Alpha Magnetic Spectrometer 02 (AMS-02) Experiment/Vacuum Case Payload Integration Hardware (PIH) Interfaces

Space and Life Sciences Directorate
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Lyndon B. Johnson Space Center
Houston, Texas
Alpha Magnetic Spectrometer 02 (AMS-02) Experiment/Vacuum Case Payload integration Hardware (PIH) Interfaces

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January 2002
Alpha Magnetic Spectrometer 02 (AMS-02)  
Experiment/Vacuum Case Payload integration  
Hardware (PIH) Interfaces

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January 2002
## Document Change/Revision Log

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PREFACE

This Interface Control Document (ICD) represents the interface agreement between the Alpha Magnetic Spectrometer – 02 (AMS-02) Experiment and the Vacuum Case Payload Integration Hardware (PIH) for the version of the payload to be operated on the International Space Station (ISS) for approximately three (3) years. The mission baseline is 1000 days of operational time (24,000 hours) in full deep space view.

A precursor flight (AMS-01) was accomplished on the Space Shuttle during the STS-91 flight and was addressed in an ICD similar to this document. The AMS on STS-91 was operated for approximately 8.5 days during the flight.
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# ACRONYMS AND ABBREVIATIONS

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<td>CM</td>
<td>COLD MASS</td>
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<td>CMR</td>
<td>COLD MASS REPLICA</td>
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<td>DOE</td>
<td>DEPARTMENT OF ENERGY</td>
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<td>GROUND SUPPORT EQUIPMENT</td>
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<tr>
<td>GSFC</td>
<td>GODDARD SPACE FLIGHT CENTER</td>
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<tr>
<td>ICD</td>
<td>INTERFACE CONTROL DOCUMENT</td>
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<td>ISS</td>
<td>INTERNATIONAL SPACE STATION</td>
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<tr>
<td>JSC</td>
<td>LYNDON B. JOHNSON SPACE CENTER</td>
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<tr>
<td>LMSO</td>
<td>LOCKHEED MARTIN SPACE OPERATIONS</td>
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<tr>
<td>LSR</td>
<td>LOWER SUPPORT RING</td>
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<tr>
<td>MIT</td>
<td>MASSACHUSETTS INSTITUTE OF TECHNOLOGY</td>
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<td>NATIONAL AERONAUTICS AND SPACE ADMINISTRATION</td>
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<td>PIB</td>
<td>JSC PLANNING AND INTEGRATION BRANCH (SF3)</td>
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<td>PIH</td>
<td>PAYLOAD INTEGRATION HARDWARE</td>
</tr>
<tr>
<td>PM</td>
<td>PHOTO MULTIPLIER</td>
</tr>
<tr>
<td>SCL</td>
<td>SPACE CRYOMAGNETICS LTD.</td>
</tr>
<tr>
<td>SFHe</td>
<td>SUPERFLUID HELIUM</td>
</tr>
<tr>
<td>STA</td>
<td>STRUCTURAL TEST ARTICLE</td>
</tr>
<tr>
<td>STE</td>
<td>SPECIAL TEST EQUIPMENT</td>
</tr>
<tr>
<td>TBD</td>
<td>TO BE DETERMINED</td>
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<tr>
<td>TCS</td>
<td>THERMAL CONTROL SYSTEM</td>
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<tr>
<td>USR</td>
<td>UPPER SUPPORT RING</td>
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<tr>
<td>USS</td>
<td>UNIQUE SUPPORT STRUCTURE</td>
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<tr>
<td>VC</td>
<td>VACUUM CASE</td>
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1.0 INTRODUCTION

1.1 General

In this Interface Control Document (ICD) “AMS” will refer to the total complement of activities, hardware, software, test, integration and operation of the Alpha Magnetic Spectrometer – 02 (AMS-02). The flight hardware is referred to as the “AMS Payload” and is comprised of two parts: the “AMS Experiment” provided by the international AMS Experiment Collaboration and the “AMS Payload Integration Hardware (PIH)” provided by the JSC Planning and Integration Branch (PIB) of the Flight Projects Division with the support of Lockheed Martin Space Operations (LMSO).

This ICD pertains only to the version of the AMS (AMS-02) that will be installed and operated on the International Space Station (ISS). The acronym “AMS-01” will be used for references to the precursor flight version that flew on STS-91.

1.2 AMS Payload Description

The AMS Experiment is a state-of-the-art particle physics detector containing a large, cryogenic superfluid helium superconducting magnet that will be designed, constructed, tested and operated by an international team organized under United States Department of Energy (DOE) sponsorship. The AMS Payload is shown in Figure 1.2-1. The AMS Experiment will use the unique environment of space to advance knowledge of the universe and potentially lead to a clearer understanding of the universe’s origin. Specifically, the science objectives of the AMS are to search for cosmic sources of antimatter (i.e., anti-helium or heavier elements) and dark matter.
1.3 Document Purpose

This ICD is only to define the interfaces between the PIH Vacuum Case and the Eidgenössische Technische Hoschschule (ETH) Cryomagnet and the AMS-02 Tracker and the Anti-Coincidence Counter (ACC).
2.0 MECHANICAL REQUIREMENTS

This section describes the mechanical and physical interfaces associated with the PIH Vacuum Case, ETH/Space Cryomagnetics Limited (SCL) Cryomagnet and the AMS-02 Tracker and ACC.

2.1 Coordinate System

The AMS-02 payload and AMS-02 experiment coordinate axis systems are identical and are shown in Figures 2.1-1 and 2.1-2. Dimensions are in inches. The AMS-02 origin is at the geometric center of the Vacuum Case and Tracker. All coordinate systems shown in this document are based on the right hand rule.

