Electromagnetic Interference Test Plan for the
Alpha Magnetic Spectrometer-02 (AMS-02)

Systems Architecture and Integration Office
Engineering Directorate

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(http://ams-02project.jsc.nasa.gov/html/Documents.htm)

February 17, 2010 – Revision F

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The AMS-02 payload has been reviewed by the Department of State and has been declared public domain data under ITAR (see ODTC Case CJ 015-01). The payload has also been reviewed by the Department of Commerce and has been categorized 1A999 (see CCATS# G026926), which allows free distribution of data to foreign nationals of all countries apart from North Korea, Syria, and Sudan. All data included in this package has been reviewed and found to be in the public domain.
Electro-Magnetic Interference
Test Plan
For the
Alpha Magnetic Spectrometer-02

February 17, 2010 – Revision F

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1 Background

1.1 Purpose

The purpose of the Electro-Magnetic Interference Test Plan for the Alpha Magnetic Spectrometer-02 is to outline the test requirements and methodologies for Electro-magnetic Interference (EMI) testing of the Alpha Magnetic Spectrometer (AMS-02) payload, as a guideline from which a detailed test procedure can be generated. EMI testing of the AMS-02 is required to ensure electromagnetic compatibility with the Shuttle Transportation System (STS) Orbiter and the International Space Station (ISS). The test will be performed at the Maxwell EMI test facility at the European Space Research Technology Center (ESTEC) located in Noordwijk, The Netherlands. The test program will be performed in calendar year 2009.

1.2 Scope

This Plan covers the required EMI testing for the AMS-02 attached payload, as described in this document. It includes the frequency ranges, amplitude limitations, pass/fail criteria, and test setups required to conduct the tests.

1.3 Test Objectives

The specific test objectives of the AMS-02 EMI test are:

- To verify that the AMS-02 payload does not generate EMI that will adversely affect the surrounding STS and ISS systems (emissions)
- To verify that the AMS-02 payload’s performance is not adversely affected by the expected EMI environment of STS and ISS (susceptibility)

1.4 Reference Documents

The following documents, in latest revision, are referenced in this document, or are otherwise considered applicable in the development and execution of the specific EMI test procedures.

- SSP 57003 Attached Payload Interface Requirements Document
- SSP-30237, Space Station Electromagnetic Emission and Susceptibility Requirements
- SSP-30238, Space Station Electromagnetic Techniques
- SSP 30243, Space Station Requirements for Electromagnetic Compatibility
- SSP 30240, Space Station Grounding Requirements

1.5 Test Item Description

The following sections are included to provide a top-level review of the major components of the AMS-02 flight hardware, and the AMS-02 experiment and its mission, and thus provide an understanding of the various EMI tests / operations.
Figure 1-1 provides an overall view of the AMS-02 payload.

**1.5.1 Mission Scenario**

The AMS-02 experiment is a state-of-the-art particle physics detector being designed, constructed, tested, and operated by an international team organized under United States Department of Energy (DOE) sponsorship. The AMS-02 experiment will use the unique environment of space, outside the limitation imposed by Earth’s atmosphere, 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 antimatter (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 cosmic ray propagation and confinement time in the galaxy).

An Implementing Arrangement (IA) between NASA and DOE signed in September 1995 established two flights for AMS: an Engineering Test on Shuttle (STS-91 – June 1998) and a 3-year Science Mission on ISS (Launch Ready September 2007 – Date under review). The flight of AMS-01 was a precursor flight of the detectors proposed for AMS-02. AMS-01 utilized a permanent magnet in place of the Cryomagnet. The purpose of the precursor flight was to verify operation of the AMS experiment, verify command and data communications, collect thermal data for the ISS flight, determine actual accelerations on some AMS internal instruments and establish experimental background data.
The AMS-02 will be transported to the International Space Station (ISS) in the cargo bay of the Space Shuttle (Figure 1-2 and 1-3) for installation on the external truss of the ISS (Figures 1-4 and 1-5). Once on-orbit the AMS-02 will remain on the ISS for at least three operational years of data collection, and due to limited space shuttle flights, AMS-02 will not return to Earth and will remain on the ISS.

Figure 1-2 AMS-02 in Shuttle Orbiter Payload Bay
Figure 1-3 AMS-02 in Shuttle Orbiter Payload Bay
(From above looking forward)
Figure 1-4 AMS-02 on the ISS

Figure 1-5 AMS-02 on the ISS S3 – Z Inboard PAS Site
1.5.2 Experiment Overview
The AMS-02 Experiment utilizes large cryogenic superfluid helium (SFHe @ 1.8K) superconducting magnet to produce a strong, uniform magnetic field (~ 0.8 Tesla) within the interior of the Cryomagnet. The experiment has planes of detectors above, in the center of, and below the Cryomagnet (Figures 1-1 and 1-6). Electrically charged particles will curve when they pass through the magnetic field. Due to the differences in electrical charge, particles made of matter will curve one way, and the same particles of antimatter will curve the opposite way. Due to the various interactions with the AMS-02 detectors, the unique particle signatures will be electronically recorded (Figure 1-7). Physicists will be able to study the trajectory of curvature and determine the charge of the particles from the direction of curvature. They will also be able to determine the mass of the particles from the amount of curvature. They will then be able to tell whether it was matter or antimatter.
Figure 1-6 AMS-02 Detectors

TRD

Upper TOF

Star Trackers (2)

Vacuum Case
SFHe Tank
Cryomagnet
ACC Tracker

Lower TOF

RICH

ECAL
1.5.3 AMS ELECTRONICS

The AMS avionics primary functions are front end data collection for the scientific instruments, data and command communication interface between the various portions of the payload, as well as between the payload and the STS and ISS; and power distribution throughout the payload. The details provided in this section are broken down into the following subsections:

- AMS-02 Electronics Systems Architecture Description
- Power Distribution System (PDS)
- On-Board Pump
- AMS-02 Data Systems and Interfaces
- Grounding/Bonding Scheme for the AMS-02 Experiment

