Payload Integration Agreement for Alpha Magnetic Spectrometer-02 (AMS-02)

International Space Station Program

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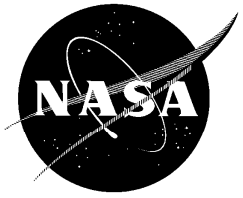

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INTERNATIONAL SPACE STATION PROGRAM

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MARCH 2006

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MARCH 2006

PREFACE

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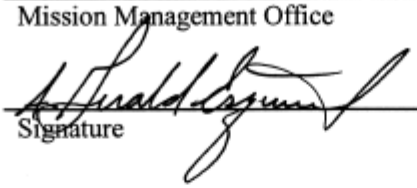
INTERNATIONAL SPACE STATION PROGRAM

**PAYLOAD INTEGRATION AGREEMENT FOR
ALPHA MAGNETIC SPECTROMETER-02 (AMS-02)**

CONCURRENCE

MARCH 2006

Concurred By:	A. Gerald Esquivel Mission Management Office	OZ2/NASA Org
	 Signature	6/20/06 Date
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	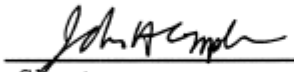 Signature	4/5/06 Date
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	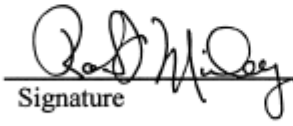 Signature	4/5/06 Date
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	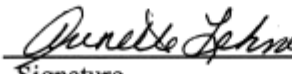 Signature	4/6/06 Date

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1.0 PURPOSE

Pursuant to the requirements established in SSP 57061, Standard Payload Integration Agreement for Attached Payloads, Revision B, this Payload Integration Agreement (PIA) documents the joint agreements to manage and execute the roles and responsibilities of the technical integration requirements, processes, services, and resources between the Alpha Magnetic Spectrometer-02 (AMS-02) Project, represented by the Johnson Space Center (JSC) Engineering Directorate AMS-02 Project Manager, and the International Space Station (ISS) Program, represented by the Space Station Payloads Office. These agreements include transportation services to and from ISS, including the proviso for Orbiter resources to the AMS-02 payload for non-science system operations during the transport phase, and the on-orbit ISS resources and operations of the AMS-02 as a truss attached ISS payload and an EXpedite the PRocessing of Experiments to Space Station (EXPRESS) rack locker payload. The AMS-02 Project and the Space Station Payloads Office shall be in compliance with the latest revision of SSP 57061 at the date of signature on this PIA. All signatories of this PIA will provide the best effort to execute the flight and the on-orbit mission life of the AMS-02 payload.

Transportation services to and/or from ISS, including the proviso for Orbiter resources to the AMS-02 payload are recognized by the signatories of this PIA as resources with limitations for launch support consistent with NASA Headquarters direction.

2.0 BACKGROUND

The United States Department of Energy (DOE), in its role of payload sponsor and under an inter-agency implementing arrangement between the DOE and National Aeronautics and Space Administration (NASA) is conducting a state-of-the-art high-energy physics cryogenic superconductive magnet experiment that is designed to search for anti-matter and dark matter. This joint agency implementing agreement required a Space Shuttle pre-cursor engineering test flight (AMS-01, completed on STS-91, June 1998) and a long-term science data gathering flight (AMS-02) on the ISS.

Major changes between AMS-01 and AMS-02:

- Permanent magnet replaced by a low temperature (1.8 degrees Kelvin) super-conducting electromagnet.
- Individual detectors have been replaced or augmented to increase science capability.
- The Unique Support Structure (USS-01) for AMS-01 has been completely redesigned and is designated USS-02.
- The AMS-01 mission length was 100 hours; the AMS-02 mission length is nominally planned for a 3-year duration.

3.0 SCOPE

3.1 EFFECTIVITY

The effectivity of this PIA is immediate and continues through the AMS-02 payload planned on-orbit operational mission life. AMS-02 science mission operations on the ISS are nominally planned for a 3-year duration in full deep space view. However, AMS-02 science operations can be extended indefinitely beyond this nominal duration contingent upon the availability of both AMS-02 and ISS Programmatic resources. Consistent with both the AMS-02 and Space Shuttle Programs' budget planning, no end-of-mission AMS-02 return to Earth via Shuttle is required.

3.2 JOINT AGREEMENTS

This PIA establishes the basic joint working agreements between the AMS-02 Project and the ISS Program Space Station Payloads Office to provide for integration/analyses, transportation services, installation, and command and data handling of the AMS-02 payload.

The AMS-02 Project will perform and/or support the required analytical, physical, and testing activities; operational and training activities; and safety reviews as specified within SSP 57061 for integration of the AMS-02 onto the ISS Integrated Truss Segment (ITS) S3 zenith inboard Payload Attach System (PAS) site.

The ISS Program will transport the AMS-02 payload's internal and external components on separate Space Shuttle flights to ISS approximately 3-to-6 months apart; perform the payload accommodation engineering, and necessary AMS-02 transportation integration services for each component as specified in SSP 57061.

The ISS Program will provide services for transfer to and installation of the AMS-02 payload onto the ISS as an externally attached payload, and on-orbit accommodations and resources to the payload for power and data.

Refer to the Space Shuttle Mission Integration Plan (MIP) for the mission specific agreements and hardware provisioning required for Space Shuttle transport, power and data, and robotic services.

3.3 SIGNATORIES

All signatories of this PIA will provide the best effort to execute the flight of the AMS-02 payload.

3.4 PRECEDENCE

This PIA, with any unique agreements or exceptions, takes precedence over the generic ISS Program payload integration requirements in SSP 57061, with the exception of the applicable ISS Program safety documents.

