

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

## **International Space Station Program**

**Baseline (Draft – June 2003)**

**June 2003** (*last updated 4/7/03 Miley*)

**TYPE 1, Pending NASA Approval**

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**National Aeronautics and Space Administration  
International Space Station Program  
Johnson Space Center  
Houston, Texas**



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REVISION AND HISTORY PAGE

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**SSP 57113**  
**Baseline (Draft – June 2003)**

**INTERNATIONAL SPACE STATION PROGRAM**

**PAYLOAD INTEGRATION AGREEMENT FOR  
ALPHA MAGNETIC SPECTROMETER-02**

CHANGE SHEET

Month XX-XX-XX

Baseline

Space Station Control Board Directive 006999, dated XX-XX-XX

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CHANGE INSTRUCTIONS

SSP 57113, Payload Integration Agreement for Alpha Magnetic Spectrometer-02, has been baselined by the authority of SSCD 006999. All future updates to this document will be identified on this change sheet.

**SSP 57113**  
**Baseline (Draft – June 2003)**

**INTERNATIONAL SPACE STATION PROGRAM**

**PAYLOAD INTEGRATION AGREEMENT**  
**ALPHA MAGNETIC SPECTROMETER-02**

Baseline (Reference SSCD 006999, dated XX-XX-XX)

LIST OF EFFECTIVE PAGES

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The current status of all pages in this document is as shown below:

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**INTERNATIONAL SPACE STATION PROGRAM**  
**PAYLOAD INTEGRATION AGREEMENT**  
**FOR**  
**ALPHA MAGNETIC SPECTROMETER-02 (AMS-02)**

**APPROVAL**

**June 2003**

_____	_____	<u>NASA/SM2</u>
James R. Bates	Date	Org.
AMS-02 Mission Manager		

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## **1.0 PURPOSE**

Pursuant to the requirements established in SSP 57061, Standard Payload Integration Agreement for Unpressurized Payloads, 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) Program, represented by the Space and Life Sciences Directorate AMS-02 Mission Manager, and the International Space Station (ISS) Program, represented by the ISS Program 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 standard truss attached ISS payload. The AMS-02 Program 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.

## **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 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) superconducting 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.
- AMS-01 used a Digital Data Recording System (DDRS) to continuously record, on-board, all of the science and engineering data. The AMS-02 will utilize a similar DDRS during Space Shuttle operations; however, during ISS operations, the AMS Crew Operating Post (ACOP), an EXPedite the PROcessing of Experiments to Space Station (EXPRESS) Locker payload, will be provided for continuous recording and playback (for downlink) of science and engineering data to ensure that AMS-02 science data will not be lost during any normal or unplanned communications outages of the ISS.
- The AMS-01 mission length was 100 hrs; AMS-02 mission length is 3-years of recorded science data.

### **3.0 SCOPE**

The effectivity of this PIA is immediate and continues through the AMS-02 payload planned on-orbit operational mission life of 3-years in full deep space view. This agreement terminates after post-flight processing of the payload at the John F. Kennedy Space Center (KSC) is completed and the payload physically departs from KSC.

**3.1** This PIA establishes the basic joint working agreements between the AMS-02 Program and the ISS Program Payloads Office to provide for integration/analyses, transportation services, installation, and data retrieval of the AMS-02 payload.

**3.1-1** The AMS-02 Program 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 Assembly (ITA) S3 zenith inboard Payload Attach System (PAS) site.

**3.1-2** The ISS Program will transport the AMS-02 payload's external and internal components on separate Space Shuttle flights to ISS; perform the payload accommodation engineering, and necessary AMS-02 transportation integration services for each component as specified in SSP 57061.

**3.1-3** The ISS Program will provide services for transfer to, installation onto the ISS, and fly the AMS-02 payload on station as an externally attached payload furnishing on-orbit services to the payload for data retrieval. The AMS-02 payload after completing its 3-years on-orbit mission life will be transferred from the ISS to a Space Shuttle flight for return of the payload to the KSC landing site for de-integration and return of the AMS-02 flight hardware to the AMS-02 Program.

