DISTRIBUTION OF MINUTES ALPHA MAGNETIC SPECTROMETER-02 VACUUM JACKET LEAKAGE SPECIAL DISCUSSION MEETING ON OCTOBER 11, 2001.

CB/G. Bonse
DO12/J. M. Childress
DO6/Payload Operations Branch
EA4/L. C. Benal
EA4/D. E. Tadlock
EM2/G. M. Ecord
ES2/V. A. Fogt+
EV15/D. C. Sykes
MA2/V. S. Ellerbe
MA2/S. N. Hardee
MA2/J. D. Holt
MA2/A. M. Larsen
MA2/D. E. O'Brien
MA2/J. Williams
MS2/C. R. Miller
MS3/K. Packard
MT/M. Brekke
MT2/R. Miley
NC4/M. L. Ciancone
NC44/SAIC/M. A. Fox
NC44/SAIC/P. J. Gothreaux
NC44/SAIC/P. L. Mitchell
NC55/SAIC/S. E. Loyd
NE2/G. L. Priest
OE/L. W. Gana
OR/CSA/H. L. Williams
OT/ESA/U. Thomas
OZ/M. A. Culp
OZ/G. W. McCollum
OZ3/D. W. Hartman
SD2/M. E. Coleman
SF2/D. J. Grounds
KSC/UB-F3/J. C. Dollberg
KSC/UB-F3/P. D. Kirkpatrick
MSFC/CR90/V. P. Kulpa
LMSO/B25/P. D. McDonald
LMSO/C20/D. G. Russell
LMSO/C80/H. G. Beaird
BNA-Houston/ZC01/A. B. Green
BNA-Houston/ZC01/V. H. Ruhe
Boeing/HS-12/M. P. Hudson
Boeing/HS-44/J. D. Blalock
Boeing/HS-44/R. DuBose
USH/700D/L. Lo
USH/700D/H. A. Maltby

See Attachment 1 for a list of meeting attendees/
additional minutes recipients.

For nondeliverable mail, please return to JSC/NC4/Brenda L. Smith.

NASA JSC
Payload Safety Review Panel
Alpha Magnetic Spectrometer-02
Vacuum Jacket Leakage Special Discussion Meeting

Minutes of Meeting
October 11, 2001

1.0 INTRODUCTION

1.1 **General:** The Payload Safety Review Panel (PSRP), chaired by JSC/MA2/A. M. Larsen, met on October 11, 2001, with representatives of the PSRP and support personnel, at the Regents Park III Conference Facility for an Alpha Magnetic Spectrometer-02 (AMS-02) Special Discussion Meeting. JSC/NC44/A. N. Nelson, Jr., one of the supporting Payload Safety Engineers (PSEs), introduced the meeting and attendees (see Attachment 1). NC44/S. J. Daniel is the PSE also supporting this payload.

1.2 **Background:** The AMS is a Department Of Energy, NASA, and various high-energy physics institutes-funded state-of-the-art cryogenic superconductive magnet that is designed to search for anti-matter and dark matter. The AMS-02 experiment is a 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 the Cosmic Ray propagation and confinement time in the galaxy). The AMS-02 experiment will utilize a Cryogenic Superconducting Magnet (Cryomag) with planes of detectors on top, inside, and below the magnet. The precursor Space Shuttle flight of AMS-01 used a permanent magnet in place of a cryomagnet. LMSO will provide analysis and design for the Cryomag Vacuum Case hardware. The superfluid helium tank has a capacity of about 2500 liters, and the cryogenic insulation system includes 160 layers of MLI superinsulation.

1.2.1 **Hardware Overview:** The AMS-02 hardware is made up of several subsystems, including: the Cryogenic Superconducting Magnet (Cryomag), Unique Support Sutructure-02 (USS-02), Synchrotron Radiation Detector (SRD), Transition Radiation Detector (TRD), Time-Of-Flight (TOF) Scintillator Assemblies, Ring Imaging Cherenkov Counter (RICH), Electromagnetic Calorimeter (ECAL), data and interface electronics, electrical cables, two Monitoring and Control computers (MCCs), Power Distribution Box (PDB), AMS Crew Operations Post (ACOP), Thermal Control System (TCS), Micro Meteoroid and Orbital Debris (MM&OD) shields and a passive Payload Attach System (PAS).

