DATE PREPARED: **October 18, 2007 Rev. A: 10-28-10 Rev. B: 11-17-10**	**ISS PAYLOAD OFFICE PIRN/EXCEPTION FORM**	**PAGE 1 OF 9**

Doc. No., Rev. & Title: **SSP 57213, Revision A** **Alpha Magnetic Spectrometer (AMS) Interface Control Document**	PIRN No: **57213-NA-0014B**

TITLE:

AMS (Alpha Magnetic Spectrometer) – DC Magnetic Field Exceedance

Originator: Name: **Trent Martin** Agency: **NASA JSC AMS Project Office / EA** Phone: **281-483-3296** Email: **trent.d.martin@nasa.gov**	PIRN Type: ***Check one*** ☐ Standard PIRN ☒ Exception	FAX Approval Signatures to this Number: **314-777-2866**
Utilization Change Engineer: Name: **Henry Hoang** Agency: **Boeing PEI** Phone: **281-226-6054** Email: **henry.hoang2@boeing.com**	SSCN/CR **TIA 1133d** **Hamilton Sundstrand Certification EMU 1-13-054**	RELATED PIRN No.: **N/A**
Agency Tracking No.: **57213-0008**	SYSTEM/ELEMENT AFFECTED & STAGE EFFECTIVITY: **ULF6 through end of life for All ISS except Russian ***	

REASON FOR CHANGE OR REQUIREMENT(S) VIOLATION:

The Alpha Magnetic Spectrometer-02 (AMS-02) AMS does not meet SSP 30237, D.5 DC Magnetic Field requirements flowed down from SSP 57003, Paragraphs 3.2.2.4.7. The EME panel has approved the exception to the requirement by EMEP TIA # 1133d.
* Affected parts are listed in TIA # 1133d.

Revision A: Add EMU assessments to the Rationale on page 2 per EVA/AIT request on 10/28/10 and replace TIA 1133b with TIA 1133c.
Revision B: To include revision d of TIA # 1133.

PARAGRAPHS, FIGURES, TABLES AFFECTED (For PIRN use only)

Page	Paragraph(s)	Figures(s)	Table(s)	R	A	D
3-45	3.2.2.4.7	N/A	N/A			

AFFECTED INTERFACING PARTIES

	SIGNATURE & ORGANIZATION	DATE	SIGNATURE & ORGANIZATION	DATE	SIGNATURE & ORGANIZATION	DATE
CONCUR	/s/ Mike Miller/ OZ3	1/14/11	/s/ Jean Huber/ NASA GSFC	1/12/11	/s/ Lonnie Cundieff for Michael Berdich/ OM7	11/19/10
	/s/ Vic Sanders/ Boeing PEI	1/12/11	/s/ Stephanie Sipila/ NASA EVA/AIT	11/19/10	/s/ Larry Grissom/ NASA ER3	11/19/10
	/s/ Bill Bowers/ S&MA	11/21/10	/s/ Chris Schmitt/ Boeing EVA	11/22/10	/s/ Rod Jones/ PCB	1/14/11
	/s/ Trent Martin/ AMS	11/21/10	NASA EME Approved TIA # 1133d-Matt McCollum	9/29/10		
			Boeing EME Approved TIA # 1133d-Bob Armstrong	9/29/10		

SSP 57003 Requirement:

3.2.2.4.7 DIRECT CURRENT (DC) MAGNETIC FIELDS

Payloads containing devices that intentionally generate magnetic fields (electromagnets and permanent magnets) shall not generate DC magnetic fields that exceed 170 dB above a picotesla (dBpT). The requirement applies at a distance of 7 centimeters (cm) from a point on the enclosure of the Attached Payload or equipment case nearest to source of the field.

Note: Requirements are not applicable to solenoid valves, solenoid relays, and electric motors with power consumption of less than 120 Watts.

Proposed AMS Payload Exception:

3.2.2.4.7 DIRECT CURRENT (DC) MAGNETIC FIELDS

Payloads containing devices that intentionally generate magnetic fields (electromagnets and permanent magnets) shall not generate DC magnetic fields that exceed 170 dB above a picotesla (dBpT). The requirement applies at a distance of 7 centimeters (cm) from a point on the enclosure of the Attached Payload or equipment case nearest to source of the field **except the AMS-02 payload with a magnetic field strength of approximately 179 dBpT (8.75 Gauss) at approximately 7 cm (2.8 inches) from the vacuum enclosure**.