4.0 REQUIREMENTS

4.1 SAFETY

It is the responsibility of the AMS-02 Project to ensure compliance with safety requirements, and verify compatibility of payload physical and functional interfaces with the applicable ISS and Space Shuttle Program interface agreements and documents. All payload physical and functional compliance shall be accomplished prior to installation for flight. Similarly, the ISS Program is responsible for verifying ISS interface compliance prior to payload transportation. The payload shall be in compliance with this PIA, SSP 57061, and any updates directed by the ISS Program Payloads Control Board (PCB) and/or NSTS 1700.7B ISS Addendum, Safety Policy Requirements for Payloads Using the ISS.

4.2 REQUIREMENTS SOURCE

The PIA requirements source for the AMS-02 hardware and software interfaces, the Payload Data Sets, and other applicable technical requirements and processes are baselined in SSP 57061, Section 2.1, Applicable Documents, with exceptions indicated in this PIA.

4.3 EXPORT CONTROL

The DOE is responsible for the overall export control of the payload, while NASA is responsible for the export control of the payload integration hardware and software. NASA Export Control has classified the NASA payload integration hardware and software as EAR-99-NLR under the United States Department of Commerce (DOC) Export Administration Regulations (EAR). At the request of the DOE, the United States Department of State (DOS) reviewed the export status of the AMS-02 payload on May 18, 2001 and has determined that the AMS-02 payload is not subject to the export-licensing jurisdiction of the DOS, and referred AMS-02 export concerns to the DOC. The DOC subsequently ruled on October 10, 2002 that the AMS-02 and parts/systems specifically designed for use in the final assembly of AMS-02 are classified as 1A999 under the DOC EAR (i.e., no export license required except to proscribed countries, none of which are AMS International Collaboration members).

4.4 INTERFACE AGREEMENTS

Reference SSP 57213, Alpha Magnetic Spectrometer (AMS-02) Attached Payload Hardware Interface control Document, for interface definition and documentation of ISS Program approval for all exceptions to ISS Program requirements.

5.0 PAYLOAD DESCRIPTION

5.1 OVERVIEW

The AMS-02 is a state–of–the–art particle physics detector containing a large, cryogenic superfluid helium superconducting magnet that will be designed, constructed, tested and operated by an international team organized under DOE sponsorship. AMS-02 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-02 are to search for the presence or absence of antimatter in distant galaxies through detection of anti-nuclei (i.e., anti-helium or heavier elements) and the origin and structure of dark matter.

5.2 TRANSPORTATION

For transport to and from the ISS, the AMS-02 payload utilizes a direct interface in the Orbiter's payload bay via the payload supplied (USS-02). The USS-02 attaches directly to the Orbiter via four longeron trunnions and one keel trunnion, and is also used to support the vacuum case assembly, the cryomagnet, the payload detectors, and the interface to the ISS S3 PAS site. Electrical attachment to the Orbiter shall be made through a Remotely Operated Electrical Umbilical (ROEU).

If the AMS-02 after a No-Stay decision is to be returned, then the ISS Program will provide its best effort to reinstall AMS-02 into the Orbiter during the same mission and return it to Kennedy Space Center (KSC) or an alternate landing site for deintegration and return of the AMS-02 hardware to the AMS-02 Project. AMS-02 return will be via a direct interface in the Orbiter's payload bay utilizing the USS-02, i.e., attaching by means of four (4) longeron trunnions and one (1) keel trunnion. Power to the AMS-02 is required for return and the electrical attachment to the Orbiter shall be made through a ROEU.

5.3 HARDWARE

The USS-02 is employed to support the AMS-02 cryomagnet, detectors, and provides the interface for the entire AMS-02 with the Orbiter and the ISS. The cryogenic superconducting magnet (Cryomagnet) system consists of a superconducting magnet and a Superfluid Helium (SFHe) dewar with a capacity of about 2500 liters enclosed in a vacuum case. The vacuum case serves a dual purpose as a primary structural support to the USS-02 and as a vacuum vessel for the cryosystem and magnet. In addition, the USS-02 is comprised of the following subassemblies: Upper USS-02 Assembly, Vacuum Case Assembly, Lower USS-02 Assembly, Keel Assembly, and the Payload Attach System (PAS)/Umbilical Mating Assembly (UMA). The USS-02 primary members consist of extruded tubing with aluminum walls fastened with rivets and bolts. Several AMS-02 components are mounted to the USS-02.

5.4 ON-ORBIT OPERATIONS

5.4.1 ON-ORBIT SCIENCE OPERATIONS

The AMS-02 is an external, full truss mounted payload that will utilize a Cryomagnet with planes of detectors above, inside and below the magnet. The payload identifies the elemental composition of electrically charged particles that pass through the magnetic field will curve. Charged particles made of matter will curve one way, and those of anti-matter will curve the opposite way. The positions of the charged particles will be electronically recorded. In near real-time and without crew intervention, physicists will be able to study the trajectory of curvature and determine the charge of the particles from the direction of curvature and signal size. They will also be able to establish the mass of the particles from the amount of curvature and other measurements. This identified composition of the charged particles can then be analyzed to determine whether it was matter or anti-matter. Figure 5.4.1-1, AMS-02 On S3 PAS Looking ISS Zenith Starboard, provides an isometric view of the integrated AMS-02 installed on the ITS S3 zenith inboard PAS. To maximize the field of view and provide an unobstructed line-of-site into deep space, and to decrease encroachment into the adjacent attach site payload envelope, the payload is tilted 12-degrees inboard.

5.4.2 ON-ORBIT ROBOTIC INSTALLATION

The AMS-02 is a robotically deployable payload, requiring scheduled Extravehicular Robotics (EVR) operations for payload deployment and installation. This robotic installation of the AMS-02 requires that the Shuttle Remote Manipulator System (SRMS) remove the payload from the Orbiter's payload bay and hand off the payload to the Space Station Remote Manipulator System (SSRMS). The AMS-02 payload design incorporates two grapple fixtures, a Flight Releasable Grapple Fixture (FRGF) and a Power and Video Grapple Fixture (PVGF) for completing these dual arm operations, and the required External Berthing Camera System (EBCS) avionics package to monitor attachment of AMS-02 to the designated ITS S3 PAS site.