**3.2** All signatories of this PIA will provide the best effort to execute the flight of the AMS-02 payload. In the event that the ISS Program is unable to accomplish the successful transportation and installation of AMS-02 onto the ISS, and to provide the agreed upon services to AMS-02, through no fault of AMS-02, the ISS Program will exert its best efforts to schedule a reflight of AMS-02 to the ISS at the first available launch opportunity to obtain science results.

**3.3** 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** It is the responsibility of the AMS-02 Program to assure compliance with safety requirements, and verify compatibility of payload physical and functional interfaces with the applicable ISS interface agreements and documents. The ISS Program, however, intends maximum flexibility in determining the manner or method to be used to accomplish this verification. 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).

**4.2** The PIA requirements source for the AMS-02 hardware and software interfaces, the AMS-02 PIA Increment Addendum, 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** 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. The DOE has declared that the AMS-02 core experiment is controlled by Export Administration Regulations (EAR), 15 CFR 730-774, and is classified as EAR99 - Basic Research - No License Required (NLR). NASA Export Control has also classified the NASA supplied payload integration hardware and related interface technical information as EAR99-NLR. The Department of State reviewed the AMS-02 export status on May 18, 2001 and referred all further reviews and recommendations to the Department of Commerce.

#### **5.0 PAYLOAD DESCRIPTION**

The AMS-02 experiment is a state-of-the-art particle physics detector. The science objectives of the AMS-02 experiment are to search for anti-matter (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).

The AMS-02 is an external full truss mounted payload that will utilize a Cryogenic Superconducting Magnet (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 anti-matter.

A portion of the AMS-02 payload, the ACOP, resides within the pressurized volume of an ISS module for data storage, monitoring and linkage to the ISS systems for command and downlink. The ACOP is to be delivered and checked out before the arrival of the external AMS-02 unpressurized payload. The ACOP will be delivered to the ISS by the Space Shuttle and will be installed into an Express Rack.

## **6.0 UNIQUE AGREEMENTS, CONSTRAINTS, OR SERVICES**

The following paragraphs identify deviations and unique requirements 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.

AMS-02 is a robotic-deployable payload, requiring scheduled Extravehicular Robotics (EVR) operations for payload deployment, installation, release and retrieval. Payload design incorporates two grapple fixtures, a Flight Releasable Grapple Fixture (FRGF) and a Power Video Grapple Fixture (PVGf), and the required External Berthing Camera System avionics package for installation on the payload's USS-02 allowing for dual robotic arm operations for attachment of AMS-02 to the designated ITA S3 PAS site.

ACOP related pressurized agreements and requirements are detailed in the ACOP Express Integration Agreement.

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 Mission Manager. The ISS Program will provide deployment of AMS-02 from the Orbiter no later than flight day 4 to the ISS S3 zenith inboard PAS in order to allow AMS-02 to perform a functional checkout and assess a second Go/No-Go decision to stay or return prior to Orbiter undock. A minimum of 48-hours is required for payload functional checkout after the AMS-02 electrical connections with the truss site is 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 the second No-Go 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.

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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.

The AMS-02 Program will comply with the Lockheed Martin Quality System Manual for Science, Engineering, Analysis, and Test (SEAT) Operations, LMSEAT-31041 problem tracking and reporting system for hardware built and processed by Lockheed Martin or its subcontractors, and the NASA Lyndon B. Johnson Space Center (JSC) Quality Management System (QMS), JPD-5335 Revision C, for the hardware built and processed at JSC facilities. LMSEAT-31041 maintains reporting of problems using a Non-Compliance Failure Reporting system similar to the ISS Program Problem Reporting and Corrective Action (PRACA) system. The AMS-02 Project shall maintain this closed loop reporting system of problems, meeting the Level 1 criteria that affect common station hardware, and entering this information into the ISS Program PRACA system.

