**NASA JSC**
**Payload Safety Review Panel**
**Alpha Magnetic Spectrometer-02**
**Phase II Flight Safety Review**

**Minutes of Meeting**
**May 21-24, 2007**

## 1.0 INTRODUCTION

1.1 **General:** The Payload Safety Review Panel (PSRP) and Station Safety Review Panel (SRP), chaired by JSC/OE/M.B. Schwartz and G. Baumer, met on May 21-24, 2007, with representatives of the US Department of Energy (DOE), the Payload Organization (PO), at the Regents Park III Conference Facility for an Alpha Magnetic Spectrometer-02 (AMS-02) Phase II Flight Safety Review (FSR). JSC/NA2450/P. Mensingh, R. Rehm, K. Chavez, and D. Santiago, the supporting Payload Safety Engineers (PSEs), introduced the meeting and attendees (see Attachment 1).

1.2 **Background:** The PSRP held a Helium Venting Technical Interchange Meeting (TIM) on 4/20/2000, the Phase 0/I Safety Review on 1/16/2001, and a TIM 1/17/2003. The PO held working group (WG) meetings the week prior to the FSR to discuss comments generated by the technical review of the safety data package (SDP). While the PSRP reviewed hazard reports (HRs) during the meeting, the PO and JSC technical experts held a splinter group meeting on burst disks in series. Minutes of this splinter group meeting are Attachment 3.

1.3 **Scope:** This meeting focused on The Phase II FSR of the hardware. The PSRP reviewed three previous Action Items (AIs) associated with this payload in this meeting.

1.4 **Conclusion:** Twelve agreements and three action items resulted from this meeting (Attachment 2). Eighteen HRs were approved for Phase II, two HRs were withdrawn prior to the review, and two HRs remain open pending AI approval. The Phase II FSR remains open pending approval of remaining HRs, AI closure, and NCR approval.

## 2.0 SIGNIFICANT SAFETY DISCUSSION

2.1 **NASA AMS-02 Project Manager Introduction:** The AMS-02 Experiment is a state-of-the-art particle physics detector being constructed, designed, tested, and operated by an international team organized through the US DOE. The AMS-02 experiment intends to advance knowledge of the universe and the likelihood of a clearer understanding of the universe's origin. The scientific goals of the AMS-02 are to search for antimatter (anti-helium and anti-carbon), to search for dark matter (90% of the missing matter in the universe), and to study astrophysics (specifically, cosmic ray propagation and confinement time in the Galaxy). A sophisticated cryogenic system is used to cool the magnet (Cryomagnet) which generates the required magnetic fields for the experiment. This cryogenic system uses superfluid helium (SFHe) as the primary source for removal of heat generated by the Cryomagnet. The AMS-02 launches with an un-powered main system and requires no on-orbit maintenance. Only the Cryomagnet monitoring system and nominal vent valve are active during launch and ascent. The PO indicated that the AMS hardware in the Shuttle middeck that is used for on-orbit checkout prior to mounting AMS-02 on station will remain in the Shuttle for return and will not be transferred to Station. Without the Shuttle in service to return AMS, the AMS project intends for AMS-02 to remain on Station indefinitely with no limited-life materials or structures issues. The PO intends to operate main systems for three to five years and continue with reduced science collection until Station is de-orbited. The PSRP assigned AI2 to JSC/OB/M. Bennett to provide a limited age life requirement for AMS-02 by June 15,

2007. The PO agreed to perform an assessment of the limited-life hardware items, based on the remaining life of the Station, for AMS-02 hardware identification and disposition when the certification of AMS-02 expires before the Station is de-orbited (Agreement 3.1).

2.2 **Hardware Overview:**

2.2.1 Transition Radiation Detector (TRD): The TRD separates relativistic light and heavy particles.

2.2.2 Silicon Tracker: The Silicon Tracker detects the trajectory of the incoming particles and identifies the magnitude and polarity of the particles' electrical charge.

2.2.3 Time of Flight (TOF): The TOF Scintillator produces flashes of light when struck by particles or photons. The TOF serves as the fast trigger for the experiment. When an incoming particle crosses the bore of the Cryomagnet, the TOF's resolution is sufficient to distinguish between upward and downward traveling particles.

2.2.4 Anti-Coincidence Counter (ACC): Detects and identifies the particles entering or exiting through the side or that have not cleanly traversed the Silicon Tracker. The ACC provides a means of rejecting particles that may confuse the charge determination of the incoming particles that are of interest.

2.2.5 Ring Imaging Cherenkov (RICH) Counter: Used to measure the velocity of the particles that traverse the AMS-02. The RICH is able to determine the velocity of charged particles by measuring the vertex angle of the cone of Cerenkov light. The Cerenkov light is emitted as the particle passes through a tile of silica aero-gel or sodium fluoride. The light guide material in the Unit Cell assembly is Polymethyl Methacrylate (PMMA) (Plexiglas™).

2.2.6 Electromagnetic Calorimeter (ECAL): The ECAL measures the energy of electrons, positrons, and gamma rays up to 1 TeV.

2.2.7 Unique Support Structure – 02 (USS-02) with integral Vacuum Case (VC): The Unique Support Structure – 02 (USS-02) is a structural support for the Cryomagnet and AMS-02 Experiment during launch, on-orbit loading, and ISS integration. It consists of five subassemblies: Upper USS-02, Lower USS-02, Vacuum Case (VC), Keel, and AMS-02 Payload Attach System (PAS). The VC is attached to the Cryomagnet by sixteen support straps and serves as a heat-sink. The VC encloses the coils and SFHe tank.

2.2.8 Tracker Alignment System (TAS): A system that will periodically monitor the X- and Y-position of the Silicon Tracker by passing infra-red (IR) laser beams through selected spot areas called Alignment Holes.

2.2.9 Star Tracker: The AMS-02 star tracker is the Astro Mapper for Instrument Check of Attitude (AMICA), which is equipped with a pair of small optical telescopes (AMICA Star Tracker Cameras or ASTCs), and each telescope acquires an image of the stars and then compares the image to an on-board sky map for orientation.

