1. INTRODUCTION

This Phase II Flight Safety Data Package for the Alpha Magnetic Spectrometer-02 (AMS-02) is submitted in response to the safety requirements of NSTS 1700.7B, "Safety Policy and Requirements for Payloads Using the Space Transportation System", and NSTS 1700.7B, ISS Addendum, “Safety Policy and Requirements for Payloads Using the International Space Station. This safety package has been prepared in accordance with NSTS/ISS 13830C, "Payload Safety Review and Data Submittal Requirements for Payloads Using the Space Shuttle/International Space Station”. Also, JSC 26943, "Guidelines for the Preparation of Payload Flight Safety Data Packages and Hazard Reports for Payloads Using the Space Shuttle", was used as a guideline document.

2. SCOPE

This safety data package contains the safety analysis performed for the AMS-02 Payload flight hardware and the flight operations of the AMS-02 mission. The major subsystems of the AMS-02 included in this safety analysis are listed below. Each subsystem and the operational scenarios will be discussed in detail in Section 5 of this safety data package.

- Cryogenic Superconducting Magnet (Cryomag)
- Unique Support Structure – 02 (USS-02) with integral Vacuum Case (VC)
- Transition Radiation Detector and associated Gas System (TRD)
- Time-of-Flight (TOF) Scintillator Assemblies
- Silicon Tracker
- Tracker Alignment System (TAS)
- Anti-Coincidence Counters (ACC)
- Ring Imaging Cerenkov Counter (RICH)
- Electromagnetic Calorimeter (ECAL)
- Star Tracker
- Global Positioning System (GPS)

- Data and Interface Electronics
- Thermal Control System (TCS)
- Micrometeoroid and Orbital Debris (MMOD) Shields
- Payload Attach System (PAS) (Passive Half)
- Digital Data Recording System – 02 (DDRS-02)
- Space Shuttle Program (SSP) and ISS Program (ISSP) Provided Hardware
    - Flight Releasable Grapple Fixture (FRGF) SSP
    - Remotely Operated Electrical Umbilical (ROEU) SSP
    - Power Video Grapple Fixture (PVGF) ISSP
    - Umbilical Mechanism Assembly (UMA) (passive half) ISSP
    - External Berthing Camera System (EBCS) ISSP

The AMS-02 Payload also requires the use of the Shuttle Remote Manipulator System (SRMS) and the Space Station Remote Manipulator System (SSRMS) for removing the payload from the Orbiter Cargo Bay and berthing it on the station. The payload requires an active PAS and an active UMA, which are ISS hardware and part of the Integrated Truss Segment (ITS). The safety analyses for the SSP and ISS provided hardware are not included in this data package. However, the safety of the use and interfaces of the SSP and ISS provided hardware with the AMS-02 Payload are a part of this AMS-02 safety data package.

3. PURPOSE

The purpose of this safety analysis is to identify potential flight hazards associated with the AMS-02 Payload design and operation; to evaluate their cause and impact on the Space Shuttle, Orbiter, ISS, and flight crews; to define methods for eliminating or controlling the hazards; to verify the elimination or control methods; and to document the status of the verification methods. This safety package is intended to provide the information necessary for a Phase II review of the AMS-02 Payload by the JSC Payload Safety Review Panel (PSRP).

4. AMS-02 PROJECT OVERVIEW

The AMS-02 experiment is a state-of-the-art particle physics detector 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 (90% of the missing matter in the universe) and to study astrophysics (to understand Cosmic Ray propagation and confinement time in the Galaxy).

4.1 AMS-02 EXPERIMENT

The AMS-02 Experiment utilizes a large cryogenic superfluid helium (SFHe @ 2° K) superconducting magnet (Cryomag) to produce a strong, uniform magnetic field (~ 0.8 Tesla) within the interior of the magnet. The experiment has planes of detectors above, in the center of, and below the magnet (Figures 4.1-1 and 4.1-2). Electrically charged particles will curve when they pass through the magnetic field. Particles made of matter will curve one way, and those of antimatter will curve the opposite way. The positions of electrons released as the charged particles pass through the detectors will be electronically recorded (Figure 4.1-3). 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.

An Implementing Arrangement (IA) between NASA and DOE signed in September 1995 established two flights for AMS: an Engineering Test on Shuttle (STS-91 – June 1998) and a 3-year Science Mission on ISS (Launch Ready September 2007 – Date under review). The flight of AMS-01 was a precursor flight of the detectors proposed for AMS-02. AMS-01 utilized a permanent magnet in place of the cryomagnet. The purpose of the precursor flight was to verify operation of the AMS experiment, verify command and data communications, collect thermal data for the ISS flight, determine actual

accelerations on some AMS internal instruments and establish experimental background data.

The AMS-02 will be transported to the International Space Station (ISS) in the cargo bay of the Space Shuttle (Figure 4.1-4) for installation on the external truss of the ISS (Figures 4.1-5 and 4.1-6). The AMS-02 is scheduled to remain on the ISS for at least three operational years of data collection. Do to limited space shuttle flights, AMS-02 is not scheduled to return to Earth and will remain on the ISS.

