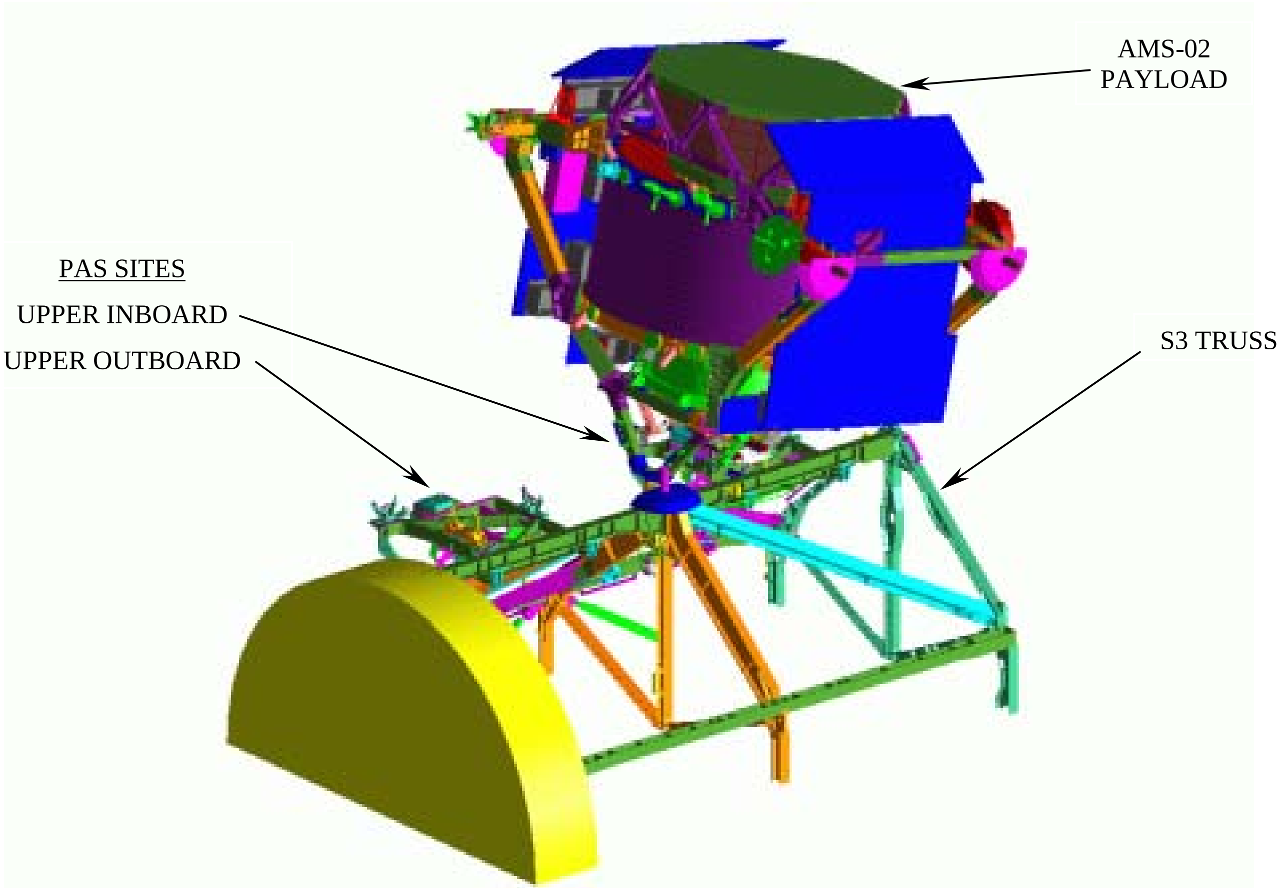

Figure 3.1.2.2-2 AMS-02 Payload Attached to the Active PAS on the S3 – Z Inboard PAS Site

The AMS-02 will be equipped with an ISS Program-provided passive UMA that will be mated to the ISS active UMA when the AMS is installed on the ISS. EA/LMSO-provided power and data cables will run from the back side of an EVA accessible interface panel to the Power Distribution System (PDS) box (power for experiment) and J-Crate (data) on the AMS, and to the EBCS (power for heaters). (See Figure 3.1.2.2-3) Also, EA/LMSO will add the appropriate EVA connectors to the cable bundle supplied with the passive UMA for attachment to the front of the EVA Interface Panel (See Figure 3.1.2.2-3). This will provide the interfacing (via the UMA) between the AMS-02 power/data interface electronics and the ISS power/data distribution system, including pathways to the AMS Crew Operations Post (ACOP) and the ISS Ku Band and S-Band System.

