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Test Plan for the Static and Modal Tests of the Alpha Magnetic Spectrometer 02 (AMS-02)

Prepared by

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For

Engineering Directorate
Flight Projects Division

National Aeronautics and
Space Administration

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Test Plan for the Static and Modal Tests of the AMS-02

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Preface

This test plan was prepared by the Engineering and Science Contract Group (ESCG) in support of the Alpha Magnetic Spectrometer - 02 (AMS-02) Project under contract NNJ05HI05C for the National Aeronautics and Space Administration (NASA).

This test plan presents the approaches and techniques for conducting the static and modal tests of the AMS-02 static test article. This test plan has been developed in accordance with the requirements set forth in JSC-28792, Revision D, *Alpha Magnetic Spectrometer-02 Structural Verification Plan*.

Written concurrence/approval will be obtained from the Structures Working Group which is chaired by the NASA Johnson Space Center (JSC) Structural Engineering Division.

Table of Contents

List of Figures

List of Tables

List of Acronyms and Abbreviations

AMS-02	Alpha Magnetic Spectrometer
CMR	Cold Mass Replica
ESCG	Engineering and Science Contract Group
FEM	Finite Element Model
IABG	Industrieanlagen-Betriebsgesellschaft GmbH
ISS	International Space Station
JE	Jacobs Engineering
JSC	Johnson Space Center
MFL	Maximum Flight Load
MIP	Mandatory Inspection Point
NCR	Non-Conformance Report
P/N	Part Number
QA	Quality Assurance
SSP	Space Station Program
STA	Static Test Article
TPS	Task Performance Sheet
TRR	Test Readiness Review
USS-02	Unique Support Structure
VC	Vacuum Case
VLA	Verification Loads Analysis

1.0 INTRODUCTION

1.1 Background

The Alpha Magnetic Spectrometer (AMS) is a space-based particle physics experiment that is currently scheduled for transportation to the International Space Station (ISS) by the Space Shuttle. The AMS primary mission is scheduled to remain active for at least three years on the ISS. The scientific mission of AMS seeks to understand fundamental issues shared by physics, astrophysics and cosmology on the origin and structure of the Universe. One objective of the AMS experiment is to locate antimatter and dark matter by collecting particles from cosmic sources emanating from stars and galaxies far beyond our own solar system. The AMS payload is designed and constructed by an international team of physicists and engineers from over 50 institutions and companies in 16 countries. Along with the international support of the experiment, the project represents a joint effort by the United States Department of Energy and the National Aeronautics and Space Agency. Figure 1.1-1 provides a view of the fully assembled AMS-02 payload.

1.2 Overview

This static and modal tests are portions of the overall structural verification plan for the AMS-02 payload that has been defined in JSC 28792, Revision D. These tests will be performed on a test article consisting of the flight Unique Support Structure (USS-02) and structural test articles (STAs) of the vacuum case (VC) and several of the detectors. Inside the vacuum case, a set of sixteen, flight-like strap assemblies support a magnet and helium tank replica, known as the Cold Mass Replica (CMR). The force versus displacement response for the magnet support straps has a distinct nonlinear characteristic. Correlation of this nonlinear response will be done through a high-level sine sweep test of the VC and CMR. Results from these tests will be used to correlate the linear response of AMS-02 finite element model (FEM) to static and small dynamic loads prior to submittal to NASA for the final Verification Loads Analysis (VLA).

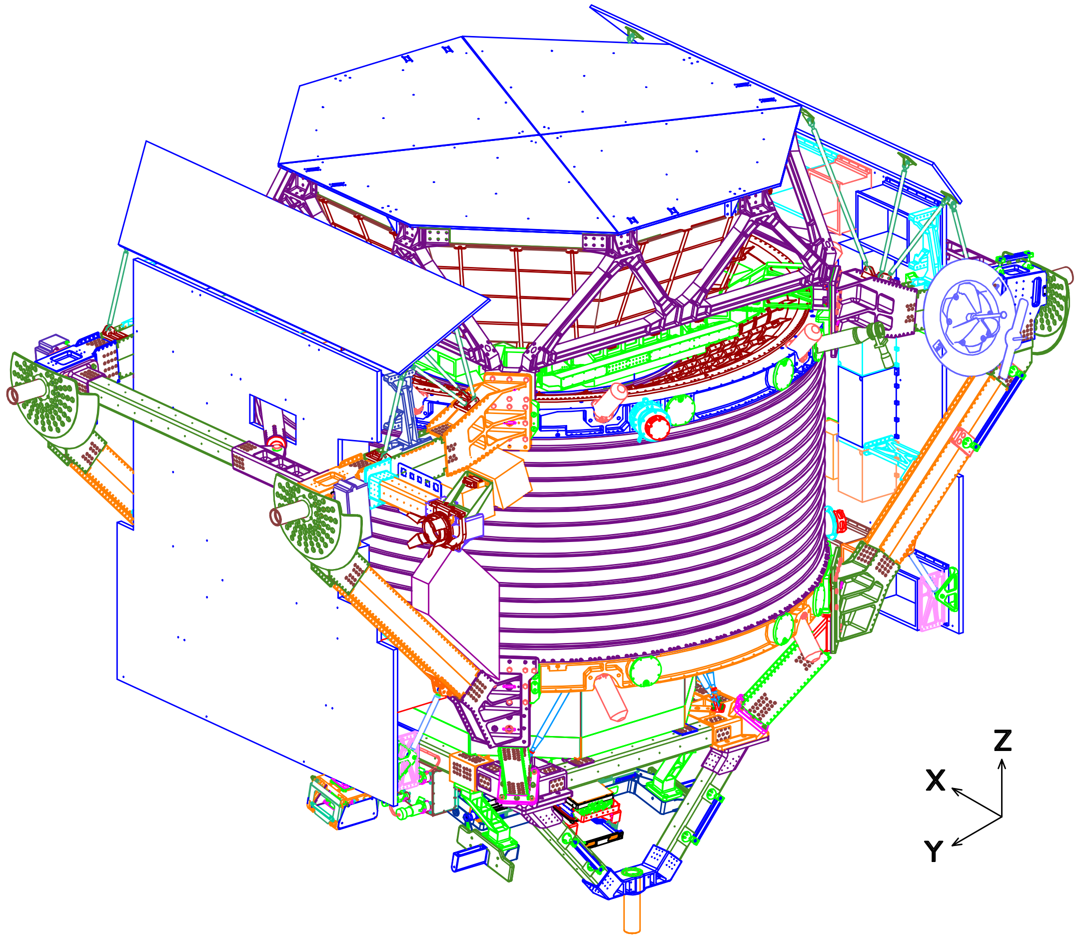

Figure 1.1-1 View of the fully assembled AMS-02 payload

1.3 Test Schedule

The schedule for the major milestones of the vacuum case and magnet system sine sweep test are presented in Table 1.3-1.

Table 1.3-1 Major Milestones for the AMS-02 Static and Modal Tests

	Milestone	Date
1	Test Hardware Critical Design Review	15 Dec 2006
2	ESCG delivers integrated test article to IABG	2 Apr 2007
3	Static Test Readiness Review	15 May 2007
4	Static Test Post Test Review	30 May 2007
5	Modal Test Readiness Review	25 Jun 2007
6	Modal Test Post Test Review	28 Jun 2007
7	Hardware tear down and return to CERN	13 Jul 2007
8	Final Test Reports delivered	9 Aug 2007

1.4 Success Criteria

The primary intent of the static test is to induce flight-equivalent loads into the critical areas of the AMS-02 primary structure and measure the strains generated in those locations. A secondary but no less important goal is to obtain test measured strain data that can be used to correlate the math model. The static test will be considered successfully completed when the following criteria have been accomplished:

(1) each identified low-margin point has been subjected to the maximum expected flight level loads
(2) for each load case used to achieve the first goal, strain measurements at each instrumentation location have been recorded
(3) the measured data is successfully recorded and delivered to ESCG

The primary intent of the modal test is to determine the natural modes of vibration of the AMS-02 structure under low-level dynamic loading and obtain accelerometer data at sufficient locations to allow correlation of the math model. The modal test will be considered successfully completed when the following criteria have been accomplished:

(1) the system has been vibrated at enough locations to allow identification of the target natural modes of vibration identified in the pre-test analysis
(2) all dynamic response seen during the test have been resolved into individual mode shapes
(3) the measured data is successfully recorded and delivered to ESCG

2.0 APPLICABLE DOCUMENTS

(1) NASA, JSC, Houston, Texas. *Alpha Magnetic Spectrometer – 02 Structural Verification Plan for the Space Transportation and the International Space Station*, (JSC-28792, Revision D) January, 2005.

(2) NASA, JSC, Houston, Texas. *Alpha Magnetic Spectrometer – 02 Structural Assembly and Testing Integration Plan,* (JSC-63123) February 21, 2006.