The AMS-02 has no planned Extravehicular Activity (EVA). Therefore, AMS-02 will perform/submit only safety related EVA analyses and/or tests instead of all the EVA related analyses and tests.

AMS-02 will submit the payload requirements verifications for review and approval by the ISS Program in accordance with SSP 57213, AMS-02 Attached Payload Hardware Interface Control Document (ICD). The payload unique ICD will identify the applicable Interface Requirements Document (IRD) requirement, its verification method, required submittal data, due date, and status. The detailed description of the tests will be included in the respective Task Preparation Sheet, procedure, or test plan retained by Lockheed Martin.

The Umbilical Mechanical Assembly (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 NASA.

The Flight Releasable Grapple Fixture (FRGF) will be furnished to AMS-02 as NASA/GFE, at no cost to the AMS-02, and will be certified by NASA.

## **7.0 ATTACHMENT 1 - BASIC PAYLOAD HARDWARE AND DATA**

Reference the contents of Attachment 1 – Basic Payload Hardware and Data.

## **8.0 PROGRAM MANAGEMENT AND FUNDING**

The DOE with the AMS-02 Collaboration provides the AMS-02 Experiment to NASA for integration onto the ISS via the NASA Headquarters/Code U. Code U, via the AMS-02 Mission Management team at JSC, furnishes the USS-02 carrier and the assembled AMS-02 Core Experiments which comprises the AMS-02 Payload as a standard ISS truss attached payload. The NASA/JSC Mission Manager represents the AMS-02 Program to the ISS Program and Space Shuttle Program.

AMS-02 PAYLOAD INTEGRATION AGREEMENT (PIA)

ATTACHMENT 1 – BASIC PAYLOAD DATA (PAGE 1 OF 3)

ATTACHMENT 1 – BASIC PAYLOAD DATA				
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: 3-years Full-View, Full Power, Magnet-On Data Acquisition.				
Payload Data	Prior Flight Internal Resource Requirements (ACOP)	Internal Resource Requirements		External Resource Requirement
		ISS PCS	STS DDRS-02	
Payload On-Orbit Mass [lbm(kg)]	144 (65)	0	72 (32.7)	14,809 (6,717)
Payload On-Orbit Volume [ft <sup>3</sup> (m <sup>3</sup> )]	5.8 (0.16)	N/A	2 (0.9)	1,400 (39.6)
Initial Payload Up Mass [lbm(kg)]	144 (65)	0	72 (32.7)	14,809 (6,717)
Initial Payload Down Mass [lbm(kg)]	144 (65)	0	72 (32.7)	14,009 (6,354)
Initial Payload Up Volume [ft <sup>3</sup> (m <sup>3</sup> )]	5.8 (0.16)	0	2 (0.9)	1,400 (39.6)
Initial Payload Down Volume [ft <sup>3</sup> (m <sup>3</sup> )]	5.8 (0.16)	0	2 (0.9)	1,400 (39.6)
Total Resupply Rate-per-Year Up Mass [lbm(kg)]	72.0 (32.7) Replace As Needed	N/A	N/A	N/A
Total Resupply Rate-per-Year Down Mass [lbm(kg)]	72.0 (32.7) Replace As Needed	N/A	N/A	N/A
Total Resupply Rate-per-Year Up Volume [ft <sup>3</sup> (m <sup>3</sup> )]	2.0 (0.9) Replace As Needed	N/A	N/A	N/A
Total Resupply Rate-per-Year Down Volume [ft <sup>3</sup> (m <sup>3</sup> )]	2.0 (0.9) Replace As Needed	N/A	N/A	N/A
Minimum Start-up Power (W and sec)	200 – Continuous.	0	60 – Continuous	2300 – 3 hours
Continuous Power (W)	200	0	60	2,000
Minimum Continuous Power (“keep alive/survival”) (W)	0	0	0	1,500 <sup>[13]</sup>
EVA Crew Time (hours per year)	N/A	N/A	N/A	N/A
IVA Crew Time (hours per year)	20 (ISS)	See ACOP	10	N/A
Communications Downlink (Yes/No Mbps)	Yes / 1–40	See ACOP	Yes / 1–2	Yes / 1–2
Communications Uplink (Yes/No Mbps)	Yes	See ACOP	Yes	Yes
Late/Early Access (launch/return/both/none)	None	N/A	None	L–88 Hrs
Support Equipment	PCS, ISIS Rack Laptop	See ACOP	PGSC	APCU (2)
Co-location or Co-manifest Coordinated Payloads {Payload Name}	AMS-02	ACOP	ACOP	ACOP