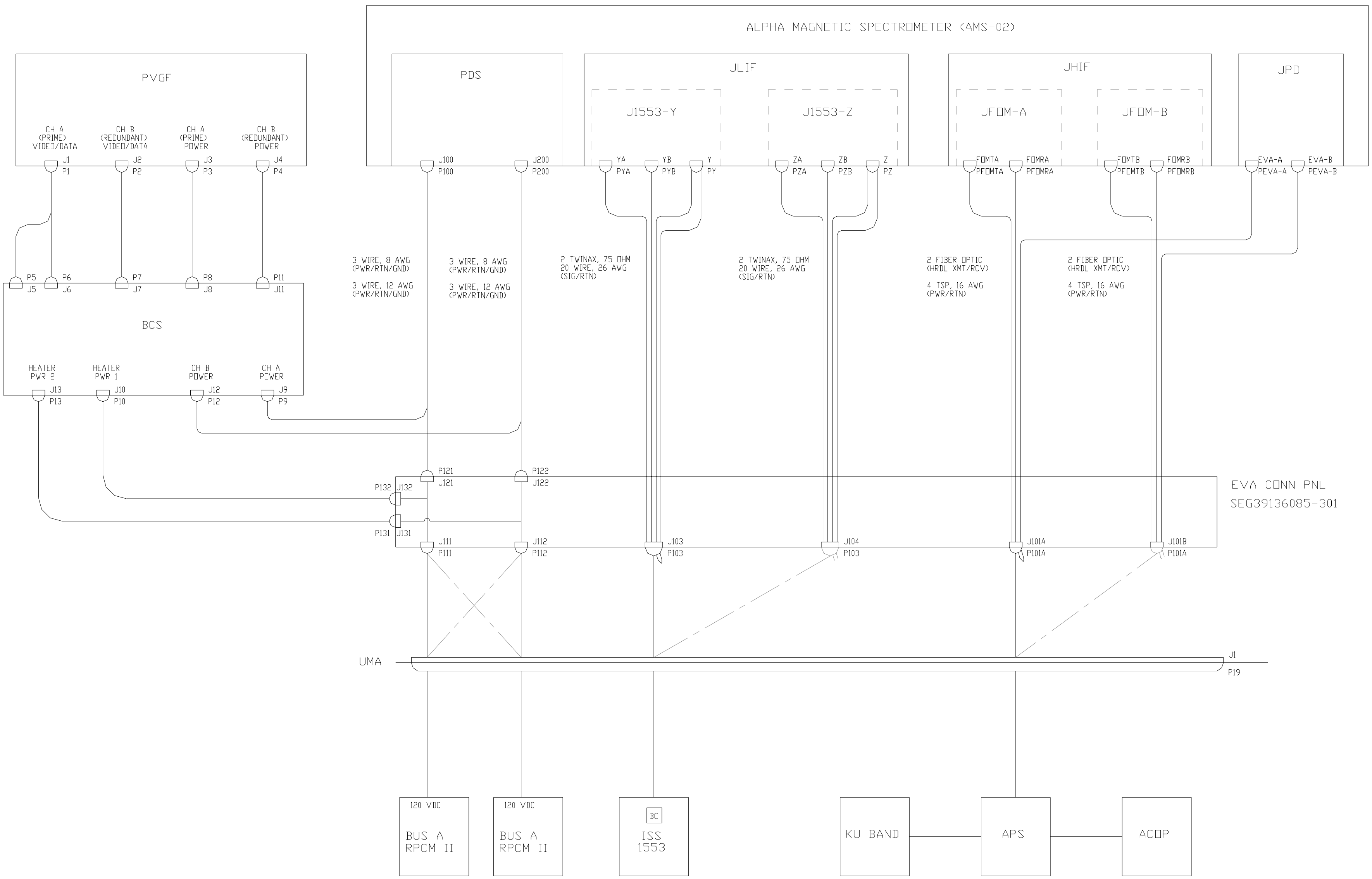

Figure 3.1.2.2-3 AMS-02/ISS Avionics Interconnect Diagram

Some AMS-02 electrical cables will be required in the pressurized module to provide data interfacing between the ACOP and the AMS-02 payload located on the S3 Truss. The ACOP will house the hard drive recorder and other data interfaces for the AMS-02. Electrical cables will also be required to provide power to the ACOP from the EXpedite the PRocessing of Experiments to Space Station (EXPRESS) Rack. The ACOP is not a part of the PIH, as it will be provided by the AMS Experiment Team.

The AMS-02 PDS is mounted on the USS-02. The purpose of the PDS is to provide the power interface circuitry between the AMS-02 and the ISS and STS. The PDS receives 120 Vdc power from either or both of the ISS power buses or 124 Vdc from the STS APCUs. It converts this voltage to 28 Vdc for distribution to the various AMS-02 subsystems, assuring compliance to the power requirements of SSP 57003 and NSTS-21000-IDD-ISS. The PDS also distributes the 120 Vdc (or 124 Vdc) power to the AMS-02 Cryomagnet Avionics Box (CAB), the Cryocooler Electronics Box (CCEB), and heaters. The PDS is not a part of the PIH, as it will be provided by the AMS Experiment Team.

3.2 CHARACTERISTICS

3.2.1 Functional Performance

The AMS-02 PIH will perform the following functions:

- The PIH will serve as the structure for mounting the detectors and components of the AMS Experiment including the Cryomagnet.
- The PIH will provide the mechanical and electrical interfaces between the AMS Experiment and the Orbiter for launch, transfer to orbit, return from orbit, and landing.
- The PIH will provide a method for recording data from payload during launch, transfer to orbit, return from orbit, and landing, and transferring the data to the ground.
- The PIH will provide the mechanical and electrical interfaces between the AMS Experiment and the ISS for the duration of the on-orbit life of the experiment.
- The PIH will provide interfaces to the SRMS and the SSRMS via the Program-provided FRGF and PVGF.
- The PIH will provide protection from meteoroids and orbital debris for safety-critical components of the AMS-02 payload.
- The PIH will provide thermal insulation for safety-critical components of the AMS-02 payload.

3.2.1.1 Experiment Interfaces Functional Requirements

The PIH will provide interfaces with the experiment hardware per JSC 29095, Part II, Alpha Magnetic Spectrometer - 02 (AMS-02) Experiment/Payload Integration Hardware (PIH) Interfaces and JSC 29202, AMS-02 Experiment/Vacuum Case PIH Interfaces. Reference Figure 3.2.1.1 for the AMS-02 Payload experiment configuration. Structural verification requirements for the AMS-02 Payload are documented in JSC 28792, Alpha Magnetic Spectrometer – 02 Structural Verification Plan for the Space Transportation System and the International Space Station.

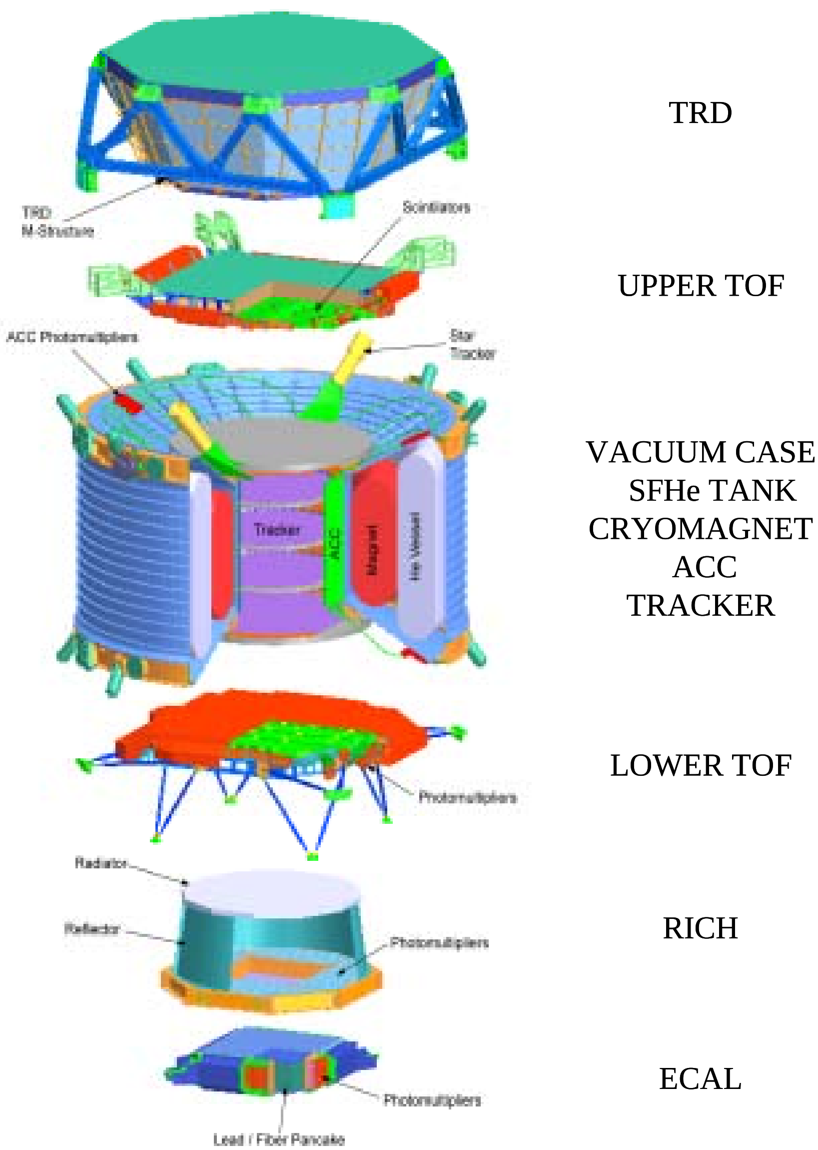

Figure 3.2.1.1 AMS-02 Experiment Configuration

3.2.1.1.1 Transition Radiation Detector (TRD) and Upper Time of Flight (TOF)

The PIH shall provide structural interfaces to locate the TRD and Upper TOF at the top of the AMS-02 experiment stack so that the TRD/Upper TOF is centered above the Cryomagnet and the top surface of the TRD is 57.48 inches above the AMS-02 origin X-Y plane. [NOTE: Upper TOF is attached to the TRD at the TRD Corner Brackets. (Reference JSC 29095, paragraph 4.1.6.1-D-1)]

3.2.1.1.2 Cryomagnet System (Includes Cryomagnet, SFHe Tank, and Support System)

A. The PIH/Vacuum Case shall provide structural interfaces to locate the AMS-02 Cryomagnet System within the Vacuum Case.