1.5.3.1 AMS-02 Electronics Systems Architecture Description

AMS-02 contains numerous electronics boxes, some termed “Crates,” that supply the necessary readout/monitor/control electronics and power distribution for each detector (Figures 1-8 and 1-9). The box nomenclature is generically x-Crate or xPD, where “x” is a letter designating the detector function, and “Crane” refers to the readout/monitor/control electronics box and “PD” refers to the Power Distribution box for that specific detector. Similarly xHV bricks provide high voltage for some detectors. Values of “x” are designated as follows:
• E  ECAL
• J  Main Data Computers (MDC) and Command & Data Handling interfaces
• JT  Trigger and central data acquisition
• M  Monitoring
• R  RICH
• S  Time of Flight (TOF) Counters and Anti-Coincidence Counters (ACC)
• T  Tracker
• TT  Tracker Thermal
• U  Transition Radiation Detector (TRD)
• UG  TRD Gas

Additionally, electronics are mounted in the Power Distribution System (PDS), the Cryomagnetic Avionics Box (CAB), the Uninterruptible Power Supply (UPS) associated with the CAB, and the Cryocooler Electronics Box (CCEB).

The interface boxes PDS and J-Crate provide the isolation and protection functions necessary to protect the STS and ISS vehicles from damage.

Preliminary testing has been performed, before payload integration, at the payload subsystem, or box, level, as summarized in Table 6-1, using the testing techniques in SSP 30238. The box level tests were not a means of qualifying the AMS-02 payload, but are a method to demonstrate that the payload will be compatible internally to itself, and also as a means to identify potential sources for EMI problems that may be encountered during this integrated payload EMI testing. Detailed test reports for the EMI testing performed at the piece part level may be provided for reference if required.
Figure 1-8 Electronics Crate Locations
1.5.3.2 Power Distribution System (PDS)

The AMS-02 Power Distribution System (PDS), Figure 1-10, serves as the primary front-end for the power distribution to the subsystems and experiment detector electronics. It performs power conversion and distribution functions. The power isolation within the PDS is designed to meet the 1 Mega Ohm Isolation requirement defined in SSP-57003.

Power for the AMS-02 Payload is supplied from several sources dependent upon mission phase.

The PDS consists of four distinct sections: 120 Vdc Input; 120 Vdc Output; 28 Vdc Output; and Low Voltage Control and Monitor. The bus to bus isolation of the 120Vdc outputs is provided by the end-subsystem, by either DC-to-DC or AC converters, or
relays. The isolation for all other outputs is provided internally to the PDS by DC-to-DC converters. The PDS has two independent “channels”: side A and side B (Figure 1-11), which have four identical subsections. The only difference between the two channels is that side A is the only side that provides power to the Cryomagnet Avionics Box (CAB) for magnet charging.

The AMS-02 payload operation of charging the magnet will not be considered for the purposes of this test. Charging the magnet is a transient operation that, under a nominal mission profile, will only be performed once on-orbit. Moreover, the presence of ferrous shielding materials within the floor of the Maxwell EMI test facility, and the mechanical stresses that the payload structure would endure in the magnetic field if it were energized, make including charging the magnet during the EMI test impossible. The portion of the CAB that performs the magnet charging operation underwent piece part EMI testing, as described in Section 1.5.3.1, while under a simulated load.

The PDS also underwent extensive power quality testing at the NASA/JSC Sonny Carter Test Facility, Integrated Power Lab. During this testing, which simulated the input power condition requirements found in SSP-57003, it was determined that the PDS, also under representative load, performed as required and did not propagate faults back to the ISS vehicle electrical power systems portion of the test bed. Additionally, the PDS underwent piece part EMI testing, as described in Section 1.5.3.1, while under a simulated load.
Figure 1-11  AMS-02 Power Distribution System, Sides A and B
1.5.3.3 On-board Pump

A small vacuum pump is located on the payload itself, as shown in Figure 1-12, and will be used for pre-launch activities to vent the Helium tank vapor pressure after the payload bay doors are closed and prior to lift-off. A remotely controlled and monitored GSE 110 VAC power supply will power this pump for pre-launch pad operations. Since this pump is AC powered, the LE01 Leakage Current EMI test shall be performed eventually, but only used as pre-launch (non-flight) reference data. The design of this pump is in flux at this time, so the LE01 Leakage Current EMI test shall not be part of the ESTEC EMI test.

Figure 1-12 AMS-02 On-Board Pump Location

1.5.3.4 AMS-02 Data Systems and Interfaces

The AMS-02 payload uses a series of computers to process commands and data. The top level-computer, to which command and data services are interfaced on both the STS and the ISS, is called the Main Data Computer (JMDC), located in the J-Crate. Figure 1-13 provides an overview of the AMS avionics elements, and Figure 1-14 depicts the NASA provided interfaces on the ISS and STS, as they are routed to the AMS-02 experiment top-level avionics.

For the JMDC, as well as all other electronics, AMS-02 has taken the high performance technologies used in particle physics and implemented them for use in low Earth orbit. A unified approach has been made to meet the requirements imposed by the different AMS-
02 sub-detectors, by NASA and most importantly, by the physics goals. Particular effort has been made to ensure that the data acquisition and trigger electronics will meet the performance requirements on orbit during the 3-5 years of operation. Meeting the challenges of implementing high performance, space qualified electronics has been a key activity of the entire AMS-02 collaboration.

Figure 1-13 AMS-02 Electronics Elements
Figure 1-14 AMS-02 Electronics Interfaces
1.5.3.4.1 Data Interface for On-Orbit Operations on the STS

Once on-orbit, and while in the Shuttle payload bay, command and monitoring capability is supplied via both 1553 Bus and RS422 serial communications each routed through the ROEU to the experiment electronics.