Figure 2.1-1 AMS-02 Payload and Experiment Coordinate Axis and Origin (1 of 2)
Figure 2.1-2  AMS-02 Payload and Experiment Coordinate Axis and Origin (2 of 2)
2.2 AMS Experiment to Vacuum Case Interfaces

2.2.1 Cryomagnet System to Vacuum Case (VC)

The Cryomagnet Vacuum Case is being developed by NASA/LMSO and will interface to the Cryomagnet, Super Fluid Helium Tank, and a Cryogenic System internally. It will also interface to the Tracker, Anti-Coincidence Counter (ACC), and various other experiment hardware externally. Figure 2.2.1-1 shows the overall Vacuum Case Assembly and Figure 2.2.1-2 shows a section view of the Vacuum Case Assembly. Details of the inner joint, outer joint, and O-ring grooves are shown in Figures 2.2.1-3, 2.2.1-4, and 2.2.1-5, respectively.

Figure 2.2.1-1 Vacuum Case Assembly
Figure 2.2.1-2  Vacuum Case Cross-Section
Figure 2.2.1-3 Inner Joint Detail

Figure 2.2.1-4 Outer Joint Detail
Figure 2.2.1-5 O-Ring Groove Detail

- UNCOMPRESSED O-RING PARKER CORD STOCK
- ENDS ARE JOINED WITH A HOT VULCANIZING PROCESS (Ø.250) ACTUAL Ø.275
- MINIMUM 95% GROOVE FILL MATERIAL: VITON DUROMETER: 75
- LUBRICATE O-RINGS WITH DOW CORNING HIGH VACUUM GREASE
- SAE J1926/1 PORT MODIFIED LENGTH 2X 180° APART
- NOTE: ALL DIMENSIONS ARE TBD PENDING THE RESULTS OF THE SMALL SCALE O-RING TEST.
2.2.2 Temporary Seal

A temporary seal will be used prior to the final closeout weld in order to test the Vacuum Case and Cold Mass. This seal is shown in Figure 2.2.2-1 and will be at both ends of the VC. The temporary seal will be provided by ETH/SCL.

Figure 2.2.2-1 Temporary Seal
2.2.3 Magnet Support System

The Cryomagnet, Super Fluid Helium Tank, and Cryosystem are all supported to the Vacuum Case through the Magnet Support System. The Magnet Support System is comprised of 16 non-linear composite straps that connect to the Vacuum Case as shown in Figures 2.2.3-1 through 2.2.3-6. The Closeout Cap (provided by ETH/SCL) for these straps is shown in Figure 2.1.3-7.

Figure 2.2.3-1 Support Strap Locations
Figure 2.2.3-2  Section Thru Strap Port C1W1 (X-direction)
Figure 2.2.3-3  Section Thru Strap Port C2W2 (Y-direction)
NOTE: Strap angle shown is generic. Specific feed-thru angles are defined in Figures 2.2.3-2 and 2.2.3-3.

Figure 2.2.3-4  Strap Feed-Thru Detail

Figure 2.2.3-5
**Figure 2.2.3-5** Strap Feed-Thru Face View

- **GSE HOLES (USED FOR ASSEMBLY AIDS AND TESTING FIXTURES)**
  - 4X
- **SEALING SURFACE (16 MICROINCH FINISH)**
  - This surface must be protected at all times during the cold mass assembly
- **GSE HOLES (USED FOR ASSEMBLY AIDS)**
  - 8X
- **BLEED / WIRE ROUTING HOLES**

---

**Figure 2.2.3-6** ISO View of Strap Port

- **GSE HOLES (USED FOR ASSEMBLY AIDS)**
  - 8X
- **BLEED / WIRE ROUTING HOLES**

---

**Figure 2.2.3-5** Strap Feed-Thru Face View

- **GSE HOLES (USED FOR ASSEMBLY AIDS)**
  - 8X
- **Bleed / Wire Routing Holes**

---

**Figure 2.2.3-6** ISO View of Strap Port

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---

**Figure 2.2.3-5** Strap Feed-Thru Face View

- **GSE HOLES (USED FOR ASSEMBLY AIDS AND TESTING FIXTURES)**
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**Figure 2.2.3-6** ISO View of Strap Port

- **GSE HOLES (USED FOR ASSEMBLY AIDS)**
  - 8X
- **BLEED / WIRE ROUTING HOLES**

---
Figure 2.2.3-7 Strap Closeout Cap (Provided by ETH/SCL)
2.2.4 Feed-Thru Port Locations

There are numerous plumbing lines and electrical cables that need to penetrate the Vacuum Case. All of the ports will be in the upper and lower support rings of the Vacuum Case. The orientations are shown in Figures 2.2.4-1, 2.2.4-2 and 2.2.4-3. Temporary port closeout covers (flat plates) will be provided by LMSO/NASA in order to perform vacuum leak checks prior to the installation of the final port closeout covers and caps. All Plumbing and Electrical flight closeout covers and caps will be provided by ETH/SCL. The temporary port closeout covers provided by LMSO/NASA will be available for flight closeout on ports that do not require any feedthru cables or tubes.
Figure 2.2.4-1 Plumbing and Electrical Port Locations
Figure 2.2.4-2  Port Locations – Front ISO View

Figure 2.2.4-3  Port Locations – Back ISO View
2.2.5 Plumbing and Electrical Feed-Thru Ports