Rationale:
The rationale is documented in the attached TIA # 1133d. The Alpha Magnetic Spectrometer-02 (AMS-02) employs a large permanent magnet to attain its science goals. Every effort has been made to reduce the magnetic field outside of the AMS-02 envelope while maintaining sufficient internal field, but the fringe field exceeds the DC magnetic field requirements as defined in SSP-57003, Section 3.2.2.4.7. A study by the Electromagnetic Effects Panel (TIA 1133d) showed that there was no ISS hardware on the S3 Truss that could be affected by the AMS magnetic field.

This TIA # 1133d is similar to TIA # 0310, dated 22 August 2000, and approved 24 October 2001 in its entirety.

According to Hamilton Sundstrand Certification EMU 1-13-054 dated on 12/2001, the EMU operates nominally during EVA exposure to DC Magnetic source of up to 300 Gauss. Therefore, the EMU will not be affected by the AMS magnetic field strength.

PEI Analysis:

1. PEI agrees with the EME Panel analysis and rationale documented in the attached EMEP TIA # 1133d.

2. This exception is for all ISS except Russian.

3. The exceedance of the DC Magnetic Fields limits will not affect other payload operations of the ELC2. The EME panel has evaluated the effects of the exceedances and approved the TIA.

4. The Canadian Space Agency (CSA) has concurred with the AMS-02 DC Magnetic Fields exceedance.

PEI Recommendation:
Approve this exception based on the approved EMEP TIA # 1133d, the rationale stated above.

Operational Constraints:
None identified at this time

Operational Constraints Rationale:
None identified at this time

PTR Recommendation:

Approve as written

PCB Disposition:

Approve as written

ATTACHMENTS: TIA #1133d and Hamilton Sundstrand EMU 1-13-054

ISS Electromagnetic Effects Panel
Tailoring/Interpretation Agreement

SUBMITTAL DATE	AGREEMENT NO.	REV.	FLIGHT #(s)	Page 1 of 3
14 May 2010	TIA # 1133	d	ULF6	

SYSTEM	ORIGINATOR and PHONE NO.	ORGANIZATION / CONTRACTOR
AMS-02 Magnet	Robert J. Armstrong/281-226-6132	Boeing/Houston EME

END ITEM/CONFIG. ID NO.	PART NUMBER(s)	DESCRIPTION	ASSEMBLY(s)	GFE	Payload
Alpha Magnetic Spectrometer	AMS-02	AMS-02 DC Magnetic Field	All ISS Except Russian	No	Yes

SPECIFICATION NUMBER	SPEC. PARAGRAPH NO.	MANUFACTURER	CRITICALITY	SEVERITY
SSP 30237	D.5	ETH, Zurich	3	1

ISSUE DESCRIPTION: (use continuation pages if required)

The Alpha Magnetic Spectrometer-02 (AMS-02) payload utilizes an on-board permanent magnet with a magnetic field strength of 1400 Gauss at the magnetic center. The magnetic field was measured to be 10 Gauss at a distance of 61.5 inches from the magnetic center which corresponds to the edge of the AMS-02 vacuum enclosure. The magnetic field strength at 7 cm (about 2.8 inches) from the enclosure was calculated to be 8.75 Gauss at a distance of 64.3 inches.

SSP 30237, paragraph D.5 specifies a maximum magnetic field strength, for DC magnetic devices, of 3.16 Gauss at a distance of 7 cm (2.76 inches) from the magnetic center. The AMS-02 exceeds the required value of 3.16 Gauss.

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

The Alpha Magnetic Spectrometer-02 (AMS-02) permanent magnet is allowed to meet the requirements of SSP 30237, paragraph D.5 (DC Magnetic Fields) with a magnetic field strength of approximately 8.75 Gauss at approximately 2.8 inches (7 cm) from the vacuum enclosure of the AMS-02.

This TIA supersedes TIA # 0310, dated 22 August 2000, and approved 24 October 2001 in its entirety.

RATIONALE: (use continuation pages if required)

The AMS-02 permanent magnet's field strength at the magnetic center is 1400 Gauss. A magnetic field strength of 10 Gauss was measured at 61.5 inches from the magnetic center which is the closest distance from the outside of the AMS enclosure. The far field approximation of magnetic field strength as a function of increasing distance can be written as:

B2 = B1 * (R1)^^3 / (R2)^^3

where "^^3" denotes the cube of the quantity in parentheses and "*" denotes multiplication.