(3) NASA, JSC, Houston, Texas. *Pretest Analysis for the Static Test of the Alpha Magnetic Spectrometer – 02,* (JSC-#####) ***TBD***, 2006.

(4) NASA, JSC, Houston, Texas. *Pretest Analysis for the Modal Test of the Alpha Magnetic Spectrometer – 02,* (JSC-#####) ***TBD***, 2006.

(5) NASA, JSC, Houston, Texas. *Lift Plan for the Static and Modal Tests of the Alpha Magnetic Spectrometer – 02 Vacuum Case and Magnet System,* (JSC-#####) ***TBD***, 2006.

(6) NASA, JSC, Houston, Texas. *Test Article Installation Procedures for the Static and Modal Tests of the Alpha Magnetic Spectrometer – 02 Vacuum Case and Magnet System,* (JSC-#####) ***TBD***, 2006.

3.0 TEST ROLES AND RESPONSIBILITIES

The following organizations have roles and responsibilities for the vacuum case and magnet system sine sweep test:

(1) National Aeronautics and Space Administration, Johnson Space Center
(2) Engineering and Science Contract Group
(3) Industrieanlagen-Betriebsgesellschaft GmbH (IABG).
(4) Scientific Magnetics

A list of key personnel and their roles is provided in Table 3.0-1.

The general roles and responsibilities of each organization are described in section 3.1 through section 3.5. These roles may be modified with the agreement of all parties.

3.1 Project Manager

An IABG representative will serve as the facility project manager for the combined static and modal tests. The project manager has the following responsibilities:

(1) coordinate and schedule all test activities at the IABG facility
(2) coordinate with ESCG on all test and management activities
(3) coordinate delivery and handling of test hardware within IABG
(4) conduct the Test Readiness Reviews

3.2 Test Manager

IABG representatives will serve as the test managers for the static and modal tests. The test manager of a given test has the following responsibilities:

(1) supervise pretest activities including fabrication and installation of support hardware, instrumentation installation, and test hardware setup
(2) supervise activities during the execution of the test to ensure that all requirements of the test plan are satisfied
(3) prepare the final Test Report
(4) support the Test Readiness Review

3.3 Quality Manager

An IABG representative will serve as the Quality Manager for the combined static and modal tests. The Quality Manager has the following responsibilities:

(1) ensure all handling, shipping, and safety procedures are followed
(2) perform inspections of test hardware at all Mandatory Inspection Points (MIPs) defined in the test procedures.
(3) coordinate resolution of any Non-Conformance Reports (NCRs) which occur during the test.
(4) support the Test Readiness Reviews

3.4 Test Director

An ESCG representative will serve as the test director for the combined static and modal tests. The test director has the following responsibilities:

(1) coordinate with IABG on all test and management activities
(2) coordinate delivery of test hardware to IABG facility
(3) authorize tear-down at the completion of each test
(4) support the Test Readiness Reviews

3.5 Test Engineer

ESCG representatives will serve as the test engineers for the static and modal tests. The test engineer for a given test has the following responsibilities:

(1) perform pretest analyses to ensure that the test will meet all success criteria without damaging the AMS-02 test article
(2) develop the test plan
(3) provide real-time data assessment and recommend modifications to the test procedures, if necessary, to meet the test objectives
(4) review measured data and provide concurrence to tear-down at test completion
(5) support the Test Readiness Review

Table 3.0-1 Personnel for the AMS-02 Static and Modal Tests

Role	Representative	Organization	Contact Info
Project Manager	Dr. Anton Grillenbeck (***TBD***)	IABG	***TBD***
Static Test Manager	Dr. Walter Albrecht (***TBD***)	IABG	***TBD***
Modal Test Manager	Dr. Stefan Dillinger (***TBD***)	IABG	***TBD***
Quality Manager	(***TBD***)	IABG	***TBD***
Test Director	Bruce Sommer	ESCG	+1-281-461-5700 Bruce.Sommer@escg.jacobs.com
Static Test Engineer	Howard Carter	ESCG	+1-281-461-5529 Howard.Carter@escg.jacobs.com
Modal Test Engineer	Carl Lauritzen	ESCG	+1-281-461-5586 Carl.Lauritzen@escg.jacobs.com
AMS-02 Certification & Testing Lead	Phil Mott	ESCG	+1-281-461-5712 Phillip.Mott@escg.jacobs.com
AMS-02 Design Engineer	Hsing Ju	ESCG	+1-281-461-5683 Hsing.Ju@escg.jacobs.com
AMS-02 Project Engineer	Chris Tutt	ESCG	+1-281-461-5703 John.Tutt@escg.jacobs.com

4.0 TEST ARTICLE

4.1 Test Article Structure

The configuration of the AMS-02 STA during both the static and modal tests is shown in Figure 4.1-1 and Figure 4.1-2. Of the major components identified in the figures, only the USS-02 is flight hardware. All other items shown are structural test articles.

The most significant structure within the assembly is the STA Vacuum Case (VC). Prior to the test, the interior of the vacuum case will be reduced to a pressure of no greater than 10^{-3} torr. The interior of the vacuum case will remain at ambient temperature during the test. Monitoring of this pressure will not be required during activities at IABG.

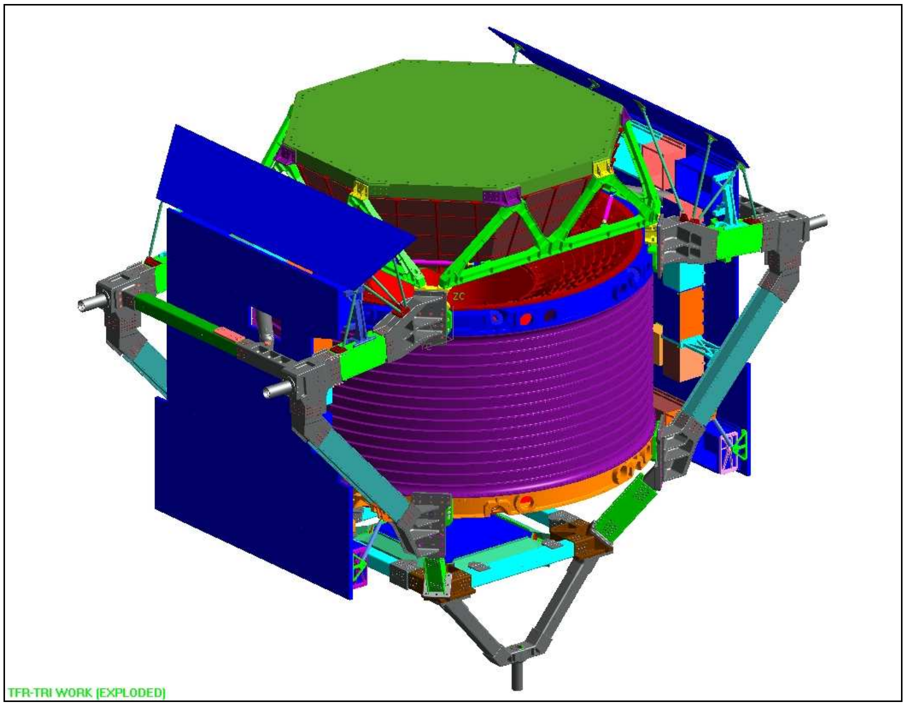

Figure 4.1-1 AMS-02 Test Configuration Components

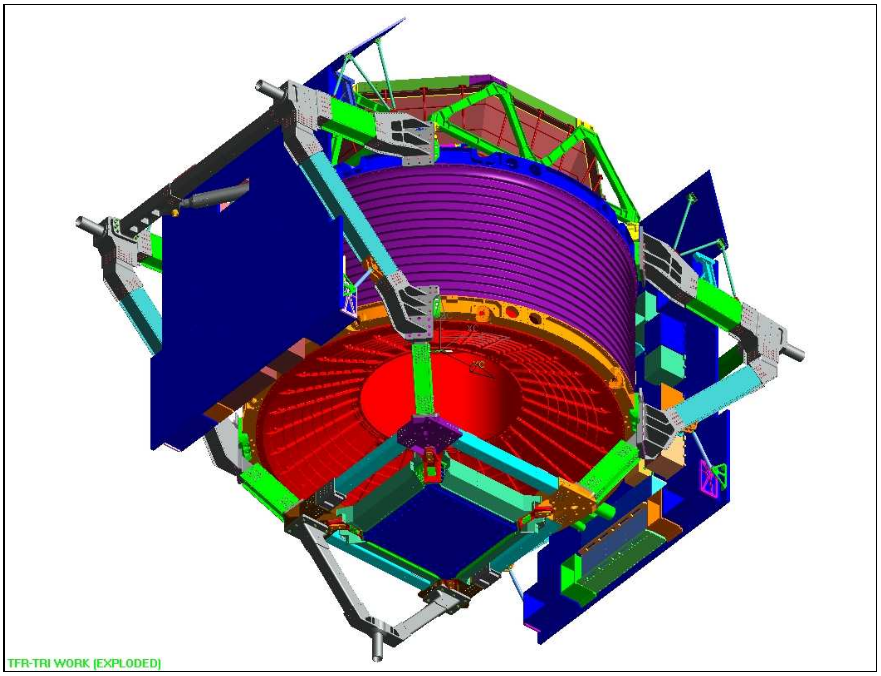

Figure 4.1-2 AMS-02 Test Configuration Components

Within the Vacuum Case is a structural test article of the flight magnet known as the Cold Mass Replica (CMR). The CMR is attached to the Vacuum Case Upper and Lower Support Rings by sixteen composite strap assemblies. These assemblies have a piecewise linear force-displacement relationship. At the low force levels foreseen during this test, no strap-induced nonlinear responses are foreseen and correlation of the nonlinear modes of the structure is not a test goal. Exact loadings during the modal test will be reviewed as part of the modal pre-test analysis and reduced to prevent any contamination of the linear results.