The plumbing and electrical feed-thru port is shown in Figure 2.2.5-1. The mating surface of the hardware that will attach to this port is shown in Figure 2.2.5-2. All mating hardware will incorporate a test port between the o-ring grooves so that each o-ring can be tested individually for vacuum integrity. LMSO/NASA will provide temporary closeout plates for the plumbing/electrical ports. The final flight closeout ports or caps will be provided by ETH/MIT/SCL/GSFC. The temporary port closeout covers provided by LMSO/NASA will be available for flight closeout on ports that do not require any feedthru cables or tubes.
Figure 2.2.5-2 Mating Component for Plumbing/Electrical Port
2.2.6 Cryocooler Interfaces and Ports

Four cryocoolers will be mounted to the Vacuum Case Upper and Lower Rings. The current mounting location (Figures 2.2.4-1, 2, and 3) and ports are shown in Figure 2.2.6-2. Figure 2.2.6-1 shows a front and back ISO view the port. The cryocooler access port is identical to the cryocooler port and allows access to the cold head once the cryocooler is installed. The ports are essentially the same as the 4 inch diameter ports shown in Figure 2.2.5-1 and 2 with the addition of the 4 mounting holes at the corners on the outside and the inside. The VC design includes enough ports to actually mount five cryocoolers, but the fifth location will only be used in a contingency event. LMSO/NASA will provide temporary closeout plates for the cryocooler ports. The final flight closeout ports or caps will be provided by ETH/MIT/SCL/GSFC. All cryocoolers and flight closeout caps will incorporate a test port between the o-ring grooves so that each o-ring can be tested individually for vacuum integrity. The temporary port closeout covers provided by LMSO/NASA will be available for flight closeout on ports that do not require any feedthru cables or tubes.

Figure 2.2.6-1 Cryocooler Port ISO Views
Figure 2.2.6-2 Cryocooler Interfaces and Ports
### 2.2.7 Cryo Service Port

A cryo service port will be mounted to the Vacuum Case Upper Ring. The current mounting location (Figures 2.2.4-1, 2, and 3) and port are shown in Figure 2.2.7-1. The cryo service port is used to service the cryogenic system on the ground. The ports are essentially the same as the 4 inch diameter ports shown in Figure 2.2.5-1 and 2 with the addition of the 4 mounting holes at the corners on the outside. The VC design includes enough ports to actually mount five cryocoolers, but the fifth location will only be used in a contingency event. LMSO/NASA will provide temporary closeout plates for the cryocooler ports. The final flight closeout ports or caps will be provided by ETH/MIT/SCL. The cryo service port will incorporate a test port between the o-ring grooves so that each o-ring can be tested individually for vacuum integrity.

![Figure 2.2.7-1 Cryo Service Port](image-url)
Figure 2.2.7-2  Cryo Service Port Layout – Front ISO View

Figure 2.2.7-3  Cryo Service Port Layout – Back ISO View
Figure 2.2.7-4  Cryo Service Port Layout
2.2.8 Keep In/Out Zones

Due to space station envelopes, shipping constraints and interfaces to other experiments, several keep in/out zones have been established. Figures 2.2.8-1 and 2.2.8-2 show the keep in zone for the cold mass hardware around the Upper and Lower Support Rings. The keep in zones extend through the thickness of each Support Ring and include the strap closeout caps protruding out of the zone. Figures 2.2.8-1 through 2.2.8-4 also show the keep out zone for the Vacuum Case to USS-02 assembly. This area must remain clear until the Vacuum Case is installed. After that, cable routing can cross this area. The area between the Support Ring interface to the Outer Cylinder on both ends can also be used for cable routing and is shown in Figure 2.2.8-4. Figure 2.2.8-5 shows the cryocooler keep in zone for the locations outside of the USS-02. The keep in zone for the Cryo Service Port is shown in Figure 2.2.8-6. This keep in zone will include both flight and ground configurations. Because of the numerous cable routings from all of the experiments, all cable routings and protrusions have to be coordinated with LMSO (Phil Mott and Ross Harold) and MIT (Robert Becker).

All hardware that attaches to the VC must meet the requirements in the Thermal ICD.
Figure 2.2.8-1  Keep In/Out Zones for the Upper Support Ring

Figure 2.2.8-3

Figure 2.2.8-4

Figure 2.2.8-5

SHIPPING FIXTURE/OUTER SURFACE BOTH SIDES

SCL KEEP-IN ZONES

KEEP-OUT ZONES FOR ASSEMBLY OF THE VACUUM CASE INTO THE USS-02
4X UPPER 4X LOWER

REMOVED FOR SHIPPING

2X 59.00 [1498.60]

2X 54.63 [1387.55]

2X 6.00°

2X 14.00°

(55.00°)

20.31°

125.00 [3175.10]

7.87

(200.00)

2X 7.00°

2X 3.00 [76.20]

109.26 [2775.11]

JSC-29202
Revision B

ISS

X (RAN)

Z

Y

ORBITER

LAUNCH DIRECTION
Figure 2.2.8-2  Keep In/Out Zones for the Lower Support Ring

KEEP-OUT ZONES FOR ASSEMBLY OF THE VACUUM CASE INTO THE USS-02
4X UPPER
4X LOWER

SCL KEEP-IN ZONES

SHIPPING FIXTURE OUTER SURFACE BOTH SIDES

Figure 2.2.8-4

LAUNCH DIRECTION
Figure 2.2.8-3  Detail View of the Keep Out Zone for the VC/USS-02 Assembly
Figure 2.2.8-4 Section View of Keep Out Zone for the VC/USS-02 Assembly