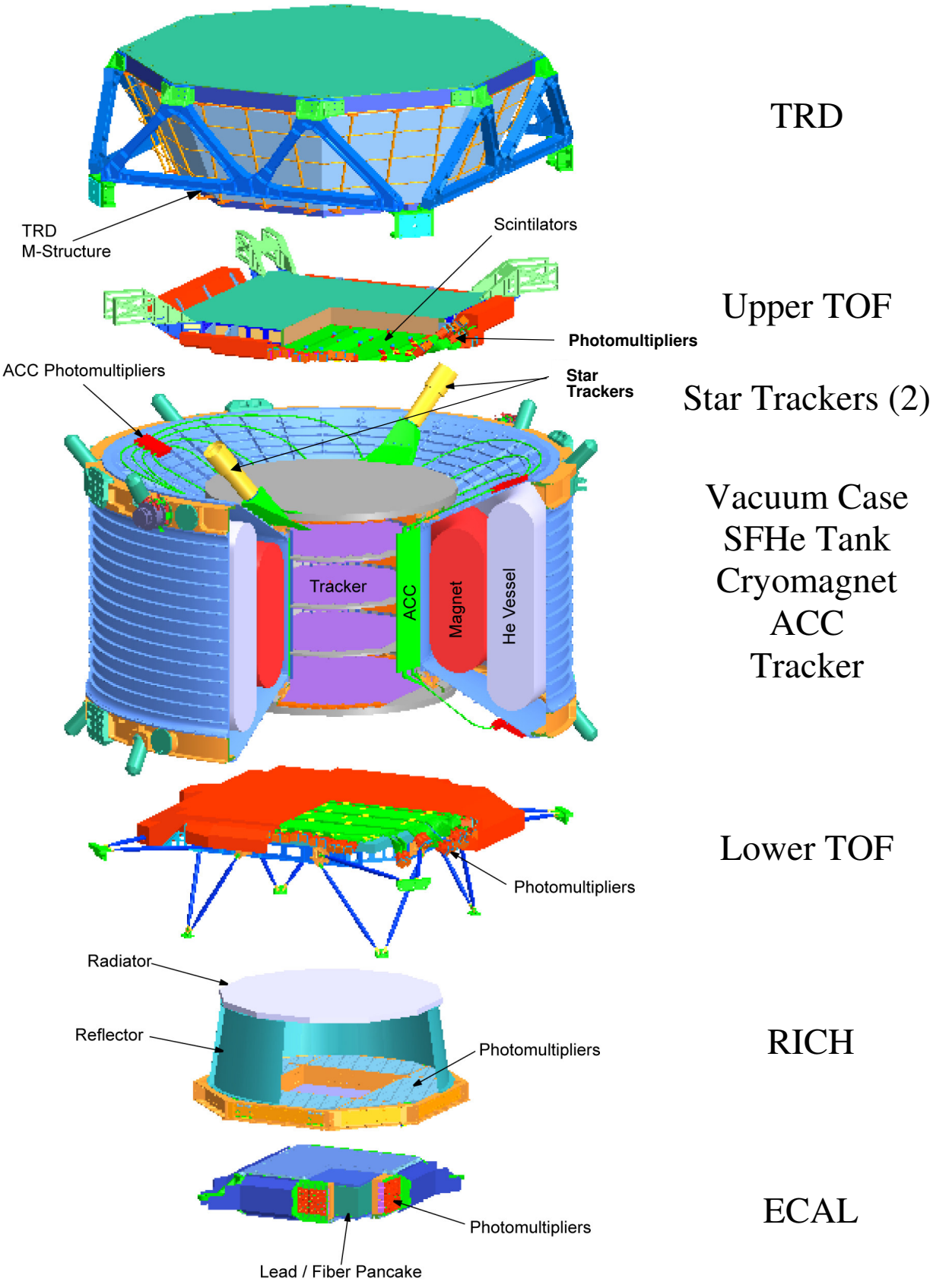


Figure 4.1-1 The AMS-02 Experiment

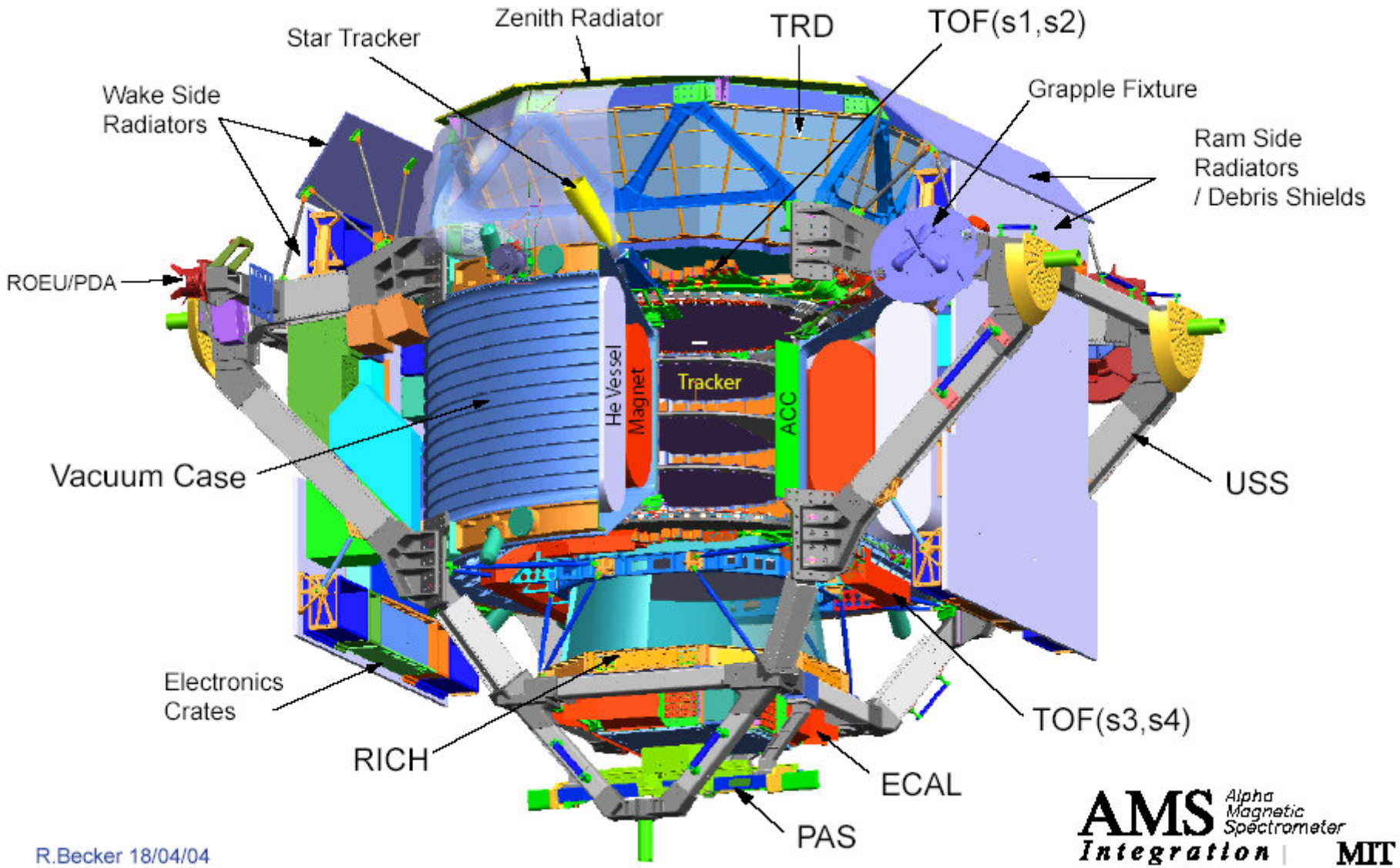