The mass replica of the magnet and helium tank is only intended to represent the mass and moments of inertia of the flight hardware for a configuration without helium. It does not have any capability to function as a magnet or as a tank for helium. Figure 4.1-2 shows a view of the mass replica of the magnet and helium tank. Figure 4.1-3 shows the mass replica of the magnet and helium tank attached to the vacuum case rings with the support straps.

Other than test instrumentation, the test article does not have any active electronic components. The estimated weight of the test article is 5925 pounds (2687 kg).

Figure 4.1-3 STA vacuum case

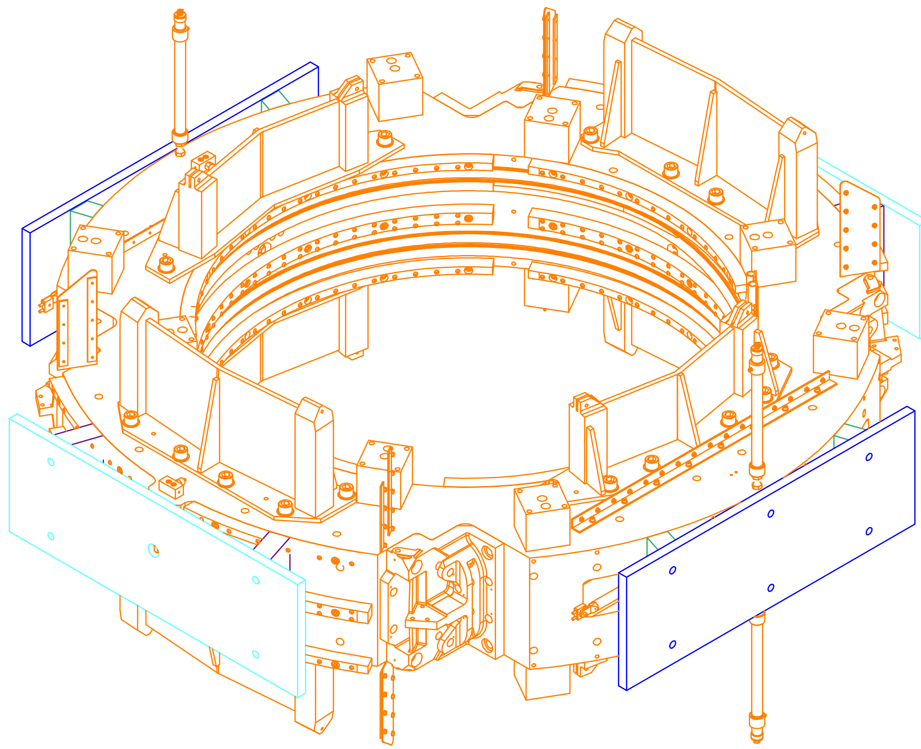

Figure 4.1-4 Mass replica of magnet and helium tank

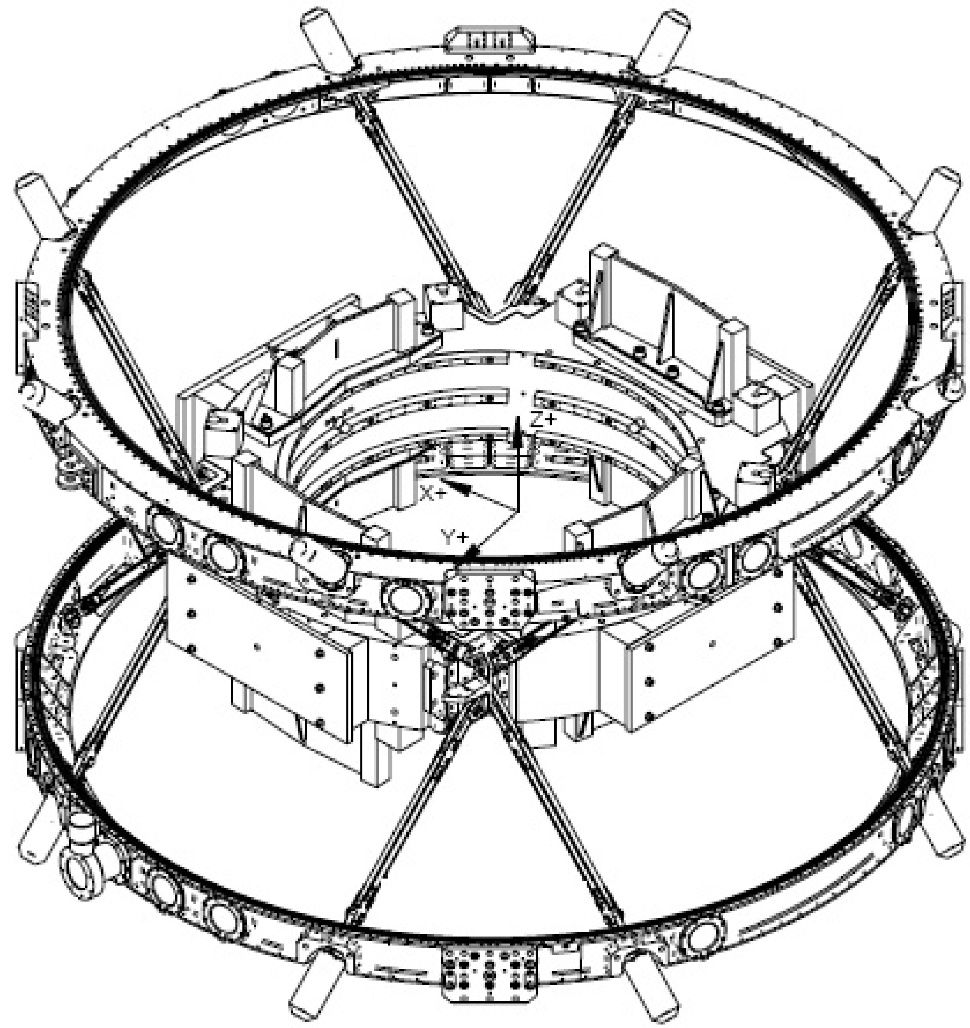

Figure 4.1-5 Mass replica of magnet and helium tank with support straps attached to VC rings

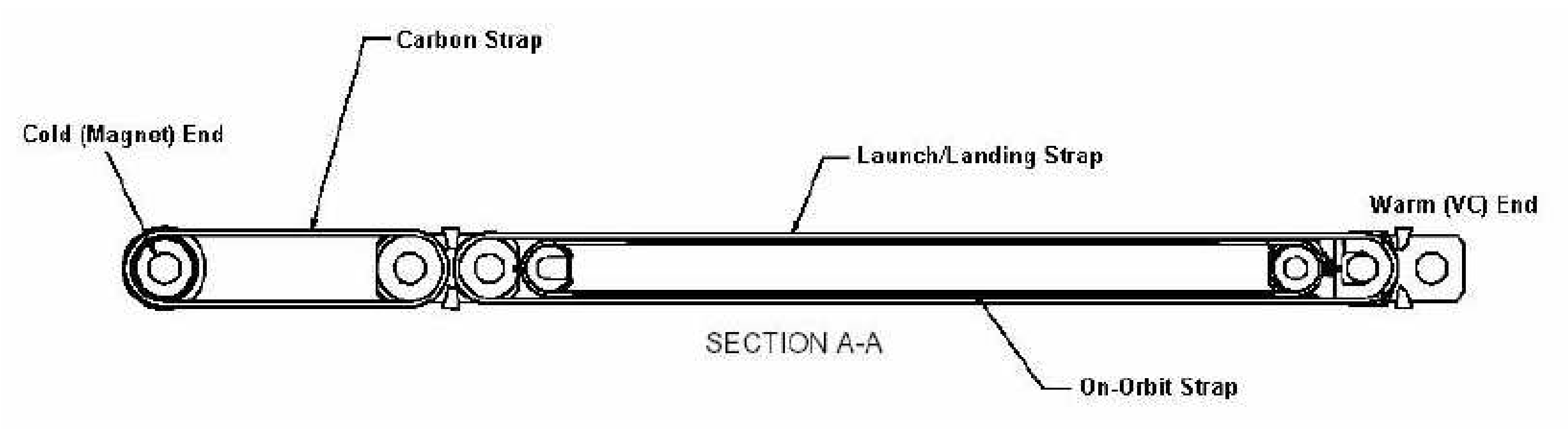

Figure 4.1-6 Side view of individual magnet support strap (without glass bod and wineglass assembly with Bellville washers)