KEEP-OUT ZONES FOR ASSEMBLY OF THE VACUUM CASE INTO THE USS-02 4X

USS-02 UPPER JOINT

USS-02 LOWER JOINT

THESE TWO AREAS MAY BE USED FOR CABLE/TUBE ROUTING PRIOR TO AND AFTER VACUUM CASE/USS-02 ASSEMBLY
Figure 2.2.8-5  Keep In Zone for the Cryocoolers

TBD

Figure 2.2.8-6  Keep In Zone for the Cryo Service Port
2.2.9 Generic Bolt Pattern Interfaces on Inside of VC

Inside the Vacuum Case Upper and Lower Support Rings, a generic hole pattern has been incorporated, as shown in Figure 2.2.9-1, to allow the AMS-02 experiment team to mount additional lightweight hardware internal to the vacuum space. The pattern consists of numerous inserts for #10 bolts. The maximum allowable load for each of these #10 bolts is 10 lb under a 1g acceleration in each axis. The pattern includes a bolt approximately every 6 inches around the circumference on both the top and bottom ring. There are additional bolt inserts near the strap feed-thru ports as shown in Figures 2.2.9-2 through 2.2.9-4.

Masses attached to the generic holes must not create more than 10 pounds of force in any direction at any hole when subjected to 1 g of acceleration simultaneously in each of the three axis.

Figure 2.2.9-1 ISO View Section of Generic Holes for CM
Figure 2.2.9-2  Upper Support Ring Generic Hole Pattern for CM
Figure 2.2.9-3  Lower Support Ring Generic Hole Pattern for CM
Figure 2.2.9-4  Detail Views of Generic Hole Pattern for CM
2.2.10 GSE Holes at Strap Locations

A set of holes has been incorporated on the outside of the VC around each strap port. These holes are for supporting the strap preload operation during the installation of the CM into the VC. These holes are in addition to the holes that are located on the strap closeout cap mating surface. Figures 2.2.10-1 through 2.2.10-4 detail these hole locations.

![Figure 2.2.10-1 ISO View of Strap GSE Holes](image-url)
Figure 2.2.10-2  Top/Bottom View of Hole Locations

Figure 2.2.10-3  Section View of Side Hole Locations
Figure 2.2.10-4 Detail View of Side Holes
2.2.11 Experiment Interfaces to Vacuum Case

The Tracker and Anti-Coincidence Counter mount to the inner diameter of the Vacuum Case Conical Flanges. An ISO view section of the Conical Flange with the interfaces is shown in Figure 2.2.11-1.

**Figure 2.2.11-1 ISO View Showing Experiment Interfaces on Conical Flange**

2.2.11.1 Tracker Support Feet

The Tracker Support Feet are mounted to the Vacuum Case as shown in Figures 2.2.11.1-1 and 2.2.11.1-2.
Figure 2.2.11.1-1 Tracker Mounting Pattern

Mounting fasteners to be provided by NASA/LMSO.

Figure 2.2.11.1-2 Tracker Mounting Cross-Section
2.2.11.2 Anti-Coincidence Counter Support Feet

The ACC support feet mount to the inner diameter of the upper and lower conical flanges of the Vacuum Case. These mounting locations are shown in Figure 2.2.11.2-1. The hole pattern shown in Figure 2.2.11.2-1 exists between each of the conical flange ribs, but the ACC will only utilize the pattern between every other pocket. The additional bolt inserts can be used for other mounting as required by the experiment.

![Figure 2.2.11.2-1 ACC Mounting Pattern](image)

2.2.11.3 Generic Bolt Pattern Interfaces on Outside of VC

A generic bolt hole pattern exists on the Vacuum Case Conical Flange Ribs as shown in Figure 2.2.11.3-1. The maximum allowable force on each hole is 4.5 lbf. Additional generic bolt hole patterns will be incorporated into the upper and lower rings of the VC as shown in Figures 2.2.11.3-2 through 2.2.11.3-6. The maximum allowable force on each hole is 16 lbf. This pattern includes numerous #10 bolt inserts and thru holes at approximately 3 inch spacing around the circumference of both the upper and lower support rings and the upper and lower outer cylinder mating flanges. Several of the holes will need to be reserved to attach thermal blankets and other PIH. Details of this are TBD.
Masses attached to the generic holes must not create more than 4.5 pounds of force in any direction at any hole when subjected to 1 g of acceleration simultaneously in each of the three axis.

All hardware mounted to the VC must meet the requirements in the Thermal ICD.
All hardware mounted to the VC must meet the requirements in the Thermal ICD.

Masses attached to the generic holes must not create more than 16 pounds of force in any direction at any hole when subjected to 1 g of acceleration simultaneously in each of the three axis.
All hardware mounted to the VC must meet the requirements in the Thermal ICD.

Masses attached to the generic holes must not create more than 16 pounds of force in any direction at any hole when subjected to 1 g of acceleration simultaneously in each of the three axis.
All hardware mounted to the VC must meet the requirements in the Thermal ICD.

Masses attached to the generic holes must not create more than 16 pounds of force in any direction at any hole when subjected to 1 g of acceleration simultaneously in each of the three axes.

Figure 2.2.11.3-5 Generic Bolt Hole Pattern on VC Outer Cylinder Lower Flange
Masses attached to the generic holes must not create more than 16 pounds of force in any direction at any hole when subjected to 1 g of acceleration simultaneously in each of the three axis.

All hardware mounted to the VC must meet the requirements in the Thermal ICD.

Figure 2.2.11.3-6 Generic Bolt Hole Pattern on VC Lower Support Ring
2.2.11.4 Anti-Coincidence Counter Photomultiplier Mounts

The ACC photomultipliers mount to the top and bottom conical flanges at the PM mounted locations as shown in Figure 2.2.11.4-1.