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<b>ATTACHMENT 1 – BASIC PAYLOAD DATA</b>				
ISS Program Transportation Vehicle				
- Orbiter Payload Cargo Bay				Yes
- Orbiter Middeck	Yes		Yes	
- ATV Transfer Vehicle				
- H-IIA Transfer Vehicle				
ISS Program Cargo Carrier/Logistics Carrier				
- Express Pallet				
- Spacelab Logistics Pallet				
- Pressurized Module (Passive Stowage)	Yes			
- Other				
ISS Unpressurized On-orbit Attach Site				
- ISS Truss Location				PAS S3 Zenith Inboard
- ESA External Payload Facility				
- NASDA Exposed Facility				
- Other (Non-Standard)				
Additional Requirements (specify)	[9], [12]	[7]	[8]	[1], [2], [3], [4], [5], [6], [10], [11], [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 at 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 & 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 magnet charging prior to ISS Go/No-Go decision.
- [7] Portable Computer System (PCS) is ISS provided and will already be on-orbit, so no payload provided hardware is necessary on ISS with the exception of ACOP. (See Note 9 for ACOP requirements)
- [8] For the Digital Data Recording System (DDRS-02), 1 Middeck Locker Equivalent (MLE) is required for interface hardware between the Payload General Support Computer (PGSC)/AMS-02 and 1 Middeck Locker Equivalent (MLE) passive stowage is required for recording media.
- [9] ACOP requirements provided for information only. The latest ACOP requirements are provided in Express Payload Integration Agreement.

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- Earlier ISS flight (L-3 to L-6 months) required to stage/install the ACOP assembly in ISS locker and install/initialize/checkout in the pressurized volume before AMS-02 truss-attached payload assembly portion is integrated and berthed on station. Passive stowage until arrival on station of the AMS-02 truss-attached payload assembly.
- Utilize two (2) MLEs for subrack payload equipment transport to and from the ISS pressurized volume for AMS-02 pressurized payload assembly.
- Utilize one (1) International Standard Payload Rack (ISPR) ISS locker for the planned 3-years of payload mission life.
- Installation of one (1) pair of non-standard fiber optic interconnect cables for high rate data link (HDRL) connections between the ISS locker and HDRL port on Utility Interface Panel (UIP).
- On-orbit payload stowage required for exchange of payload media (e.g., removable hard drives) in addition to the one (1) ISS locker utilized as the AMS-02 Crew Operations Post. Passive stowage for 20 exchangeable payload computer media components.
- At AMS-02 berthed on station, the AMS-02 requires ISS Command and Data Handling connectivity of the truss-attached payload assembly and the pressurized volume payload assembly.
- ACOP/AMS-02 internal hardware will be resupplied at the rate needed shown for the life of AMS-02. Requirement is 2 MLE's at the initial launch of AMS.

[10] Once on orbit, the AMS-02 will require a maximum of 2000W during its stay in the Orbiter Payload Bay. While the actual power draw may not be 2000W 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.

[11] 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.

[12] The AMS-02 + ACOP average downlink rate = 2Mbps. However, the ACOP has the capability to downlink larger burst of 40 Mbps.

[13] The AMS-02 Payload is designed to operate for 3-years continuously, 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 Experiment team can provide a more detailed description of overall impacts.