Following Post-Insertion activities, payload activation activities are expected to begin at approximately MET 00/02:30. At this time, a mid-deck locker stowed, STS provided, Payload General Support Computer (PGSC) will be un-stowed, set-up, and activated on the Orbiter Aft Flight Deck (AFD). Setup includes the removal of the payload provided cable between front panel “J103” and “J105” connectors on PDIPD2, on the AFD, and attachment of a new payload provided cable to the PDIP2 to interface with the PGSC, as shown in Figure 1-15. The cable will include a built-in multiplexer to interface the RS-422 signals into a USB on the NGLS for recording. This PGSC in conjunction with the payload cable is referred to as the AMS-02 Digital Data Recording System (DDRS-02); and will be used to record all high rate data generated by AMS-02 during checkout activities. Concurrent to these activities, or prior to them, the Orbiter Interface Unit (OIU) should be powered up and checked out in preparation for communication with the AMS-02 payload via PDIP2, with “AMS-02 1553” switch in “OIU” position. The DDRS-02, and its operation, is not considered for the purposes of this EMI test, as the device has undergone previous separate EMI testing.

During avionics checkout, RS-422 data is recorded on the hard-drive of the NGLS continuously, and AMS-02 RS-422 data from another feed-thru on the Payload Data Interface Panel #1 (PDIP1) assembly, with the “Ku-Band” switch in the “AMS-02” position, will be down-linked via the STS Ku-Band as coverage and scheduling permit.
1.5.3.4.2 Data Interface for Extra Vehicular Robotics (EVR) Activities

Just prior to transfer activities, the AMS-02 is powered down and the ROEU is disconnected from the PDA attached to the AMS-02. The AMS-02 is grappled by the SRMS via a FRGF attached to the payload. The FRGF has no data interface capabilities.

The SRMS maneuvers the AMS-02 for an Arm-to-Arm transfer to the SSRMS. The SSRMS grapples the payload via a PVGF located on the opposing side of the AMS-02 from the FRGF. The primary PVGF electrical interface, with respect to the AMS-02 payload, is two 120VDC power buses, one prime and one redundant, which are operated singularly to provide keep-alive heater power to maintain thermally sensitive payload elements within their non-operational temperature ranges during the SSRMS translation and berthing maneuver. The PVGF provides video data interface for use by the EBCS camera during berthing operations. Additionally, the PVGF has 1553 Bus interface capability; however, this is not being utilized by the AMS-02 payload.

The PVGF and EBCS camera were EMI tested under previous Government Furnished Equipment (GFE) certification, and will not be installed on the AMS-02 payload. For these reasons, the PVGF, the EBCS camera, and their operation, are not considered for this EMI test.

1.5.3.4.3 Data Interface for ISS Operations

All data services for the AMS-02 payload are provided through an Umbilical Mechanism Assembly (UMA) mounted to the Payload Attach Site. The interface consists of a low data rate
link (LRDL) and a high data rate link (HRDL).

The UMA was EMI tested under previous GFE certification, and will not be installed on the AMS-02 payload for this EMI test. For these reasons, the UMA, and its operation, is not considered for this EMI test.

1.5.3.4.3.1 ISS Low Rate Data Link (LRDL) Interface

The LRDL used on ISS, like the STS LRDL, is based on the MIL STD 1553B dual serial bus. This is split to each of the four JMDCs in the J-Crate, one of which is selected by telecommand to actively manage the link. Along the way the ISS crew and NASA ground controllers can monitor this data and, should the need arise, have the facility to issue a few key commands, for example to put the experiment into a standby state. In nominal conditions, all commands originate in the AMS-02 remote Payload Operations and Control Center (POCC) and follow the inverse path.

As commanding and telemetry are critical to the operation of the experiment and as the NASA provisions for payloads are not fault tolerant, substantial effort has been made to implement a parallel set of the LRDL data paths over the HRDL for both monitoring and commanding of AMS-02.

1.5.3.4.3.2 ISS High Rate Data Link (HRDL) Interface

The HRDL is the main data conduit out of AMS-02. It is based on a NASA specific implementation of fiber optic communications. The link can move data on the ISS at a higher rate and larger bandwidth. On the HRDL the data flows over the paths shown in Figure 1-16. On the ground the data is routed to the AMS-02 POCC and Science Operation Center.

1.5.3.5 Flight Grounding/Bonding Scheme for the AMS Experiment

The AMS-02 payload shall comply with the bonding requirements as defined in SSP 57003 Attached Payload Interface Requirements Document, Revision B. The AMS-02 payload, with
respect to the overall grounding system, shall comply with *SSP 30240 Space Station Grounding Requirements, Revision C*.

The AMS-02 payload structure is mechanically grounded, depending on mission phase, as follows:

- **STS** – via the payload mounting trunnions
- **SSRMS** – via the SSRMS / PVGF interface
- **ISS PAS site** – via the PAS guide vane pins
2 Test Responsibility / Team Organization

- ESA / ESTEC:
  - Facility Test Director
  - Facility Test Engineering and Operations
  - Facility Test Procedures
- AMS-02 collaboration organizations:
  - Payload Test Director
  - Payload Engineering, including configuration, transportation and operations:
    - Payload
    - EGSE
    - CGSE
    - Software
  - Payload Test Procedures
- AMS-02 / NASA JSC / ESCG: Test review and consultation
3 Test Organization

3.1 Electrical Validation Test
The AMS-02 Thermal Vacuum Test performed in the ESTEC Large Space Simulator chamber prior to EMI testing will be considered the pre-test, full-blown electrical validation test. However, once the AMS-02 payload is transported into the EMI chamber following the TVT, and prior to commencement of EMI testing, a smaller sub-set AMS-02 functional check-out shall be performed.

3.2 Test Readiness Review
A Test Readiness Review shall be conducted once the detailed test procedures have been written, and prior to the payload arriving in the ESTEC EMI chamber.

3.3 Intermediate Reviews
Intermediate reviews shall be conducted at the conclusion of each test (see Section 6.0), and shall ensure that all individual test objectives have been successfully met.

3.4 Post-Test Review
A post-test review shall be conducted at the conclusion of the overall test program, and shall ensure that all of the overall test objectives have been successfully met, and that all data items have been received from the ESTEC facility.
4 Test Configuration

4.1 Chamber Configuration

The AMS-02 EMI test shall be conducted in the Maxwell EMI chamber at the ESTEC test facility. The AMS-02 payload shall be approximately centered within the EMI chamber (Figures 4-1 and 4-2) on an ESTEC provided wooden transportation pallet, Figure 4-3. As detailed in the Ground Support Equipment (GSE) sections later, the Cryogenic GSE (CGSE) vacuum lines will be connected from the Rosetta Clean Room to the Maxwell EMI Chamber via the Entry Box behind the Main Door, and the Electrical GSE (EGSE) cables will enter the Maxwell EMI Chamber from the Maxwell EGSE Customer Room via floor panels. The CGSE lines and EGSE cables are the same items used in the TVT at the LSS test facility at ESTEC, and no additional materials, including feed-throughs, are foreseen.