B. The PIH/Vacuum Case shall provide feed-thru ports for cabling to the Cryomagnet system.

C. The PIH/Vacuum Case shall prevent air from contacting the surfaces of the SFHe Tank and the Cryomagnet system by maintaining a vacuum of at least 1×10^{-6} torr.

D. The PIH/Vacuum Case shall provide interfaces for five cryocoolers used to help maintain the cryogenic temperature of the SFHe in the tank.

E. The PIH/Vacuum Case shall provide access ports at the five cryocooler locations.

F. The PIH/Vacuum Case shall provide an interface for the SFHe Tank fill port.

G. The PIH/Vacuum Case shall provide an interface for an emergency vent for the SFHe Tank.

H. The PIH/Vacuum Case shall provide interfaces for an emergency pressure relief system for the Vacuum Case.

I. The PIH/Vacuum Case shall provide feed-thru ports for the plumbing of gas lines to the gas-operated valves for the SFHe.

J. The PIH shall provide structural interfaces for the Cryomagnet Avionics Box (CAB).

K. The PIH shall provide structural interfaces for the Uninterruptible Power Supply (UPS).

L. The PIH shall provide structural interfaces for the Cryomagnet Dump Diodes (CDD)

3.2.1.1.3 Anti-Coincidence Counter (ACC)

The PIH shall provide structural interfaces for mounting the ACC within the inner cylinder of the Vacuum Case.

3.2.1.1.4 Tracker

The PIH shall provide structural interfaces for mounting the Tracker within the inner cylinder of the Vacuum Case.

3.2.1.1.5 Lower TOF

The PIH shall provide structural interfaces to locate the Lower TOF within the Lower Conical Flange of the AMS-02 Vacuum Case directly below the Tracker and centered below the Cryomagnet.

3.2.1.1.6 Ring Imaging Cherenkov Counter (RICH)

The PIH shall provide structural interfaces to locate the RICH directly below the Lower TOF and centered below the Cryomagnet.

3.2.1.1.7 Electromagnetic Calorimeter (ECAL)

The PIH shall provide structural interfaces to locate the ECAL directly below the RICH and centered below the Cryomagnet.

3.2.1.1.8 TRD Gas Supply System

The PIH shall provide structural interfaces for the TRD Gas Supply System.

3.2.1.1.9 Integrated Radiator, Debris Shield and Electronic Box Assemblies

The PIH shall provide structural interfaces for the Ram and Wake Integrated Radiator, Debris Shield and Electronic Box Assemblies.

3.2.1.1.10 AMS Experiment Plumbing, Cabling, and Other Miscellaneous Hardware

The PIH/Vacuum Case shall provide generic interfaces for securing gas and fluid lines, electrical cables, and other miscellaneous experiment hardware.

3.2.1.2 STS Interfaces Functional Requirements

The PIH will provide the mechanical and electrical interfaces between the AMS Experiment and the Orbiter for launch, transfer to orbit, return from orbit, and landing. All interfaces with the Orbiter will be formally controlled in NSTS/AMS ICD-A-(TBD-1), Shuttle Orbiter/AMS-02 Cargo Element Interfaces, a Space Shuttle Program (SSP) published ICD. Per the Generic Schedule Template, the ICD will be baselined at L-15 months.

3.2.1.2.1 STS Structural Interfaces

A. The PIH shall provide structural interfaces with the Shuttle Orbiter (in the Cargo Bay) via four sill trunnions and one keel trunnion.

B. The sill and keel trunnions shall meet the requirements of NSTS-21000-IDD-ISS, Section 3.3.1.

3.2.1.2.2 STS Power and Data Interfaces

A. The PIH power and data interfaces shall be through the Remotely Operated Electrical Umbilical/Payload Disconnect Assembly (ROEU/PDA) on the Orbiter side.

B. The PIH shall provide pass-through 124 Vdc power up to 2 kilowatts (kW) from the APCUs on the Orbiter to the PDS via the ROEU/PDA and Interface Panel A.

C. The PIH shall provide pass-through GSE 120 Vdc power up to 2 kW from the T-0 umbilical to the PDS via the ROEU/PDA and Interface Panel A.

D. The PIH shall provide pass-through GSE TBD Vdc power at 200 watts (W) from the T-0 umbilical to the Vent Pump via the ROEU/PDA and Interface Panel A.

E. The PIH shall provide pass-through momentary 28 Vdc ascent power at up to 4 amps (A) from a Standard Switch Panel (SSP) in the Orbiter Aft Flight Deck (AFD) to the AMS-02 Vent Valve Electronics via the ROEU/PDA and Interface Panel A.

F. The PIH shall provide pass-through command and data handling cables from the Orbiter to the AMS-02 front-end data acquisition box (J-Crate) via the ROEU/PDA and Interface Panel A. Two sets of cables (including bus couplers) shall be used for 1553 communications at 20 kilobytes per second (kbps) to two separate Remote-Terminals (RTs) on AMS-02, and one set of cables shall be used for a redundant set of high rate data at 2 Megabytes per second (Mbps) via RS-422 connection.

G. The PIH shall provide pass-through command and data handling cabling from the Orbiter Backup Flight System (BFS) General Purpose Computer (GPC) to the AMS-02 Vent Valve Electronics via the ROEU/PDA and Interface Panel A (Discreet Output, Low 5 Vdc).

H. The PIH shall provide a digital data recording system-02 (DDRS-02) for recording high rate data (2 Mbps avg) from the AMS-02 payload on-orbit operations. The DDRS-02 shall consist of an Orbiter Payload General Support Computer (PGSC) and Payload provided interface boards, cabling, and software.

I. The PIH shall provide cables to route one channel of the RS-422 data (2 Mbps) to the T-0 during ground operations and another cable to route the same data to the DDRS-02 via the Payload Data Interface Panel (PDIP) on the Orbiter mid-deck

J. The PIH shall provide cabling to route another channel of the RS-422 data (2 Mbps) to the Ku-Band at the PDIP.

3.2.1.3 ISS Interfaces Functional Requirements

The PIH will provide the mechanical and electrical interfaces between the AMS Experiment and the ISS for the planned on-orbit operational mission life of 3 years with a +2 year contingency. All interfaces with the ISS will be formally controlled by SSP 57213, Alpha Magnetic Spectrometer (AMS–02) Attached Payload Hardware Interface Control Document.

3.2.1.3.1 ISS Structural Interfaces

A. The PIH shall provide structural interfaces with the ISS upper inboard Payload Attach Site on the Starboard 3 (S3) Integrated Truss Segment (ITS) via the active Payload Attach System (PAS) on the truss and the passive PAS on AMS-02.

B. The PIH/PAS shall permit/facilitate the robotic berthing of the AMS-02 Payload.

C. The PIH/PAS shall provide an EVA flight releasable capture bar to facilitate payload unberthing in a contingency situation.