1.2.2 **Cryomagnet:** The Cryogenic Superconducting Magnet (Cryomagnet) system consists of a superconducting magnet and a Superfluid Helium (SFHe) dewar enclosed in a Vacuum Case. The total magnet system including the Vacuum Case (VC) is estimated to weigh ~ 6508 lbs. (2952 Kg). The VC serves a dual purpose as a primary structural support and as a vacuum vessel for the cryosystem and magnet. They are suspended inside the VC by sixteen support straps. The main structural components of the VC are: upper conical flange, lower conical flange, upper support ring, lower support ring, inner cylinder and outer cylinder. On the VC inner joints, the upper and lower flanges will be butt welded to the inner cylinder. On the VC outer joints, the upper and lower flanges will be attached to the outer cylinder with 192 fasteners at each interface. Double O-rings will be used at each outer joint interface. There will be test ports between the O-rings to test them. There will be 41 ports in the VC. Sixteen ports will be for the cryosystem support straps and 25 ports will be for plumbing lines, burst disks, electrical connections, etc. Double O-rings will be used at each of the ports. All pump-out ports will also have redundant seals. The VC will also have three burst disks in series for emergency venting.

1.2.3 **Unique Support Structure-02 (USS-02):** The USS-02 is used to support the AMS-02 cryomagnet and detectors and to interface the entire AMS-02 Experiment with the Shuttle and International Space Station. The VC is also an integral part of the USS-02. The USS-02 is comprised of the following subassemblies: Upper USS-02 Assembly, Vacuum Case Assembly, Lower USS-02 Assembly, Keel Assembly, and the Payload Attach System (PAS)/Umbilical Mechanism Assembly (UMA) Assemblies. The USS-02 primary members consist of layered tubing with aluminum walls. They are fastened with rivets and bolts. The USS-02 attaches to the Shuttle with four longeron trunnions and one keel trunnion. Several AMS-02 components are mounted to the USS-02. These include: the SRD, TRD, TRD gas supply system, TOF, RICH, ECAL, electronics crates, RICH electronics, ECAL electronics, Cryo Avionics Box, cryomag rectifiers, electrical cables and components of the Thermal control System. The AMS-02 payload will be attached to the ISS using the Payload Attach System (PAS). The PAS hardware on the AMS-02 is the passive half and consists of three guide pins and a capture bar.

1.2.4 **Synchrotron Radiation Detector (SRD):** The SRD is located on the top of the experiment stack and attaches to the top of the TRD support at four locations. A large honeycomb panel supports the SRD detector. The SRD is a particle physics experiment with different detector materials configurations to measure photons, X-rays and low energy charged particles.

1.2.5 **Transition Radiation Detector (TRD):** The TRD's role is to discriminate between e^-/p^- and e^+/p over the range E = 3 – 300 GeV. This is accomplished by detecting the presence of X-ray photons emitted by electrons and positrons when they pass through a radiator. p, p- and nuclei do not emit such radiation. The radiation is detected in 5248 proportional tubes filled preferentially with $Xe:CO_2$, since Xenon gives a very high efficiency for photon detection. By proportional multiplications, the ionization electrons are converted into a measurable signal.

The proportional tubes are made from a multi-layer composite structure comprised of layers of poluyurethane, conductive carbon-polyamide, aluminum, and kapton that are grouped into 44 separate segments connected through gas manifolds. A straw module consists of 16 straws glued together with 6 CFC stiffeners running alongside the straws and polycarbonate end pieces that contain the wire fixation pieces, the gas distributor, and the gas seal. The TRD is built from 20 layers of the straw modules with a radiator material in the gaps between the layers. The upper 4 layers and the lower 4 layers are oriented in the X-direction and the 12 middle layers are oriented in the Y-direction.