Figure 4-1 AMS-02 Location in the Maxwell EMI chamber at the ESTEC test facility
Figure 4-2 AMS-02 Location in the Maxwell EMI chamber at the ESTEC test facility

Figure 4-3 Wooden Transportation Pallet
4.2 AMS-02 Test Specimen Configuration

A top level description of the AMS-02 payload is provided in Section 1. The payload will be fully integrated, with the exception of the following items, which will be installed at NASA KSC after the EMI test, and the lack of these items does not significantly impact the payload configuration or operations for the purpose of the EMI test:

- ISS Payload Attach System (PAS), including EBCS camera, EVA Connector Panel and the Umbilical Mating Assembly (UMA)
- USS Keel
- Handrails
- PVGF and FRGF

The payload will be mounted in the Payload Support Structure, as described in the following GSE section. The payload will be tested under a single hardware configuration, and a single software configuration, which will be established or referenced in the detailed payload operating procedures for the EMI test. The payload interfaces are the Interface Panel A (IPA) for STS power and data services, and the Test Connector Panel (TCP) for ISS power and data services, as depicted in Figure 4-4. The TCP is a temporary interface panel that takes the place of the EVA Connector Panel, which will not be installed until final payload integration at KSC following the EMI test.

Figure 4-4 Integrated Payload
4.3 Electrical Ground Support Equipment (EGSE) Subsystems

The EGSE for AMS-02 is Commercial Off-The Shelf (COTS) equipment. A list of the EGSE is in development, but a preliminary version is shown in Table 4-1. The EGSE will be located in the Maxwell EGSE Customer Room, as shown in Figure 4-1. EGSE connections will be connected to the payload in the Maxwell EMI chamber via the floor penetration panels for the duration of the test. These connections are shown schematically in Figure 4-5. The EGSE shall require a minimum of 15, quantity, 220 VAC 50Hz power sources.

The AMS-02 payload shall be responsible for any GSE cable adaptors that may be required. In addition to the equipment normally deemed necessary to conduct the EMI testing specified later, the following equipment is required of the ESTEC Maxwell EMI test facility:

- Low noise power supply model DHP 150-66 M1
- Line Impedance Simulation Network (LISN) – details for this equipment may be resolved at a later date in conjunction with the NASA JSC Electromagnetic Effects Panel (EMEP) and ISS Electrical Power Systems (EPS) teams
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<td>EPPCAN</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td></td>
<td>EEP CAN interface, 5V</td>
<td>2</td>
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<tr>
<td></td>
<td>20</td>
<td>AMS</td>
<td>USB422</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td></td>
<td>RS422-USB interface (DDRS)</td>
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<tr>
<td>POCC (located in &quot;user area&quot; for controlling the payload during ground operations)</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td>21</td>
<td>Hewlett-Packard</td>
<td>DC7700-CMT</td>
<td>Yes</td>
<td>UL</td>
<td>No</td>
<td>No</td>
<td>Personal computer (POC/GSC)</td>
<td>4</td>
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<td></td>
<td>22</td>
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<td>DC7800-CMT</td>
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<td>Personal computer (POC)</td>
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<td>23</td>
<td>D-Link</td>
<td>DGS-1016D</td>
<td>Yes</td>
<td>UL</td>
<td>No</td>
<td>No</td>
<td>Gigabit network switch</td>
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<td>24</td>
<td>3Com</td>
<td>4400 24PT</td>
<td>Yes</td>
<td>UL</td>
<td>No</td>
<td>No</td>
<td>10/1000 network switch</td>
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<td></td>
<td>25</td>
<td>NEC</td>
<td>Multisync LCD2170NX</td>
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<td>UL</td>
<td>No</td>
<td>No</td>
<td>LCD Monitors</td>
<td>13</td>
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<td>26</td>
<td>Dell</td>
<td>PowerEdge 2900 III</td>
<td>Yes</td>
<td>UL</td>
<td>No</td>
<td>No</td>
<td>Personal computer (SOC)</td>
<td>2</td>
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<td></td>
<td>27</td>
<td>Dell</td>
<td>Dell Power Vault DP 600</td>
<td>Yes</td>
<td>UL</td>
<td>No</td>
<td>No</td>
<td>Disk server (POC)</td>
<td>1</td>
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<td></td>
<td>28</td>
<td>UPS</td>
<td>Yes</td>
<td>No</td>
<td>Yes, Commercial</td>
<td>No</td>
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<td>UPS for disk server</td>
<td>1</td>
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<tr>
<td></td>
<td>29</td>
<td>Hewlett-Packard</td>
<td>Laserjet printer</td>
<td>Yes</td>
<td>UL</td>
<td>No</td>
<td>No</td>
<td>Network printer</td>
<td>1</td>
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</tbody>
</table>