3.2.1.3.2 ISS Power and Data Interfaces

A. The PIH power and data interfaces shall be through the Umbilical Mechanism Assembly (UMA) active half on the ISS side and the UMA passive half on the AMS-02 side.

B. The PIH shall provide two (Power A, Power B) pass-through 120 Vdc power feeds (2.4 kW continuous, 2.8 kW max) from the ISS to the PDS via the UMA and the EVA Interface Panel.

C. The PIH shall provide two (Bus A, Bus B) pass-through MIL-STD-1553 command and data handling buses (20 kbps) from the ISS to the AMS-02 front-end data acquisition box (J-Crate) via the UMA and the EVA Interface Panel.

D. The PIH shall provide a pass-through fiber optic High Rate Data Link (HRDL) interface (125 Mbaud, 40 Mbps peak, 2 Mbps) from the ISS to the AMS-02 front-end data acquisition box (J-Crate) via the UMA and the EVA Interface Panel.

E. The PIH shall provide a secondary fiber optic HRDL interface (125 Mbaud, 40 Mbps peak, 2 Mbps orbit avg) from the EVA Interface Panel to the AMS-02 front-end data acquisition box (J-Crate). This will only be used for contingency purposes.

3.2.1.4 Remote Manipulator Systems (RMS) Interfaces Functional Requirements

The AMS-02 is a robotic-deployable payload, requiring scheduled Extravehicular Robotics (EVR) operations for payload deployment and installation. Payload design incorporates two grapple fixtures, a FRGF and a PVGF. An ISSP-provided EBCS avionics package will be installed on the passive PAS for aligning the payload when berthing the AMS-02 to its designated ITS S3 PAS site utilizing the SSRMS.

3.2.1.4.1 Shuttle Remote Manipulator System (SRMS) Interfaces Functional Requirements

A Space Shuttle Program (SSP) provided FRGF serves as the interface between the AMS-02 Payload and the SRMS. The FRGF shall be mounted to the PIH to facilitate grappling of the payload in the Orbiter payload bay with the SRMS, removing it from its berthed position, and extending it to the robotic hand-off position.

3.2.1.4.2 Space Station Remote Manipulator System (SSRMS) Interfaces Functional Requirements

An International Space Station Program (ISSP) provided PVGF serves as the mechanical interface between the AMS-02 Payload and the SSRMS for berthing the payload to the ITS S3 PAS site. The SSRMS and PVGF also provide interfaces for electrical power, video, and command and data telemetry between the ISS and the payload. The SSRMS and PVGF provide redundant circuits for all power, video, command and data handling functions. (NOTE: AMS does not use the command and data telemetry capabilities of the SSRMS.)

A. The PVGF shall be mounted on the PIH to facilitate robotic hand-off of the payload from the SRMS and subsequent berthing on the S3 Truss by the SSRMS.

B. The PIH shall provide cabling for redundant (Bus 1 & Bus 2) pass-through 120 Vdc power (<1800 W) from the SSRMS via the PVGF to the EBCS.

C. The PIH shall provide pass-through 120 Vdc power (<1800 W) for both Bus 1 and Bus 2 from the EBCS to the AMS-02 payload, to supply contingency heater power during transfer operations.

D. The PIH shall provide routing for redundant video cabling from the EBCS to the SSRMS via the PVGF for the transmission of video signals to the ISS.

E. The PIH shall provide a method to secure and terminate cables from the PVGF that provide services that are not used by AMS.

3.2.1.5 EVA Interfaces Functional Requirements

A. Attached Payloads shall be designed such that all operations are performed via EVR with contingency EVA capability.

B. Attached Payloads shall be designed to the sharp edge, protrusion, and glove temperature requirements of NSTS 07700, Volume XIV, Appendix 7, even if EVA is not planned or anticipated.

C. EVA contingency operations shall be performed by a crewmember restrained at the end of the SSRMS. (TBR)

D. EVA aids shall be provided in all locations necessary to support SSRMS based EVA contingency operations as specified in SSP 50005, paragraph 12.3.

E. All loose equipment and cargo operated on or by an EVA crewmember shall have attachment points or restraints so it can be secured or tethered at all times during transfer and at the worksite during EVA contingency operations as specified in SSP 50005, paragraph 12.3.

F. EVA worksites shall provide a force reaction mechanism independent of the robotic stabilization platform for forces greater than 10 lbf within 24 inches of the task site.

3.2.1.5.1 Extravehicular Activity Translation

The ISS truss provides a translation path to each of the six PAS/UCCAS sites for contingency support of the ORUs at the interface and contingency operations involving the PAS/UCCAS. These translation paths allow for EVA contingency operations involving the PAS/UCCAS active half UMA, the three PAS/UCCAS guide vanes at each site, the PAS/UCCAS capture latch, the Attached Payload passive half UMA, and the Attached Payload EVA releasable capture bar.

Attached Payloads shall provide for EVA translation for contingency operations.

3.2.1.5.2 Payload Attach System/Unpressurized Cargo Carrier Attach System Clearances

Attached Payloads shall be designed not to violate the PAS/UCCAS EVA access envelopes as defined by SSP 57003, paragraph 3.1.3.1.1.3A to allow for attach site ORU removal and replacement.

3.2.1.5.3 Extravehicular Activity Translation Corridor Protrusion

Attached Payloads impinging on EVA translation corridors and worksites shall provide EVA fixtures serving the same functions as those obscured by the payload as specified in SSP 50005, paragraph 14.5.3.

3.2.1.6 Micrometeoroid and Orbital Debris (MM/OD) Shields Functional Requirements

The AMS-02 PIH shall provide protection from micrometeoroids and orbital debris for all safety critical elements of the AMS-02 Payload per paragraph 3.2.3.9 of this PTRS.

3.2.1.7 Thermal Insulation Functional Requirements

The AMS-02 PIH shall provide thermal insulation for safety critical elements of the AMS-02 Payload that require protection from thermal extremes to ensure safe operations.

3.2.2 Physical

3.2.2.1 Weight/Center of Gravity (CG)

A. Total weight of the PIH shall not exceed 3,828 lbs (1736 kg).

B. Design of the PIH shall not cause the center of gravity (CG) of the AMS-02 Payload to exceed the maximum allowable CG offsets on the ISS. The maximum allowable offsets are:

X +/– 32 inches, Y +/– 32 inches, Z between 0 and +75 inches

All dimensions are with respect to the PAS local coordinate system as defined in SSP 57003, Figure 3.1.3.1.2.1–1.

3.2.2.2 Dimensions/Volume

The PIH shall not cause the AMS-02 Payload to exceed the operational envelope as defined in SSP 57003, Figure 3.1.3.1.1.1-1. [NOTE: The AMS-02 Payload does not meet this requirement. An Exception (Reference No. AMS-02 / 01) will formally document the exceedence. Inputs on the exceedence were provided to the ISS Program on March 28, 2001. Numerous assessments have been performed by the Manipulator Analysis, Graphics, and Integrated Kinematics (MAGIK) Team and reviewed by ISS. The resulting reports will provide the basis for approval of this Exception.]

3.2.2.3 Power Consumption

With the exception of the DDRS-02, the AMS PIH does not consume electrical power.