For B1 = 10 Gauss, R1 = 61.5 inches, and R2 = 64.3 inches, B2 is calculated to be 8.75 Gauss which exceeds the requirement of 170 dB above a picotesla which is equivalent to 3.16 Gauss.
(Continued on page 2)

AGREEMENT DISPOSITION

PRIME EME	NASA EME	DATE	APPROVE	WITHDRAW	REJECT
Bob Armstrong	Matt McCollum	9/29/2010	X		

COMMENTS:
6/1/2010 Updated TIA per discussion at meeting to clarify content per direction of M. McCollum.
6/1/2010 TIA deferred to allow M. McCollum to submit Rev. A of the TIA to the Canadian Space Agency for their review.
9/29/2010 Canadian Space Agency concurrence received.
9/29/2010 TIA approved out of board.
10/18/2010 Rationale changed: location corrected from S4 to S3, per EMEP co-chair.
11/11/2010 Rationale updated per mandatory reviewer comment, in second-to-last paragraph.

ISS Electromagnetic Effects Panel
Tailoring/Interpretation Agreement Continuation Page

SUBMITTAL DATE	AGREEMENT NO.	REV.	FLIGHT #(s)	Page 2 of 3
14 May 2010	TIA # 1133	d	ULF6	

SYSTEM	ORIGINATOR and PHONE NO.	ORGANIZATION / CONTRACTOR
AMS-02 Magnet	Robert J. Armstrong/281-226-6132	Boeing/Houston EME

Include Heading of Each Continuation Paragraph

RATIONALE: (continued)

The AMS-02 will be permanently located on the S3 Truss with the magnet assembly center at ISS coordinates, in inches, of X-33.7, Y-840.9, and Z-152.8. Two ISS assemblies in the vicinity of these coordinates are the ISS Mobile Transporter (IMT) at a distance of approximately 157 inches and the Expedite the Processing of Experiments to Space Station (ExPRESS) Logistics Carrier 2 (ELC2) at a distance of approximately 170 inches from magnetic center. The maximum magnetic field strength at the IMT was calculated to be 0.6 Gauss and the maximum magnetic field strength at the ELC2 was calculated to be 0.5 Gauss.

The Houston Electromagnetic Effects (EME) Group evaluated the impact of the AMS-02 permanent magnet on the IMT and the ELC2 and found that the AMS-02 field strength fell off to 0.6 Gauss and 0.5 Gauss respectively. Since the IMT and ELC2 are able to withstand a DC magnetic field strength of greater than 35 Gauss no impact is expected.

The Canadian Space Agency (CSA) specified the maximum magnetic field strength exposure limit is 6.0 Gauss for the Space Station Robotic Manipulator System (SSRMS). The magnetic field strength at the grapple fixtures was determined by the AMS-02 project to be 3.89 Gauss for the Flight Releasable Grapple Fixture (FRGF) and 3.28 Gauss for the Power and Video Grapple Fixture (PVGF). These values are on page 6 of the document "Permanent Magnet Impacts to STS/ISS/MOD" that was presented at the AMS-02 Delta Critical Design review (CDR) held on 04 May 2010 and 05 May 2010.

The AMS-02 magnetic field was calculated to be 8.75 Gauss at the specified measurement distance of 2.8 inches (7 cm). Since the field strengths at the FRGF and PVGF grapple fixtures are below the 6.0 Gauss limit for the SSRMS, CSA will not need to evaluate any additional impact of the 2.75 Gauss exceedance of the AMS-02 permanent magnet on the SSRMS.

This is criticality 3 and severity 1 hardware. This TIA does not impose any operational constraints. This TIA is for all of the ISS except the Russian Segment. This TIA is similar to TIA # 0310.