CGSE (CGSE that uses electricity directly, all needed at SSPF and in PCR)
<table>
<thead>
<tr>
<th>Location</th>
<th>Item</th>
<th>Manufacturer</th>
<th>Model Number</th>
<th>Commercial Yes/No</th>
<th>Electrical Code</th>
<th>3-Phase Yes/No</th>
<th>Batteries Yes/No</th>
<th>Commercial/Custom</th>
<th>Functions</th>
<th>Quantity</th>
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<tbody>
<tr>
<td></td>
<td>31</td>
<td>BOC Edwards</td>
<td>XDS5</td>
<td>Yes</td>
<td>CE</td>
<td>No</td>
<td>No</td>
<td></td>
<td>PVVV Vacuum Pump</td>
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<td>32</td>
<td>Infincon</td>
<td>UL 1000</td>
<td>Yes</td>
<td>CE</td>
<td>No</td>
<td>No</td>
<td></td>
<td>He leak detector</td>
<td>1</td>
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<td></td>
<td>33</td>
<td>DAIKIN EUROPE NV</td>
<td>EUWAB8KAZW1 - - G</td>
<td>Yes</td>
<td>CE</td>
<td>Yes</td>
<td>No</td>
<td></td>
<td>Chiller for PCR??</td>
<td>1</td>
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<td>34</td>
<td>APC</td>
<td>2200UX Smart UPS</td>
<td>Yes</td>
<td>UL</td>
<td>No</td>
<td>Yes, Commercial</td>
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<td>UPS for CGSE</td>
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<td></td>
<td>35*</td>
<td>Le Guan</td>
<td>Lead-Acid Battery Pack</td>
<td>Yes</td>
<td>UNK</td>
<td>No</td>
<td>Yes, Commercial</td>
<td></td>
<td>UPS for CGSE</td>
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<td>36</td>
<td>ADVANTECH</td>
<td>610H</td>
<td>Yes</td>
<td>CE</td>
<td>No</td>
<td>Yes, Commercial</td>
<td></td>
<td>Industrial PC for CGSE</td>
<td>3</td>
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<td>37</td>
<td>ADVANTECH</td>
<td>AWS-8259TP-T</td>
<td>Yes</td>
<td>CE</td>
<td>No</td>
<td>Yes, Commercial</td>
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<td>Industrial PC Display</td>
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<td>38</td>
<td>SIEMENS</td>
<td>PanelPC 557</td>
<td>Yes</td>
<td>CE</td>
<td>No</td>
<td>Yes, Commercial</td>
<td></td>
<td>Industrial PC for CGSE</td>
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<td>39</td>
<td>SIEMENS</td>
<td>FieldBus Modules</td>
<td>Yes</td>
<td>UL</td>
<td>No</td>
<td>No</td>
<td></td>
<td>PLC crates for CGSE</td>
<td>10</td>
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<td>40</td>
<td>Scientific instrumtions</td>
<td>9350-T</td>
<td>Yes</td>
<td>UL</td>
<td>No</td>
<td>No</td>
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<td>Temperature Indicator</td>
<td>1</td>
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<td>41</td>
<td>Yudain</td>
<td>UNK</td>
<td>Yes</td>
<td>CE</td>
<td>No</td>
<td>No</td>
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<td>Alarm MUX?</td>
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<td>42</td>
<td>TPLink</td>
<td>UNK</td>
<td>Yes</td>
<td>CCC</td>
<td>No</td>
<td>No</td>
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<td>Ethernet hub</td>
<td>1</td>
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<td>43</td>
<td>AMI</td>
<td>135-2K</td>
<td>Yes</td>
<td>CE</td>
<td>No</td>
<td>No</td>
<td></td>
<td>Liquid He level probe</td>
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<td></td>
<td>44</td>
<td>Shanghai YunJie Vacuum Equip.</td>
<td>2DF-1B</td>
<td>Yes</td>
<td>UNK</td>
<td>No</td>
<td>No</td>
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<td>&quot;Complex Vacuum Meter&quot;</td>
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<td>TBD</td>
<td>Transformer</td>
<td>Yes</td>
<td>UL</td>
<td>No</td>
<td>No</td>
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<td>110-220V transformer</td>
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<td>46</td>
<td>AMS</td>
<td>EPPCAN</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td></td>
<td>EEP CAN interface, 5V</td>
<td>2</td>
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<td></td>
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<tr>
<td>E-CGSE</td>
<td>47</td>
<td>SIEMENS</td>
<td>FieldBus IO Modules</td>
<td>Yes</td>
<td>UL</td>
<td>No</td>
<td>No</td>
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<td>CGSE Monitoring &amp; Control</td>
<td>~30</td>
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<td>48</td>
<td>TBD</td>
<td>FieldBus IO Modules</td>
<td>Yes</td>
<td>UL</td>
<td>No</td>
<td>No</td>
<td></td>
<td>CGSE Monitoring &amp; Control</td>
<td>~20</td>
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<tr>
<td>Offices/POCC</td>
<td>49</td>
<td>Various</td>
<td>Laptop computers</td>
<td>Yes</td>
<td>UL</td>
<td>No</td>
<td>Yes, Commercial</td>
<td></td>
<td>Laptop computer</td>
<td>40</td>
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<td></td>
<td>50</td>
<td>Hewlett-Packard</td>
<td>Laserjet printer</td>
<td>Yes</td>
<td>UL</td>
<td>No</td>
<td>No</td>
<td></td>
<td>Network printer</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 4-1 AMS-02 EGSE

E-CGSE (electronics associated with CGSE, located nearby in 5 enclosed 19" racks, ~2ftx2ftx5ft, e.g. on floor of SSPF or in PCR)

E-CGSE (electronics associated with CGSE, mounted onto the CGSE elements themselves)

Offices/POCC (wherever people can find to sit and work)
Figure 4-5 AMS-02 Test Article and EGSE Interfaces
4.4 Cryogenic Ground Support Equipment (CGSE) and Thermal Control System (TCS) GSE Subsystems

The CGSE is used on the AMS-02 flight equipment to cool the liquid helium to transition the liquid helium to super-fluid helium and to keep the fluid in that state. The integrated CGSE is composed of a number of subsystems that have applications in the cryogenic preparation of the AMS-02. Some of these systems will only be used for contingency operations because the AMS-02 will arrive with some quantity of cryogenic helium in place—that is, it will arrive “cold” and should not need to be taken from ambient temperatures to its cryogenic operating temperatures. To minimize errant test results, the CGSE and TCS GSE will be powered down (TBR) during EMI testing. Periodically, depending on thermal conditions, it may be necessary to pause the test and operate these systems until proper thermal conditions are restored. The CGSE and TCS GSE will also be used after EMI test activities are complete.

