Space Station Requirements for Electromagnetic Compatibility

International Space Station

Revision E
June 9, 1998

NASDA
National Space Development Agency of Japan

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european space agency

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National Aeronautics and Space Administration
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PREFACE

This requirements document defines the International Space Station requirements for Electromagnetic Effects (EME) Control including provisions for control of the induced electromagnetic environment. Provisions are included for lightning effects, static electricity, bonding and grounding. This document is under the control of the Space Station Control Board.

SPACE STATION PROGRAM OFFICE

SPACE STATION REQUIREMENTS FOR ELECTROMAGNETIC COMPATIBILITY

JUNE 9, 1998

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INTERNATIONAL SPACE STATION PROGRAM

SPACE STATION REQUIREMENTS FOR ELECTROMAGNETIC COMPATIBILITY

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Reference SSP 50019 Joint Management Plan and JESA 30000, Section 3, Appendix B DATE

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INTERNATIONAL SPACE STATION PROGRAM
SPACE STATION REQUIREMENTS FOR ELECTROMAGNETIC COMPATIBILITY

LIST OF CHANGES
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All changes to paragraphs, tables, and figures in this document are shown below:

SSCBD	ENTRY DATE	CHANGE	PARAGRAPH(S)
000002	02–17–94	Revision C	ALL
000008 R1	06–03–94	Revision D	ALL
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	06/09/98	Revision E	ALL

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1.0 GENERAL

The International Space Station (ISS) system requirement for Electromagnetic Effects Control (EMEC) shall be achieved by design within all segments, subsystems and equipment within the ISS, by interface design with the National Space Transportation System (NSTS), and by design with the external electromagnetic environment.

1.1 INTRODUCTION

This requirements document establishes the Electromagnetic Effects (EME) process design and verification requirements for the ISS. The requirements of this document are applicable to hardware providers (HWPs) including Space Station Flight Segments (SSFS), Ground System Segment (GSS), Government Furnished Equipment (GFE), Ground Support Equipment (GSE), Flight Support Equipment (FSE), Orbital Support Equipment (OSE), Payloads, and Commercial Off–the–Shelf equipment (COTS).

1.1.1 PRIME CONTRACTOR RESPONSIBILITIES

The prime contractor shall establish an overall integrated Electromagnetic Effects (EME) process for the ISS. The overall process shall include the necessary design, planning, technical criteria, and management controls needed to achieve overall EMEC and to ensure that the design and verification requirements specified herein are met. The ISS EME process shall be based on the requirements of SSP 30243 and the prime Statement of Work (SOW). The prime contractor shall direct each HWP to establish the technical effort and management controls necessary to accomplish their individual parts of the overall EMEC process.

1.1.2 HARDWARE PROVIDER RESPONSIBILITIES

HWPs shall have the responsibility for compliance with all requirements subsequent to paragraph 1.1.1 in accordance with the prime contractor’s responsibilities of paragraph 1.1.1. The prime contractor shall be advised when compliance with these requirements compromises operational capabilities or when compliance will not ensure EMC. The prime contractor shall be notified a minimum of 10 working days before any test start and shall have the option to witness the test.

1.2 PURPOSE

The purpose of this requirements document is to define a common electromagnetic design, control, test, and verification process for the ISS.

1.3 SCOPE

This document defines the ISS requirements for electromagnetic effects control including the responsibilities of all program participants for implementation, analysis, test, and verification.

1.4 INTENDED USE

This document is intended for use by the ISS, and is a requirement for the HWPs, and, as determined, the International Partners, is also, in whole or part, a requirement for their subcontractors.

1.5 ELECTROMAGNETIC EFFECTS CONTROL BOARD

An Electromagnetic Effects Control Board (EMECB) has been established by the Electromagnetic Effects AIT to serve as the technical forum for maintenance of EME requirements, evaluation of reports and plans, and resolution of issues relative to EM environmental effects on the Space Station. This team ensures HWPs establish uniform application of program EME requirements. The EMECB provides a means for expediting the solutions of technical problems, and establishing channels for coordination. The details of operation for the EMECB are included in the EMECB charter, contained in Appendix C of this document. The Team is chaired by the NASA EME lead and co–chaired by the Prime Contractor EME lead. Members of the Team include representatives from NASA Shuttle, Tier I Contractors, International Partners and Payload Providers (as required).

1.6 PRECEDENCE

In the event of conflict between this document and any other EMI requirements document, e.g. SSP 30237, SSP 30238, SSP 30240, SSP 30242, and SSP 30245, this document shall take precedence.