3.2.2.3.1 Power Consumption on STS

The DDRS-02 is based on an STS-provided Payload General Support Computer (PGSC). The PGSC is Government furnished equipment (GFE). It requires 60 watts of power from the Shuttle Orbiter. Line losses between the STS and the AMS-02 Payload due to the PIH-provided cabling will be considered in the Experiment STS power budget.

3.2.2.3.2 Power Consumption on ISS

While attached to the ISS, the PIH does not include any power consuming devices. Line losses between the ISS and the AMS-02 Payload due to the PIH-provided cabling will be considered in the Experiment ISS power budget.

3.2.3 Environmental

3.2.3.1 Thermal

The AMS-02 PIH shall meet the thermal requirements as specified in SSP 57003, Paragraph 3.5.1.2.

3.2.3.2 Pressure

The AMS-02 PIH shall meet the pressure requirements as specified in SSP 57003, paragraph 3.5.1.1.

3.2.3.3 Vibration

The AMS-02 PIH shall meet the vibration requirements as specified in NSTS-21000-IDD-ISS, International Space Station Interface Definition Document, section 4.1.1.6, Vibration (paragraphs 4.1.1.6.1 & 4.1.1.6.2).

3.2.3.4 Acceleration

A. The AMS-02 PIH shall be designed to show positive structural margins of safety during all flight and ground handling phases. Initial design load factors are listed in Table 3.2.3.4-1. These load factors may be superceded by the load factors from the official Verification Loads Analysis when the analysis is complete.

TABLE 3.2.3.4-1 LIFTOFF AND LANDING DESIGN LIMIT LOAD FACTORS

Event	N_x	N_y	N_z	R_x	R_y	R_z
	g	g	g	rad/sec^2	rad/sec^2	rad/sec^2
Liftoff	±5.7	±1.6	±5.9	±10	±25	±18
Landing	±4.5	±2.0	±6.5	±20	±35	±15

Note: Apply in AMS Coordinate System, which coincides with Orbiter Coordinate System directions.

B. The AMS-02 PIH shall be designed to withstand an on-orbit acceleration environment including reboost having peak transient accelerations of up to 0.085 g's, a vector quantity acting in any direction.

C. The AMS-02 PIH shall be designed to withstand berthing the Attached Payload in its berthing configuration having peak transient accelerations of up to 0.185 g's, a vector quantity acting in any direction. This criteria is to be used as a component load factor applied to the subsystem's center of gravity.

3.2.3.5 Shock

Due to the large mass (14,809 lbs) of the AMS-02 Payload, shock loads are not considered to be a credible failure scenario. The PIH has no requirements to protect against shock.

3.2.3.6 EMI/EMC

The AMS-02 PIH does not include any powered equipment, thus radiated electromagnetic interference (EMI) is not an issue. Cables that are part of the PIH shall be shielded if testing of the full AMS-02 Payload indicates that EMI shielding is necessary.

3.2.3.7 Humidity

3.2.3.7.1 Transportation Humidity Environment

All components of the AMS-02 PIH shall operate satisfactorily after being exposed to non-condensing relative humidity ranges up to 95% and condensing relative humidity up to 100% during transportation.

3.2.3.7.2 Storage Humidity Environment

All components of the AMS-02 PIH shall operate satisfactorily after being exposed to an external environment of up to 75% relative humidity during storage.

3.2.3.7.3 Pre-Launch Humidity Environment

All components of the AMS-02 PIH shall operate satisfactorily after being exposed to an external environment of up to 55% relative humidity during pre-launch processing.

3.2.3.7.4 On-Orbit Humidity Environment

The AMS USS-02 will be exposed to an external environment of 0% relative humidity during on–orbit operations. This is to be used for design and analysis purposes.

3.2.3.7.5 Orbiter Cabin Humidity Environment

The AMS DDRS-02 shall meet the humidity environments as defined in NSTS 2100-IDD-MDK specification.

3.2.3.8 Acoustic Emissions

The AMS-02 PIH does not have any components that produce acoustic emissions.

3.2.3.9 Micrometeoroids and Orbital Debris

The Attached Payload will be exposed to the MM/OD environments as specified in SSP 30425, paragraph 8.0. Parameters of ISS MM/OD environments definition are given in Table 3.2.3.9-1 and NASA TM 104825. This is to be used for design and analysis purposes. For the safety critical structures of AMS, this environment translates into a Probability of No Penetration (PNP) of 0.997. For non-safety critical AMS structures, a goal of 0.95 PNP has been established.

TABLE 3.2.3.9-1 PARAMETERS FOR MICROMETEOROIDS AND ORBITAL DEBRIS ENVIRONMENTS DEFINITION

Altitude	215 nautical miles (400 km)
Orbital inclination	51.6 degrees
Space Station attitude	LVLH 10% of the time (Orbiter attached) TEA 90% of the time (Orbiter not attached)
Solar flux	70 x 104 Jansky (F10.7 – 70)
Orbital debris density[1]	2.8 gm/cm3
Maximum debris diameter[2]	20 cm
Note: [1] For MM/OD critical items (see 6.1) only. [2] High degree of confidence of collision avoidance for this size and larger orbital debris objects.	

3.2.3.10 Atomic Oxygen

The AMS-02 PIH will be exposed to a flux of 5.0×10^{21} atoms per cm^2 per year for the on-orbit exposure duration. This is to be used for design and analysis purposes. Silver plated hardware shall not be used per SSP 57003, paragraph 3.6.4.

3.2.3.11 External Contamination

The AMS-02 PIH will be exposed to on-orbit external contamination environments as defined in SSP 30426, External Contamination Control Requirements, paragraphs 3.4 and 3.5. This will be used for design and analysis purposes.

3.2.3.12 Ionizing Radiation

3.2.3.12.1 Ionizing Radiation Dose

The AMS-02 PIH shall be designed to not produce an unsafe condition or one that could cause damage to external equipment as a result of exposure to a total dose specified in SSP 30512, Space Station Ionizing Radiation Design Environment, paragraph 3.1.2.

3.2.3.12.2 Nominal Single Event Effects Ionizing Radiation

The AMS-02 PIH shall be designed to operate in and to not produce an unsafe condition or one that could cause damage to other equipment as a result of exposure to the radiation dose environment specified in SSP 30512, paragraph 3.2.1.

3.2.3.12.3 Extreme Single Event Effects

The AMS-02 PIH shall be designed to not produce an unsafe condition or one that could cause damage to external equipment as a result of exposure to extreme Single Event Effect (SEE) ionizing radiation assuming exposure levels specified in SSP 30512, paragraph 3.2.2.

3.2.4 Reliability

3.2.4.1 Failure Tolerance

3.2.4.1.1 Failure Tolerance Structure

The AMS-02 PIH structure will be designed utilizing the Design for Minimum Risk (DFMR) philosophy.

3.2.4.1.2 Failure Tolerance Power and Data Interfaces

The AMS-02 PIH cabling for power and data interfaces shall be single fault tolerant.

3.2.4.1.3 Failure Tolerance O-ring Seals

AMS-02 PIH Vacuum Case interfaces containing O-rings shall be two fault tolerant.

(NOTE: The Payload Safety Review Panel has approved an equivalent fault tolerant approach for the two O-ring seal on the Vacuum case. The approach establishes a verification regimen for the two O-ring seal that would be equivalent to design, test and verification of a two fault tolerant system.)

3.2.4.2 Failure Propagation

A single failure of the AMS-02 PIH end item in a functional path shall not induce any other failures external to the failed end item.