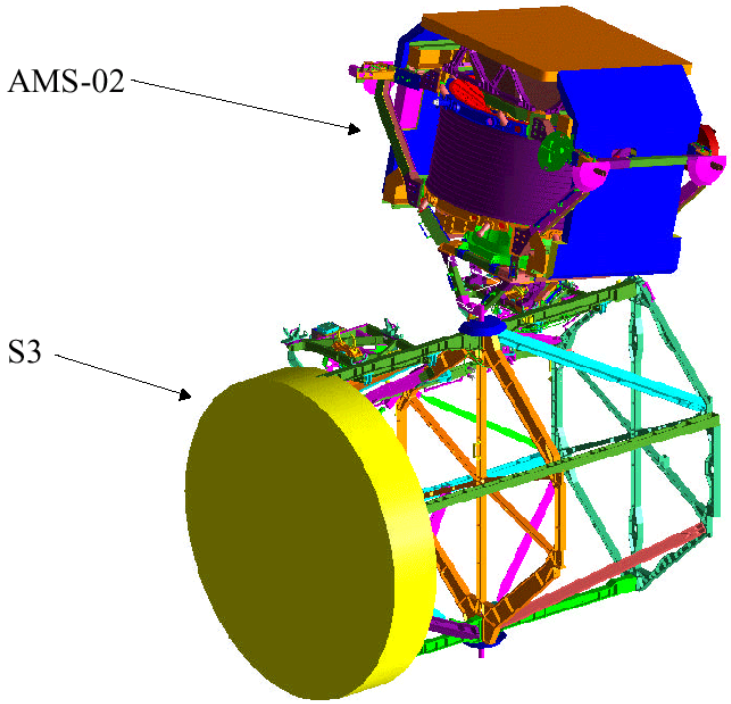

FIGURE 5.4.1-1 AMS-02 ON S3 PAS LOOKING ISS ZENITH STARBOARD

The current robotics operation scenario calls for the SRMS to remove and lift AMS-02 out of the Orbiter's payload bay using the FRGF, which is located on the forward/port side of the X_o axis of the USS-02 when installed in the Orbiter's payload bay (reference Orbiter coordinate system). The SRMS brings the AMS-02 to the handoff position. The SSRMS, based on the Mobile Remote Servicer (MRS) Base System (MBS) Power Data Grapple Fixture (PDGF) #1, with the Mobile Transporter (MT) at truss segment S1-Bay 6, accepts the handoff using the AMS-02 aft-port PVGF and then moves the AMS-02 in the station starboard direction toward the S3 ITS. The AMS-02 is then robotically installed by the SSRMS onto the S3 zenith inboard PAS site. The EBCS avionics package, installed on the AMS-02 passive PAS, is utilized for aligning the payload to the ITS S3 PAS during the berthing operation. Power is supplied to the EBCS avionics package and the thermostatically controlled AMS heaters (via the EBCS) from the SSRMS via the AMS-02 PVGF.

Actual heater usage will be dependent on attitude, beta angle, and EVR duration, to maintain the payload above the non-operational temperature limits. The AMS-02 has no command and data handling requirements while on the SSRMS. Figure 5.4.2-1, AMS-02 Grapple Fixture Locations, provides an isometric orientation of the two AMS-02 grapple fixture locations.

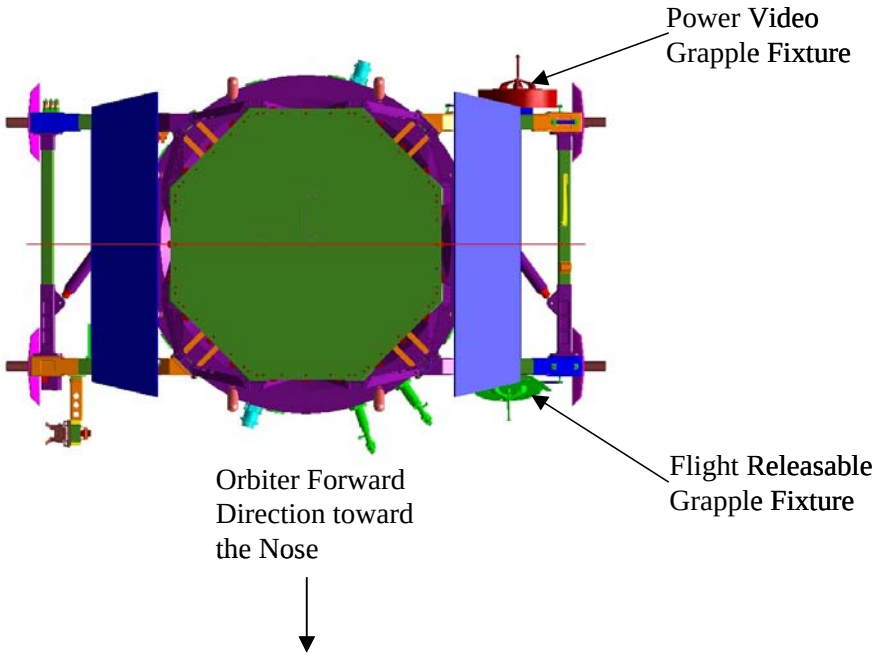

FIGURE 5.4.2-1 AMS-02 GRAPPLE FIXTURE LOCATIONS

The AMS-02 violates the Payload Attach System On-Orbit Operational Envelope, as defined in SSP 57003, Attached Payload Interface Requirements Document, Revision B, i.e., the clearance from the AMS-02 to an adjacent truss-attached element is less than 24 inches. The ISS Program recognizes the clearance issue and will make a best effort attempt to keep the adjacent S3 PAS site vacant during the AMS-02 payload's nominal 3-year science mission.