2.0 APPLICABLE DOCUMENTS

The following applicable documents of the exact issue shown in the current issue of SSP 50258 form a part of this specification to the extent specified herein. Inclusion of applicable documents herein does not in any way supersede the order of precedence identified in paragraph 1.6. The references show where each applicable document is cited in this document.

DOCUMENT NO.	TITLE
NSTS–21000–IDD–ISS	International Space Station Interface Definition Interfaces Paragraphs: 3.2.8.1, 3.2.8.2, 3.2.8.3
KSC–STA–61.01	Space Station Freedom Station Support Plan Paragraph: 3.2.8.2
MIL–B–5087	Bonding, Electrical, and Lightning Protection, for Aerospace Systems Paragraph: 3.2.2
MIL–STD–461	Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interference Paragraph: 3.2.2
MIL–STD–1576	Electroexplosive Subsystem, Safety Requirements and Test Methods for Space Systems Paragraph: 3.2.3
MIL–STD–1686	Electrostatic Discharge Control Program For Protection of Electrical And Electronic Parts, Assemblies And Equipment (Excluding Electrically Initiated Explosive Devices) Paragraph: 3.2.10
SSP 30233	Space Station Requirements for Materials and Processes Paragraph: 3.2.13
SSP 30237	Space Station Electromagnetic Emission and Susceptibility Requirements Paragraphs: 3.2.2, 3.5.3.1, 3.6.2.1.2, 3.6.2.2.1

DOCUMENT NO.	TITLE
SSP 30238	Space Station Electromagnetic Techniques Paragraphs: 3.2.2, 3.6.2.1.2, 3.6.2.2.1
SSP 30240	Space Station Grounding Requirements Paragraphs: 3.2.2, 3.2.8, 3.2.11, 3.6.2.1.2
SSP 30242	Space Station Cable/Wire Design and Control Requirements for Electromagnetic Compatibility Paragraphs: 3.2.2, 3.2.6 and 3.6.2.1.2
SSP 30245	Space Station Electrical Bonding Requirements Paragraphs: 3.2.2, 3.2.8, 3.2.11, 3.6.2.1.2
SSP 30482, Volume 1	Electrical Power Specifications and Standards Volume 1: EPS Electrical Performance Specifications Paragraphs: 3.2.7, 3.5.3.3
SSP 30482, Volume 2	Electrical Power Specifications and Standards Volume 2: Consumer Constraints Paragraphs: 3.2.7, 3.5.3.3

3.0 REQUIREMENTS

3.1 DEFINITION OF ELECTROMAGNETIC COMPATIBILITY REQUIREMENTS

The system and all associated subsystem/equipment, both on–orbit and ground, shall be designed to achieve electromagnetic compatibility. The HWP specification and interface documents shall contain supplementary requirements as necessary to achieve electromagnetic compatibility. As a minimum, the Tier I Contractors, Payload Providers and International Partners EME control process shall cover the following areas:

— Bonding and grounding

— Corona

— Degradation criteria

— Electrical power and electrical interface

— Electromagnetic Interference (EMI) safety margins for critical equipment

— EME analysis requirements and methodologies

— External environment effects

— Interactions with other technologies including, but not limited to, functionality, maintainability, plasma, reliability, materials and processes, and safety

— Interference and susceptibility control

— Launch element transportation, storage, handling and launch environments

— Lightning protection

— Material and processes

— Personnel hazards

— Pyrotechnics and Bridge Wire Actuated Devices (BWADs)

— Spacecraft charging controls

— Static electricity

— Subsystem compatibility

— Subsystems and equipment requirements

— Wiring and cable

3.2 CHARACTERISTICS

3.2.1 SYSTEM/SUBSYSTEM COMPATIBILITY

Compatibility shall be demonstrated between system/subsystems by functionality with the required safety margin. The Ground Systems segment along with training devices and simulators shall be designed for compatibility.

3.2.2 SYSTEM, SUBSYSTEM AND EQUIPMENT REQUIREMENTS

The ISS system, segments, subsystems and equipment shall be designed to meet the requirements of this document. Electrical and electronic equipment, as mounted and enclosured (including racks, non–conductive mounting, cold plate mounting, portable enclosures, etc.), shall meet the requirements of SSP 30237 when tested in accordance with SSP 30238. Electrical grounding shall meet the requirements of SSP 30240. Electrical bonding shall meet the requirements of SSP 30245. Electrical cable design shall meet the requirements of SSP 30242. GSE for PGs only shall meet the requirements of MIL–STD–461 and MIL–B–5087. Approved EME waivers shall be included in the HWPs EME Design Analysis Report. See appendix F for exception (EMECB TIA–0061) to this paragraph.