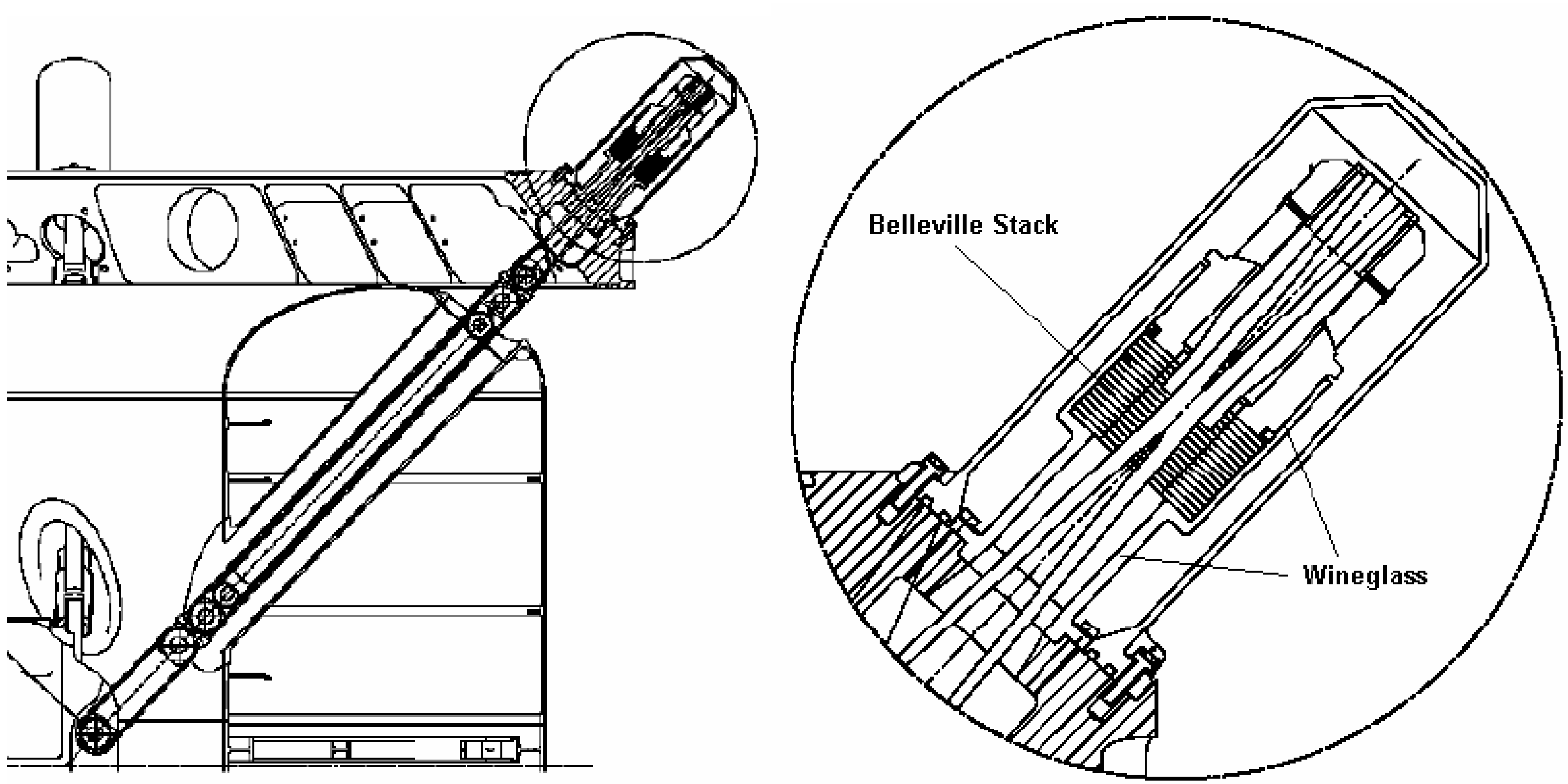

Figure 4.1-7 Cross-section of vacuum case showing view of the magnet support strap assembly with a detailed view of items that are external to the vacuum case port

4.2 ESCG-Provided Instrumentation

Measurement of the load in the magnet support strap assemblies and the acceleration of the Cold Mass Replica (CMR) are required to properly correlate the AMS-02 model. As these items are sealed inside the Vacuum Case (VC), they will not be accessible to IABG. ESCG must therefore install appropriate instrumentation during STA assembly.

ESCG will provide two Vishay N2A-13-S054Y-350 uniaxial strain gages on each of the sixteen magnet support strap assemblies. The location of the strain gages on the magnet support straps are shown in Figure 4.2-1. These strain gages will be wired to a Type and P/N? feed-through located on the Lower Support Ring of the Vacuum Case, as shown in Figure 4.2-2. The feed through itself is shown in Figure 4.2-3. The pin map for the feed-through is provided in Table 4.2-1.

ESCG will also provide 16 Metra Meß- und Frequenztechnik Radebeul (MMF) KS94.100 uniaxial accelerometers on the CMR. The cables for the accelerometers on the CMR will be routed to a group of vacuum connectors located on the Upper Support Ring of the Vacuum Case. These cables will terminate in UNF 10-32 connectors to facilitate connection to the data acquisition system. The cabling from the connectors to the data acquisition system will be provided by SERMS. The locations of the 16 accelerometers on the CMR are shown in Figure 4.2-4. The location of the feed-through port is shown in Figure 4.2-2. The feed-through itself is shown in Figure 4.2-5.

Calibration data for all this instrumentation will be provided by ESCG with the test article.