5.4.3 ON-ORBIT RETRIEVAL OPERATIONS

No end-of-mission for AMS-02 return to Earth is required. This is consistent with the AMS-02 Project and the ISS Program budget planning. ISS Program resource availability and support after the nominal end-of-mission is to be negotiated with the ISS Program.

5.5 AMS-02 RESOURCE REQUIREMENTS

5.5.1 AMS-02 POWER REQUIREMENTS

The AMS-02 experiment will require 2830 watts maximum for all operations throughout its nominal 3-year on-orbit mission life. Availability of this power level is not guaranteed and is dependant upon stage specific ISS operational constraints.

5.5.2 AMS-02 DATA REQUIREMENTS

The AMS-02 will generate an average of 2 megabits per second (Mbps) of High Rate Data Link (HRDL) data throughout its nominal 3-year on-orbit mission life. AMS-02 has a requirement for downlink of all this data in real-time or near real-time. Additionally, AMS-02 will generate 20 kilobits per second (kbps) of housekeeping data Low Rate Data Link (LRDL) on the 1553 Bus. AMS-02 also has a requirement for the downlink of this data in real-time or near real-time.

The probability of AMS-02 mission success may be seriously compromised by lack of insight into experiment operation. Therefore, a small subset of AMS-02 critical health data will be generated at a rate of 10 bytes per second (Bps) for downlink via the ISS S-Band system. This payload critical health data will be used to verify AMS-02 system health during ISS Ku-Band blockage periods. The availability of downlink capability for this data via the ISS S-Band system is a schedulable resource to be managed by the ISS real-time flight control team pending ISS operational priorities, as the ISS S-band telemetry system is currently over subscribed with critical core systems data. The ability to free up 10 Bps of telemetry bandwidth within the S-band data stream for use by a payload is not guaranteed by this PIA.

5.6 SPACE SHUTTLE RESOURCE REQUIREMENTS

5.6.1 SPACE SHUTTLE POWER REQUIRMENTS

The AMS-02 cryomagnet system vent valve operations primary control is via a payload barometric switch with vent valve electronics power supplied by momentary 28-volt (direct current) (Vdc) power during ascent (no crew interaction required). The 28 Vdc power will be supplied from the Orbiter Standard Switch Panel and will be limited to less than 5 amps. A Backup Flight System (BFS) General Purpose Computer (GPC) time-tagged command, a Discrete Output Low (DOL), shall be used as a backup to the barometric switch.

The AMS-02 will require continuous power of up to 2000 watts for Orbiter payload bay operations on-orbit after opening of the payload bay doors. This continuous power is needed for activation of the AMS-02 heaters by payload bay door opening +1 hour or as early as practical, and continuously afterward until ROEU disconnect sequence activation. The Orbiter will supply this continuous power at the station voltage of 120 Vdc to AMS-02 during on-orbit operations. Contingencies involving the return of AMS-02 via the Orbiter should be budgeted for using the same power requirements until payload deactivation during AMS-02 deorbit preparation operations.

5.6.2 SPACE SHUTTLE DATA REQUIREMENTS

The AMS-02 will generate an average of 2 Mbps of RS-422 data throughout checkout and thermal conditioning operations in the Orbiter's payload bay. The AMS-02 has a requirement for downlink of all this data in real-time or near real-time. A Space Shuttle Program provided Payload General Support Computer (PGSC) with payload provided interface cabling and communications cards shall be used as the AMS-02 Digital Data Recorder System-02 to record

this data throughout AMS-02 operations on the Orbiter. This AMS-02 data will be downlinked whenever its priority is sufficient to permit use of the Orbiter's Ku-Band link.

Additionally, AMS-02 will generate 20 kbps of housekeeping data (Low Rate Data Link) on the Orbiter's Interface Unit (OIU) 1553 Bus. The OIU will create payload data interleaver frames for this data. AMS-02 has a requirement for the downlink of this data in near real-time.

6.0 UNIQUE AGREEMENTS, CONSTRAINTS OR SERVICES

The following paragraphs identify AMS-02 unique requirements and deviations from SSP 57061. Since the AMS-02 utilizes only the United States On-orbit Segment (USOS) accommodations, resources, and services, the payload usage requirements of the European Space Agency Columbus Module Systems and the Japanese Experiment Module Systems are not applicable to AMS-02. Therefore, any SSP 57061 requirements that refer to International Partner documents are not applicable to AMS-02, and those documents and requirements are not specifically called out in this PIA as deviations.

6.1 ISS PROGRAM VERIFICATION AGREEMENT

AMS-02 Project will submit the payload verification data and Certificate of Compliance for review and approval by the ISS Program in accordance with SSP 57213. The payload unique Interface Control Document (ICD) will identify the applicable Interface Requirements Document (IRD) requirement, its verification method, required submittal data, due date, and status. The AMS-02 Project Office shall retain the detailed verification data for inspection upon request.

6.2 ISS PROGRAM PROVIDED SERVICES/EQUIPMENT

The UMA passive half, and associated cables and connectors will be furnished to AMS-02 as NASA/Government Furnished Equipment (GFE), at no cost to the AMS-02, and will be certified by the ISS Program. Integration work is an AMS-02 responsibility.

The FRGF will be furnished to AMS-02 as NASA/GFE, at no cost to the AMS-02, and will be certified by the ISS Program. Integration work is an AMS-02 responsibility.

The PVGF will be furnished to AMS-02 as NASA/GFE, at no cost to the AMS-02, and will be certified by the ISS Program. Integration work is an AMS-02 responsibility.

The EBCS will be furnished to AMS-02 as NASA/GFE, at no cost to the AMS-02, and will be certified by the ISS Program. Integration work is an AMS-02 responsibility. EBCS camera alignment work is a NASA responsibility. NASA will provide a direct current power source for the EBCS camera alignment work at 0-150 Vdc at 1.2 amps. Any other power source required by AMS-02 for this camera alignment work is an AMS-02 responsibility.