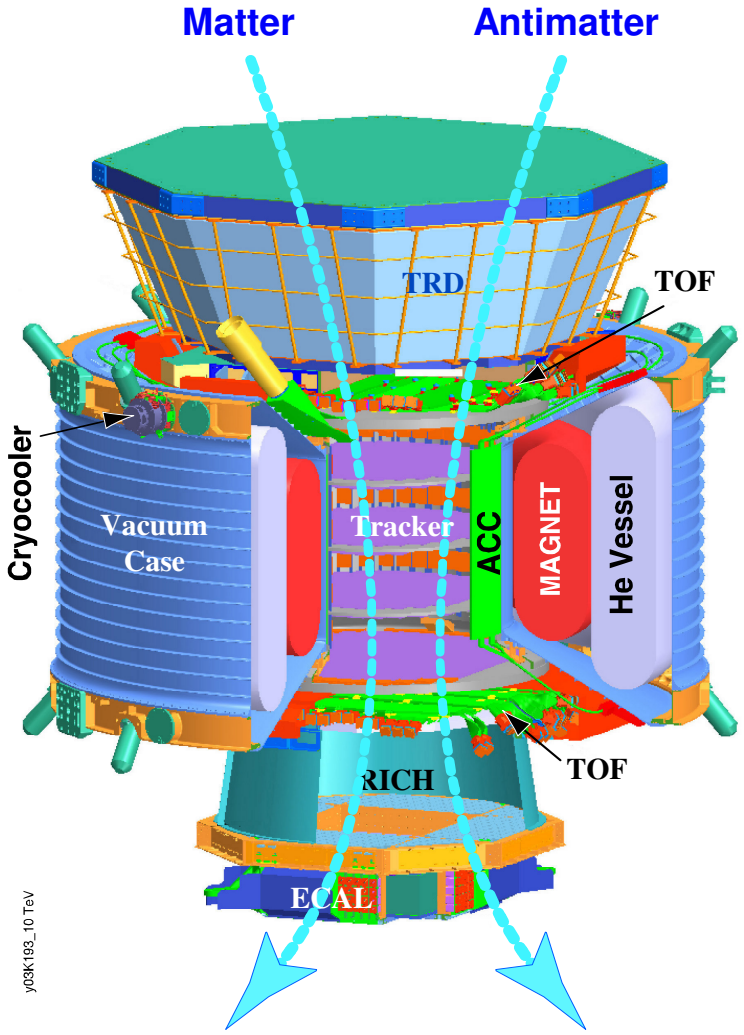
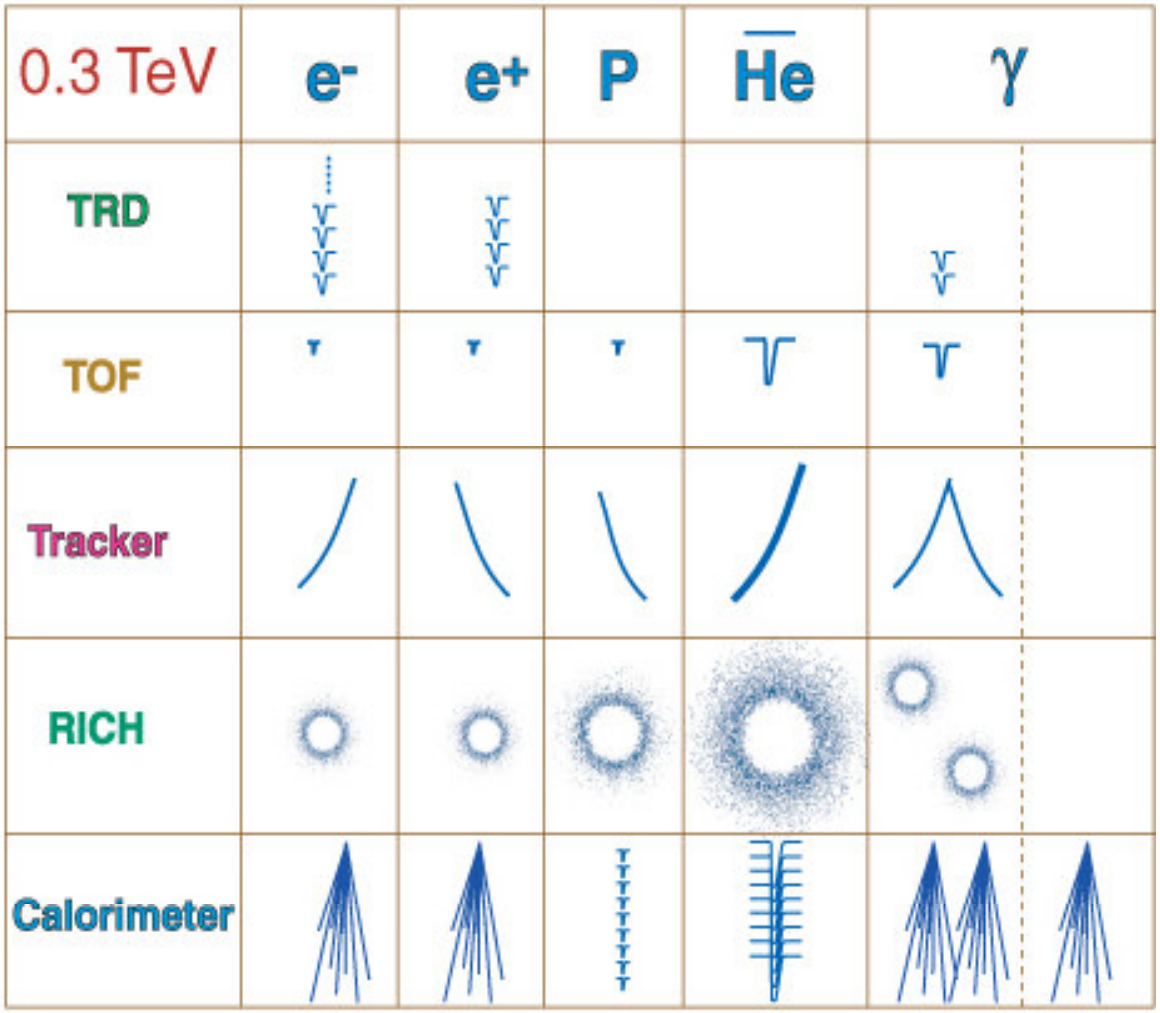