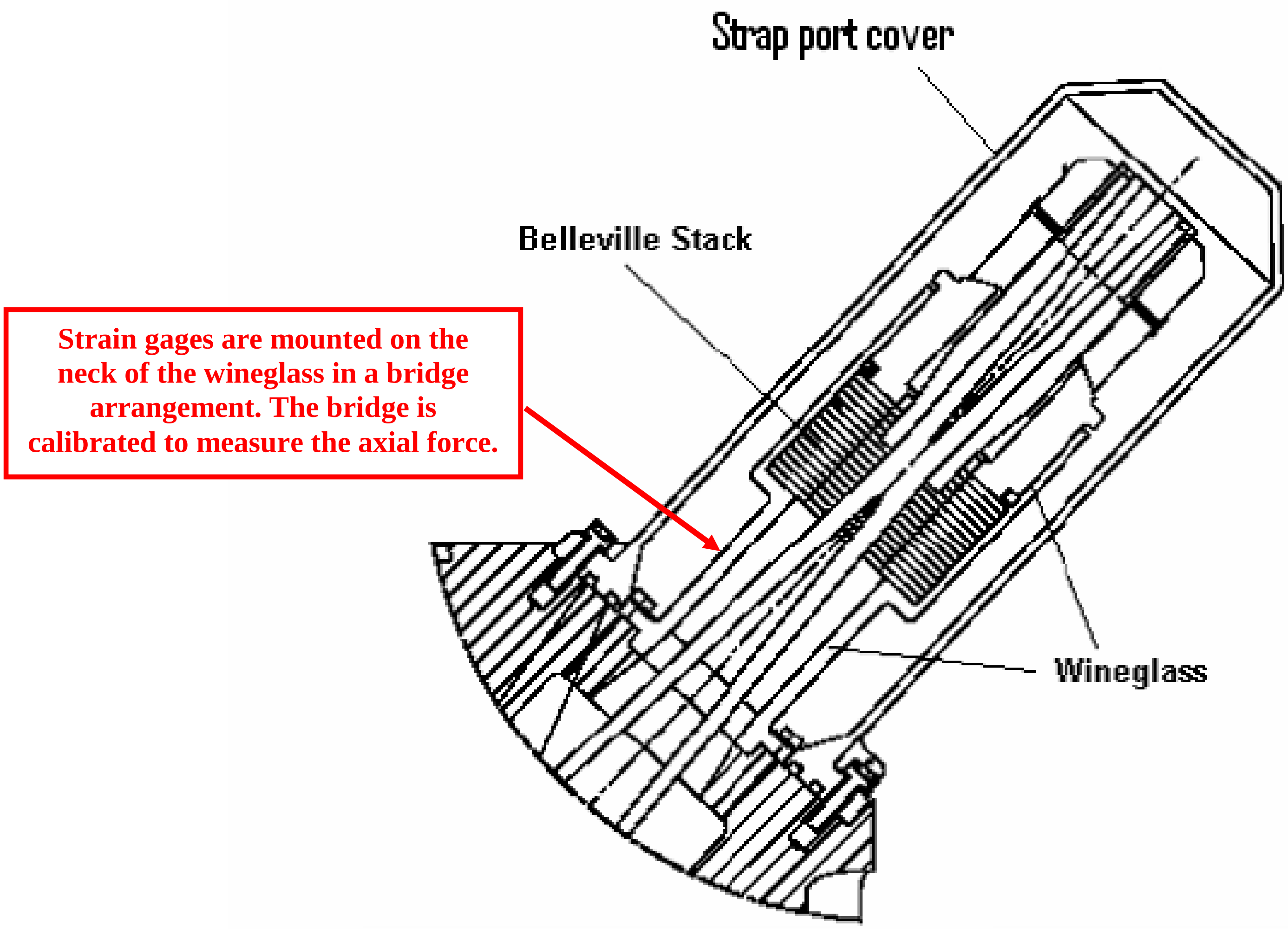

Figure 4.2-1 Location of strain gages on the magnet support straps

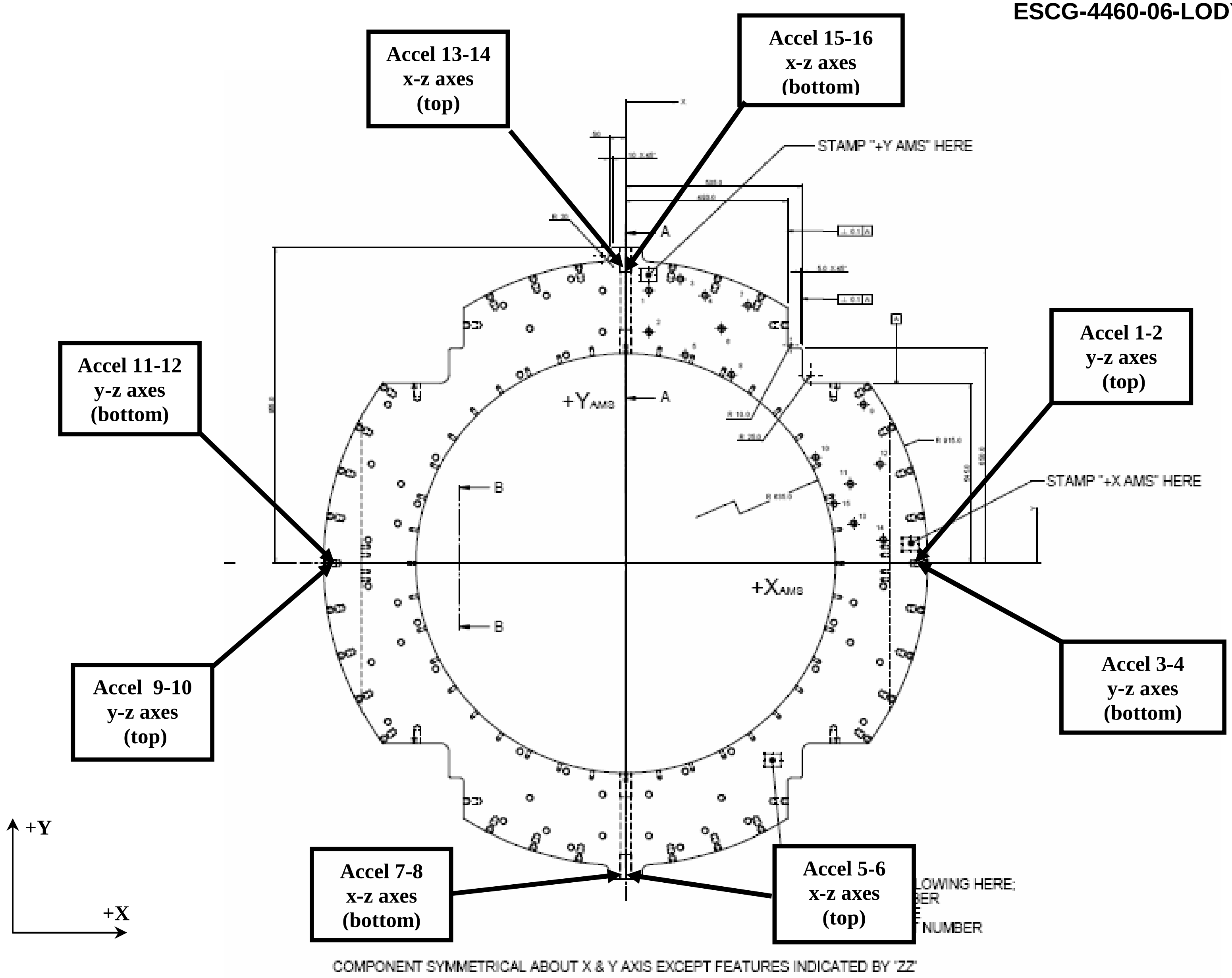

Figure 4.2-4 Location of accelerometers on the cold mass replica

4.3 Shipping Configuration

The AMS-02 Structural Test Article will arrive at IABG in two pieces. The bulk of the hardware will be in the Primary Support Stand (PSS), which will be in the middle configuration. The Keel Assembly will arrive in a separate crate. Upon arrival, ESCG(?) will convert the PSS to the high configuration and the Keel Assembly will be reattached.

Two lifting fixtures and associated slings will be provided to perform this operation. The Primary Lifting Fixture (PLF) will be used to lift the PSS, while the Multi-Purpose Lifting Fixture (MPLF) will be used to lift all other hardware. ESCG will develop Task Performance Sheets (TPSs) for all lifting and assembly operations required to complete the STA.

There will be an estimated 17m x 11m of floor space needed for storage of the transportation containers. This space should be visibly clean but is not required to be environmentally controlled.

Table 4.3-1 AMS-02 Shipping List

Assembly	Size (mm)	Mass	Qty
PSS and AMS-02 STA	203 x 125 x 89.1	6350 kg	1
USS-02 Keel Assembly	59.9 x 33.3 x 8.8	68 kg	1
Multi-Purpose Lifting Fixture	125.3 x 109 x 14.0	1180 kg	1
Primary Lifting Fixture and slings	190.8 x 123.9 x 17.9	1815 kg	1
Multi-Purpose Lifting Fixture slings	Crate Size (?)	n/a	12
Primary Lifting Fixture slings	Crate Size (?)	n/a	12

5.0 GENERAL TEST OPERATIONS

5.1 Test Definition and Control

All operations for the static and modal tests will be defined and controlled by a Test Procedure. The Test Procedure will be prepared by IABG under the direction of the specific Test Manager based on the recommendations presented in this document and reviewed by ESCG representatives.

If necessary, changes which do not significantly alter the technical intent of the test can be made to the Test Procedure during test operations. These changes must be agreed to by the following people or their representatives:

(1) the Test Manager
(2) the Test Director
(3) the Test Analyst
(4) the Quality Manager

These changes will be documented as “red lines” to the Test Procedure. The version with red lines will be attached to the final test report as the “As Run Test Procedure” for post-test documentation purposes.

5.2 Test Environment

The static and modal tests will be conducted at the prevailing ambient environment of the test facility. There are no specific requirements for control of temperature or humidity during the test. For reference purposes, temperature and humidity measurements will be recorded at the beginning and ending of each day of testing.

There are no specific clean room requirements for the static and modal tests. The test articles will be maintained at visibly clean levels. The test article will be protected from general debris at all times. The test article will be specifically protected from debris and hydraulic fluids during operation of the overhead cranes.

5.3 Test Readiness Review

Test Readiness Reviews (TRRs) will be held prior to start of each test. At a minimum, the representatives specified in Section 3.0, Test Roles and Responsibilities, will participate in each TRR.

5.4 Photographic Coverage

A digital still camera will be used to produce photographic documentation of the following:

(1) all test fixturing used
(2) installation of test article in test fixture for each test configuration
(3) location of all transducers on the test fixture and external portion of the test article

At least one video camera will be used to record video of the test article during each test case. The motion of the test fixture and test article are not expected to be visible. This video is recorded to ensure that any failures or anomalies are captured. If a failure or anomaly occurs, the video will be transferred to DVD and delivered to ESCG; otherwise, the video recording does not need to be retained.

If any failures or damage occurs, a digital still camera will also be used to produce documentation.

Electronic files of all digital photographs will be delivered to ESCG with the final test report.

5.5 Damage or Failure

If the test article or test fixturing sustains damage or fails at any time during test operations, all operations will be stopped. The test conditions and anomalies will be documented. Photographs of the damaged or failed item will be taken.

A failure will be deemed to have occurred for any of the following reasons:

(1) physical damage to test hardware is observed
(2) any test measurement exceeds limits as specified in the test procedure
(3) failure of test instrumentation or recording equipment

Following a failure, a review meeting will be held to assess the situation. At a minimum, the participants will include the Project Manager, the Test Manager, the Test Director, the Test Engineer, and the Quality Manager. If this review team can agree on a means of proceeding with low risk of further failure, then the test can continue. Otherwise, the no further testing will be performed.