2.2.10 Global Positioning System (GPS): The GPS uses a signal for precision time correlation that exceeds the ISS capabilities. The need for the GPS is to correct the time drift that occurs over time within the precision timing systems that trigger the particle events.

2.2.11 Payload Attach System (PAS) (Passive Half)**:** The PAS is the passive side of the ISS Common Attach System (CAS), carries the External Berthing Camera System (EBCS), and contains capture bar release mechanisms (by requirement). The PAS provides the structural connection between ISS and AMS-02 experiment and is subject to extra-vehicular activity (EVA) contingency operations (i.e., payload removal). The PAS Release Mechanism load is released by advancing a drive screw to retract a wedge and lower the position of the capture bar. The capture bar is free to be removed, although it remains captive. This mechanism is lubricated with Everlube 610 dry film. The PO indicated that the

AMS-02 Passive PAS was static load tested, evaluated for fit and function against the flight upper inboard S3 CAS site at KSC, and interface-tested by crew members both at the Neutral Buoyancy Lab and at a tabletop review in 2003. The PAS will undergo thermal extreme testing in July 2007.

2.2.12 Digital Data Recording System – 02 (DDRS-02): The DDRS-02 will be used to record all high rate data generated by AMS-02 during check-out activities.

2.2.13 Vacuum Case (VC) Design Overview: The PO explained that there is no multi-layer insulation (MLI) between the SFHe tank and the magnet.

2.2.14 Unique Support Structure (USS), Payload Integration Hardware (PIH), and EVA Hardware Design Overview: The final stress corrosion/cracking report is not complete, but the preliminary results are positive. The PO is not performing an assessment on the berthing actions with the Space Station Remote Manipulator System regarding the braking actions and the breaking potential. The folding ROEU bracket will be assessed to determine if there is a need for new crew training for contingency EVA. The PO clarified that all EVA work is contingency activity. They have no planned EVAs for deployment/installation.

2.2.15 Thermal Control System: The heaters on the TRD gas tanks are for fill volume monitoring purposes and are not in place for safety reasons.

2.2.16 Tracker Thermal Control System: The Tracker is completely encased inside the inner bore of the Vacuum Case and generates 144 watts, which needs to be rejected while minimizing heat flow to the vacuum case inner cylinder. The TTCS thermal design includes thermal bars, a pumped $CO^2$ cooling loop, radiators, manifolds, accumulators, and numerous other components.

2.2.17 Avionics and Uninterruptible Power Supply (UPS)/Batteries: It is not possible to charge the magnet while it is installed in the Shuttle payload bay during launch/ascent. AMS-02 control is from the ground only—no Crew interaction is required for nominal experiment operations. The PO agreed to determine whether the Shuttle wire sizing requirements, specified in letter TM-102-179, "Selection of Wires and Circuit Protection Devices for NSTS Orbiter Vehicle Payload Electrical Circuits," are the appropriate requirements for this Station-operated hardware (Agreement 3.2). At the end of the three-year experiment cycle the PO has no safety issues with the certification life of the batteries. The PO will investigate and coordinate an assessment for compliance with Station life or cessation of battery charging with JSC/EP5.

2.3 **Cryomagnet Overview:** The Cryomagnet is the heart of the AMS-02 system. Fourteen coils create an internal magnetic field-strength of 8,600 Gauss (G) (0.86 $Tm^2$) and a maximum external field-strength of 2000G. The generated magnetic field bends incoming particles' trajectory path. Once the magnet is fully charged, it will maintain its charge with no additional electrical power and after three years will still have 96% of the full charge. The PO can both dissipate and quench the magnetic field and recharge it if needed. Each time a restart takes place, a minimum of two weeks of operational life-time is lost. The individual magnet coils were tested separately and each passed, but the integrated testing has yet to be performed. The tank has been tested at room temperature. The support straps see some "hammering" effect as they support the helium tank, but the margins are such that the small hammering effect does not pose a safety issue. The latch valves have been tested for susceptibility to the magnetic field, and all passed with no issues.

2.4 **Cryogenics Safety and Venting Burst Disks:** If the vent valves do not function, the pressure would increase until the burst disks release, but the timing of the vent valves are not for safety-critical functions nor are they considered a hazard control to protect against over-pressurization of the pressure system. The relief valves are operated for mission success purposes. The PO uses burst disks for better leak-tightness. All burst disks have been leak- and vibration-tested to assure no leakage. The PO has

assessed venting plume effects in the Shuttle payload bay but not for the mounting location on Station and any plume effects on the solar arrays. They have provided data to Boeing for them to perform the analysis. The PO indicated that the hardware complies with the Station micro-meteoroid and orbital debris strike requirement.

Burst disk testing— The burst disks are reverse-buckling with a peripheral score and cutting teeth in the vent ring. The PO considers this design intrinsically single-failure tolerant. In addition, the pressure is initially controlled (the first failure would allow this), and the burst disk operating is the second failure. The PO indicated that the dome of the burst disk sets the pressure at which it will function. The PSRP reminded the PO to assure that cleaning agents are compatible with the disk material to preclude corrosion that would lead to premature failure of the disks. The PO explained that the testing circumstances were comparable to the flight conditions and the welding was electron-beam welding. The PO clarified that the two burst disks in series on the helium and vacuum vessels were directed by JSC/Pressure Systems to assure two-fault tolerance to premature failure that would result in back-fill from the leakage. The PO agreed to provide an explanation of the leak paths as it relates to the burst disks and valves (Agreement 3.3). JSC\Pressure systems will continue discussing the design with the PO and provide a recommendation on the series of burst disks.

2.5 **Cryomagnet Quench:** "Quenching" is when the magnet energy is dissipated as heat in the coils. The PO plans to perform the magnet training quenches prior to launch so that no quenches will occur on-orbit after installation. The Cryomagnet Self Protection (CSP) unit is in place to protect the magnet for mission success purposes only—it is not required for safety purposes. The PO agreed to calculate and document the amount of heat transferred into the tank during a quench (eddy current impulse analysis) to assure that the vent system adequately provides the relief needed (Agreement 3.4). The heat loads will increase, but this does not pose a safety hazard.