3.2.4.3 Failure Detection, Isolation, and Recovery (FDIR)

The AMS-02 PIH is a passive support structure and has no FDIR requirements.

3.2.5 Maintainability

The AMS-02 PIH is a passive support structure designed such that no on-orbit maintenance is required for the life of the mission.

3.2.6 Transportability

3.2.6.1 Ground Transportability

The AMS-02 Payload and associated ground handling equipment (GHE) is being designed primarily for air transport. The Primary Support Stand (PSS) and Lower USS-02 Support Fixture are being designed specifically to be compatible with Boeing 747 cargo aircraft. Unassembled components of the AMS-02 PIH shall be designed to be compatible with transportation by truck.

3.2.6.2 Transport to Orbit

The AMS-02 payload shall be capable of being transported to orbit by the Orbiter in accordance with NSTS 21000-IDD-ISS. The AMS-02 payload will be transported in the Orbiter cargo bay. Design loads are defined in JSC 28792, AMS-02 Structural Verification Plan for the STS and the ISS.

3.3 DESIGN AND CONSTRUCTION

3.3.1 Materials, processes and parts

3.3.1.1 Materials and Processes

A. Materials and processes for flight hardware shall meet the requirements of SSP 30233, “Space Station Requirements for Materials and Processes,” as implemented by JSC 27301, “Material Control Plan for JSC Space Station GFE”.

B. Materials and process for payloads shall meet the requirements of SE-M-0096, “General Specification for Materials and Processes for JSC Controlled Payloads”.

C. Material Certification will be documented with a Materials Memorandum for inclusion in the Certification Data Package (Ref: SMD-TQM Form 3 per JSC 27622, Section 12.5.2). Materials Usage Agreements will be provided only as needed.

D. The project will utilize the standard JSC inspection and bonded stores practices for parts handling and control.

E. All Commercial-Off-The-Shelf (COTS) hardware that cannot provide material certifications, traceable parts, or workmanship processes will be evaluated for further testing that will be used to supplement the acceptance testing for that hardware.

F. Materials and processes shall meet the materials requirements of NSTS 1700.7B, section 209 and NSTS 1700.7B ISS Addendum 209.

G. Nonmetallic materials shall be selected to the maximum extent possible from JSC 09604, "JSC GFE Materials Selection List and Materials Documentation Procedures."

H. Selection of materials shall be approved by the Structural Mechanical Design and Analysis Branch (ES5) of the JSC Structures and Mechanics Division.

3.3.1.2 Electrical, Electronic and Electromechanical (EEE) Parts

A. EEE parts for all Payload Integration Flight Hardware shall be selected in accordance with JSC 61360, "Engineering Directorate Certified Parts Approval Process (EDCPAP) and SSP 30312, Electrical, Electronic, and Electromechanical (EEE) and Mechanical Parts Management and Implementation Plan for Space Station Program.

B. LMSO shall provide an as-built parts list and perform component stress analysis for all Payload Integration Hardware (PIH). EEE parts traceability to the serial and lot number will be provided for PIH. Parts shall be derated in accordance with SSP 30312, Electrical, Electronic, and Electromechanical (EEE) and Mechanical Parts Management and Implementation Plan for Space Station Program, Appendix B.

3.3.2 Structural Design

The AMS-02 PIH shall be designed to meet the structural design requirements of SSP 57003, paragraphs 3.1.1.7 and 3.1.1.8

3.3.3 Nameplates and Product Marking

A. Nameplates shall conform to the requirements of JSC-SPEC-M1B.

B. All other labels, decals, placards and product marking shall conform to the requirements of SSP 57003, paragraph 3.10.

3.3.4 Workmanship

Workmanship standards shall comply with:

A. NASA-STD-8739.3, "Soldered Electrical Connections"

B. NASA-STD-8739.4, "Crimping, Interconnecting Cables, Harnesses and Wiring"

C. IPC-6011, "Generic Performance Specification for Printed Boards"

D. IPC-6012A, "Qualification and Performance Specification for Rigid Printed Boards"

E. NASA-STD-8739.1, "Workmanship Standard for Staking and Conformal Coating of Printed Wiring Boards and Electronic Assemblies"

F. IPC-2221, "Generic Standard on Printed Board Design" and IPC-2222, "Sectional Design Standard for Rigid Organic Printed Boards"

G. ANSI/ESD S20.20-1999, Development of an Electrostatic Discharge Control Program for Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices)

H. NASA-STD-8739.2, "Workmanship Standard for Surface Mount Technology"

I. NASA-STD-8739.5, "Fiber Optic Terminations, Cable Assemblies, and Installation"

J. The external surfaces of the AMS-02 Payload shall conform to Visibly Clean–Standard (VC–S) as specified in SN–C–0005, NSTS Contamination Control Requirements Manual.

3.3.5 Human Engineering

A. The AMS-02 Payload shall be designed to meet the requirements of SSP 57003, section 3.8.3, Human Engineering Design.

B. The AMS-02 Payload shall be designed to meet the requirements of SSP 57003, section 3.8.4, Human Engineering Safety.

3.3.6 Safety

Safety issues and abatements for the AMS-02 Payload are documented in JSC 29075, Phase 0/I Flight Safety Data Package for the Alpha Magnetic Spectrometer-02 (AMS-02) and JSC 29076, Phase 0/I Ground Safety Data Package for the Alpha Magnetic Spectrometer-02 (AMS-02). Additional documentation will be provided to support the Phase II and Phase III Safety Reviews in accordance with NSTS 1700.7B, ISS Addendum and NSTS/ISS 13830 C.

3.3.7 Lifetime

The AMS-02 PIH will be designed to operate on-orbit for a minimum period of seven years.

3.3.8 Security

The AMS-02 PIH has no unique security requirements.

3.4 LOGISTICS

3.4.1 Maintenance

3.4.1.1 On-Orbit Maintenance

The AMS-02 PIH has no planned on-orbit maintenance activities. Accommodations for contingency EVAs (i.e. for the mating of connectors) will be considered in the design of the hardware.

AMS-02 has no planned on-orbit maintenance requirements. The AMS-02 will provide, as appropriate, preflight imagery sufficient for documenting fabrication and assembly to satisfy requirements for historical documentation and subsequent on-orbit operations. These images and associated data will be delivered to the Digital Imagery Management System (DIMS) and/or the Video Access Management System (VAMS) for cataloguing and archiving.

Alternatively, the AMS-02 may decide to retain and manage additional imagery to develop a procedure for on-orbit troubleshooting and/or maintenance to be negotiated in real-time, should a situation arise after the installation of the payload.

3.4.1.2 Ground Maintenance

There is no planned nominal ground maintenance required for any PIH. In the event that a contingency arises that requires a repair to the PIH, the situation will be assessed and a repair plan developed.

3.4.2 Supply

The Payload Integration Hardware is not foreseen to require a supply source for critical parts. If complications develop during fabrication this issue may be re-addressed; however, the purchase of spares is foreseen as a more viable solution based on the hardware.

3.4.3 Spares

The Payload Integration Flight Hardware is not foreseen to require flight spares; however this may be re-addressed based on complications that may arise during fabrication/testing.