See Figure 2.2.11.4-2 for the angle between the PM mounts.

**Figure 2.2.11.4-1  ACC PM Mounting Locations**

This is a view looking down the conical flange between the ribs based on the section lines shown in Figure 2.2.11.3-1.

**Figure 2.2.11.4-2  Keep-In Zone for ACC and Tracker Electrical/Plumbing Lines**

All hardware mounted to the VC must meet the requirements in the Thermal ICD.
2.2.11.5 Thermal Control System Interface to Vacuum Case

Although the TCS has not been determined at the time of the signing of this ICD, it is anticipated that the TCS will utilize the generic hole patterns on the upper and lower rings of the Vacuum Case. See Figures 2.2.11.3-2 through 2.2.11.3-6 for the generic hole pattern.

2.2.12 Structural Finish and Flatness

All AMS-02 experiment structural interfaces shall have a surface finish of 125 micro-inches or better. Mounting surfaces shall not be painted, but shall be anodized or alodined aluminum. All vacuum sealing surfaces will be cleaned, polished and protected with a thin film of vacuum grease or equivalent.
3.0 ASSEMBLY REQUIREMENTS

3.1 Assembly Procedure Between VC And Cold Mass

The assembly procedure of the Vacuum Case / Cold Mass (CMR or Flight Magnet) will be performed in England at ETH/SCL facilities. Figure 3.1-1 shows the assembly procedure for the Vacuum Case / Cold Mass.

**Figure 3.1-1  VC/Cold Mass Assembly Procedure (shown below)**

**Step 1:**
Fabricate and assemble all 12 racetrack coils and test each one individually.

**Step 2:**
Assemble 6 together, twice. One for each side.

**Step 3:**
Fabricate and assemble 2 Dipoles and test each one individually.
**Step 4:**
Assemble all coils together
Including Racetrack End frames.

**Step 5:**
Complete all plumbing, up to helium vessel

**Step 6:**
Turn to –z axis upwards

**Step 6:**
Fit helium vessel and
Connect to coil pipework
**Step 7:**
Fit cold-warm supports (except warm end item)

**Step 8:**
Complete all 1.8 K instrumentation (this includes accelerometers on CMR)

**Step 9:**
Lift cold mass and put in assembly frame inverted (‘top’ is down). Transfer loads to four C1W1 supports (only)

**Step 10:**
Assemble all Pipework, Superinsulation, Radiation Shields, Radiation shield Supports, Current leads, Instrumentation; (access from above and below).
**Step 11:**
Fit from above the VC Lower Support Ring (shown in green), supported on Assembly Frame, with warm Bods in place (retracted).

**Step 12:**
Transfer load to 4 C2W2 supports.

**Step 13:**
Re-tension 4 C1W1 supports to VC Lower Support Ring.
Complete pipework etc to VC Lower Support Ring.

**Step 14:**
Lift whole cold mass via the VC Lower Support Ring and install in the pre-assembled (inverted) VC Outer Cylinder / VC Upper Support Ring.

**Step 15:**
Re-install VC / Cold mass into re-built Assembly Frame to allow tension loads to be reacted so as to retain circularity of VC Upper and Lower Support Rings.

**Step 16:**
Tension remaining cold to warm supports and complete pipework etc to VC Upper Support Ring.
**Step 17:**
Set up all CTW straps correctly to tension values based on the cold mass replica (CMR) assembly sequence.

**NOTE:** During the CMR assembly sequence, the cold mass will have been supported via a load cell to simulate zero g and all supports tensioned to the warm, zero ‘g’, preload. Load cell is then removed and the resulting tensions in all supports are recorded. These tensions are used during the assembly of the flight article.

**Step 18:**
Complete all work to internals of VC, fit cryocoolers.

**Step 19:**
Fit Upper Conical Flange of VC to underside of assembly.

**Step 20:**
Fit Inner Cylinder of VC.

**Step 21:**
Fit Lower Conical Flange of VC to top of assembly.

**Step 22:**
Fit temporary O-ring seal fixtures to Inner Cylinder, perform pressure test and leak test on all systems and operate cryosystem.

**Step 23:**
Rotate to where the z axis is horizontal and weld the Inner Cylinder to the Conical Flanges.

**Step 24:**
Pressure test and leak test Vacuum Case.

**Step 25:**
Complete external pipework and instrumentation.
### 3.1.1 Hardware

The hardware provided by each group and the description is shown in Table 3.1.1-1.