1.2.6 **Time Of Flight (TOF):** The four layers of TOF Scintillator Counters are located across the top and bottom of the cylindrical magnet, with two layers on the top and two layers on the bottom. The scintillators provide the trigger function for selection of a single particle or nucleus cleanly traversing the magnet bore. The counters are made of polyvinyl toluene enclosed in a cover made of carbon fiber with an aluminum foil surface on the inside and outside. At the ends of each panel are light guides which direct the light of scintillation to photomultipliers. Two large flat aluminum honeycomb panels are used to support the scintillator counters. The upper TOF honeycomb is attached to the TRD, which is then attached to the USS-02 just above the USS-02-to-VC interface. The lower TOF honeycomb is supported to the lower USS-02.

1.2.7 **Ring Imaging Cherenkov Counter (RICH):** The RICH is located near the bottom of the experiment stack and is composed of one section containing all the Photomultiplier Tubes (PMTs) and one section that is the reflector. The first section is made of aluminum cross braces that attach to the USS-02 at eight locations that are made with pins/bolts and isolated with Bellville washers. The PMT units are screwed in place in between the welded cross bracing. The reflector section is extremely light and is made of a composite material that is spray coated with reflective aluminum that must be light tight.

1.2.8 **Electromagnetic Calorimeter (ECAL):** The ECAL functions to attain the main physics goals of the payload. These physics goals include: measuring the energy of electrons, positrons, and gammas up to 1 TeV and ensuring the identification of electromagnetic (e.m.) and hadronic cascades with a discrimination capability better that 10^{-4}. ECAL must be able to reconstruct the electromagnetic showers development with high accuracy in order to attain these goals.

ECAL is located at the bottom of the experiment stack and is mounted to the USS-02 at four attach locations via radially slotted holes. The active part is subdivided into nine sub-samples, called "superlayers". Each superlayer consists of eleven layers of the glued lead foils, with the fibers running in the same direction. The superlayers are assembled so that the fibers are running in orthogonal directions on the X and Y directions, alternatively. This kind of structure enables the study of electromagnetic showers development with the required accuracy. The primary materials for ECAL include the following: aluminum housing and brackets, aluminum honeycomb top and bottom plates, lead foil 'pancake' superlayers, and scintillating fibers.

1.2.9 **Data and Interface Electronics:** The data and interface electronics for the AMS-02 experiment will be housed in electronics crates with aluminum covers on the outside of the USS-02. The data and interface electronics will enable the connection of the AMS-02 experiment to the ISS data system.

1.2.10 **Electrical Cables:** AMS-02 will be equipped with an ISS provided passive Umbilical Mechanism Assembly (UMA), which will be mated to the ISS active UMA when the AMS is installed on the ISS. Mission Integration provided cables will run from the umbilical connector on the ISS to an input connector on the Ams-02 instrument for both data and power cables. This will be to provide the interfacing between the AMS-02 data/interface electronics and the ISS data systems, and the AMS-02 experiment and the ISS electrical power system via the ISS umbilical connector.

1.2.11 **Monitoring and Control Computers (MCCs):** Two MCCs are mounted on the USS-02 or the electronics racks. The MCCs provide the primary data interface between the AMS-02 Experiment low rate data system and the ISS 1553 data bus. The ISS 1553 data bus provides the housekeeping data from the AMS-02 Experiment and command capability to the AMS-02 Experiment through the ISS for transmission to the ground.

1.2.13 **Power Distribution Box (PDB):** The AMS-02 PDB is mounted on the USS-02 near the passive UMA. The purpose of the PDB is to provide the power interface circuitry between the ISS and AMS-02. The PDB receives power from either or both of the ISS power buses and converts this voltage to 28v dc for distribution to the various AMS-02 subsystems. The PDB also distributes power to the AMS-02 Magnet Cryo Avionics Box. In addition, the PDB provides unswitched power for the AMS-02 mission critical systems, controllers, computers, monitoring circuits, etc.