4. PREPARATION FOR DELIVERY

The requirements specified herein will govern the preparation for shipment and the transportation of the AMS-02 PIH to all contractor and Government facilities or test sites. The methods of packaging, as well as the necessary special controls during transportation, will adequately protect the AMS-02 PIH from damage or degradation in reliability or performance that could be incurred from natural and induced environments encountered during transportation and subsequent storage.

Packaging, handling, and transporting will be in general accordance with the guidelines of NHB-6000.1 (1D), “Requirements for Packaging, Handling and Transportation for Aeronautical and Space System Equipment and Associated Components,” as supplemented or amended by the following paragraphs.

4.1 PACKAGING LEVELS AND METHODS

Packaging and packing shall be in general accordance with MIL-STD-2073-1D, “Standard Practice for Military Packaging.”

4.2 PACKAGING DESIGN VERIFICATION/QUALIFICATION

Tests to verify that packages meet performance requirements (including vibration, drop (shock), superimposed load, tip over, and impact) will not be performed because verification can be accomplished by analysis, assessment, or similarity.

4.3 MILITARY TRANSPORTATION PROCEDURES DOCUMENTATION AND REPORTS

Shipments entered into the military airlift system shall be documented and reported in accordance with DODR-4500.32R, “Military Standard Transportation and Movement Procedures.”

4.4 MARKING FOR SHIPMENT

Interior and exterior containers will be marked and labeled in accordance with MIL-STD-129, “Marking for Shipment and Storage,” except that labels with lettering of an appropriate size may be used in lieu of stenciling for all markings.

APPENDIX A ACRONYMS AND ABBREVIATIONS

ACC	Anti-Coincidence Counter
ACOP	AMS Crew Operations Post
AMS	Alpha Magnetic Spectrometer
APCU	Assembly Power Converter Unit
CAB	Cryomagnet Avionics Box
CCB	Configuration Control Board
CCEB	Cryocooler Electronics Box
CDD	Cryomagnet Dump Diodes
CDR	Critical Design Review
CG	Center of Gravity
cm	centimeter
CMR	Cold Mass Replica
COTS	Commercial Off The Shelf
CR/DIR	Change Request/Directive
DC	Direct Current
DDRS-02	Digital Data Recording System-02
DOE	Department Of Energy
EA	JSC Engineering Directorate
EBCS	External Berthing Cue System
ECAL	Electromagnetic Calorimeter
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EVA	Extravehicular Activity
EXPRESS	EXpedite the PRocessing of Experiments to Space Station
F	Fahrenheit
FOR	Flight Operations Review
FPSR	Flight Planning And Stowage Review
FRGF	Flight Releasable Grapple Fixture
FRR	Flight Readiness Review

APPENDIX A ACRONYMS AND ABBREVIATIONS (Continued)

g	gram (also gravity)
G	Gravity (also g)
GFE	Government Furnished Equipment
GHE	Ground Handling Equipment
GSE	Ground Support Equipment
He	Helium
HRDL	High Rate Data Link
Hz	Hertz
ICD	Interface Control Document
IDD	Interface Design Document
in	inch
IPT	Integrated Product Team
ISS	International Space Station
ISSP	International Space Station Program
ITS	Integrated Truss Segment
JSC	Lyndon B. Johnson Space Center
K	Kelvin
kg	kilogram
KHB	KSC Handbook
KSC	John F. Kennedy Space Center
L	Liter (also l)
lbs	pounds
LMSO	Lockheed Martin Space Operations
MAGIK	Manipulator Analysis, Graphics, and Integrated Kinematics
MIL	Military
MIT	Massachusetts Institute Of Technology
MLI	Multi-layer Insulation
MM/OD	Micrometeoroid and Orbital Debris

APPENDIX A ACRONYMS AND ABBREVIATIONS (Continued)

N/A	Not Applicable
NASA	National Aeronautics And Space Administration
NBL	Neutral Buoyancy Laboratory
NHB	National Aeronautics And Space Administration Handbook
NSTS	National Space Transportation System
PAS	Payload Attach System
PCS	Portable Computer System
PDA	Payload Disconnect Assembly
PDIP	Payload Data Interface Panel
PDR	Preliminary Design Review
PDS	Power Distribution System
PFR	Portable Foot Restraint
PIH	Payload Integration Hardware
PSS	Primary Support Stand
PVGF	Power Video Grapple Fixture
RICH	Ring Imaging Cherenkov Counter
ROEU	Remotely Operated Electrical Umbilical
S&MA	Safety and Mission Assurance
SCSI	Small Computer Systems Interface
SFHe	Superfluid Helium
SPEC	Specification
SRMS	Shuttle Remote Manipulator System
SSP	Space Station Program
SSRMS	Space Station Remote Manipulator System
STA	Structural Test Article
STD	Standard
STE	Special Test Equipment
STS	Space Transportation System
TBD	To Be Determined
TCS	Thermal Control System

APPENDIX A ACRONYMS AND ABBREVIATIONS (Continued)

TOF	Time Of Flight
TRD	Transition Radiation Detector
UMA	Umbilical Mechanism Assembly
UPS	Uninterruptible Power Supply
USS-02	Unique Support Structure-02
Vdc	Volts Direct Current
VAR	Verification Acceptance Review
VC	Vacuum Case
WIF	Worksite Interface Fixture

APPENDIX B AMS-02 Drawing Tree

http://www4.jsc.nasa.gov/eaprojects/ea-projects/flightgfe/ams_02/team_internal/ams02_drawing_tree.pdf

APPENDIX C AMS-02 PIH DRAWING LIST (FLIGHT HARDWARE)

Drawing Number		Assembly Level									
		1	2	3	4	5	6	7	8	9	10
SIG	39135719	AMS-02 Drawing Tree									
SEG	39135720	AMS-02 Payload Assembly									
SDG	39135724		USS-02 Assembly								
SEG	39135726			Upper USS-02 Assembly							
SDG	39135727				joint, upper VC interface						
SEG	39135728				beam assy, upper trunnion bridge						
SDG	39135729					channel, upper trunnion bridge					
SDG	39135730				joint, sill						
SEG	39135731				pin, tapered						
SDG	39135732				trunnion, sill						
SDG	39135733				plate, cover						
SDG	39135734				elbow, lower trunnion bridge beam						
SEG	39135735				beam assy, lower trunnion bridge						
SDG	39135736					channel, lower trunnion bridge					
SDG	39135737				joint, lower VC interface						
SDG	39135738				bracket, sill						
SDG	39135739				tube, sill						
SDG	39135740				bracket, diagonal sill						
SEG	39135741				strut assy, diagonal						
SDG	39135742					tube, diagonal strut					
SDG	39135743					endfitting, diagonal strut					
SDG	39135744				tentative…upper vc joint cover plate						
SDG	39135745				tentative…lower vc joint cover plate						
SDG	39135749				plate, bushing						
	-001					-001	Lg				
	-003					-003	Sm				
SDG	39135750				shim, large, joint to bushing						
	-001					-001					
	-003					-003					
	-005					-005					
SDG	39135751				shim, small, joint to bushing						
	-001					-001					
	-003					-003					
SDG	39135752				shim, lower vc joint						
SDG	39135753				shim, lower uss to upper uss						
SDG	39135754				shim, upper vc joint						
SDG	39135755				pin, shear						

APPENDIX C AMS-02 PIH DRAWING LIST (FLIGHT HARDWARE) (Continued)