2.6 **Cryosystem Flight Operations:** The PO clarified that the cryosystem provides venting (starting at about L+3 minutes on the basis of a barometric switch opening) during launch to preclude a safety hazard, but the venting rate is not a safety concern. Venting is performed more for mission success reasons. The PO has assessed all circumstances for venting during launch and has found that the worstcase vent loads and flow rates pose no safety issues (other than from L+30 to L+60 minutes, for which the systems are fault tolerant to venting) for the Shuttle. The PO agreed to document this explanation in HR AMS-02-F04 (Agreement 3.5).

2.7 **Station Hardware Magnetic Susceptibility Testing and Analysis:** The Space Station Remote Manipulator System (SSRMS) is only certified for 10G, so AMS-02 operations will need to be stopped or reduced when the SSRMS is in the vicinity. No EVA translation paths are within the 300G fields except for the contingency operations associated with AMS-02. The PO agreed to provide more information on the gradient of the magnet, the maximum force, and diagrams of the keepout zones (Agreement 3.6).

2.8 **Pressure Systems:** During discussing the TRD gas tank heaters the PO agreed to provide the stress analyses on the TRD gas tanks (Agreement 3.7).

2.9 **Testing Flow/Testing of Primary Structures:** AMS-02 Primary Structure Testing includes: Non-Linear Cryomagnet Support Strap Tests (which include component, system, and sine-sweep testing), Magnet Tests, Static Tests (which include component, system, and Full STA Payload Testing), Modal Tests (which include Full STA Payload Testing), Vibration Tests, and Thermal Tests.

2.10 **Micro Meteoroid/Orbital Debris (MM/OD) Testing and Analysis:** The NASA-designed shielding is to protect the pressure systems from any MM/OD strikes. The PO determined four major MMOD risk components: the Main Helium Tank, the Warm Helium Gas Supply, the TRD Gas Supply Tanks, and the Mixing Tank. The PO assumes a nominal endurance of three years for the Main Helium

Tank and Warm Helium Gas Supply and a nominal endurance of five years for the TRD Gas Supply and Mixing Tanks. The PO is investigating three shield designs: a multi-shock shield on the starboard side of the TRD Gas Supply; a stuffed-whipple shield on the port side of the TRD Gas Supply; and an aluminum honeycomb shield to surround the Warm Helium Supply. In addition the design team continues to look at ways to optimize shielding by moving components to reduce exposure, optimizing shield design to save weight, and reviewing shielding/multi-layer insulation (MLI) requirements to see if items can be combined. Any changes will be reassessed using the BUMPER modeling program and will be shown to meet requirements. JSC/MM/OD concurs with this analysis and testing approach. The PO indicated that, since the battery boxes are not considered pressure vessels, they were not included in the MM/OD analysis.

2.11 **Structural Analysis:** The PO will be providing the math model to Boeing for the integrated verification loads analysis (VLA) as part of the standard certification process. The structural straps underwent additional fatigue testing and are acceptable. All composite straps that are fracture critical underwent proof testing to 1.2 times maximum anticipated loads.

2.12 **Thermal Analysis:** The PO has performed extensive thermal modeling and analyses on AMS-02 at an integrated system level as well as at more detailed subsystem and component levels. Carlo Gavazzi Space (CGS) has overall responsibility for system level design and analysis, while the AMS-02 Thermal Working Group (TWG) provides oversight and review for all thermal activities. The TWG includes NASA, ESCG, and AMS collaboration members with sub-detector teams responsible for their own thermal design and analysis.

Top Level analyses were performed using a "reduced" AMS-02 model, integrated with a Station or Orbiter model. System-level analyses were performed both at CGS/Milan and at ESCG, using SINDA/FLUINT, TSS, and Thermal Desktop modeling programs. System Level Models were used for the survey to determine extreme cases, to directly analyze many subsystems, and to provide interface data for detailed subsystem models.

The System-level model included reduced (lower fidelity) models for several subsystems. CGS provided thermal interface data to subsystem analysts for detailed analyses. Comparison of results and iterations between the system-level and subsystems assured the validity of the interface data.

The PO also performed a survey of possible Station attitudes to determine extreme cases for all AMS-02 subsystems that accounted for the entire range of solar beta angles (-75º to +75º). Possible Station attitudes included: Roll = +/-15º, Yaw = +/-15º, Pitch = -20º to +15º (0º to +25º when orbiter docked), and altitudes from +150 to 270 nmi. The PO screened 256 survey cases to determine extreme cases for AMS-02 components. All extreme cases were re-run using additional analytical detail and extreme hot or cold natural environments. Additional analyses the PO considered included: in the payload bay (undocked), in the payload bay (docked to Station), transfer (between Shuttle and Station), and on Station unpowered (8 hours for mission success, continuous for safety). The PO also analyzed the following special cases:

- Potential freezing of fluid systems (documented in reports TTCS [ESCG-4470-06-TEAN-DOC-0032] and TRDGB [ESCG-4470-06-TEAN-DOC-0086])
- EVA Touch Temperature [documented in report ESCG-4470-07-TEAN-DOC-0033]
- Analysis of heaters with two failures [documented in report AMS02-TN-CGS-007, Issue 2]
- Magnet charging/discharging
- Auto-ignition evaluation (report pending)
- Stuck open vent door evaluation (report pending)

2.13 **Mission Operations and Contingency EVA:**

Pre-launch: The vacuum case (VC) within the superfluid helium (SFHe) tank will be monitored for breach/leak. Ground controllers will continue monitoring until T–9 minute hold, then make a "Go/No Go" decision based on the health of the SFHe tank.

Launch and Ascent: AMS-02 requires momentary power to operate the SFHe nominal vent valve. The vent valve must be operational once the pressure in the payload bay drops below the pressure of the SFHe tank due to ascent.

On-orbit check-out: On the Orbiter Aft Flight Deck, the AMS-02 Digital Data Recording System (DDRS-02) is activated to record all high rate data generated during check-out activities. The Orbiter Interface Unit (OIU) that communicates with the AMS-02 payload is also supplied with power. Front-end data interface electronics are activated, as well as the Cryocoolers, detectors, and subsystems on AMS-02. The Electronic Berthing Camera System (EBCS) on the Station feeds power to the AMS-02 heaters to maintain payload design temperature limits. Once proper mechanical mating of the AMS-02 and Station truss S3 is completed, the AMS-02 heaters and EBCS are deactivated.