5.6 Post-test Review

After all operations for a given test have been completed, a post-test review will be conducted. The purpose of the review will be to confirm that the test objectives have been met, coordinate post-test plans, and identify “lessons learned” that may influence future AMS-02 project activities.

5.7 Test Data Delivery

Following completion of each test, all data from the test instrumentation will be written to compact disc (CD) or digital versatile disc (DVD) and delivered to ESCG. The data should be recorded as ASCII (text only) format files. A final test report will be prepared by IABG. This report will summarize the results of the test, provide critical measured data in tabular and graphical format, and fully document any anomalies that occurred during testing.

5.8 Test Article Disposition

Upon completion of both tests, all instrumentation and cabling will be removed from the USS-02 by IABG. The test article will be returned to the Primary Support Stand and prepped and packed for shipping. All shipping arrangements will be made by ESCG.

6.0 TEST PROCEDURE

6.1 Static Load Cases

There are a total of three load cases that are necessary to match the loads and stresses for the critical regions of the USS-02 and Vacuum Case. The coordinates for the actuator load inputs, listed in Table 2, are based on the AMS-02 coordinate system as defined in Figure 6.1-1. For each load case, the test article should be loaded in steps of 25% of maximum load, recording measurements at each step. These should be provided to the Test Engineer for review before any further loading steps are performed.

It is anticipated that minor revisions to the input load levels and actuator placement may be necessary in order meet the specified safety and design criteria for the test hardware. Final locations and load levels will be fully documented in the actual Test Procedures.

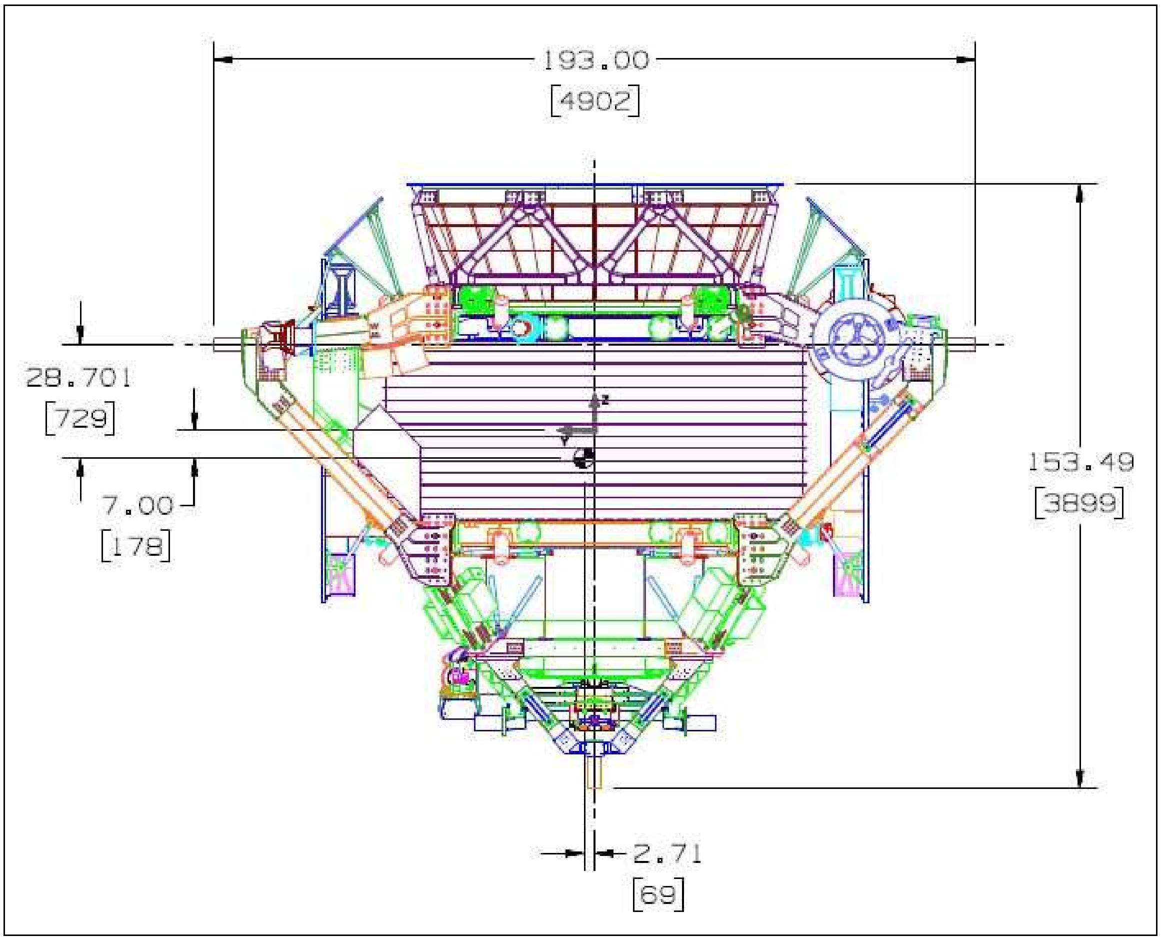

Figure 6.1-1 AMS-02 Coordinate System Definition

The actuator locations, shown in Figure 6.1-2 are aligned along the centerline of the USS-02 beams. The coordinate system shown in the bottom left portion of each figure is to be used only as a directional reference.

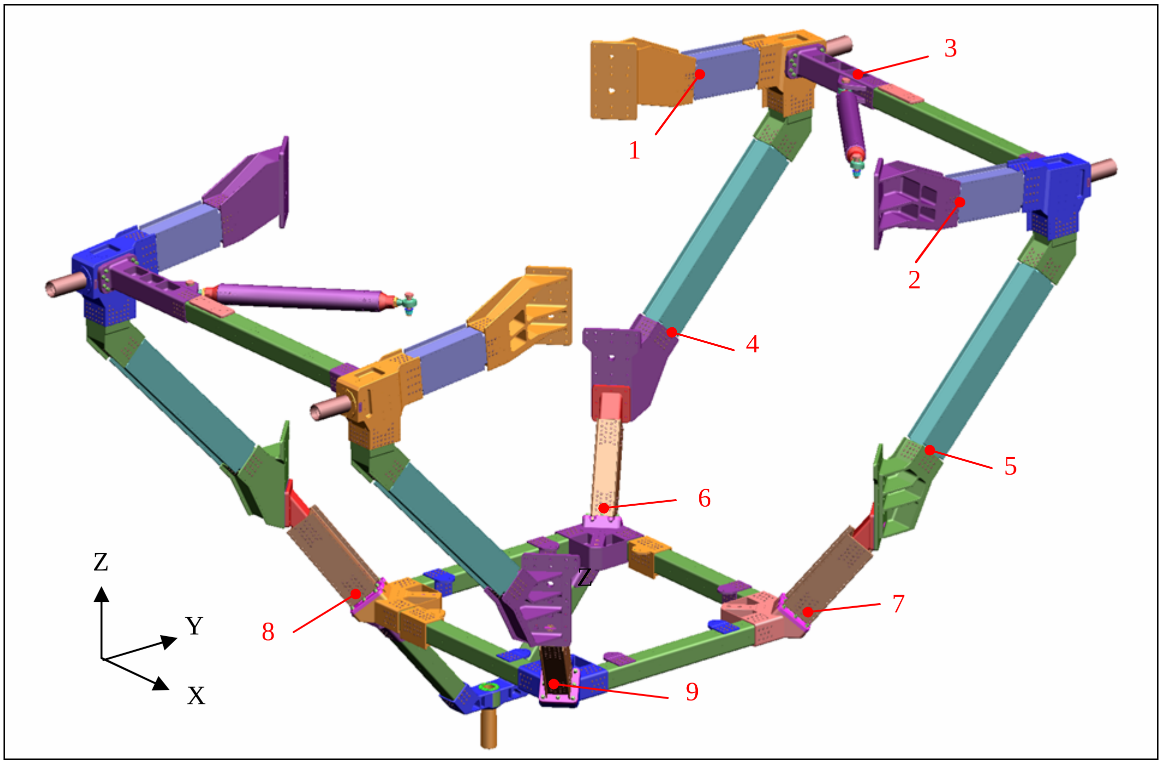

Figure 6.1-2 Actuator Locations on USS-02

Table 6.1-1: Actuator Input Coordinates in the AMS-02 Coordinate System

Actuator ID	X(in)	Y(in)	Z(in)
1	-39.335	57.183	25.150
2	39.335	57.183	25.150
3	-24.523	83.198	22.715
4	-39.335	50.909	-23.308
5	39.335	50.909	-23.308
6	-29.023	29.023	-52.881
7	29.023	29.023	-52.881
8	-29.023	-29.023	-52.881
9	29.023	-29.023	-52.881

The loads applied to the primary structure are limited to translational loads oriented along the x, y, and z axis in order minimize the complexity of the loads application hardware. The test hardware needed to apply the loads shall be designed based on the specified vector for the three load cases shown in Figures 6.1-3 thru 6.1-5 and the applied actuator loads for each static test case are listed in Tables 6.1-2 thru 6.1-4.