The CGSE used to maintain the cryogens will be a subset of the CGSE needed for the TVT in the ESTEC LSS, and during KSC ground operations. As such, details of the CGSE, and the services they require, can be found in the following documents:

- AMS-02 TVT Test Plan
- JSC 64275, Phase II Ground Safety Data Package for the Alpha Magnetic Spectrometer-02 (AMS-02) and Ground Support Equipment

The CGSE will be located in the Rosetta Clean Room, as shown in Figure 4-1. The CGSE lines will be routed into the Maxwell EMI chamber via the entry box and connected to the AMS-02 payload, and will be remain connected for the duration of the EMI test, although only used intermittently as previously described. The subsystems and elements of the CGSE subset required for cryogen maintenance during the EMI test campaign include:

- Main Vacuum Pump System
- Pilot Valve Vacuum Vessel (PVVV) Vacuum Pump
- CGSE Electrical System

The TCS GSE consists of 12 type A fans and three type B fans. The following are the specifications for each type of fan:

- **Type A Fans**
  - Diameter: >.45 m
  - Flow Rate: 4100 m³/hr
  - Power: 135 W
  - Voltage: 110 V
  - Frequency: 60 Hz

- **Type B Fans**
  - Diameter: >.18 m
  - Flow Rate: >740 m³/hr
  - Power: 50 W
  - Voltage: 110 V
  - Frequency: 60 Hz

The first set of four type A fans will provide ventilation to the electronic units mounted on the Ram radiator. The second set of four type A fans will provided ventilation to the electronic units...
mounted on the Wake radiator. The third set of four type A fans will provide ventilation to the zenith radiator. One type B fan will be dedicated the PDS. The other two type B fans will be used to provide ventilation to the CAB.

All fans will be commercial off the shelf (COTS) and have the Underwriter’s Laboratory “UL” or European “CE” quality symbol on it. The supplier of the fans is Honeywell. These fans will not be used during EMI testing, to minimize incidental RF noise, but will be placed in the chamber and used during pauses or after testing, as required.

4.5 Primary Support Stand (PSS)

The AMS-02 PSS is a support stand for the AMS-02 payload during EMI testing. The PSS is made of 6061 aluminum and measures 195.0 in. (4.95 m) L x 125 in. (3.18 m) W x 135.7 in. (3.45 m) H in its “high” configuration.

As much of the non-essential bracing of the PSS shall be removed, once the payload / PSS / wooden pallet stack are placed, so as to provide a clearer radio-frequency (RF) line-of-sight into the payload for radiated testing purposes. The specific members to be removed shall be determined by the Jacobs project engineering office based upon structural integrity analyses, and shall be documented in the detailed test procedures.
Figure 4-6 Lower USS and Keel Attached to Upper USS-02 (PAS not shown) Located in PSS (High Configuration)
Figure 4-7 Lower USS and Keel Attached to Upper USS-02 (PAS not shown) Located in PSS (High Configuration)
4.6 Grounding Configuration for EMI Testing

As discussed in Section 1.5.3.5, the grounding mechanism for the ISS flight operations will be at the ISS CAS site, via the PAS guide vane pins. Since the EMI testing is being performed under the auspices of ISS EMI testing requirements and environments, then the ISS PAS guide vane pins would normally be the preferential grounding means. However, since the PAS will not be integrated until payload arrival at KSC following the EMI test, then the next best option is the STS grounding means, and shall be utilized for the purposes of this EMI test.

Therefore, the AMS-02 payload shall be grounded using payload provided ground straps that will clamp directly to the portion of the payload mounting trunnions exposed outside of the PSS clamps, and these ground straps will interface ESTEC test facility. The ground points at the payload mounting trunnions have been designed to conform with Class R bonding requirements, as defined in SSP 30245. Therefore, once the ground straps have been installed, a micro-ohm meter shall be used to measure the DC resistance at each interface point, or end, of the strap, and each junction shall have a resistance of 2.5 mOhms or less. The PSS should also be grounded to Maxwell EMI test chamber and be < 2.5 mohms.
5 Environmental Conditions

The ESTEC Maxwell EMI chamber shall be maintained at the following environmental conditions:

- Thermal: 25 °C, or less (the lower, the better to improve thermal performance)
- Humidity: 55 (+/- 3) %
- Cleanliness: 5 CWA
6 Test Sequence

The AMS-02 payload shall meet all Electromagnetic Interference (EMI) requirements of SSP 30237. This shall be demonstrated by a full compliment of EMI tests, as summarized in the following Table 6-1, using the testing techniques in SSP 30238. The detailed specifications and requirements for these tests are provided in the following section.

<table>
<thead>
<tr>
<th>Type of Test/Requirement</th>
<th>Name of Test</th>
<th>Coverage</th>
<th>Applicability to AMS-02</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grounding</td>
<td>SSP, 30245</td>
<td>DC Resistance at ground point</td>
<td>Required</td>
<td>≤ 2.5 mOhm</td>
</tr>
<tr>
<td>Conducted Emissions</td>
<td>SSP 30237, Rev F CE01</td>
<td>DC power, lo freq, 30 Hz to 15 kHz.</td>
<td>Required</td>
<td>Tailored to +120 VDC bus</td>
</tr>
<tr>
<td>Conducted Emissions</td>
<td>SSP 30237, Rev F CE03</td>
<td>DC power, 15 kHz to 50 MHz.</td>
<td>Required</td>
<td>Tailored to +120 VDC bus</td>
</tr>
<tr>
<td>Conducted Emissions</td>
<td>SSP 30237, Rev F CE07</td>
<td>DC power leads, spikes, time domain.</td>
<td>Required</td>
<td>Tailored to +120 VDC bus</td>
</tr>
<tr>
<td>Conducted Susceptibility</td>
<td>SSP 30237, Rev F SSP 30237 SSCN 3282 D.2 CS01</td>
<td>DC power leads, 30 Hz to 50 kHz.</td>
<td>Required</td>
<td>Invoked by power quality requirements to demonstrate immunity to known ripple voltage and noise conditions on the +120 VDC bus</td>
</tr>
<tr>
<td>Conducted Susceptibility</td>
<td>SSP 30237, Rev F SSP 30237 SSCN 3282 D.2 CS02</td>
<td>DC power leads, 50 kHz to 50 MHz.</td>
<td>Required</td>
<td>Invoked by power quality requirements to demonstrate immunity to known ripple voltage and noise conditions on the +120 VDC bus</td>
</tr>
<tr>
<td>Conducted Susceptibility</td>
<td>SSP 30237, Rev F SSP 30237 SSCN 3282 D.2 CS06</td>
<td>Spikes, power leads.</td>
<td>Required</td>
<td>Invoked by Power Quality requirements to demonstrate immunity to switching transients on the +120 VDC bus</td>
</tr>
</tbody>
</table>
Table 6-1 - EMI Requirements Applicable to AMS-02 (continued)