On-orbit Operations: Power from Station to AMS-02 via the Umbilical Mechanism Assembly (UMA) is activated. Once power supply and data links are verified by AMS-02 ground personnel, all unnecessary power devices must be deactivated to remain within the power budget. Now the 90-minute charging of the Cryomagnet can begin. Once fully charged, the Cryomagnet is disconnected from the charger and the detectors are powered. Recording of scientific data begins at this point. The health and status of AMS-02 will continue to be down-linked via the Station Ku-band. Commands must be uplinked—none are stored onboard AMS-02.

EVA Compatibility: The PO evaluated EVA translation paths by worksite analysis and in the NBL and determined that EVA translation in proximity to and in contact with AMS-02 is approved for both Shuttle and Station EVAs. The EVA suit certification for operations in magnetic field is 300 G and 175 G for the Orlan suit. This hazard can be avoided by magnet discharge prior to EVA or by limiting EVA exposure via Keep Out Zones for AMS-02-specific EVAs. Translation is allowed between attach sites on the truss with magnetic field. The AMS-02 Vacuum Case (VC) ribs are not designed to withstand EVA kickloads. The PO worked with the EVA Projects Office and reviewed the design during NBL operations, but the translation path for the foldable Remotely Operated Electrical Umbilical (ROEU) may require NBL validation. This was not deemed a concern because the VC is classified as an EVA keepout zone, as are the Star Tracker Baffles (sharp edges). The PO will perform a detailed thermal analysis to determine if any additional areas of concern are identified as EVA touch temperature violations. Contingency EVA Operations include: ROEU, PRLA, and FRGF Release on Shuttle and EVA Connector Panel Operations, PAS and PVGF Release, and ROEU Folding Bracket on Station.

NBL Testing: First access test in the NBL was completed in March 2002 with a low-fidelity mockup (only Passive PAS), and the second NBL access test (with higher fidelity mockup, full experiment envelope) was performed in November 2002. No mission-specific NBL testing and no specific EVA training requirements were required. Testing to evaluate AMS-02 Contingency EVA interfaces was performed November 12-15, 2002 (five astronauts performed tasks). Testing included: PVGF Contingency Release, PVGF Grapple Release, LEE Release, Capture Bar Unloading and Release, Connector Panel Access/Evaluation, Passive Umbilical Mating Assembly (UMA) bolt access, and crew translation path evaluation. All tested tasks were deemed "acceptable" as documented in Crew Consensus Report (reference letter CB-02-129). The Crew identified only minor issues with labeling (updates are completed and approved), the fit-checks (verified with flight hardware at Lockheed Martin), and connector clocking (updated and approved). The remaining potential future work is for foldable ROEU contingency operations.

Mission Abort: In the event of a mission abort (any return with AMS-02 still in the payload bay with PRLAs engaged) the following must occur: Close the vent valve when payload bay pressure exceeds 15–20 millibars; standard switch panel-supplied 28 VDC only; APCU-supplied 120 VDC to payload power distribution system must be powered off. Upon landing, services should be applied via the T0 umbilical to allow internal electronics to monitor helium tank pressure, to operate the vent valve and vent pump (Not a safety concern, but rather a refurbishment concern [don't want to rupture the burst disks]). The initial projection from KSC for nominal landing indicates approximately 10 hrs. Mission success issues, but no safety concerns.

2.14 **Safety Assessment Summary:** Major hardware no longer part of AMS-02 includes: the Synchrotron Radiation Detector (SRD) and the AMS-02 Crew Operations Post (ACOP). (The ACOP was the only Station interior element of AMS-02.) No elements or systems of AMS-02 are considered series or reflown as some were at Phase 0/I. All of AMS-02 is assessed in the unique configuration and environments of this mission in the hazard reports. This also facilitates integrated safety control and verification efforts.

Design changes include: addition of zenith radiators and cryocooler loop heat pipes; removal of the lower radiator panels, incorporation of the folding ROEU Support Bracket, addition of the Star Trackers and GPS Receiver, tilting AMS-02 12° for clearance and viewing, and increased weight.

New System- and Subsystem-Level safety analyses, performed and documented in the SDP, include the Energy Analysis, the Historical Comparative Analysis, and the Maintenance Safety Analysis.

Since the PO does not plan to perform maintenance activities on AMS-02, the PO has not developed a maintenance hazard analysis. None is required.

Unmodified HRs from Phase I include:

- AMS-02-F02, Toxic Material Offgassing
- AMS-02-F10, Flammable Materials in the Payload Bay
- AMS-02-F15, Thermal Extremes from Cryogenics
- AMS-02-F18, Rapid Safing/Payload Reconfiguration
- AMS-02-F20, Crew Exposure to Coherent Light
- STD-AMS-02-F02, Standard Hazard Report, Orbiter Interior Elements

2.14.1 Form 1428, Fire Detection and Suppression Reporting Form: *Not applicable to this hardware.*

2.14.2 Form 622 - Reflown and Series Payload Hardware Reflight Assessment Reporting Sheet: *Not applicable to this hardware.*

2.15 **Hazard Report Discussion:**

2.15.1 STD-AMS-02-F01, Form 1230, Flight Payload Standardized Hazard Control Report–Alpha Magnetic Spectrometer-02 Exterior Elements - Shuttle/Station: *Approved as discussed in this meeting*. The PO agreed to transfer the data from this HR into the appropriate existing or new unique HRs for Phase III (Agreement 3.12).

2.15.2 STD-AMS-02-F02, Form 1230, Flight Payload Standardized Hazard Control Report–Alpha Magnetic Spectrometer-02 Interior Elements – Shuttle: *Approved as presented in this meeting*.