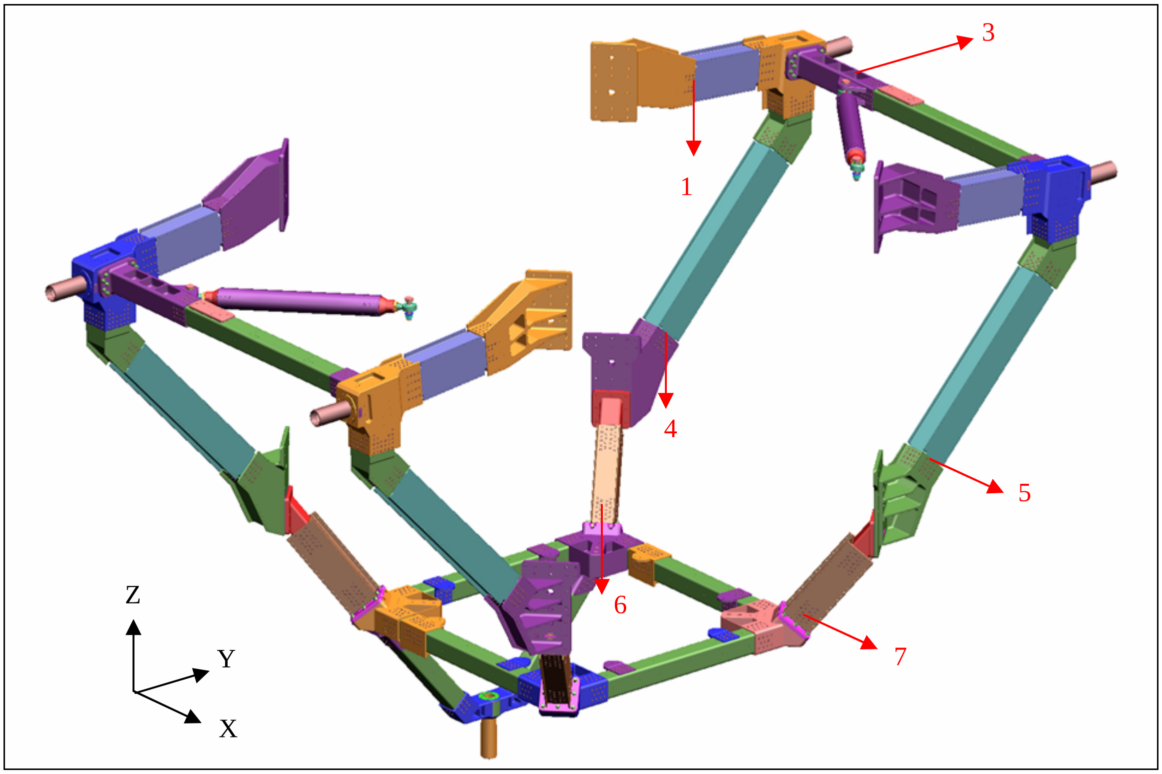

Figure 6.1-3: ST101 Actuator Locations and Load Directions

Table 6.1-2: ST101 Actuator Loads

Load Case ST101			
Actuator ID	Fx (lbs)	Fy (lbs)	Fz (lbs)
1	0.	0.	-10500.
3	0.	10000.	0.
4	0.	0.	-10400.
5	14000.	0.	0.
6	0.	0.	-15000.
7	12000.	0.	0.

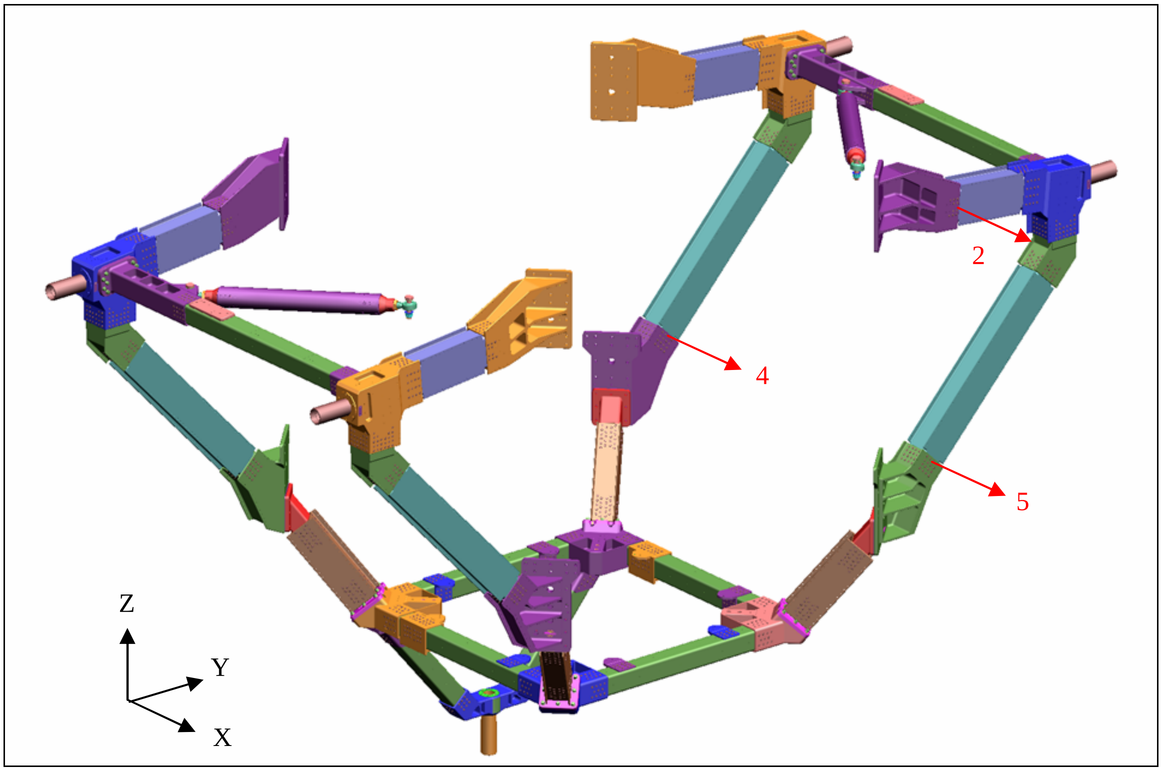

Figure 6.1-4: ST102 Actuator Locations and Load Directions

Table 6.1-3: ST102 Actuator Loads

Load case ST102	
Actuator ID	Fx (lbs)
2	15000.
4	15500.
5	16000.

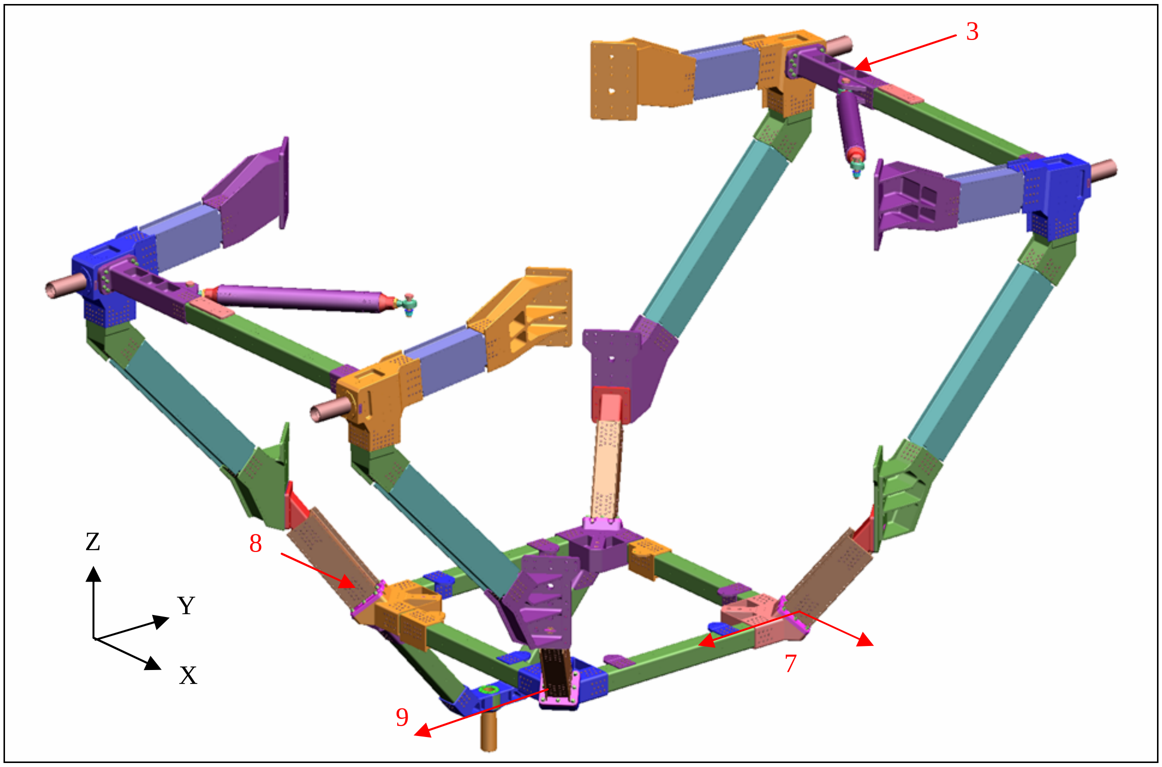

Figure 6.1-5: ST110 Actuator Locations and Load Directions

Table 6.1-4: ST110 Actuator Loads

Load Case ST110		
Actuator ID	Fx (lbs)	Fy (lbs)
3	0.	-6500.
7	7500.	-7000.
8	13000.	0.
9	0.	-7000.