1.2.14 **Cryomagnet Avionics Box (CAB):** The CAB is mounted between the horizontal and diagonal members of the USS-02 near the sill trunnion. The purpose of the CAG is to provide power to the Charging Circuitry in the Magnet as well as to provide control and monitoring circuitry for charging/discharging operations. The CAB receives unswitched power directly from ISS Bus A via the PDB. Magnet charging operations depend upon the operation of Bus A from the ISS. A transformer contained within the Cryo Magnet Current Source, which is contained within the CAB, performs isolation from the magnet.

The CAB also controls the discharge circuitry for the magnet. Controlled discharges are commanded either by automatic control circuitry or crew/ground commanding. The commanding causes opening of the magnet persistent switch, which then routes the current to a set of eighteen rectifiers. These rectifiers cause the discharge of the magnet and convert the energy into heat. Each rectifier is capable of dissipating 200 Watts. The magnet discharges in approximately 90 minutes and each rectifier will remain below 212 F (100 degrees C).

The control system for the discharge circuitry will require an Un-interruptable Power Source that will allow AMS to perform a quench or a controlled run-down of the magnetic field in the event of loss of power for an extended (unplanned) period.

1.2.15 **AMS Crew Operations Post (ACOP):** The AMS Crew Operations Post (ACOP) system consists of a 4PU EXPRESS rack payload drawer assembly and one middeck locker of hard drive media, payload provided external cables, and spares. ACOP serves as a management system for the AMS-02 science data as well as a crew operations post. ACOP is capable of simultaneously receiving, processing, and downlinking the AMS-02 science data stream as provided on the High Data Link. Crew control is provided at a low level via the front panel interface. Payload Support Computer based applications software will provide robust operations and monitoring ability via network sessions with ACOP. Mounted within the payload drawer are six hot swap hard drive bays, a power supply, and operations interface consisting of a graphic LCD display and push buttons, a drawer cooling fan, and a Compact PCI card cage assembly. The stowage volume will contain twenty hard drives, payload provided data cables, and spares.

1.2.16 **Thermal Control System (TCS):** The AMS-02 Thermal Control System (TCS) design is currently being developed by the AMS experiment team. Preliminary indications are that this system will consist of radiators mounted either directly to the AMS-02 electronics or mounted on the USS-02. One or more cooling loops will be used to transport heat from various electronic boxes to the radiators. These loops will probably be driven by a pump and controlled with valves. Working fluids being considered are carbon dioxide (CO_2) and ammonia (NH_3). Required heaters for various experiment components are yet to be defined. Standard NASA Multilayer Insulation (MLI) thermal blankets will also be used.

1.2.17 **Meteroid and Orbital Debris Shielding (MOD):** The MOD shielding is designed to protect the pressure systems on the AMS-02 experiment. These systems include the Cryomagnet system including the warm helium tank, the TRD Gas System, and possibly the TCS. Much of the shielding will be thin aluminum plates with small standoffs from other AMS-02 experiment hardware.

1.2.16 **Reflight/Series Hardware:** The AMS-02 Silicon Tracker Assemblies, Tracker Alignment System (TAS), Anti-Coincidence Counter (ACC) and Digital Data Recording System (DDRS) are reflown/series elements from AMS-01. The reflown/series safety assessments for these elements will be included in the AMS-02 Phase III Flight Safety Data Package. AMS-02 is scheduled for launch in October 2003.

1.3 **Scope:** This meeting focused on determining how to guide the PO to avoid the potentially catastrophic hazard of venting of the AMS dewar helium pressure vessel during Orbiter ascent.

1.4 **Conclusion:** No agreements and no action items resulted from this meeting. The objective of this meeting was to obtain PSRP and support personnel consensus regarding the off-nominal venting of the AMS dewar helium pressure vessel.