2.15.3 AMS-02-F01, Structural Failure of Hardware: *Approved as modified in this meeting*. In discussing Control 1.1 the PO specified that the analysis was to the Shuttle and Station loads (a 2.0 factor of safety [FOS]), which envelopes the required 1.5 FOS. The PO agreed to confirm that the 1.4 launch and 1.5 Station FOSs, identified in Control 1.1, envelope the requirements for dynamic loading for the Phase III review (Agreement 3.8). JSC/Structures is closely monitoring the analysis, testing, and documentation of the composite-material straps (including long-term creep) to assure that they are acceptable for the

loads the hardware will experience. The negative margins in verification 1.4.1 are accepted, but the PO is working with JSC/Structures to resolve the negative margins out of the design. The PO added the details of which composite structures are tested and the criteria used to determine which ones to test. Verification 8.1.1 is a mandatory inspection point to verify the pre-load at installation. The PO indicated that brazing is not used in structural applications. The JSC/Mechanical Systems Working Group (MSWG) has reviewed the PAS mechanisms.

The PO will need to communicate any changes to the AMS hardware (particularly capture bar integrated loads) to Boeing for the integrated Station assessment. The PSRP will request the MSWG to provide the list of data required for the integrated assessment from Boeing on the capture claw on the Space Station Remote Manipulator System (SSRMS) and the capture bar. The PO agreed to provide Boeing the capture bar capability for Boeing to perform the integrated assessment (Agreement 3.9).

2.15.4 AMS-02-F02, Toxic Material Offgassing: *Approved as presented in this meeting.*

2.15.5 AMS-02-F03, Rupture of Superfluid Helium Tank, Vacuum Case and/or Pressurized System: *Approval deferred pending AI 3 approval.* JSC/Pressure Systems has no issues with the three burst disks in series in the design. JSC/ES4 is writing a comprehensive materials certification for this payload to assure that all areas meet the materials and processes requirements. Cause 5.2 keeps atmosphere out of the lines to plug them. Discussion of the specific provisions and the associated verifications led the PO to list the mandatory inspection points that relate to this hazard cause. The PSRP determined that the PO needs JSC/Engineering concurrence with the helium tank factor of safety of 1.5 (instead of the 2.0 requirement) if a non-compliance report (NCR) is required. The Chair will consult with Station Program management regarding the need for an NCR on this issue (associated with AI3). The PO clarified that the bellows proof test that resulted in deformation is a performance issue but not a safety issue.

2.15.6 AMS-02-F04, Overpressurization of Orbiter Payload Bay: *Approved as modified in this meeting.* The data submittal provided in support of this HR closes Phase 0/I AI2. The PSRP agreed to request Cargo Integration to update concurrence memo TS-TM-02-064 to clearly approve of all the gases/fluids used in the AMS-2 system prior to Phase III (Agreement 3.10). The PO clarified that the vacuum leak check includes checking the O-rings. JSC/Shuttle Program agreed to provide an updated letter/documentation for closure of the safety verification method by Phase III.

2.15.7 AMS-02-F05, Rupture of AMS-02 Pressurized Systems: TRD Gas System (Xe & CO2), Cryomagnet Warm Helium Gas System, Tracker Thermal Control System, Thermal Control Systems, Cryocooler: *Approved as modified in this meeting*. The PO added a statement about the relief valves leaking faster and more than the burst disks. The relief valves are set at 295psi and the burst disks are set at 265psi. The burst disks are two-fault tolerant to leakage. Control 7.2 is deleted because the valves were removed from the design. The PSRP discussed the general recent issue of composite over-wrapped pressure vessels (COPVs) leaking and the applications to these tanks. The PO is meeting the requirements, but the PSRP assigned internal AI 07-04 to JSC/Engineering to provide the PSRP with more information about the status of the research into COPV failures.

2.15.8 AMS-02-F06, Excessive Thrust/Overturning Moments: *Approved as modified in this meeting*. The PO added a reference to the impingement analysis due to venting, controls for cool down circuit, and verification 5.1.2 on the sloshing assessment. The PO stated that they have a way to detect tank volume. The PSRP directed the PO to add quenching the magnet as it may impart a significant change in magnetic torque on Station in the modifications to this HR for approval.

2.15.9 AMS-02-F07, Excessive Radiated Field Strengths, EMI, Magnetic: *Approved as modified in this meeting.* There are no magnetic effects to other vehicles that may approach Station (Soyuz, Progress, ATV, HTV) because the other vehicles are well outside the maximum magnetic field generated by AMS-02. The PO agreed to address this in the HR for Phase III (Agreement 3.11). The EVA suit

compatibility for magnetic fields was approved to 300G and Orlan to 175G with no detrimental effects. The PO added a reference to a waiver to SSP57003 in Control 1.2 and deleted the last line of Control 1.3. The PO requires SSRMS activity near AMS-02 only during initial installation. The PO has no need for SSRMS contact in nominal activity after installation. The PO will need to confirm that AMS-02 is powered down/quenched prior to SSRMS activity if the approach is within the field strength that affects operation. JSC/MOD concurs with the operational control approach in the HR and the references to the Operational Controls Agreement Documents (OCADs). The PO explained that seven discreet sequenced and timedcommands must be given to charge the magnet in Control 1.5 and that Control 1.6 helps with establishing a keepout zone for EVAs in the area. The magnetic field is monitored. The PO will provide data for determining keepout zones for OCAD development, including a reference to the diagram and database availability to be used. Control 1.7 addresses the power lines are not charged during AMS-02 transfer from Shuttle to Station. For Phase III the PO will add a reference to the description of the levels of control in Control 1.8.

2.15.10 AMS-02-F08, Electric Shock/Discharge: *Approved as modified in this meeting*. The operational control verifications 1.1.1, 1.1.2, 2.6.1, 3.1.2 become OCADs. The PO deleted Control 1.1 as addressed in 1.2, 1.3, and 1.4. The PO deleted the reference to HR AMS-02-F12

2.15.11 AMS-02-F09, Exposure of the Crew to Excessive Ionizing Radiation: *Approved as modified in this meeting*. The JSC/Radiation Group will need to review and approve the Form 44 at the Phase III level prior to flight.

2.15.12 AMS-02-F10, Flammable Materials in the Payload Bay: *Approved as modified in this meeting.* The PO indicated that the reference to nitrous oxide is not applicable because there is not intent to use nitrous oxide in AMS-02.