To test the AMS-02 HRDL protocol, the Transparent Asynchronous Transmitter-Receiver Interface (TAXI) Analyzer or a flight equivalent HRFM will be furnished to AMS-02 as NASA/Ground Support Equipment (GSE), at no cost to the AMS-02, and will be certified by the ISS Program. Verification test work is an AMS-02 responsibility.

6.3 AMS-02 PROVIDED SERVICES/EQUIPMENT

Unique gas requirements for the AMS-02 payload, such as Xenon gas or large quantities of liquid helium gas, will be furnished by AMS-02 Project. Any unique ground support equipment

or fixtures required by AMS-02 to use and/or process these unique gases will also be furnished by AMS-02 Project.

The Extravehicular Activity (EVA) tools and aids (EVA handrails and Worksite Interface Fixture (WIF)) may be ISS Program furnished as GFE to an ISS Program-approved payload, as negotiated, if the hardware is in NASA inventory. If not in the NASA inventory, the EVA tools and aids required by the payload will be procured by the AMS-02 Project and will be certified by the ISS Program. Integration work is an AMS-02 responsibility.

6.4 AMS-02 LAUNCH CONSTRAINT

At Launch minutes (L-9) minutes, a Go/No-Go decision to launch AMS-02 will be made based on the AMS-02 Super Fluid Helium Tank health and status by the AMS-02 Project Manager in accordance with NSTS 07700, Volume XIV, Appendix 5, Section 6, Space Shuttle System Payload Accommodations, System Description and Design Data - Ground Operations, Launch Countdown Operations.

6.5 AMS-02 ON-ORBIT CONSTRAINTS

Prior to the robotic removal of AMS-02 from the Orbiter, a Go/No-Go decision to deploy will be made based on the AMS-02 systems status by the AMS-02 Project Manager. It is highly desirable that the AMS-02 checkout start as soon as possible once berthed on the ISS S3 zenith inboard PAS in order to allow AMS-02 to perform a functional check and assess a Stay/No-Stay decision to stay or return prior to Orbiter undock. A minimum of 48 hours on-orbit is required for payload functional checkout after the AMS-02 electrical connections with the truss site are verified. The majority of this functional checkout is to be carried out with ground command and control; however, minimal crew involvement will be required. If the AMS-02 after a No-Stay decision is to be returned, then the ISS Program will provide its best effort to reinstall AMS-02 into the Orbiter during the same mission and return it to KSC.

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. Payload regulations and procedures will be developed for pre-established failure conditions.

6.6 AMS-02 ROBOTIC AGREEMENTS

AMS-02 is a robotically deployable payload, requiring scheduled EVR operations for payload deployment, installation, release and retrieval. The payload design incorporates two (2) grapple

fixtures, a FRGF and a PVGF, for robotic operations and the required EBCS avionics package for installation onto the designated ITS S3 PAS site.

To support the ISS Program End-to-End Berthing and Integration Team (EBIT) berthing loads analysis effort, AMS-02 will provide detailed drawings of the AMS-02 passive half side to the active PAS truss interface, in addition to the normal information showing compliance with the EVR flight planning limit loads for the grapple fixture-mounting interface. This information will include all dimensions and the final as-designed configuration of the AMS-02 features within a 6.5-foot radius from the center of the AMS-02 PAS interface.

6.7 AMS-02 MAGNETIC FIELDS CONSTRAINTS

AMS-02 will meet the Electromagnetic Interference (EMI) requirements, except the direct current (DC) magnetic fields as evidenced by the approved ISS Electromagnetic Effects Panel (EMEP) Tailoring/Interpretation Agreement (TIA) #0310.

An Extravehicular Maneuvering/Mobility Unit (EMU) system level magnetic exposure test was conducted on EVA equipment, including the Space-to-Space EMU Radio (SSER), Simplified Aid for EVA Rescue (SAFER), and Pistol Grip Tool (PGT), for the development of Certification and Keep Out Zone limits for EVA in proximity to the AMS-02 or other magnetic sources. Based on actual test results, the certification limit of the equipment is 300 gauss. Hence, an EVA Keep Out Zone will be established at 300 gauss based on field mapping of the actual AMS-02 magnetic field. Reference the ISS EMEP TIA #0310 for additional information.

In the event than an EVA must occur which requires the crew to translate within the 300 gauss Keep Out Zone, AMS-02 will be required to discharge the magnet and be powered down.

The Canadian Space Agency (CSA) conducted an analysis of the SSRMS and Special Purpose Dexterous Manipulator (SPDM) independently, and determined that the magnetic susceptibility of the space station robotic equipment to operate safely in a magnetic field is 10 gauss. In the event robotic operations must occur which require any part of the SSRMS or SPDM to be within the 10 gauss Keep Out Zone, AMS-02 will be required to discharge the magnet and be powered down.

The AMS-02 shall the limit payload's magnetic dipole strength to less than 40,000 Amp-meters squared along ISS Y-axis, 100,000 Amp-meters squared along ISS X-axis, and 190,000 Amp-meters squared along ISS Z-axis, to avoid ISS control moment gyroscope saturation and/or excessive ISS attitude variations/rates caused by the magnetic dipole of AMS-02 during microgravity station operations.

7.0 BASIC PAYLOAD DATA

7.1 REQUESTED MISSION AND RESOURCE REQUIREMENTS FOR FLIGHT OPERATIONS

Reference the contents of Appendix A, Table A-1 – Basic Payload Data for AMS-02 mission and resource requirements for flight operations.

7.2 REQUESTED GROUND DATA SERVICES REQUIREMENTS FOR FLIGHT OPERATIONS

Table 7.2-1, Ground Data Services Requirements, documents the AMS-02 Ground Data Services requirements needed during simulations and real-time on-orbit operations at the AMS-02 ground operating location.