2.0 SIGNIFICANT SAFETY DISCUSSION

2.1**: Issue Description:** EP4/H. Flynn presented the information provided by the PO to date. The specific hazard is the overpressurization of the payload bay during ascent. The venting would result directly from the leakage of the vacuum case and the subsequent helium vessel warm-up. AMS venting analysis conservatively assumed complete loss of vacuum (LOV). The assumption was consistent with payload preference. The worst-case assumption drives the time between the start of the vacuum case leak and the time to the venting of the helium vessel. The critical time period for the AMS LOV is just at launch (T-0) and/or shortly after. The most critical time period for AMS venting into the Payload Bay is between T+30 and T+60 seconds.

The original vacuum case leakage analyses indicated that the critical time period for AMS LOV was at ~T-190 to ~T-120 seconds. The Phase 0/I safety review hazard control approach included the following:

- Qualification and acceptance testing of the AMS structural test article and flight unit;
- Independent leak testing of each flight unit o-ring during acceptance testing;
- Monitoring the flight unit vacuum case in final configuration for weeks/months prior to launch up until T-31 seconds. Monitoring changed to up until T-9 minutes as a result of the PSRP review. The monitoring details are To Be Determined (TBD).

Delaying the potential venting of the dewar beyond the critical Orbiter ascent period by incorporating a cryogenic insulation around the helium vessel was investigated by AMS. The results indicated the following: the amount of insulation needed to eliminate LOV concern would reduce the on-orbit life of AMS; the original analysis assumption for the helium vessel LOV heat load was too low; and subsequent analysis indicated that the critical time period for loss of vacuum of the AMS vacuum case is no longer prior to launch, but is now at or during initial seconds of launch.

2.2 **AMS Proposed Resolution:** AMS personnel proposed what they believe is a conservative, maximum credible leak of the vacuum case to be experienced at or just prior to launch. They assumed two “hole” sizes that were presented for acceptance and subsequent testing and analysis. The hole sizes were: 3” long x 0.001” height, resulting in an equivalent orifice diameter of ~0.062” and 3” long x 0.003 height, resulting in an equivalent orifice diameter size of ~0.107”. These hole sizes were considered to be highly unlikely due to the AMS bolt spacing around the circumference of the AMS vacuum case flanges and the expected direct contact between the o-ring flanges.

2.3 **AMS Vacuum Case Testing:** Two AMS units will be built, one flight identical Structural Test Article (STA) consisting of the STA vacuum case and a Cold Mass Replica (with STA super-fluid helium tank and a simulated mass for cryo-magnet and support structure) and the flight vacuum case, flight super-fluid helium tank, and the flight cryo-magnet.

The qualification testing performed on STA vacuum case includes:

- Proof pressure test upon delivery to NASA and prior to installation of cold mass replica;
- Vacuum leak check upon delivery to NASA and prior to installation of the Cold Mass Replica;
- Proof pressure test after installation of the Cold Mass Replica;
- Vacuum leak check after installation of the Cold Mass Replica;
- High level sine-sweep test;
- Acoustic vibration test to expected levels; and
- Modal testing and static leads testing to be performed on the entire payload, including the cold mass replica, the STA vacuum case under vacuum, and mass replicas of AMS experiment components.

The acceptance testing and monitoring on the flight vacuum case includes:

- Proof pressure testing prior to installation of the magnet;
- Vacuum leak check of each o-ring after installation of the cryo-magnet and all cryo-systems;
- Proof pressure testing after installation of the cryo-magnet and all cryo-systems; and
- Monitoring the vacuum case pressure and super-fluid helium tank pressure-temperature for approximately twelve (12) months up until T-9 minutes.

2.4 **Items for Discussion:** Mr. Flynn presented four items for group discussion, with the objective of reaching a consensus determining what feedback should be provided to the PO related to each one. These discussion items included the following questions:

- Are the proposed orifice diameters of 0.062” and 0.10” acceptable for worst-case vacuum case leakage?
- Is the structural design adequately robust?
- Is the planned qualification and acceptance testing adequately robust?
- Is a waiver required?