2.15.13 AMS-02-F11, Mechanism Failure: *Approval deferred as modified in this meeting pending information from the MSWG and Fracture Control*. All PRLAs and the keel latch are needed for launch. The PO explained that Verification 1.3.2 is an OCAD. An anti-rotation device spring failure still allows the device to function properly. It takes two breaks on the same spring coil to disable the mechanism, so it is still single-fault tolerant. Analysis shows that there is not enough force to overcome the braking torque of 3 lbs, and there is no credible sustained force to cause the bolt to back out of the threads. The PSRP assigned AI 1 to the MSWG to confirm with JSC/Fracture Control the possibility of two breaks in one PAS anti-rotation device spring as a credible failure mode and review the AMS analysis. The PO point of contact is C. Tutt. The PO revised Cause 1 to refer to the integrated assessment that the Shuttle Program will perform for installation in Shuttle. The PO added a statement that the PO is addressing the passive hardware in their HRs and the Shuttle and Station Programs will perform the integrated assessments (Failure Modes and Effects Analyses) of the interactions between the active and passive sides of the mounting hardware in the Shuttle and on the Station (mounting configuration in Shuttle, unberthing operations in Shuttle, berthing operations on Station, and final mounting configuration on Station). The PO indicated that Cause 4 meets the interface control document and added a reference to the integrated assessment that the Shuttle Program will perform for installation in Shuttle.

2.15.14AMS-02-F12, Mate/Demate of Connectors: *Approved as modified in this meeting*. This HR addresses contingency activities only. Verification 1.1.1 is a roll-up to the Boeing integrated assessment OCAD item ISS EPS 309. The PO clarified that the copper path is to be disconnected per the requirement—this is an OCAD. JSC/EVA reminded the PO that interpretation letter MA2-99-170 is only applicable to the gloved hand for crew members in the EMU and not the entire suit.

2.15.15 AMS-02-F13, Battery Failure: *Approved as modified in this meeting*. JSC/Batteries wants the PO to confirm that the battery charger is good for the life of the hardware while it is on Station. The PO will

submit this data to JSC/EP5 for review and approval. The PO will assess any limited-life hardware in the battery and review methods to cease charging when the SFHe is exhausted.

2.15.16 AMS-02-F14, EVA/EVR Hazards: *Approved as modified in this meeting.* The PO noted in the HR that excessive radiation and electric shock each refer to other HRs -07 and -08. Cause 4, thermal extremes, may result in the need for an NCR at Phase III. Boeing will perform an integrated assessment of AMS-2 while attached to the SSRMS and on Station, and Boeing will provide an integrated assessment of the loads/excessive forces. The PO deleted Control 6.2 as inappropriate. Boeing will perform an integrated assessment of the berthing of AMS on Station for the keel pin contact and possible contact with other payloads (i.e., the Express Logistics Carrier). The PO explained that the magnet does not generate a plasma environment, but it may affect the plasma environment that is already there.

2.15.17 AMS-02-F15, Thermal Extremes: *Deleted as discussed in this meeting*. This HR addresses condensation issues during ground processing that might affect flight operations. The PSRP recommended that the PO include this hazard assessment in the safety summary for Phase III and delete this HR.

2.15.18 AMS-02-F16, Shatterable Material Release: *Approved as presented in this meeting*. There are no shatterable materials in any EVA translation paths and all are contained.

2.15.19 AMS-02-F17, Electrical Power Distribution Damage: *Approved as modified in this meeting*. The PO added a reference to the OCAD in HR AMS-02-F12.

2.15.20 AMS-02-F18, Rapid Safing/Payload Reconfiguration: *Approved as modified in this meeting*. No structures require special thermal conditioning in either nominal or off-nominal mission situations. Boeing will be providing an integrated assessment for Phase III to address any integrated issues. Formal acceptance of the procedure will be via an OCAD.

2.15.21 AMS-02-F19, Excessive Glare: *The PO provided sufficient rationale to withdraw this HR from review in this meeting as unnecessary.*

2.15.22 AMS-02-F20, Crew Exposure to Coherent Light: *Approved as presented in this meeting*. JSC/Lasers considers this a class 1 laser because it is enclosed and inaccessible to the crew.

## 3.0 **AGREEMENTS**

**3.1** The PO agreed to perform an assessment of the limited-life hardware items, based on the remaining life of the Station, for AMS-02 hardware disposition if the certification of AMS-02 expires before the Station is de-orbited.

**3.2** The PO agreed to determine whether the Shuttle wire sizing requirements, specified in letter TM-102-179, "Selection of Wires and Circuit Protection Devices for NSTS Orbiter Vehicle Payload Electrical Circuits," are the appropriate requirements for this Station-operated hardware.

**3.3** The PO agreed to provide an explanation of the leak paths as it relates to the burst disks and valves.

**3.4** The PO agreed to calculate and document the amount of heat transferred into the cryomagnet tank during a quench (eddy current impulse analysis) to assure that the vent system adequately provides the relief needed.

**3.5** The PO agreed to document the explanation of the cryosystem venting approach in HR AMS-02-F04.

**3.6** The PO agreed to more information on the gradient of the magnet, the maximum force, and diagrams of the keepout zones.

**3.7** The PO agreed to provide the stress analyses on the TRD gas tanks.

**3.8** The PO agreed to confirm that the 1.4 launch and 1.5 Station FOSs, identified in Control 1.1, envelope the requirements for dynamic loading for the Phase III review.

**3.9** The PO agreed to provide Boeing the capture bar capability for Boeing to perform the integrated assessment.

**3.10** The PSRP agreed to request Cargo Integration to update concurrence memo TS-TM-02-064 to clearly approve of all the gases/fluids used in the AMS-2 system prior to Phase III.

**3.11** The PO agreed to address the lack of magnetic effects on other vehicles approaching Station in HR AMS-02-F07 for Phase III.

**3.12** The PO agreed to transfer the data from HR STD-AMS-02-F01 into the appropriate existing or new unique HRs for Phase III.