Figure 4.1-2 The AMS-02 Payload

AMS: A TeV Magnetic Spectrometer in Space





300,000 channels of electronics Δt = 100 ps, Δx = 10μ

Figure 4.1-3 AMS-02 Detector Signatures

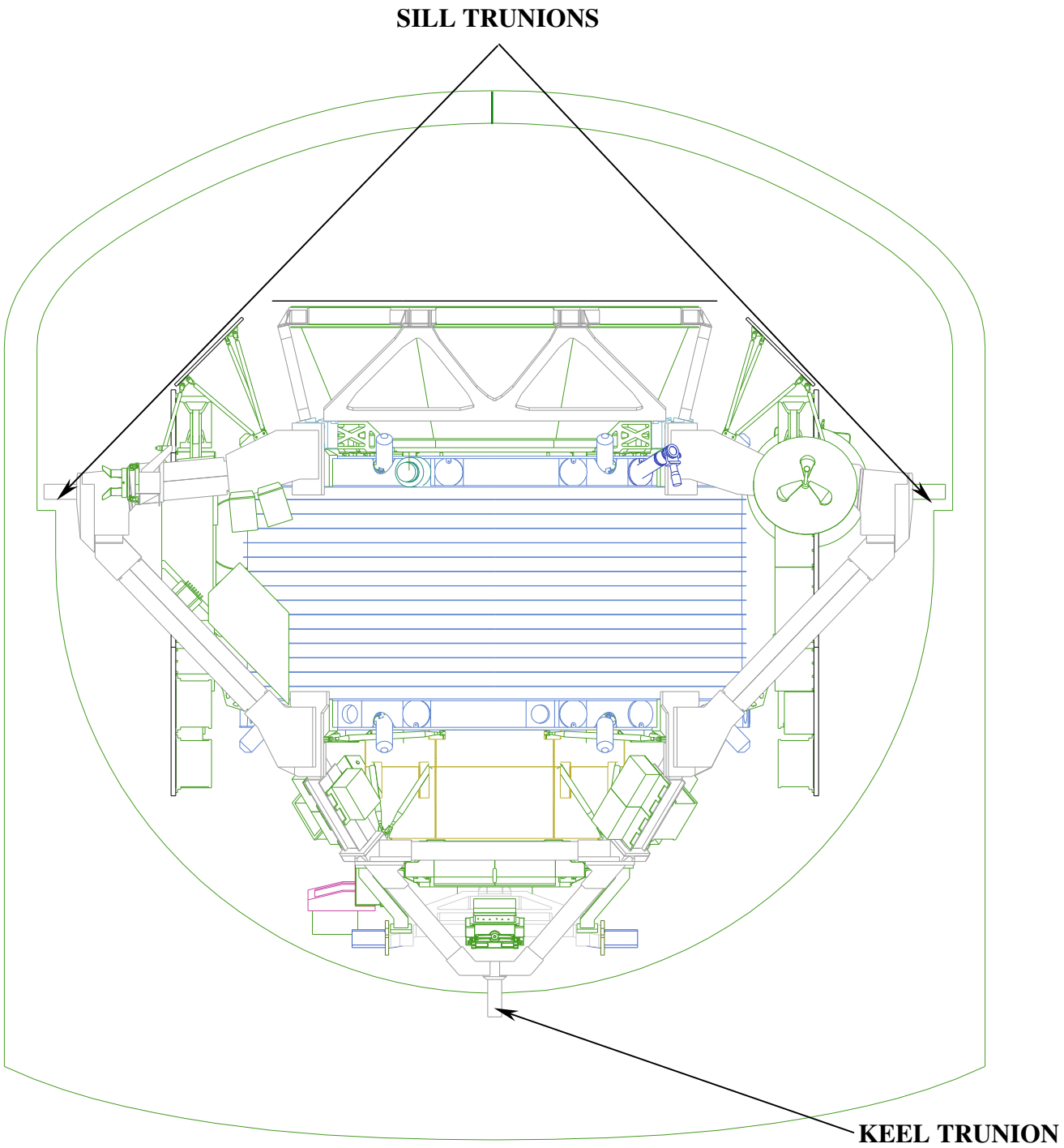


Figure 4.1-4 AMS-02 in the Space Shuttle Orbiter Cargo Bay
(From forward bulkhead looking aft.)