<table>
<thead>
<tr>
<th>HARDWARE</th>
<th>PROVIDER</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vacuum Case</td>
<td>LMSO/NASA-JSC</td>
<td>Structural Test Article (STA) and Flight Vacuum Case</td>
</tr>
<tr>
<td>Weld Fixture</td>
<td>LMSO/NASA-JSC</td>
<td>Used to support VC during welding of the inner cylinder to conical flange.</td>
</tr>
<tr>
<td>Temporary Port Closeout Covers</td>
<td>LMSO/NASA-JSC</td>
<td>Used to temporarily seal the VC (STA and Flight) during ground vacuum leak tests and proof pressure tests prior to the installation of the final closeout port covers or caps. Also used for flight spare ports</td>
</tr>
<tr>
<td>Hydra - Set</td>
<td>LMSO/NASA-JSC</td>
<td>Will be on loan to SCL for use in the VC/Cold Mass assembly process.</td>
</tr>
<tr>
<td>Plumbing and Electrical Feed Thru Port Covers and Caps, and Support Strap Closeout Caps</td>
<td>SCL/ETH</td>
<td>Used to seal the VC (STA and Flight) during ground vacuum leak tests and proof pressure tests after installation of cryosystem.</td>
</tr>
<tr>
<td>Cryocooler Feed Thru Port Covers / Cryocooler Support Bracket-Compliant Mount</td>
<td>ETH/MIT/NASA-GSFC</td>
<td>Used to support the cryocoolers to the VC, to seal the cryocooler port, and to mechanically &amp; thermally isolate the cryocoolers. Use temporary covers for spare ports.</td>
</tr>
<tr>
<td>Cryocoolers</td>
<td>ETH/MIT/NASA-GSFC</td>
<td>Mount to the Upper and Lower Support Rings on the VC.</td>
</tr>
<tr>
<td>Cryocooler Heat Rejection System</td>
<td>TBD</td>
<td>Used to draw the heat away from the cryocooler warm end and distribute it to the AMS-02 Thermal Control System (TCS).</td>
</tr>
<tr>
<td>Cold Mass Replica (CMR) Assy.</td>
<td>SCL/ETH</td>
<td>The CMR will match the mass and inertia properties of the flight magnet to within ±5%. It will be installed in STA Vacuum Case.</td>
</tr>
<tr>
<td>Cold Mass Replica Straps</td>
<td>SCL/ETH</td>
<td>Flight identical non-linear straps to be used with STA VC and CMR. Must be capable of changing these straps to linear response during the modal and static testing of the AMS-02 payload. Details to be discussed.</td>
</tr>
<tr>
<td>STA SFHe Tank</td>
<td>SCL/ETH</td>
<td>To be used with STA Vacuum Case &amp; CMR.</td>
</tr>
<tr>
<td>Pressure Gauge for the STA Acoustic Test</td>
<td>SCL/ETH</td>
<td>The pressure gauge will be used to check the pressure of the Vacuum Case before, during and after the acoustic test.</td>
</tr>
<tr>
<td>STA Cryosystem</td>
<td>SCL/ETH</td>
<td>To be used with STA Vacuum Case &amp; CMR.</td>
</tr>
</tbody>
</table>
### TABLE 3.1.1-1 PROVIDED HARDWARE SUMMARY TABLE

<table>
<thead>
<tr>
<th>HARDWARE</th>
<th>PROVIDER</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cryomagnet</td>
<td>SCL/ETH</td>
<td>To be used with the flight Vacuum Case and Flight SFHe Tank.</td>
</tr>
<tr>
<td>Flight SFHe Tank</td>
<td>SCL/ETH</td>
<td>To be used with flight Vacuum Case and Cryomagnet.</td>
</tr>
<tr>
<td>Flight Cryosystem</td>
<td>SCL/ETH</td>
<td>To be used with flight VC, flight Cryomagnet, and SFHe Tank</td>
</tr>
<tr>
<td>Flight Straps</td>
<td>SCL/ETH</td>
<td>Support the Flight SFHe Tank, the Flight Cryosystem, and the Cryomagnet.</td>
</tr>
<tr>
<td>Burst Disks: VC = 0.8 atm</td>
<td>SCL/ETH</td>
<td>All burst disks for STA &amp; Flight VC and STA &amp; Flight SFHe will be provided</td>
</tr>
<tr>
<td></td>
<td></td>
<td>by SCL/ETH as defined by the SCL/ETH cryogenic schematic.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Temporary O-ringed Seal for Inner Cylinder to Conical Flange Interface of VC</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SCL/ETH Will be used with the STA and Flight VC to perform vacuum leak</td>
</tr>
<tr>
<td></td>
<td></td>
<td>checks. Must be provided to NASA/LMSO to perform this early testing on the</td>
</tr>
<tr>
<td></td>
<td></td>
<td>VC before the VC arrives in England.</td>
</tr>
<tr>
<td>Ground Support Hardware</td>
<td>SCL/ETH</td>
<td>- Must be capable of rotating complete magnet system.</td>
</tr>
<tr>
<td>for Magnet / Vacuum Case</td>
<td></td>
<td>- Must be capable of maintaining the required shape of the VC during the</td>
</tr>
<tr>
<td>Assembly</td>
<td></td>
<td>assembly process.</td>
</tr>
<tr>
<td>Cryosystem GSE</td>
<td>SCL/ETH</td>
<td>To be used to support the filling and operations associated with helium or</td>
</tr>
<tr>
<td></td>
<td></td>
<td>superfluid helium. This hardware will be used in England, Zurich, KSC,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>wherever the vibration testing occurs, and wherever the thermal vacuum</td>
</tr>
<tr>
<td></td>
<td></td>
<td>testing occurs.</td>
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#### 3.1.2 Strap System

The Strap System is completely designed, built and tested by SCL / ETH. Since the design of this system affects the design of the Vacuum Case, the load verses deflection envelope shown in the following Figures will be adhered to. Any changes to these curves must be agreed to by all parties affected by the change.
### Table 3.1.2-1 Non-Linear Strap Load Data

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<tr>
<th>Condition</th>
<th>Strain</th>
<th>Stress (N/mm²)</th>
<th>Stress (psi)</th>
<th>Force (kN)</th>
<th>Force (lbf)</th>
<th>Deflection (mm)</th>
<th>Deflection (inch)</th>
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<td></td>
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<td></td>
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<tr>
<td>Cold</td>
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Figure 3.1.2-1 Force Versus Deflection for C1W1 Strap - Cold

Figure 3.1.2-2 Force Versus Deflection for C1W1 Strap - Warm
**Figure 3.1.2-3**  Force Versus Deflection for C2W2 Strap - Cold

**Figure 3.1.2-4**  Force Versus Deflection for C2W2 Strap - Warm
3.2 Assembly Procedure Between VC and ACC

The assembly procedure of the Vacuum Case / ACC will be performed in Zurich. Figures 3.2-1 and 3.2-2 show the assembly procedure for the operation. The details of this procedure are listed below. NASA/LMSO will drill holes as shown in Figure 2.2.11.2-1. Aachen will provide the ACC including mounting fixtures.