*Original Signed by:*

JSC/NA2450/P. Mensingh
Payload Safety Engineer

*Original Signed by:*

JSC/NA2450/R. Rehm
Payload Safety Engineer

*Original Signed by:*

JSC/NA2450/K. Chavez
Payload Safety Engineer

*Original Signed by:*

JSC/NA2450/D. Santiago
Payload Safety Engineer

*Original Signed by:*

JSC/NA2450/W. Stauffer
Technical Writer

**Status of Hazard Reports Presented**

*(Note: See the text of the minutes for more details.)*

| Number | Title | Status | Comments |
|---|---|---|---|
| STD-AMS-02-F01 | Form 1230, Flight Payload Standardized Hazard Control Report Exterior Elements - Shuttle/Station | Approved/Ph II | 2.15.1 |
| STD-AMS-02-F02 | Form 1230, Flight Payload Standardized Hazard Control Report Interior Elements - Shuttle | Approved | 2.15.2 |
| ----- | Form 1428, Fire Detection and Suppression Reporting Form | N/A | ----- |
| AMS-02-F01 | Structural Failure of Hardware | Approved/mods | 2.15.3 |
| AMS-02-F02 | Toxic Material Offgassing | Approved | 2.15.4 |
| AMS-02-F03 | Rupture of Superfluid Helium Tank, Vacuum Case and/or Pressurized System | Deferred/AI | 2.15.5 |
| AMS-02-F04 | Overpressurization of Orbiter Payload Bay | Approved/mods | 2.15.6 |
| AMS-02-F05 | Rupture of AMS-02 Pressurized Systems: TRD Gas System (Xe & CO2), Cryomagnet Warm Helium Gas System, Tracker Thermal Control System, Thermal Control Systems, Cryocooler | Approved/mods | 2.15.7 |
| AMS-02-F06 | Excessive Thrust/Overturning Moments | Approved/mods | 2.15.8 |
| AMS-02-F07 | Excessive Radiated Field Strengths, EMI, Magnetic | Approved/mods | 2.15.9 |
| AMS-02-F08 | Electric Shock / Discharge | Approved/mods | 2.15.10 |
| AMS-02-F09 | Exposure of the Crew to Excessive Ionizing Radiation | Approved/mods | 2.15.11 |

| | | | |
|---|---|---|---|
| AMS-02-F10 | Flammable Materials in the Payload Bay | Approved/mods | 2.15.12 |
| AMS-02-F11 | Mechanism Failure | Deferred/AI | 2.15.13 |
| AMS-02-F12 | Mate/Demate of Connectors | Approved/mods | 2.15.14 |
| AMS-02-F13 | Battery Failure | Approved/mods | 2.15.15 |
| AMS-02-F14 | EVA/EVR Hazards | Approved/mods | 2.15.16 |
| AMS-02-F15 | Thermal Extremes | Deleted | 2.15.17 |
| AMS-02-F16 | Shatterable Material Release | Approved | 2.15.18 |
| AMS-02-F17 | Electrical Power Distribution Damage | Approved/mods | 2.15.19 |
| AMS-02-F18 | Rapid Safing/Payload Reconfiguration | Approved/mods | 2.15.20 |
| AMS-02-F19 | Excessive Glare | Withdrawn | 2.15.21 |
| AMS-02-F20 | Crew Exposure to Coherent Light | Approved | 2.15.22 |

**Previous Action Item Status**

| AI | Action | Status |
|---|---|---|
| 1 (01/18/01)<br>Assigned to:<br>SF3/J. Bates | Continue to assess the helium venting analysis with Shuttle Integration and EP4 and develop a history of cryostat operations to determine the necessity of a Launch Commit Criteria (LCC) inside T-9 minutes to launch. | Closed in this meeting |
| 2 (01/18/01)<br>Assigned to:<br>SF3/J. Bates<br><br>HR: AMS-02-6 | Pre-submit AMS-02 vent test data regarding TCS, warm helium supply, TRD, and the cryosystem to EP4/H. Flynn for approval; submit data to USA in April 2001 for analysis; and add results to HR AMS-02-6 for presentation at Phase II FSR. | Closed in this meeting |
| 3 (01/18/01)<br>Assigned to:<br>NC55/S. Loyd<br><br>HR: AMS-02-7 | Provide updates regarding changes to the magnetic requirements for the EMU and peripheral equipment, and status the relevant communication between the PO and EVA Project Office/XA. (PSRP may schedule a meeting with XA and AMS following review of the AI, if necessary.) | Closed 10/11/01 |

**AI Status Explanation:**

**AI1: Closed—**DUE PHASE II. As of 7/04, changed the actionee to Steve Porter (EA) since AMS has been moved from SM to EA. The actions require deliverable data at the Phase II FSR. EA plans on putting this data (or status) into the data package, but the package will not be ready until later this year (2004). Documentation of the closure activity is provided in the SDP.

**AI2: Closed—**DUE PHASE II. As of 7/04, changed the actionee to Steve Porter (EA) since AMS has been moved from SM to EA. The actions require deliverable data at the Phase II FSR. EA plans on putting this data (or status) into the data package, but the package will not be ready until later this year (2004). This AI applies to Phase II HR AMS-02-04. The data submittal provided in support of HR AMS-02-04 closes this AI.

**AI3: Closed—**CLOSED at Special Discussion Meeting on 10/11/01.

**ATTACHMENT 1**

# Payload Safety Review Attendance Log

Payload: AMS-02 Phase II Flight Safety Review
Meeting Date: May 21-24, 2007

| Mail Code | Name | Phone 281 | X |
|---|---|---|---|
| **CHAIRMAN** | | | |
| OE | Schwartz, M.B. | 483-8425 | X |
| OE | Baumer, G.J. | 244-7924 | X |
| OE | Stein, J. | 483-4414 | X |
| **SUPPORT PERSONNEL** | | | |
| CB | Rickard, J. | 483-3760 | X |
| DA8/USA | Knutson, D. | 483-4405 | X |
| EA441 | Henning, G.N. | 483-0533 | X |
| MO2/USA | Wood, W. | 280-6844 | X |
| MO2 | Kunkel, S. | 280-6844 | X |
| NE12 | Guidry, R. | 244-5510 | X |
| NE12 | Moreland, D. W. | 483-5549 | X |
| MSFC/JS-20 | Johnson, P.T. | 256-961-4646 | X |
| SM | Spann, R. | 483-3807 | X |
| NT | Staton, S. | 335-2135 | X |
| NT | Stewart, C. | 335-2128 | X |
| EP4/Jacobs | Manha, W. | 483-6439 | X |
| EP5 | Jeevarajan, J. | 483-4528 | X |
| ES4/Jacobs | Martinez, A.N. | 461-5428 | X |
| ESCG/JACOBS | Flakes, L. | 461-5946 | X |
| ESCG/JACOBS | Russell, D. | 461-5144 | X |
| ESCG/JACOBS | Beaird, H.G. | 461-5489 | X |
| ESCG/JACOBS | Barton, Q. | 461-5501 | X |
| NA2450/GHG | Chavez, K. | 335-2364 | X |
| NA2450/GHG | Mensingh, P. | 335-2363 | X |
| NA2450/GHG | Nash, S.K. | 335-2384 | X |
| NA2450/GHG | Rehm, R. | 335-2374 | X |
| NA2450/GHG | Santiago, D. | 335-2383 | X |
| NA2450/JES | Stauffer, P. W. | 335-2402 | X |