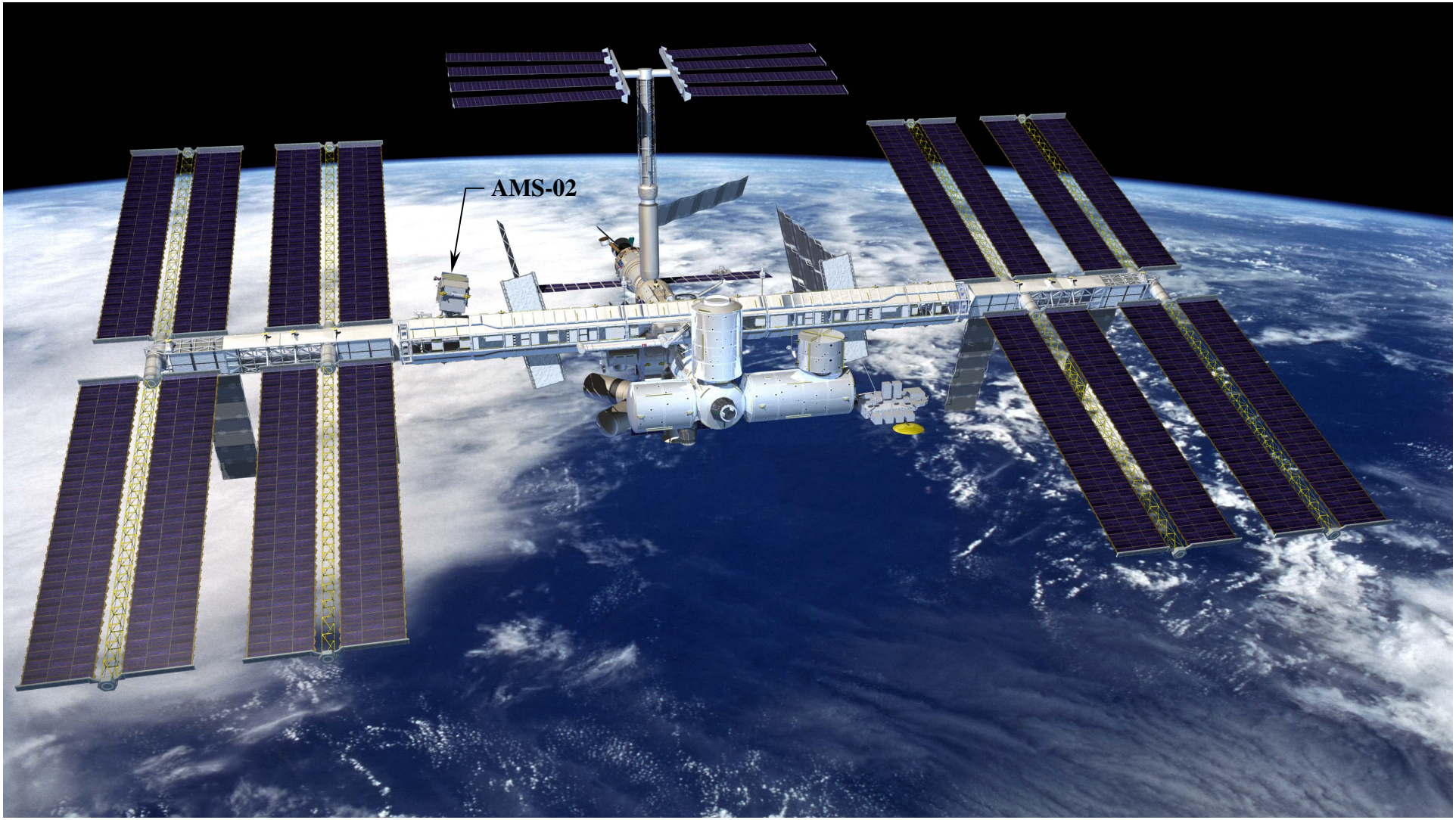


Figure 4.1-5 AMS-02 on the ISS

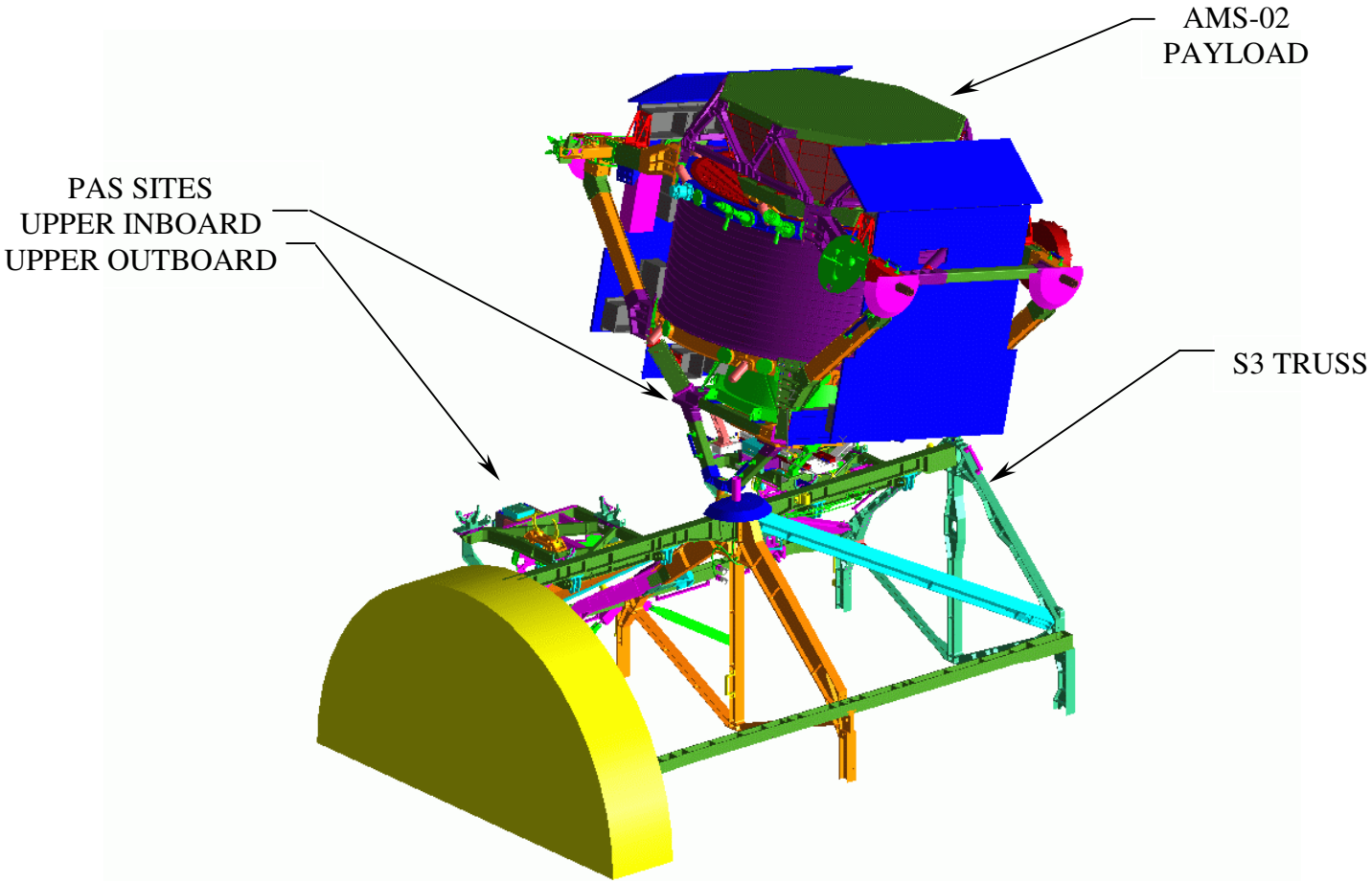


Figure 4.1-6 AMS-02 Payload Assembly on ISS S3 – Z Inboard PAS Site

4.2 AMS-02 ROLES AND RESPONSIBILITIES

The Implementing Arrangement (IA) between the Department of Energy (DOE) and the National Aeronautics and Space Administration (NASA) establishes the roles and responsibilities of DOE and NASA with respect to the Alpha Magnetic Spectrometer (AMS) Program.

4.2.1 NASA Responsibilities

NASA Headquarters is responsible for the overall NASA management of the AMS Program interface activity between NASA and DOE and for overall program management of the NASA activities required to support the implementation of the flight of AMS-02 (Figure 4.2.1-1). The AMS Project Office (APO) of the Engineering Directorate (EA) at JSC has been assigned responsibility for implementing the AMS Program. The APO serves as the AMS representative and acts as the single point of contact between the AMS Program and the Shuttle and ISS Programs. The APO reports and is responsible directly to NASA Headquarters and is the AMS NASA representative to all other NASA organizations providing equipment, materials, and services to the AMS Program.

In order to implement the AMS Program, NASA will perform or provide the following:

- Fly the AMS-02 on the ISS as an external attached payload, and provide accommodation on the ISS; all necessary services, AMS-to-carrier integration, AMS transfer to and installation on the ISS. NASA shall include the AMS-02 in the Space Station utilization planning process.