Step 1:
The ACC bottom support feet (drawing #ams-02-1619, detail V) are mounted to the VC (Figure 2.2.11.2-1, fastened to the .190-32UNF holes).

Step 2:
The 16 ACC modules are then slid into the VC down to the bottom support feet.

Step 3:
The ACC support tube (drawing #ams02-1619) will be slid in from the top and will be bolted to the bottom support feet (detail V)

Step 4:
The top support feet (drawing #ams02-1619, detail U) will be mounted to the VC. The springs contained in the top support feet allow for thermal expansions and ensure proper fixation of the ACC modules.

Step 5:
The optical connectors are fixed to the generic hole pattern on the upper and lower Conical Flange radial ribs.

Step 6:
The 16 PMT’s on the Upper Conical Flange and the corresponding 16 PMT’s on the Lower Conical Flange will be mounted at the +/-Y direction.
Figure 3.2-1 VC/ACC Assembly Procedure (1 of 2)

ACC-PM Arrangement
Figure 3.2-2  VC/ACC Assembly Procedure (2 of 2)

Upper ACC Support Clamps
ACC Support Tube
ACC Module Ring
Magnet
Lower ACC Support Clamps
Optical Connector
Light Guides
Mounted View

Details
U1.25
V1.25
W1.25
3.3 Assembly Procedure Between VC and Tracker

The assembly procedure of the Vacuum Case / Tracker will be performed in Zurich. Figure 3.3-1 shows the assembly procedure for the operation. The details of this procedure are currently TBD. NASA/LMSO will drill oversized holes as shown in 2.2.11.1-1 for the shear pins. NASA/LMSO will also drill the bolt holes as shown in 2.2.11.1-1 and 2.2.11.1-2. Aachen will measure the hole locations once the flight VC is assembled. Aachen will provide an insert for the shear pin hole, and Aachen will drill the insert to match the shear pin.

Figure is TBD

Figure 3.3-1 VC/Tracker Assembly Procedure (TBD)
4.0 VACUUM CASE VACUUM AND PRESSURE TEST REQUIREMENTS

4.1 Vacuum Test Requirements

Both the STA and Flight Vacuum Cases will be vacuum leak checked with the temporary port covers and the temporary inner cylinder to conical flange interface seal (provided by SCL/ETH). The test will be considered successful once it shows that the VCs can hold a vacuum of TBD torr for a TBD amount of time. This may be determined by measuring a leak rate of TBD standard cc / second of helium by using a helium leak detector attached to the vacuum space to measure a rate of helium molecules. This entire process is currently TBD and will be defined between NASA/LMSO and ETH/SCL at a later date. Table 4.1.1 lists the helium permeability rates for the two different o-ring groove designs along with the Parker recommended design to be used as a baseline. Table 4.1.2 lists the parameters that were used to calculate the rates. The rates calculated in the table are based on a single o-ring at each joint. Therefore, the rates listed would be the maximum plus a 50% tolerance.

Once the cold mass (CMR or flight magnet) is installed inside the VC, the system will be vacuum leak checked with the final port covers and caps and the temporary inner cylinder to conical flange interface seal. If at this point there is a problem attaining an acceptable vacuum, NASA/LMSO will work with ETH/SCL to ensure that all of the NASA/LMSO seals have been installed properly. This may include checks of these seals through the test ports that have been built into the VCs. Since NASA/LMSO will have already shown that the VC can be held within an acceptable tolerance from the previous tests and will show that the large (>90 inches) o-rings are sealed utilizing the VC test ports, NASA/LMSO will assume no responsibility for an inability to achieve acceptable vacuum results after this point.
## Table 4.1-1 Helium Permeability Rates

<table>
<thead>
<tr>
<th></th>
<th>Option 1: (SCL)</th>
<th>Option 2: (LMSO)</th>
<th>Parker: (Extruded O-Ring)</th>
<th>Parker: (Molded O-Ring)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Groove Depth</strong></td>
<td>Max 0.232</td>
<td>Max 0.211</td>
<td>Max 0.211</td>
<td>Max 0.211</td>
</tr>
<tr>
<td></td>
<td>Min 0.225</td>
<td>Min 0.204</td>
<td>Min 0.201</td>
<td>Min 0.201</td>
</tr>
<tr>
<td><strong>Groove Width</strong></td>
<td>Max 0.278</td>
<td>Max 0.310</td>
<td>Max 0.314</td>
<td>Max 0.314</td>
</tr>
<tr>
<td></td>
<td>Min 0.270</td>
<td>Min 0.305</td>
<td>Min 0.309</td>
<td>Min 0.309</td>
</tr>
<tr>
<td><strong>Groove Area</strong></td>
<td>Max 0.0644960</td>
<td>Max 0.0654100</td>
<td>Max 0.0662540</td>
<td>Max 0.0662540</td>
</tr>
<tr>
<td></td>
<td>Min 0.0607500</td>
<td>Min 0.0622200</td>
<td>Min 0.0621090</td>
<td>Min 0.0621090</td>
</tr>
<tr>
<td><strong>O-Ring Squeeze</strong></td>
<td>Max 21.05%</td>
<td>Max 28.42%</td>
<td>Max 29.47%</td>
<td>Max 28.47%</td>
</tr>
<tr>
<td></td>
<td>Min 12.45%</td>
<td>Min 20.38%</td>
<td>Min 20.38%</td>
<td>Min 21.56%</td>
</tr>
<tr>
<td><strong>Groove Fill</strong></td>
<td>Max 105.01%</td>
<td>Max 102.53%</td>
<td>Max 102.71%</td>
<td>Max 99.85%</td>
</tr>
<tr>
<td></td>
<td>Min 85.52%</td>
<td>Min 84.32%</td>
<td>Min 83.25%</td>
<td>Min 85.78%</td>
</tr>
</tbody>
</table>