TABLE 7.2-1 GROUND DATA SERVICES REQUIREMENTS

Ground Data Services Requirements	Location From	Location To	Data Rate (kbps)	POIC Process Data	Voice Distribution System	Internet Voice Distribution System (IvoDS)
Experiment Sci/Eng Data (Shuttle OD, Payload MDM, BAD, PAD)	POIC	JSC/POCC and CERN	20 kpbs	YES[1], [2]		
Experiment Sci/Eng Data (Shuttle OD, Payload MDM, BAD, PAD)	POIC	CERN	20 kpbs	YES[1], [2]		
Experiment Sci/Eng Data	MCC-H	JSC/POCC and CERN	Shuttle: 2 Mbps	NO		
Experiment Sci/Eng Data	MCC-H	CERN	Shuttle: 2 Mbps	NO		
Experiment Sci/Eng Data	POIC	JSC/POCC	ISS: 2 Mbps	NO		
Experiment Sci/Eng Data	POIC	AMS GSE at MSFC USOC	ISS: 2 Mbps	NO		
Voice	MCC-H	JSC/POCC			YES	N/A
Voice	MCC-H	JSC/SOC			YES	N/A
Voice	POIC	CERN			NO	6 IvoDS interfaces required [3],
ISS Downlink Video		JSC/POCC				
Ground Commanding (ISS)	JSC/POCC	POIC				
Ground Commanding (ISS)	CERN	POIC				
Ground Commanding (Shuttle)	JSC/POCC	MCC-H				
POIC Services		JSC/POCC				
POIC Services		JSC SOC				
POIC Services		CERN				

[1]: Some parameters in the AMS-02 Critical Health Data can be decommutated and displayed by the POIC; however, AMS-02 has no requirement for POIC processing of their data.

[2]: AMS-02 GSE at USOC will convert UDP stream for file transfer to AMS-02 SOC and CERN with 20-40 Mbps bursts.

[3]: IvoDS is the current method for voice distribution to remote locations. If voice distribution is through other means when AMS-02 operates, six voice interfaces will be provided.

The following AMS-02 additional ground data support services requirements are listed in Table 7.2-2 and must be assessed for cost and schedule impacts prior to approval for implementation by the ISS Program.

TABLE 7.2-2 ADDITIONAL REQUIREMENTS/SERVICES FOR FLIGHT OPERATIONS

Additional Requirements/Services	Description
Early testing required at L-24 months	Require AMS-02 supplied Ground Support Computers (GSCs) located in the POIC that will be used to receive and archive all AMS-02 Mission Data. This data will be available for retrieval from AMS-02 remote facilities using a Transmission Control Protocol/Internet Protocol (TCP/IP) interface. Early testing of the interface between the POIC and these GSCs will be performed to ensure compatibility and transfer rate capabilities. All resource and scheduling requirements will be coordinated through POIC scheduling.

8.0 PROGRAM MANAGEMENT AND FUNDING

For the AMS Program, the NASA officially interfaces with DOE, which is the sponsor for the AMS-02 experiment. The DOE in turn sponsors the United States portion of the AMS International Collaboration, currently consisting of scientists and engineers from 16 countries to implement the AMS-02 experiment.

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 AMS Program objectives. The Engineering Directorate at NASA/JSC has been delegated responsibility for implementing the AMS Project for NASA Headquarters. NASA/JSC furnishes the USS-02 carrier and the assembled AMS-02 core experiments that comprise the AMS-02 payload as a standard ISS truss attached payload. The NASA/JSC Project Manager represents the AMS-02 Project to the Space Station Payloads Office. NASA Headquarters is responsible for providing the AMS-02 Program Scientist and the ISS Research Program Office for the AMS-02 payload.

APPENDIX A

ACRONYMS AND ABBREVIATIONS

APPENDIX A - ACRONYMS AND ABBREVIATIONS

AMS	Alpha Magnetic Spectrometer
APCU	Assembly Power Converter Unit
ATV	Automated Transfer Vehicle
BAD	Broadcast Ancillary Data
BFS	Backup Flight System
Bps	Bytes per second
CERN	Center European Research Nuclear, Geneva, Switzerland
CSA	Canadian Space Agency
DC	Direct Current
DDRS	Digital Data Recording System
DIMS	Digital Imagery Management System
DOC	Department of Commerce
DOE	Department of Energy
DOL	Discrete Output Low
DOS	Department of State
EAR	Export Administration Regulations
EBCS	External Berthing Camera System
EBIT	End-to-End Berthing and Integration Team
EMEP	Electromagnetic Effects Panel
EMI	Electromagnetic Interference
EMU	Extravehicular Maneuvering/Mobility Unit
ESA	European Space Agency
EVA	Extravehicular Activity
EVR	Extravehicular Robotics
EXPRESS	Expedite the Processing of Experiments to Space Station
ft^3	Cubic foot
FRGF	Flight Releasable Grapple Fixture
GFE	Government Furnished Equipment
GPC	General Purpose Computer
GSC	Ground Support Computer
GSE	Ground Support Equipment

HRDL	High Rate Data Link
HRFM	High Rate Frame Multiplexer
Hrs	Hours
H-II	H-II Transfer Vehicle
ICD	Interface Control Document
IP	Internet Protocol
IRD	Interface Requirements Document
ISS	International Space Station
ITS	ISS Integrated Truss Segment
IVA	Intravehicular Activity
IvoDS	Internet Voice Distribution System
JAXA	Japan Aerospace Exploration Agency
JSC	Johnson Space Center
kbps	Kilobits-per-second
kg	Kilogram
KSC	Kennedy Space Center
L-	Launch minus
lbm	Pound mass
LRDL	Low Rate Data Link
m^3	cubic meter
Mbps	Megabits-per-second
MBS	MRS Base System
MCC-H	Mission Control Center-Houston
MDM	Multiplexer/Demultiplexer
MIP	Mission Integration Plan
MLE	Middeck Locker Equivalent
MRS	Mobile Remote Servicer
MSFC	Marshall Space Flight Center
MT	Mobile Transporter
N/A	Not Applicable
NASA	National Aeronautics and Space Administration
NLR	No License Required
OD	Orbiter Downlink