Subsequent to the PSRP discussion of the above questions, they decided to reconvene to meet with the PO, MA2/D. E. O’Brien, ES4/G. M. Ecord, and the attendees who were teleconferenced into this meeting. The follow-up meeting will be held on October 16, 2001 and should address the following issues:

- Changes to the Structural Verification Plan and approval by the Structures Working group;
- What Qualification Testing is planned or has been completed;
- Verification of structural integrity and validity of assumed hole size;
- Verification of leak rate (if any);
- Launch commit criteria in the event of a leak;
- Vibration testing;
- Whether the failure is catastrophic from a Fracture Control standpoint;
- Possibility of a waiver.

JSC/NC44/A. N. Nelson, Jr.
Payload Safety Engineer

JSC/NC44/S. J. Taylor
Technical Writer

JSC/NC44/S. J. Daniel
Payload Safety Engineer

Previous Action Item Status

AI	**Action**	**Status**
1 Assigned to:	Continue to assess the helium venting analysis with Shuttle Integration and EP4 and develop a history of cryostat	Open, due Phase II

SF3/J. Bates	operations to determine the necessity of a Launch Commit Criteria (LCC) inside T-9 minutes to launch.	Mandatory Reviewers: PSRP
2 Assigned to: SF3/J. Bates 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.	Open, due Phase II Mandatory Reviewers: PSRP
3 Assigned to: NC55/S. Loyd 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.

Status Explanation

AI 1: Not discussed at this meeting.

AI 2: Not discussed at this meeting.

AI 3: Closed at this meeting because Ms. Loyd provided the updates to the PO and the EVA Project Office/XA.

ATTACHMENT 1

Payload Safety Review Attendance Log

Payload: Alpha Magnetic Spectrometer-02 Vacuum Jacket Leakage Special Discussion Meeting

Meeting Date: October 11, 2001

Mail Code	**Name**	**Phone** 281	**X**
CHAIRMAN			
MA2	Larsen, A. M.	483-1207	
PSRP MEMBERS			
CB	Rickard, J.	483-3760	
DO12/USA	Knutson, D.	483-4405	
EA441	Henning, G.	483-5502	
MS3/USA	Maltby, H. A.	212-6014	
MS3/USA	Kunkel, S.	280-6844	
NT55	Davis, K. L.	244-55-15	
NE2	Londa, D. T.	483-6988	
Boe/HS44	Blalock, J. D.	336-4743	
SUPPORT PERSONNEL			
NC44/SAIC	Daniel, S. J.	483-3294	
NC44/SAIC	Nelson, Jr., A. N.	483-9661	
NC44/SAIC	Taylor, S.J.	483-9551	
EM/LMSO	Burns, T.	333-7216	
LMES/B25	McDonald, P. D.	333-7309	
LMES/B25	Shivers, L. H.	333-7053	

Mail Code	**Name**	**Employer**	**Phone Number**	**Technical Discipline**	**INTERNET ADDRESS**
EP4	H. Flynn		31198	Fluids	Global
OE	H. Wiley		42562	P/L Utilization	Global
MS2	R. Miller		31229	Thermal ECLS	Global
	M. Fields	Boeing/HZ 1-10	853-1657	Venting	Mark.fields@sw.boeing.com
	D. Cline	HZ1-10	853-1562		Doug.cline@sw.boeing.com
	A. R. Shamala	Boeing/HB	714-372-4719	System Safety	Altibele.shamala@west.boeing.com
	R. Rivera	Boeing	714-372-2997	Project-Thermal	Ruben.rivera@boeing.com
	H. Sexton	Boeing	714-372-0273	Gas Dynamics	Harry.sexton@boeing.com
	L. Wong	Boeing	714-372-2847	Gas Dynamics	Lung-Chuen.Wong@west.boeing.com