ISS Electromagnetic Effects Panel
Tailoring/Interpretation Agreement
Technical Concurrence

SUBMITTAL DATE	AGREEMENT NO.	REV.	FLIGHT #(s)	Page 3 of 3
14 May 2010	TIA # 1133	d	ULF6	

SYSTEM	ORIGINATOR and PHONE NO.	ORGANIZATION / CONTRACTOR
AMS-02 Magnet	Robert J. Armstrong/281-226-6132	Boeing/Houston EME

MEMBERS

NAME	DATE	ORGANIZATION
		Space Station Office, KSC
		Payloads Office, ISSP
		Engineering Directorate, JSC
		Safety and Mission Assurance/Program Risk Office, ISSP
		NASA Frequency Management Office
		Boeing Development Site – Huntsville
		Electrical Power Systems

AD HOC MEMBERS

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

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EMU 1 – 13-054
REVISION: INITIAL

**EXTRAVEHICULAR MOBILITY UNIT (EMU)
WITH 12 VOLT ACCESSORIES, EMU SAFER AND TOOLS
MAGNETIC
CERTIFICATION TEST REPORT
FOR THE
INTERNATIONAL SPACE STATION / ORBITER
ENVIRONMENTS**

DRL 13

CONTRACT: NAS 9-97150

Background:

The ISS Program plans to integrate the Alpha Magnetic Spectrometer, which includes a powerful electromagnet producing B fields up to 2000 Gauss at the perimeter of the experiment. The investigation of EMU exposure limits was proposed to understand if any hazard would exist with EVA in proximity to the Payload. In addition, ISS and Orbiter payloads are using a growing number of magnetic sources. NASA STS and ISS interface documents do not currently specify a static DC magnetic environment or limits of magnetic exposure for the EMU flight system.

EMU component analysis and test were performed to evaluate performance when exposed to high levels of magnetic fields. These tasks were done in preparation for the integrated test of the flight systems and accessories. The analysis and test showed that EMU would be susceptible to static DC magnetic exposure.

The EMU component test results showed that many susceptible functions in the flight systems could not withstand the 2000 Gauss level that may be encountered in proximity to the AMS-02 Spectrometer. Results were documented in report QLR-00-46. Analysis and calculations using the susceptibility threshold of the components and their locations within the perimeter of the EMU flight equipment were performed. Results were combined with the B field gradient data for the AMS-02 magnet. Result of this analysis showed the limit of magnetic exposure for the EVA systems would be 600 Gauss.

The most susceptible and critical component was found to be the EMU fan. Exposures to fields up to 600 Gauss show influence of the magnetic force on the Hall effect control devices. Fan current and speed increase as a result of exposure in a sensitive orientation. We found that exposure above the 600 Gauss threshold may cause the EMU current limiters to trip, stopping the fan. Reset of these circuits would require an EVA crewmember to remove the EMU from the magnetic influence, and perform a power restart. The fan would then resume nominal operation. This has not been previously performed during mission EVA and is not recommended by Hamilton Sundstrand.

The Extra Vehicular Mobility Unit (EMU) with ISS 12 Volt Accessory equipment, Space Station EMU Radio (SSER), SAFER, and Pistol Grip Tool (PGT) were tested for evaluation of exposure to Magnetic Environments for the International Space Station and Shuttle/Orbiter Missions. Tests were conducted at the NASA Lyndon B. Johnson Space Center Facilities, Sonny Carter Facility, Advanced Space Propulsion Lab, in June 2000, August 2000, and at the Hamilton Sundstrand Space Systems EMC Facility, December 2001. Tests were performed to controlled procedures in accordance with JSC TPS; 1K0020064 (ED-0918), 130020078 (ED-0918), and TS0020124 (ED-0918), and ED-1012.

Conclusion & Recommendation:

The Magnetic exposure testing demonstrates nominal operation of the Extra Vehicular Mobility Unit (EMU) with 12 Volt Accessory equipment (WVS/ERCA, Heated Glove with ILCVR), Space Station EMU Radio (SSER), and SAFER in the Magnetic environment of up to 300 Gauss. Operation of Pistol Grip Tools (PGT) is nominal up to a limit of 250 Gauss, with nominal performance restored following removal of the magnetic influence. Keep out zones and protection limits may be warranted for magnetic sources as specified herein.

The Magnetic environment defined for the International Space Station and Shuttle/Orbiter Missions may include static DC Magnetic sources from payloads and experiments including the Alpha Magnetic Spectrometer, AMS-02 with magnetic fields in excess of 2000 Gauss. Exposure to levels of static magnetic field in excess of the 300 Gauss limit may be hazardous to both equipment and crew.