OIU	Orbiter Interface Unit
PAD	Payload Ancillary Data
PAS	Payload Attach System
PCB	Payload Control Board
PCS	Portable Computer System
PD	Payload Developer
PDA	Payload Disconnect Assembly
PDGF	Power Data Grapple Fixture
PDI	Payload Data Interleaver
PGT	Pistol Grip Tool
PGSC	Payload General Support Computer
PIA	Payload Integration Agreement
POCC	Payload Operations Control Center
POIC	Payload Operations Integration Center
PVGF	Power and Video Grapple Fixture
ROEU	Remotely Operated Electrical Umbilical
SAFER	Simplified Aid for EVA Rescue
sec	second
SFHe	Superfluid Helium
SOC	Science Operations Center
SPDM	Special Purpose Dexterous Manipulator
SRMS	Shuttle Remote Manipulator System
SSC	Space Station Computer
SSER	Space-to-Space EMU Radio
SSP	Space Shuttle Program
SSRMS	Space Station Remote Manipulator System
STS	Space Transportation System
T-	Time minus
TAXI	Transparent Asynchronous Transmitter-Receiver Interface
TBD	To-Be-Determined
TBR	To-Be-Resolved
TCP	Transmission Control Protocol
TIA	Tailoring/interpretation Agreement
UDP	User Datagram Protocol

UMA	Umbilical Mating Assembly
U.S.	United States
USOC	United States Operations Center
USOS	United States On-orbit Segment
USS	Unique Support Structure
VAMS	Video Access Management System
Vdc	Volts direct current
W	Watt
WIF	Worksite Interface Fixture

APPENDIX B

GLOSSARY OF TERMS

<RESERVED>

APPENDIX C

OPEN ITEMS

APPENDIX C – OPEN WORK

Table C-1 lists the specific To Be Determined (TBD) items in the document that are not yet known. The TBD is inserted as a placeholder wherever the required data is needed and is formatted in bold type within brackets. The TBD item is numbered based on the section where the first occurrence of the item is located as the first digit and a consecutive number as the second digit (i.e., <**TBD 4-1**> is the first undetermined item assigned in Section 4 of the document). As each TBD is solved, the updated text is inserted in each place that the TBD appears in the document and the issue is removed from this table. As new TBD items are assigned, they will be added to this list in accordance with the above-described numbering scheme. Original TBDs will not be renumbered.

TABLE C-1 TO BE DETERMINED ITEMS

TBD	Section	Description	Status/Closure Date
		None	

Table C-1 lists the specific To Be Resolved (TBR) issues in the document that are not yet known. The TBR is inserted as a placeholder wherever the required data is needed and is formatted in bold type within brackets. The TBR issue is numbered based on the section where the first occurrence of the issue is located as the first digit and a consecutive number as the second digit (i.e., <**TBR 4-1**> is the first unresolved issue assigned in Section 4 of the document). As each TBR is resolved, the updated text is inserted in each place that the TBR appears in the document and the issue is removed from this table. As new TBR issues are assigned, they will be added to this list in accordance with the above-described numbering scheme. Original TBRs will not be renumbered.

TABLE C-2 TO BE RESOLVED ISSUES

TBR	Section	Description	Status/Closure Date
		None	

APPENDIX D

BASIC PAYLOD DATA

APPENDIX D

BASIC PAYLOAD DATA

TABLE D-1 BASIC PAYLOAD DATA (PAGE 1 OF 2)

Payload Title: Alpha Magnetic Spectrometer-02 (AMS-02)			
Payload Objectives: To search for antimatter in space, to search for dark matter and to study astrophysics. The experiment is a state-of-the-art particle physics detector utilizing a Cryogenic superconducting magnet with planes of detectors above, inside and below the magnet.			
Payload Mission Duration: Nominally 3-years Deep Space Full-View, Full Power, Magnet-On Data Acquisition.			
Payload Data	**Internal Resource Requirements**		**External Resource Requirement ISS/STS**
	ISS PCS	**STS DDRS-02**	
Payload On-Orbit Mass [lbm(kg)]	0	72.0 (32.7)	15,100.0 (6,849.2)
Payload On-Orbit Volume [ft^3(m^3)]	N/A	2.0 (0.06)	1,620.0 (45.9) [15]
Initial Payload Up Mass [lbm(kg)]	0	72.0 (32.7)	15,100.0 (6,849.2)
Initial Payload Down Mass [lbm(kg)]	N/A	72.0 (32.7)	N/A
Initial Payload Up Volume [ft^3(m^3)]	0	2.0 (0.06)	1,620 (45.9) [15]
Initial Payload Down Volume [ft^3(m^3)]	N/A	2.0 (0.06)	N/A
Total Resupply Rate-per-Year Up Mass [lbm(kg)]	N/A	N/A	N/A
Total Resupply Rate-per-Year Down Mass [lbm(kg)]	N/A	N/A	N/A
Total Resupply Rate-per-Year Up Volume [ft^3(m^3)]	N/A	N/A	N/A
Total Resupply Rate-per-Year Down Volume [ft^3(m^3)]	N/A	N/A	N/A
Minimum Start-up Power (W and sec)	0	60 – Continuous	2,830 – 3 hours
Continuous Power (W)	0	60	830 [13]
Minimum Continuous Power (“keep alive/survival”) (W)	0	0	2,400 [13]
EVA (Extravehicular Activity) Crew Time (hours per year)	N/A	N/A	N/A
IVA (Intravehicular Activity) Crew Time (hours per year)	N/A	10	N/A
Communications Downlink (Yes/No Mbps)	N/A	Yes / 2	Yes / 2 average; 20-40 peak [11] [12]
Communications Uplink (Yes/No Mbps)	N/A	Yes	Yes
Payload Bay Access Terminates at:	N/A	None	L–88 Hrs
Support Equipment	N/A	PGSC	APCU (2)
Co-location or Co-manifest Coordinated Payloads {Payload Name}	N/A	N/A	N/A
ISS Program Transportation Vehicle			
- Orbiter Payload Cargo Bay	N/A	N/A	Yes
- Orbiter Middeck	N/A	Yes	N/A
- ATV Transfer Vehicle	N/A	N/A	N/A
- H-IIA Transfer Vehicle	N/A	N/A	N/A
ISS Program Cargo Carrier/Logistics Carrier			
- Express Pallet	N/A	N/A	N/A
- Spacelab Logistics Pallet	N/A	N/A	N/A
- Pressurized Module (Passive Stowage)	N/A	N/A	N/A
- Other	N/A	N/A	N/A