<table>
<thead>
<tr>
<th>Type of Test/Requirement</th>
<th>Name of Test</th>
<th>Coverage</th>
<th>Applicability to AMS-02</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiated Emissions</td>
<td>SSP 30237, Rev F RE02</td>
<td>Electric field, 14 kHz to 10 GHz (narrowband), 13.5 - 15.5 GHz.</td>
<td>Required</td>
<td>Establishes that equipment unintentional radiated emissions will not interfere with platform mounted sensitive antenna connected receivers; tailored to Space Station requirements</td>
</tr>
<tr>
<td>Radiated Susceptibility</td>
<td>SSP 30237, Rev F RS02</td>
<td>Magnetic induction field</td>
<td>Required</td>
<td>Intended to determine immunity from interference inductively coupled from electrical power cables</td>
</tr>
<tr>
<td>Radiated Susceptibility</td>
<td>SSP 30237 SSCN 3282 PIRN 57003-NA-0023 RS03PL</td>
<td>Electric field, 14 kHz to 20 GHz.</td>
<td>Required</td>
<td>Demonstrates immunity to known intentionally radiated electromagnetic environment external to Space Station. Use alternate RS level for non-critical attached payloads</td>
</tr>
<tr>
<td>AC Power Usage Leakage Current</td>
<td>SSP 30237, Rev F LE01</td>
<td>AC powered equipment - only AMS-02 on-board vacuum pump</td>
<td>Required</td>
<td>The leakage current for the on-board vacuum pump, as measured between chassis and input power, at the power frequency(ies), shall not exceed 5 milliamperes.</td>
</tr>
</tbody>
</table>

NOT PERFORMED AS PART OF AMS-02 ESTEC EMI TEST
7 Detailed Test Description

Preliminary testing has been performed, before payload integration, at the payload subsystem, or box, level, as summarized in Table 6-1, using the testing techniques in SSP 30238. The box level tests were not a means of qualifying the AMS-02 payload, but are a method to demonstrate that the payload will be compatible internally to itself, and also as a means to identify potential sources for EMI problems that may be encountered during this integrated payload EMI testing. Detailed test reports for the EMI testing performed at the piece part level may be provided for reference if required.

This integrated EMI testing shall be in compliance with SSP 30237, Revision F, and shall include submission to the EMEP of test plans / procedures prior to testing. The detailed limit requirements are documented in the following sections, and the testing shall be conducted using the testing techniques in SSP 30238.
7.1 Test Limit Requirements

7.1.1 CE01 Emission Limits

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 Hz to 200 Hz</td>
<td>110 dB above 1 microampere</td>
</tr>
<tr>
<td>200 Hz to 15 kHz</td>
<td>Decreasing log linearly with increasing frequency from 110 to 74 dB above 1 microampere</td>
</tr>
</tbody>
</table>

![CE01 Emission Limit Graph](image-url)
### 7.1.2 CE03 Emission Limits

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 kHz to 500 kHz</td>
<td>Decreasing log linearly with increasing frequency from 74 to 45 dB above 1 microampere</td>
</tr>
<tr>
<td>500 kHz to 50 MHz</td>
<td>45 dB above 1 microampere</td>
</tr>
</tbody>
</table>

![CE03 Emission Limit Graph](image-url)
7.1.3 CE07 Mode Switching Transients Envelope

<table>
<thead>
<tr>
<th>Time (Microseconds)</th>
<th>Percentage of Nominal Line Voltage</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1 to 10</td>
<td>± 50 percent</td>
</tr>
<tr>
<td>10 to 50</td>
<td>Decreasing log linearly with increasing time from ± 50 percent to ± 20 percent</td>
</tr>
<tr>
<td>50 to 1000</td>
<td>Decreasing log linearly with increasing time from ± 20 percent to ± 5 percent or ± 0.5 volts, whichever is greater</td>
</tr>
<tr>
<td>1000 to 10,000</td>
<td>± 6 percent or ± 0.5 volts, whichever is greater</td>
</tr>
<tr>
<td>10,000 to 100,000</td>
<td>± 5 percent or ± 0.5 volts, whichever is greater</td>
</tr>
</tbody>
</table>
### 7.1.4 CS01 Electromagnetic Energy Injection

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Voltage</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 Hz to 2 kHz</td>
<td>5 Volts root mean square (Vrms) or 10 percent of the supply voltage (E1), whichever is less</td>
</tr>
<tr>
<td>2 kHz to 50 kHz</td>
<td>Decreasing log linearly with increasing frequency from 5 Vrms, or 10 percent of E1, whichever is less</td>
</tr>
</tbody>
</table>

The requirement is also met when the audio power source specified in SSP 30238, adjusted to dissipate 50 Watts in a 0.5 ohm load, cannot develop the required voltage at the Equipment Under Test (EUT) power input terminals and the EUT is not susceptible to the output of the signal source.
7.1.5 CS02 Electromagnetic Energy Injection

The equipment subsystem shall not exhibit any malfunction, degradation of performance, or deviation from specified indications beyond the tolerances indicated in the individual equipment or subsystem specification when subjected to 1 Vrms from a 50 ohm source, between 50 kHz and 50 MHz for equipment and subsystem dc power leads, including power returns, which are not grounded internally to the equipment or subsystem. The test signal shall be applied to the equipment power line near the equipment input terminals.

The requirement is also met under the following condition: A 1 Watt source of 50 ohms impedance cannot develop the required voltage at the EUT power input terminals and the EUT is not susceptible to the output of the signal source.
7.1.6 CS06 Limits

The EUT shall not exhibit any malfunction, degradation of performance, or deviation from specified indications beyond the tolerances indicated in the individual equipment or subsystem specification when the test spikes, each having the waveform shown in the figure below, are applied sequentially to the dc power input leads. The values of E and t are given below. Each spike shall be superimposed on the powerline voltage waveform.