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**ATTACHMENT 2**

**NASA JSC**
**Payload Safety Review Panel**
**Alpha Magnetic Spectrometer-02**
**Phase II Flight Safety Review**

**Summary of Action Items**
**May 21-24, 2007**

| AI | Action | Date Due |
|---|---|---|
| 1<br>Assigned to:<br>JSC/MSWG<br><br>HR: AMS-02-F11 | Confirm with JSC/Fracture Control the possibility of two breaks in one PAS anti-rotation device spring as a credible failure mode and review the AMS analysis. PO POC—C. Tutt | Date:<br>06/15/07<br><br>Mandatory Reviewer(s):<br>PSRP |
| 2<br>Assigned to:<br>JSC/OB/M. Bennett<br><br>HR: N/A | Provide a limited age life requirement for AMS-02. | Date:<br>06/15/07<br><br>Mandatory Reviewer(s):<br>AMS PO |
| 3<br>Assigned to:<br>JSC\Structures<br><br>HR: AMS-02-F03 | Provide the acceptance rationale for the 1.5 FOS over the 2.0 requirement against burst for the SFHe tank and the VC. | Date:<br>06/15/07<br><br>Mandatory Reviewer(s):<br>PSRP |

*Original Signed by:*

_____ May 24, 2007
JSC/OE/M.B. Schwartz Date
PSRP Chairman

**ATTACHMENT 3**

**NASA JSC**
**Payload Safety**
**Alpha Magnetic Spectrometer-02 (AMS-02)**
**Phase II Splinter Working Group**

**Minutes of Meeting**
**May 22, 2007**

## 1.0 INTRODUCTION

1.1 **General:** The Payload Safety Review Panel (PSRP) and Station Safety Review Panel (SRP), chaired by JSC/OE/M.B. Schwartz and G. Baumer, met on May 21-24, 2007, with representatives of the United States Department of Energy (DOE), the Payload Organization (PO), at the Regents Park III Conference Facility for an Alpha Magnetic Spectrometer-02 (AMS-02) Phase II Flight Safety Review (FSR).

**On May 22, 2007, technical representatives of the PSRP met with representatives of the PO in a Splinter Working Group to discuss the concern of Burst Disks in Series Configuration. This issue relates to Unique Hazard Report (HR) AMS-02-F03 (Rupture of Superfluid Helium Tank, Vacuum Case and/or Cryosystem Pressurized System Element).**

1.2 **Scope:** This meeting focused on the operation and performance of burst disks in series configuration. Referencing Figure 5.1.3-1 Cryogenic Process Diagram of the AMS-02 SDP, it is the burst disks in series configuration that are in question.

1.3 **Conclusion:** The series configuration of burst disks causes concern due to the fact that if the first burst disk in series leaks, the second burst disk in series has a higher reference of bursting pressure. This will cause the second burst disk in series configuration to rupture at a higher pressure than the system design originally required. JSC/Pressure Systems is requesting documentation of leak-testing to ensure that burst disks in series configuration leakage is not a concern.

2.0 **Hardware Overview of Burst Disks:** The PO uses burst disks in series configuration for pressure system protection. All burst disks have been leak and vibration tested to assure no leakage. The burst disks are reverse-buckling with a peripheral score and cutting teeth in the vent ring.

The PO stated that the use of burst disks in series configuration was discussed with Howard Flynn of JSC/Pressure Systems. It was also stated by the PO representative that redesign of the burst disks assembly would not be taken lightly or easily considered; this design was in place because JSC/Pressure Systems acknowledged and approved the burst disk configuration.

Howard Flynn from JSC/Pressure Systems was called to the splinter working group. He did acknowledge that he suggested and approved the series configuration of the burst disks.

Bill Manha of JSC/Pressure Systems was addressing BD11A leaking and the pressure reference changing higher will not allow BD11B to rupture at 10bar. AMS-02 representative Steve

Harrison commented that BD11B rupture point of 10bar is conditional on no leakage of BD11A. JSC/Pressure Systems requested documentation of rationale to address the issue of burst disk leakage. These documents of rationale are as follows:

1. Drawing diagrams of burst disk welding
2. Verification procedures for vacuum leak testing of burst disks
3. Procedures for crimp and welding of vent (vacuum) pipe
4. List of testing procedures performed on burst disks by Fike (manufacturer of burst disks)
5. List of cryo-testing performed by Steve Harrison (AMS-02 representative for Cryomagnet and Cryogenics Presentation at Phase II FSR)
6. Wording incorporated into HR of qualification of previously noted items
7. Drawings of burst disks
8. Drawings of crimp and welding of vent (vacuum) pipe

3.0 **Hazard Report Discussion:**

3.1 AMS-02-F03, Rupture of Superfluid Helium Tank, Vacuum Case and/or Cryosystem Pressurized System Element: *Approval deferred pending NCR approval and AI3 Closure.* JSC/Pressure Systems has concerns with the three burst disks in series configuration in the design.

_____

JSC/NA2450/P. Mensingh
Payload Safety Engineer

**Status of Hazard Reports Presented**

*(Note: See the text of the minutes for more details.)*

| Number | Title | Status |
|---|---|---|
| AMS-02-F03 | Rupture of Superfluid Helium Tank, Vacuum Case and/or Cryosystem Pressurized System Element | Deferred/NCR |