TABLE D-1 BASIC PAYLOAD DATA (PAGE 2 OF 2)

Payload Data	Internal Resource Requirements		External Resource Requirement ISS/STS
	ISS PCS	STS DDRS-02	
ISS External On-Orbit Attach Site			
- ISS Truss Location	N/A	N/A	S3 Zenith Inboard PAS
- ESA External Payload Facility	N/A	N/A	N/A
- JAXA Exposed Facility	N/A	N/A	N/A
- Other (Non-Standard)	N/A	N/A	N/A
ISS Viewing Location/Payload Pointing			
- Viewing Orientation	N/A	N/A	S3 Zenith Inboard PAS
- Payload Pointing Direction/Line-of-Site Vectors	N/A	N/A	12-degrees off vertical from ISS -Z axis tilted inboard towards ISS -Y axis (port)). Unobstructed line-of-site into deep space requires a ±50-degree viewing cone referenced to the AMS-02 origin.
- Other	N/A	N/A	N/A
- Payload Computer Requirements			
- Shuttle Payload General Support Computer (PGSC)	N/A	[8], [14]	N/A
- Space Station Portable Computer System (PCS)	[7]	N/A	N/A
- Station Support Computer (SSC)	N/A	N/A	N/A
- Payload Provided Computer/Equipment	N/A	N/A	N/A
SSP Services/ISS Program - Funded SSP Services	N/A	N/A	N/A
Payload Optional Services – Procured or Program Funded	N/A	N/A	ISS Funded GFE: UMA, FRGF, PVGF, EBCS PD Procured: EVA Handrails, WIF Socket, ROEU PDA
Program-Furnished Equipment – Ground Requirements	N/A	N/A	N/A
Non-Nominal On-Orbit Operating Requirements	N/A	N/A	N/A
Laboratory Support Equipment – Pressurized Volume	N/A	N/A	N/A
Pressurized Accommodations - Other	N/A	N/A	N/A
Ferry Flight Requirements	N/A	N/A	N/A
Additional Requirements (specify)	N/A	N/A	[1], [2], [3], [4], [5], [6], [10], [13]

[1] At AMS-02 berthed on station, the AMS-02 requires ISS Command & Data Handling connectivity of the truss-attached payload assembly.

[2] Late pad access required to top-off superfluid helium to be completed by L-88 hours prior to launch.

[3] After payload installation into the Orbiter payload bay at the pad, the AMS-02 payload requires power for pre-launch, ascent, and on-orbit Orbiter/payload operations for payload checkout and Orbiter Go/No-Go decision.

[4] After payload installation into the Orbiter payload bay at the pad, the AMS-02 requires Command and Data Handling connectivity to the payload for pre-launch and on-orbit Orbiter/payload operations.

[5] T-0 connectivity for power (120 Vdc), MIL-STD-1553 data, and RS-422 data.

[6] Require early access/transfer from STS to S3 truss, installation, power, command and data connection, for 48-hours of operation including magnet charging and checkout prior to an AMS-02 Stay/No-Stay decision on ISS.

[7] Portable Computer System (PCS) is ISS provided and will already be on-orbit, so no payload provided hardware is necessary on ISS.

[8] For the Digital Data Recording System (DDRS-02), one (1) Middeck locker equivalent (MLE) is required for interface hardware between the Payload General Support Computer (PGSC)/AMS-02 and one (1) Middeck locker equivalent (MLE) passive stowage is required for recording media.

[9] The AMS-02 will require a maximum of 2,000 watts during its stay in the Orbiter Payload Bay. While the actual power draw may not be 2,000 watts continuously, it does represent the maximum. This power is required for avionics checkout and thermal conditioning. A better assessment of the planned profile can only be provided when detailed attitude and duration information are provided as part of the nominal flight design process.

[10] Once on orbit, the AMS-02 will require an average downlink rate of 2 Mbps via the Ku-Band during its stay in the Orbiter Payload Bay. The AMS-02 payload will also require Payload Data Interleaver (PDI) downlink of 1553 data from the Orbiter Interface Unit. It is understood that Tracking and Data Relay Satellite coverage, blockage, and conflicts with ISS will restrict the downlink.

[11] The AMS-02 Payload is designed to operate for 3-years continuously with its helium gas supply, any loss or reduction of power reduces this duration. This duration is reduced even more considerably if the Cryocoolers are deactivated. Inactive Cryocoolers add a Heat Load to the Super Fluid Helium Tank and further decrease duration. Additionally, an estimate of 50 percent of the remaining avionics power must be maintained to thermally control the payload given potential attitudes. Given specific attitude and duration details, the AMS-02 Project team can provide a more detailed description of overall impacts.

[12] A time-tagged Orbiter Backup Flight System (BFS) General Purpose Computer (GPC) discrete command will be used as a back-up for the AMS-02 barometric switch whose primary function is to open the helium tank nominal vent to space.

[12] The AMS-02 volume: Payload is 9 ft (orbiter +x axis) x 15 ft (orbiter +y axis) x 12 ft (orbiter +z axis) = 1,620.0 cubic feet (45.9 cubic meters).