Parker recommended squeeze is 10% - 30%

Parker recommended groove fill is 95% maximum

<table>
<thead>
<tr>
<th></th>
<th>Option 1: (SCL)</th>
<th>Option 2: (LMSO)</th>
<th>Parker: (Extruded O-Ring)</th>
<th>Parker: (Molded O-Ring)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Helium Permeability Rate</strong></td>
<td>2.6978E-04 std cc/s</td>
<td>2.2250E-04 std cc/s</td>
<td>2.1941E-04 std cc/s</td>
<td>2.1888E-04 std cc/s</td>
</tr>
<tr>
<td><strong>Helium Permeability Rate</strong></td>
<td>6.3052E-05 std cc/s</td>
<td>5.2001E-05 std cc/s</td>
<td>5.1280E-05 std cc/s</td>
<td>5.1157E-05 std cc/s</td>
</tr>
<tr>
<td>for the O-Ring Test Fixture</td>
<td>6.3689E-05 mbar-l/s</td>
<td>5.2526E-05 mbar-l/s</td>
<td>5.1798E-05 mbar-l/s</td>
<td>5.1673E-05 mbar-l/s</td>
</tr>
</tbody>
</table>

Notes:
- The Parker groove is based on molded o-rings which have a smaller cross section tolerance.
- O-Ring material: Fluorocarbon V7895, Black, Durometer = 75 +/- 5
- The System Leak Rate is based on only one o-ring at each joint.
- A tolerance of +/- 50% can be expected for the helium permeability rate.
- Helium Permeability Rates are based on a single o-ring.
O-Ring Leak Rate Parameters (Based on formulas and graphs found in the Parker O-Ring Handbook ORD 5700)

O-Ring Diameters (D)  
- CF to SR Inner: 98.792 in
- CF to SR Outer: 99.792 in
- OC to SR Inner: 106.074 in
- OC to SR Outer: 107.074 in

Permeability Rate (F): 1.27E-07 std cc/s Based on Parker Table
Pressure Differential (P): 14.7 psi
Squeeze Factor (Q): 0.72 Based on Parker Graph
% Squeeze decimal (S): varies Based on average values from above

Approximate Leak Rate = \[ .7 \times F \times D \times P \times Q \times (1-S)^2 \]

<table>
<thead>
<tr>
<th>Option 1: (SCL)</th>
<th>Option 2: (LMSO)</th>
<th>Parker: (Extruded O-Ring)</th>
<th>Parker: (Molded O-Ring)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg Squeeze in decimal</td>
<td>0.1675</td>
<td>0.2440</td>
<td>0.2493</td>
</tr>
<tr>
<td>Leak Rate CF to SR</td>
<td>6.5071E-05 std cc/s</td>
<td>5.36661E-05 std cc/s</td>
<td>5.29215E-05 std cc/s</td>
</tr>
<tr>
<td>Leak Rate OC to SR</td>
<td>6.98193E-05 std cc/s</td>
<td>5.75822E-05 std cc/s</td>
<td>5.67833E-05 std cc/s</td>
</tr>
</tbody>
</table>

O-Ring Leak Rate Parameters (Based on formulas and graphs found in the Parker O-Ring Handbook ORD 5700)

O-Ring Diameters (D)  
- CF to SR Inner: 19.538 in
- CF to SR Outer: 20.538 in
- OC to SR Inner: 26.81 in
- OC to SR Outer: 27.81 in

Permeability Rate (F): 1.27E-07 std cc/s Based on Parker Table
Pressure Differential (P): 14.7 psi
Squeeze Factor (Q): 0.72 Based on Parker Graph
% Squeeze decimal (S): varies Based on average values from above

Approximate Leak Rate = \[ .7 \times F \times D \times P \times Q \times (1-S)^2 \]

<table>
<thead>
<tr>
<th>Option 1: (SCL)</th>
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</tr>
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<tbody>
<tr>
<td>Avg Squeeze in decimal</td>
<td>0.1675</td>
<td>0.2440</td>
<td>0.2493</td>
</tr>
<tr>
<td>Leak Rate CF to SR</td>
<td>1.33921E-05 std cc/s</td>
<td>1.10449E-05 std cc/s</td>
<td>1.08917E-05 std cc/s</td>
</tr>
<tr>
<td>Leak Rate OC to SR</td>
<td>1.8134E-05 std cc/s</td>
<td>1.49557E-05 std cc/s</td>
<td>1.47481E-05 std cc/s</td>
</tr>
</tbody>
</table>

### Table 4.1-2  Helium Permeability Rate Parameters

#### 4.2 Proof Pressure Test Requirements

Both the STA and Flight Vacuum Cases will be proof pressure tested as required by JSC-28792A (AMS-02 Structural Verification Plan).