6.2 Static Test Instrumentation

The exact instrumentation list for the static test has not yet been determined. It is anticipated that approximately 161 channels will be required. 32 of the channels will be the strain gages mounted on the magnet support strap assemblies described in Section 4.2. The remainder will be both uniaxial and rosette strain gages distributed around critical areas of the USS-02 and the STA Vacuum Case. A list of the instrumentation is provided in Table 6.2-1.

Provisions will be made for real-time monitoring of a selected set of instrumentation as the static load steps are performed. Instrumentation that is recommended by ESCG for real-time monitoring will be designated in this section.

6.3 Modal Test Target Modes

Table 6.3-1 summarizes the first 25 natural frequencies of the AMS-02 payload. Rows which have been bolded represent the target modes of the structure. These are modes with modal effective masses of >5% or higher. The lowest six modes correspond roughly to rigid-body movement of the CMR within the VC while the rest of the system remains roughly stationary. The next ten target modes correspond to movement of the entire payload. Non-target modes correspond primarily to vibration of the radiators and other secondary components which will not be present in the STA. These should be easily distinguishable.

Table 6.2-1 AMS-02 Instrumentation for Static Test

Component	Location	Type	Quantity	Gage ID	Channels
Diagional Sill Joint	Forward Starboard	Uniaxial	4	1001-1004	4
Sill Tube	Aft Starboard	Uniaxial	4	1005-1008	4
Diagional Strut	Starboard	Uniaxial	1	1009	1
	Port	Uniaxial	1	1010	1
Upper Trunnion Bridge Beams	Forward Starboard Outer	Uniaxial	8	1011-1018	8
	Forward Starboard Inner	Uniaxial	8	1019-1026	8
Upper VC Joint	Forward Starboard	Rosette	2	1027-1032	6
Lower Trunnion Bridge Beam	Forward Starboard Upper	Uniaxial	8	1033-1040	8
	Forward Starboard Lower	Uniaxial	8	1041-1048	8
Upper to Lower USS-02	Forward Starboard	Uniaxial	8	1049-1056	8
Lower Angle Beam	Forward Starboard Lower Beam	Uniaxial	8	1057-1064	8
Lower Centerbody Tubes	Forward Starboard	Uniaxial	8	1065-1072	8
Keel Tubes	Starboard Forward	Uniaxial	8	1073-1080	8
	Upper Starboard	Uniaxial	8	1081-1088	8
	Upper Port	Uniaxial	8	1089-1096	8
Upper Conical Flange	TBD	Rosette	3	2001-2009	9
Upper Support Ring	TBD	Rosette	6	2010-2027	18
Outer Cylinder	TBD	Rosette			
Inner Cylinder	TBD	Rosette	3	2028-2036	9
Lower Support Ring	TBD	Rosette	6	2037-2054	18
Lower Conical Flange	TBD	Rosette			
Upper VC Joint	Forward Starboard	Deflection	2	3001-3002	2
Lower Centerbody Joint	Forward Starboard	Deflection	2	3003-3004	2
Wake Radiator	TBD	Deflection	2	3005-3006	2
USS-02 Trunnion	Forward, left (x-axis)	Load Cell	1	4001	1
USS-02 Trunnion	Forward, left (z-axis)	Load Cell	1	4002	1
USS-02 Trunnion	Forward, right (x-axis)	Load Cell	1	4003	1
USS-02 Trunnion	Forward, right (z-axis)	Load Cell	1	4004	1
USS-02 Trunnion	Aft, left (z-axis)	Load Cell	1	4005	1
USS-02 Trunnion	Aft, right (z-axis)	Load Cell	1	4006	1
USS-02 Trunnion	Keel (y-axis)	Load Cell	1	4007	1
Actuator (input force measurement)	Actuator 1	Load Cell	1	5001	1
	Actuator 2	Load Cell	1	5002	1
	Actuator 3	Load Cell	1	5003	1
	Actuator 4	Load Cell	1	5004	1
	Actuator 5	Load Cell	1	5005	1
	Actuator 6	Load Cell	1	5006	1
Overall totals			114		161

Table 6.3-1 AMS-02 Natural Frequencies

Mode	Freq (Hz)	Modal Effective Mass TX	TY	TZ	RX	RY	RZ	Description
1	5.3604	0.000	0.325	0.000	0.035	0.000	0.000	Strap-cryomagnet motion --- lateral (y-axis) translation
2	5.4632	0.320	0.000	0.000	0.000	0.022	0.001	Strap-cryomagnet motion --- longitudinal (x-axis) translation
3	5.7629	0.000	0.000	0.000	0.000	0.000	0.147	Strap-cryomagnet motion --- rotation about z-axis
4	7.5960	0.000	0.096	0.000	0.057	0.000	0.000	Strap-cryomagnet motion --- rotation about x-axis
5	8.4636	0.081	0.000	0.000	0.000	0.125	0.000	Strap-cryomagnet motion --- rotation about y-axis
6	8.9299	0.000	0.000	0.338	0.001	0.000	0.000	Strap-cryomagnet motion --- vertical (z-axis) translation
7	13.0982	0.381	0.005	0.000	0.000	0.189	0.000	Full payload longitudinal translation, VC and magnet out of phase
8	13.4095	0.003	0.543	0.000	0.000	0.002	0.006	Full payload lateral translation, VC and magnet out of phase
9	21.7819	0.000	0.000	0.000	0.094	0.000	0.000	Upper and lower USS lateral motion, out of phase, ECAL bracket flexure
10	24.6364	0.006	0.000	0.038	0.006	0.003	0.001	Lateral motion of ram and wake radiators, out of phase
11	25.1578	0.114	0.000	0.015	0.001	0.073	0.017	Longitudinal motion of payload, ECAL y-axis translation, bracket flexure
12	26.0758	0.000	0.003	0.014	0.174	0.000	0.000	Lateral motion of ram and wake radiators, in phase
13	26.6456	0.000	0.000	0.001	0.005	0.000	0.000	Lateral motion of He tank and magnet, out of phase
14	26.8736	0.005	0.000	0.478	0.003	0.001	0.001	Full payload vertical motion, some flexure of TRD top panel
15	29.2184	0.037	0.000	0.000	0.000	0.306	0.003	Full payload, rotation about y-axis, radiators in phase
16	29.4376	0.000	0.000	0.000	0.000	0.000	0.000	Local flexure of RICH
17	30.2221	0.011	0.000	0.000	0.000	0.044	0.174	Full payload, rotation about y-axis, radiators out of phase TCS radiators oscillating
18	33.0777	0.000	0.000	0.000	0.002	0.018	0.093	
19	33.8713	0.002	0.000	0.000	0.001	0.014	0.029	
20	34.0133	0.000	0.000	0.002	0.000	0.000	0.000	
21	34.4456	0.000	0.000	0.001	0.000	0.012	0.003	
22	35.3411	0.000	0.000	0.013	0.000	0.000	0.020	
23	35.9815	0.000	0.002	0.004	0.023	0.002	0.204	Full payload rotation about z-axis
24	36.2148	0.000	0.001	0.005	0.018	0.000	0.040	
25	36.9472	0.006	0.000	0.000	0.000	0.114	0.002	Full payload rotation about y-axis

6.4 Modal Test Instrumentation

The exact instrumentation list for the modal test has not yet been determined. It is anticipated that approximately 271 channels will be required. These will be of the following types:

1) 16 uniaxial accelerometers, provided and installed by ESCG, as described in Section 4.2.
2) 32 strain gages, provided and installed by ESCG, as described in Section 4.2.
3) 85 triaxial accelerometers (255 channels) on various portions of the USS-02, VC, and radiator STAs.

Other channels will be added by the test facility as needed to remove the effects of the test fixture stiffness from the modal test results and to control the shakers used to provide the input force.