Drawing Number	Assembly Level									
	1	2	3	4	5	6	7	8	9	10
-001					-001 lower vc joint					
-003					-003 lower uss to upper uss					
-005					-005 upper vc joint					
SDG 39135756				bushing assy						
-301					-301 lower vc joint					
-303					-303 lower uss to upper uss					
-305					-305 upper vc joint					
SDG 39135757					bushing, shear pin eccentric					
-001						-001 lower vc joint, inner sml				
-003						-003 lower vc joint, outer sml				
-005						-005 lower vc joint, inner lg				
-007						-007 lower vc joint, outer lg				
-009						-009 lower uss to upper uss, inner				
-011						-011 lower uss to upper uss, outer				
-013						-013 upper vc joint, inner sml				
-015						-015 upper vc joint, outer sml				
-017						-017 upper vc joint, inner lg				
-019						-019 upper vc joint, outer lg				
SEG 39135758			Lower USS-02 Assembly							
SDG 39135759				joint, box, centerbody, primary						
SDG 39135760				joint, box, centerbody, secondary						
SDG 39135761				tube,box, emc						
SDG 39135762				joint, lower uss to upper uss						
SDG 39135763				bracket, mounting, RICH						
SEG 39135764				beam assy, angle, lower						
SDG 39135765					channel, angle, lower					
SDG 39135766				bracket, PAS RICH						
SEG 39135767				flange, lower angle beam						
SDG 39135768			Keel Assembly							
SDG 39135769				joint, angle, keel						
SDG 39135770				block, keel						
SDG 39135771				tube, keel						
SDG 39135772				trunnion, keel						
SDG 39135773				retainer, keel						
SEG 39135776			Vacuum Case Assy							
SEG 39135777			Vacuum Case Match Drilling							
SDG 39135778				Lower Conical Flange						
SDG 39135779				Outer Cylinder						

APPENDIX C AMS-02 PIH DRAWING LIST (FLIGHT HARDWARE) (Continued)

Drawing Number	Assembly Level 1	2	3	4	5	6	7	8	9	10
SEG 39135780				Lower Conical Flange Assy						
SDG 39135781				Inner Cylinder, Final						
SDG 39135782					Inner Cylinder, Stock					
SDG 39135784				Upper Support Ring						
SDG 39135785				Lower Support Ring						
SEG 39135786				Upper Support Ring Assy, Final						
SEG 39135787				Lower Support Ring Assy, Final						
SEG 39135788				Interface Plate Assy, Upper						
SEG 39135789				Interface Plate Assy, Lower						
SDG 39135790				Clevis Plate						
SDG 39135791				Cover Plate, Feedthru Port						
SDG 39135792				Cover Plate, Strap Port						
SLG 39135793				O-Rings						
SDG 39135794				Interface Plate, Blank, Upper						
SDG 39135795				Interface Plate, Blank, Lower						
SEG 39135796				Upper Support Ring Assy, Initial						
SEG 39135797				Lower Support Ring Assy, Initial						
SEG 39135798				Line Drill Assy, Upper						
SEG 39135799				Line Drill Assy, Lower						
SEG 39135800			STA Vacuum Case Test Assy							
SEG 39135801			Upper Conical Flange Assy							
SEG 39135802			Weld Test Article Assy							
SDG 39135803				Inner Cylinder, Weld Test Article						
SDG 39135805			Upper Conical Flange							
SDG 39135807			Decal, VC Assembly Part Marking							
SDG 39135810			Decal, Part Marking							
SEG 39135812			**PAS Assembly**							
SDG 39135813			Bracket, Vertex							
SDG 39135814			Bracket, Aft							
SEG 39135815			**AMS Passive PAS Assembly**							
SEG 39135816					**PAS Base Assembly**					
SDG 39135817						PAS Platform Assy				
SDG 39135818						Guide Pins				
-301							Guide Pins, Apex			
-303							Guide Pins, Aft			
SDG 39135819						Scuff Plates				
-001							Scuff Plates, Apex			
-003							Scuff Plate, Aft			
SDG 39135820						Capture bar retainer Brackets				

APPENDIX C AMS-02 PIH DRAWING LIST (FLIGHT HARDWARE) (Continued)

Drawing Number	Assembly Level 1	2	3	4	5	6	7	8	9	10
-001							Capture Bar Retainer Bracket Aft			
-003							Capture Bar Retainer Bracket Apex			
SEG 39135821					**BCS Avionics Bracket Assy**					
-301						BCS Avionics bracket Assy, left				
-303						BCS Avionics bracket Assy, right				
SEG 39135822						BCS Avionics Bracket				
-001							BCS Avionics Bracket, left			
-003							BCS Avionics Bracket, right			
SDG 39135823						Handle Retainer Bracket				
-001							Handle Retainer Bracket, left			
-003							Handle Retainer Bracket, Right			
SDG 39135824					**PAS Base Bridge Bracket**					
SDG 39135825					**Bridge Flat Bearing**					
SDG 39135826					**Bridge Pin**					
SEG 39135827						**Keyway Hardware**				
-001						Capture Bar Keyway				
-003						Keyway Retainer				
SEG 39135828					**EVA Extension Assembly**					
SDG 39135829						Cover Assy				
-001							Cover			
SDG 39135830						EVA Extension				
SDG 39135831						Release Screw Plate				
SDG 39135832			PAS Decals							
SDG 39135833			Bridge Shims (-001 temp config, -003 flight config)							
SDG 39135834						Lock Mechanism Base				
SDG 39135835						Lock Mechanism Base Retractor				
SEG 39135836					**PAS Bridge Assy**					
SDG 39135837						Bridge Assy				
SDG 39135838						Housing Assembly, Release Mechanism				
SDG 39135839						Slip Plate				
SDG 39135840						Wedge				
SDG 39135841						Wedge Components				
-001							Wedge Nut			
-003							Wedge Nut Washer			
SDG 39135842						Bushings				
-001							Wedge Bushing			
-003							Release Screw Bushing			
SDG 39135843						Wedge Release Screw				
SEG 39135844						Bearing Assembly				

APPENDIX C AMS-02 PIH DRAWING LIST (FLIGHT HARDWARE) (Continued)

Drawing Number	Assembly Level 1	2	3	4	5	6	7	8	9	10
SDG 39135845							Bearing Housing			
SDG 39135846							Bearing Housing Cover			
SDG 39135847						Limit Screws				
-001							Limit Screw Down			
-003							Limit Screw Up			
-005							Shoulder Screw			
SDG 39135848						Release Screw Cover				
SEG 39135849					**Capture Bar Assembly**					
SDG 39135850						Capture Bar				
SDG 39135851						Handle base				
SDG 39135852						Handle Bushing				
SDG 39135853						Handle extension Assy				
-001							Handle extension Assy Right			
-003							Handle extension Assy Left			
SDG 39135854						Handle				
SDG 39135855						Handle Pin				
SDG 39135856					Guide Pin Shims					
SEG 39135857					Locating Pins					
-003					Locating Pin Long					
-005					Cover, Locating Pin					
SDG 39135858		UMA Bracket								
SDG 39135862		ROEU Bracket Assembly								
SDG 39135863			Arm Flange							
SDG 39135864			Arm							
SDG 39135865			Wiring Harness Bracket							
SDG 39135866			PDA Bracket							
SDG 39135879		Integration hardware								
SDG 39135880		Integration hardware								
SDG 39135881		Integration hardware								
SDG 39135885		Integration hardware								