- Provide mission-peculiar interface hardware and software for the AMS-02 on the ISS.

- Perform AMS-to-carrier integration support, payload certification, and payload safety certification.

- Provide necessary facilities and perform related services for the AMS-02 final assembly, testing and checkout at the launch site, as well as control center accommodations for AMS-02 operation and monitoring as required for the launch and transfer-to-ISS phases.

- Provide AMS-02 housekeeping, science (unprocessed) and carrier-ancillary data products to the DOE-sponsored team at the designated NASA data handling/distribution center.

- Perform a mission management function consisting of the following tasks in support of AMS:

    - Representation of the AMS to the Shuttle Program, the ISS Program, and to various supporting NASA organizations involved in the integration and flight of AMS.
    - Design and operations consulting and guidance to the AMS Program to minimize the potential for incorporation into the AMS design of features or characteristics which could result in functional and/or safety incompatibilities with either the Shuttle or the ISS or with ground systems at the launch or landing sites.
    - Performance of detailed engineering analyses (e.g. stress, loads, etc,) to ensure compatibility of the AMS with the Shuttle and ISS through its launch, operational, and return environments.
    - Systems engineering for the development of mission-peculiar interface hardware and software needed to analytically, physically, and operationally integrate the AMS into the Shuttle and ISS system.
    - Management of the physical integration of the AMS and mission-peculiar interface hardware onto the Shuttle and ISS carriers.
    - Guidance, identification and control of hazards, and lead role in development of Safety Compliance Documentation, and representation of AMS to the Shuttle, ISS, and KSC Safety Panels.
    - Guidance in the development of requirements levied on the Shuttle and ISS and lead role in negotiation of those requirements through the Shuttle Payload Integration Plan, (PIP), the ISS PIP, the associated annexes, and required Interface Control Documents (ICDs).
    - Provision of training related to Shuttle and Station operations, including the development of training requirements.
    - Provision of documentation required for payload verification of AMS compliance with Shuttle and ISS program requirements.
    - Representation of the AMS Program at KSC and support of testing, AMS-to-carrier integration, and flight operations.
    - Real-time mission support for the delivery flight to the ISS, through AMS deployment, installation, checkout, and verification of proper operation.