- Certification is recommended for operation of the Extra Vehicular Mobility Unit (EMU) with 12 Volt Accessory equipment (WVS/ERCA, Heated Glove, and ILCVR), Space Station EMU Radio (SSER), and SAFER in the Magnetic environment. The EMU EVA exposure to static DC magnetic fields shall be limited, not to exceed 300 Gauss applied at the perimeter of the flight equipment for any axis of exposure.

- PGT Tools may not operate when exposed to magnetic field in excess of 250 Gauss. Nominal performance is restored when the magnetic source is reduced or removed.

- The WVS/ ERCA transmits video but does not switch lenses when magnetic exposure exceeds 350 Gauss. Nominal performance is restored when the magnetic source is reduced or removed.

- Magnetic attraction of EMU equipment, accessories and tools may be a hazard with exposure to large magnets. In the case of Payloads and flight components that present a strong magnetic field, such as the Alpha Magnetic Spectrometer, AMS-02, a means to limit crew exposure to the magnetic hazard is recommended. If the Magnetic force is strong and large enough to influence the magnetic materials that make up the EMU flight equipment and Tools, a protective barrier shall be placed around the source so that the crewmember is prohibited from inadvertent entry beyond recommended limits or of being pulled into the increasing strength of the magnetic field. Therefore, protective barriers or specific tethering of the EVA crewmember and tools shall be implemented surrounding powerful magnetic sources to assure that the magnetic field exposure limits are not exceeded.

- An interface or environmental requirement for exposure levels to static DC magnetic field is not currently specified in the NASA documents governing ISS or Orbiter. A requirement to limit EVA exposure of the EMU with accessory equipment and tools is recommended for addition to NASA interface documents NSTS 07700 Volume X Book 2 and NSTS-21000-IDD-ISS.

- For ISS and Orbiter equipment and payloads that include magnetic sources in excess of the recommended exposure limits for EMU equipment, a hazard should be identified prior to EVA. Analysis of the magnetic exposure threat shall be performed to provide recommended flight rules for keep out distances or other controls. Flight rules to assure that safe maximum exposure levels are not exceeded during EVA shall be implemented.

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EMU 1 – 13-054
REVISION: INITIAL

Observations:

Tests were conducted in phases to accommodate delay in availability of GFE Power Grip Tools, PGT and EMU radio, SSER. Later development of the EMU 12 Volt Glove Heater with Voltage regulator (ILCVR) was tested in December 2001. Final test results reported herein include results for each phase and include Magnetic performance for all EMU/ Accessory flight elements.

1. Maximum recommended EMU exposure limits are provided for both Shuttle and ISS mission use for both ORU and non-ORU configuration.

2. Maximum exposure limits include a 6 dB safety margin for EMU equipment as specified in NASA specifications SL-E-0001 and SSP 30243. EMU equipment, SSER, 12 Volt accessories, SAFER, PGT, and ILCVR were tested at 600 Gauss level.

3. EMU Accessory equipment WVS/ERCA and tools, PGT Tool do not perform up to 600 Gauss exposure, however, performance function is restored when the equipment is removed from the magnetic exposure. PGT Tools will not operate when exposed to magnetic fields of 250 Gauss or more. The WVS/ ERCA Assembly transmits video but cannot switch lenses when exposed to magnetic fields in excess of 350 Gauss.

4. Magnetic attraction of the EMU flight system equipment may exert a force of at least 8Lb 4oz when exposed at 600 Gauss. Results of our measurements show that the applied force increases to a point where the crewmember may become trapped unless appropriate controls are implemented to assure no inadvertent overexposure. EMU SAFER could not provide a means to rescue a crewmember trapped on a strong magnetic source without other intervention.

5. Exposure limits provided are for EMU equipment operation. Hamilton Sundstrand does not make recommendation for biological hazards. Human maximum safe exposure limits are provided in . *"Guidelines on Limits of Exposure to Static Magnetic Fields". Health Physics 66: 100-106 (1994), Source: International Commission on Non-Ionizing Radiation Protection*

Summary:

- Exposure limit is 2000 G
- Nausea, symptoms @ 4T
- Generates voltage in blood
- Circadian rhythm disruption @ 1/2 G
- Special medical considerations:
- Pacemaker users keep out >5 G
- Have users of other prostheses checked before entering areas where field >30 G
- Tool controls begin @ 30 G