SPIKE #1  \( E = \pm \) Twice the nominal line voltage, \( t = 10 \) microseconds \( \pm 20 \) percent

SPIKE #2  \( E = \pm \) Twice the nominal line voltage, \( t = 0.15 \) microseconds \( \pm 20 \) percent

Note: This figure is also used for RS02 testing.
7.1.7 RE02 Field Emission Limits (Narrowband)

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>14 kHz to 10 MHz</td>
<td>56 dBμV/m</td>
</tr>
<tr>
<td>10 MHz to 259 MHz</td>
<td>Increasing log linearly with increasing frequency from 56 to 86 dBμV/m (16 dB per decade)</td>
</tr>
<tr>
<td>259 MHz to 10 GHz</td>
<td>Increasing log linearly with increasing frequency from 46 to 72 dBμV/m (16 dB per decade)</td>
</tr>
<tr>
<td>13.5 to 15.5 GHz</td>
<td>76 dBμV/m</td>
</tr>
</tbody>
</table>
7.1.8 RS02 Limits

The EUT shall not exhibit any malfunction, degradation of performance, or deviation from specified indications beyond the tolerances indicated in the individual equipment or subsystem specification when subjected sequentially to the test spikes, shown in the figure for CS06 testing in Section 7.1.6, each having the waveform with the values of E and t are given below:

- Spike #1 \(E = \pm \text{Twice the nominal line voltage}, \ t = 10 \text{ microseconds} \pm 20 \text{ percent}\)
- Spike #2 \(E = \pm \text{Twice the nominal line voltage}, \ t = 0.15 \text{ microseconds} \pm 20 \text{ percent}\).

7.1.9 RS03 Limit Levels

The AMS-02 payloads may choose to accept a minimal increase of EMI risk with a somewhat less stringent Electric Field Radiated Susceptibility (RS03) requirement, as it is considered to be non-safety critical to the vehicle and crew. The tailored RS03 requirement, shown below, is denoted RS03PL per SSP-57003.

<table>
<thead>
<tr>
<th>FREQUENCY</th>
<th>RS03PL LIMIT (V/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>14 kHz – 400 MHz</td>
<td>5</td>
</tr>
<tr>
<td>400 MHz – 450 MHz</td>
<td>30</td>
</tr>
<tr>
<td>450 MHz – 1 GHz</td>
<td>5</td>
</tr>
<tr>
<td>1 GHz – 5 GHz</td>
<td>25</td>
</tr>
<tr>
<td>5 GHz – 6 GHz</td>
<td>60</td>
</tr>
<tr>
<td>6 GHz – 10 GHz</td>
<td>20</td>
</tr>
<tr>
<td>13.7 GHz – 15.2 GHz</td>
<td>25</td>
</tr>
</tbody>
</table>

7.1.10 LE01 Leakage Current Limits

The leakage current for all equipment and subsystems using ac power, as measured between chassis and input power, at the power frequency, shall not exceed 5 milliamperes.

As previously noted, this segment will not be performed as part of the ESTEC EMI Test.

7.2 Equipment Positioning

For conducted emissions and susceptibility testing (including AC leakage current limit testing), the injection / measurement equipment shall be placed in-line with the AMS-02 payload GSE cables, with connections / adapters as required.

For radiated emissions and susceptibility testing, the injection / measurement antennae equipment shall be placed in the primary location relative to the AMS-02 payload, as depicted in Figure 4-2. The secondary location depicted in Figure 4-2 shall only be used if testing is impossible at the primary location, for whatever reason, or if follow-on testing under a different geometric configuration is deemed appropriate.
7.3 AMS-02 Payload Operation

For each of the tests called out in table 6-1, the payload will be powered up in its nominal start-up. All systems / sub-systems shall then be powered on by the AMS-02 detailed test procedures. All systems / sub-systems shall remain powered for each test, and thermal responses shall be closely monitored. Periodically, depending on thermal conditions, it may be necessary to pause the test and operate the CGSE and TCS GSE systems until proper thermal conditions are restored. The CGSE and TCS GSE will also be used after EMI test activities are complete. This shall be governed and documented in the AMS-02 detailed test procedures.

The AMS-02 payload operation of charging the magnet will not be considered for the purposes of this test. Charging the magnet is a transient operation that, under a nominal mission profile, will only be performed once on-orbit. Moreover, the presence of ferrous shielding materials within the floor of the Maxwell EMI test facility, and the mechanical stresses that the payload structure would endure in the magnetic field if it were energized, make including charging the magnet during the EMI test impossible. The portion of the CAB that performs the magnet charging operation underwent piece part EMI testing while under a simulated load.

7.4 Test Criteria

The emissions tests shall be monitored for conducted / radiated energy levels that exceed the limits as documented in the preceding requirements section.

The susceptibility tests shall be monitored for operational anomalies in the AMS-02 systems / sub-systems when exposed to the various EMI environments, as evaluated by the AMS-02 test team.

7.5 Test Data

Test data for emissions output and susceptibility test environments shall be provided relative to the parameters as documented in the preceding requirements section. The ESTEC test facility shall furnish this data both in hardcopy and electronic format.

7.6 Waivers / Exceptions

Either one of two courses of action may be taken when the AMS-02 payload does not meet its EMI requirements:

- The discrepancy shall be corrected such that the payload complies with the requirements, at the time of testing
- An analysis shall be performed to assure that system EMC is not degraded, including the payload itself or any other part of the ISS or launch package

Requests for waivers / exceptions shall be prepared for submittal to the ISS EMEP (NASA/JSC) for approval, in the form of Tailoring and Interpretation Agreements (TIAs). Preparation and execution of the waiver / exception requests shall be in accordance with the ISS waiver request format and procedure. Waiver / exception requests shall be accompanied by technical analysis and process rationale relative to granting the waiver / exception. The analyses supporting waiver / exception requests also shall verify that the end item equipment meets its required safety margins. The analysis shall address whether the indicated out of tolerance condition will be detrimental to the ISS operation.