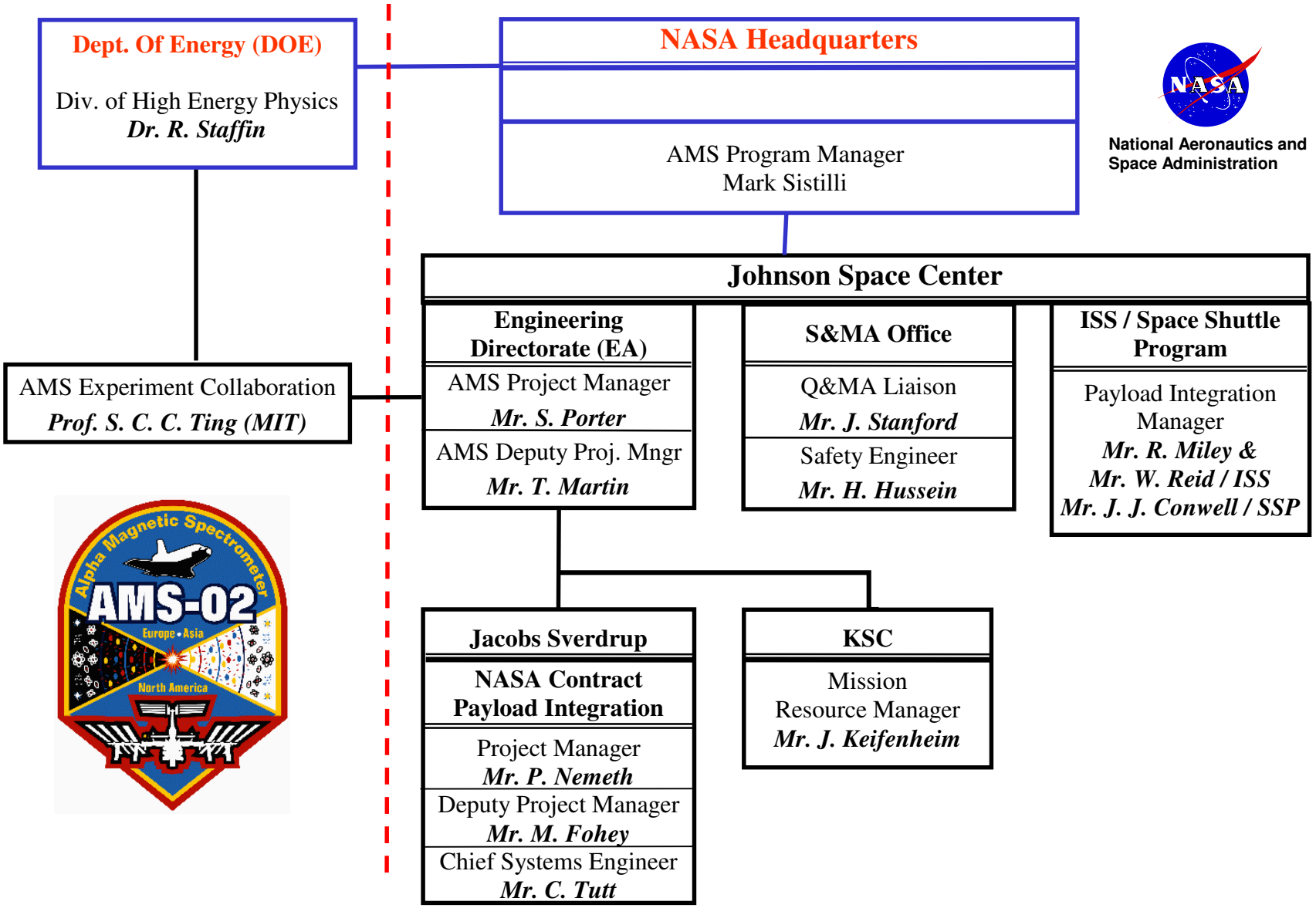


Figure 4.2.1-1 AMS Project Functional Organization

Flight hardware to be provided by NASA/APO is listed in Table 4.2.1-1.

TABLE 4.2.1-1 NASA/APO PROVIDED FLIGHT HARDWARE

ITEM	UNITS
* External Berthing Camera System (EBCS), w/cables and brackets	1
* EVA (Extravehicular Activity) Handrails/ Tether Attach Points	9
* Flight Releasable Grapple Fixture (FRGF), w/cables and brackets	1
* Portable Foot Restraint (PFR) Worksite Interface Fixture (WIF)	1 (or 2 if required by ROEU redesign)
* Power Video Grapple Fixture (PVGF), w/cables and brackets	1
* Remotely Operated Electrical Umbilical (ROEU)/Payload Disconnect Assembly (PDA), w/cables and brackets	1
* Umbilical Mechanism Assembly (UMA) (Passive Half), w/cables and brackets	1
Cryomagnet Vacuum Case (VC) (Flight Article)	1
Micrometeoroid and Orbital Debris (MMOD) Shields	2
Payload Attach System (PAS) (Passive Half)	1
EVA Interface Panel (Interface to UMA)	1
Interface Panel A (Interface to ROEU)	1
Cabling from interface panels to J-Crate and PDS	as required
DDRS–02 and associated cabling/interface cards	1
Trunnion scuff plates for deployable payload	4 (Part of USS-02)
Thermal Blankets	6
Unique Support Structure-02 (USS-02)	1

* Items (excluding brackets) supplied by NASA SSP or ISSP and integrated into AMS Payload by NASA/APO.

4.2.2 DOE Responsibilities

The DOE Headquarters Division of High Energy Physics, under the Department's Office of Energy Research is responsible for the administration of a Cooperative Agreement with the Massachusetts Institute of Technology (MIT) for a basic science program in particle physics. Under this agreement, the MIT Principle Investigator for the AMS Program has organized, and is the spokesman for, the AMS International Collaboration, currently consisting of over 200 physicists from 16 countries, to implement its part in the AMS Project (Figure 4.2.2-1). The DOE or, as appropriate, its MIT Cooperative Agreement Principle Investigator, will be responsible for: the definition, design, and development of the AMS hardware and related ground support equipment (GSE); delivery to and return from a location to be specified at the Kennedy Space Center (KSC) for integration or de-integration in the NASA processing system; and establishment of the science mission requirements. These responsibilities will include:

- All necessary interagency coordination and obtaining necessary concurrences within the U.S. Government for the AMS Project regarding international arrangements among the DOE Program Collaborators involved in the definition, design, development, fabrication, assembly, test, checkout, and operation of the AMS.
- Management of all international transfer and shipment, unless otherwise agreed. This includes, but is not limited to, customs clearances, import and export licenses required for AMS systems, subsystems, or components, or, as mutually agreed, for any NASA tests, integration, or mission-peculiar equipment or technical data that is required to be shipped abroad.
- Establishment of the AMS science plan, including science requirements, definition of data requirements, and definition of mission success criteria.
- Provision, when requested by NASA, of DOE technical and management support for all formal NASA reviews involving AMS (Safety Reviews, Cargo Integration Reviews, Ground Operations Reviews, Flight Operations Reviews, etc.) and other related NASA reviews and activities.
- Development and management of an AMS implementation schedule consistent with NASA program milestone schedules and provision of updates to keep NASA advised of AMS schedule status.
- Provision of technical and management data required by NASA to complete programmatic requirements (e.g. Safety, ICDs, MIP, reviews, material lists, etc.).

- Provision of all transport equipment (shipping containers, other AMS handling ground support equipment) required for AMS transport to and from NASA KSC.
- Management of: (1) All AMS science and engineering team activities, including travel, visa issuances, and related in-country logistical expenses; (2) support for science operations before, during, and after AMS flights; and (3) science data analysis, distribution, and publication.

Flight hardware to be provided by DOE/MIT is listed in Table 4.2.2-1.

TABLE 4.2.2-1 DOE/MIT PROVIDED FLIGHT HARDWARE

ITEMS	UNITS
Cryomagnet System including SFHe Tank, Non-linear Support Straps, and Cryomagnet Avionics Box (CAB)	1
Transition Radiation Detector and associated Gas System (TRD)	1
TRD Gas System	1
Upper and Lower Time-Of-Flight (TOF) Scintillator Assembly	1 each
AMS-02 Silicon Tracker Assembly	1
Tracker Alignment System (TAS)	1
Anti-Coincidence Counters (ACC)	1
Ring Imaging Cerenkov Counter (RICH)	1
Electromagnetic Calorimeter (ECAL)	1
Thermal Control System (TCS)	1
Star Tracker	2
Global Positioning System (GPS) Receiver	1