3.2.3 ELECTROMAGNETIC INTERFERENCE SAFETY MARGINS FOR CRITICAL CIRCUITS

Circuits implementing critical functions such that incorrect operations due to EMI could result in loss of life or loss of ISS shall be demonstrated to have an EMI safety margin of 6 dB by test or 20 dB by analysis. EMI safety margins for firing circuits of critical electroexplosive devices (see paragraph 3.2.11 for exploding bridgewire type devices) shall be demonstrated to be 20 dB by test or 34 dB by analysis.

3.2.3.1 INTERFERENCE AND SUSCEPTIBILITY CONTROL

The ISS subsystems and equipments shall function with the required margins identified in paragraph 3.2.3 when subjected to EMI produced by any of the subsystems or equipment associated with the system. This shall be accomplished through design. Verification shall be by analysis and tests as specified in this document.

3.2.4 DEGRADATION CRITERIA

Degradation criteria shall be established by the HWP for each system, subsystem, and equipment. These criteria shall be used to define and evaluate malfunctions, unacceptable, and undesirable responses.

3.2.5 WIRING AND CABLING DESIGN

Wiring and cabling shall be designed in accordance with SSP 30242. Wiring and cabling shall be selected, classified, and bundled in accordance with the requirements and procedures in SSP 30242. Cables, wires and cable/wire bundles shall be located and routed to provide a 20 dB cable to cable coupling loss using physical or electrical separation and considering the worst case steady state or transient conditions. Cable design shall include provisions for termination of shielded wires in accordance with SSP 30242. Connectors used to carry wires with overall shields shall use a conductive finish and shall use a back shell that provides for peripheral bonding of shields. Wire or cable shall be categorized according to interference and susceptibility characteristics in accordance with the requirements of SSP 30242. Wires and cables shall be marked in such a manner that personnel can visually identify the EMC category for each wire or cable. The end–to–end path of each and every wire and cable conductor shall be documented, and identification made of cable bundle, physical path, and wire code (color, marking, classification, size, type, etc.) to support EME design analysis as well as maintenance, and growth.

3.2.6 ELECTRICAL POWER AND ELECTRICAL INTERFACE

Space Station system, subsystems and equipment shall not malfunction, or have unacceptable responses due to surges, ripples, voltages, and other electrical conditions that can cause interference or susceptibility, when supplied with electrical power conforming to SSP 30482.

3.2.7 BONDING AND GROUNDING

Bonding and grounding provisions shall be in accordance with SSP 30240 and SSP 30245.

3.2.8 LAUNCH ELEMENT TRANSPORTATION, STORAGE AND LAUNCH ENVIRONMENT

3.2.8.1 LAUNCH

The ISS launch element shall be designed such that inadvertent action or failure will not occur when subject to the payload bay lightning induced environment resulting from a lightning strike to the NSTS as defined in NSTS–21000–IDD–ISS.

3.2.8.2 TRANSPORTATION AND STORAGE

The HWP electromagnetic environment during transportation and storage of the launch element shall be controlled per KSC–STA–61.01 and shall not exceed the launch environment defined in NSTS–21000–IDD–ISS.

3.2.8.3 TRANSITION PHASE

The ISS launch element during transition to orbit shall not exceed or be susceptible to electromagnetic environments defined in NSTS–21000–IDD–ISS.

3.2.9 STATIC ELECTRICITY

Unpowered electronic equipment and components shall not be damaged by Electrostatic Discharges (ESD) equal to or less than 4,000 volts to the case or to any pin on external connectors. Equipment that may be damaged by ESD between 4,000 and 15,000 volts must have a label affixed to the case in a location clearly visible in the installed position. Handling and labeling of equipment susceptible to ESD up to 15,000 volts shall be in accordance with MIL–STD–1686. These voltages are the results of charges that may be accumulated and discharged from ground personnel or crew members during equipment installation or removal. When testing or analysis for ESD susceptibility is performed, the ESD hazard from personnel shall be simulated by charging a 100–picofarad capacitance and discharging it through a 1500–ohm resistor. See appendix F for the exception from EMECB TIA–0042.

3.2.10 ELECTROEXPLOSIVE DEVICES (EEDs)

The system design shall conform to the requirements of MIL–STD–1576 as modified by Appendix E, and shall include provisions to protect EEDs from inadvertent ignition or dudding caused by any form of electromagnetic or electrostatic energy. All wiring, cabling, and hardware associated with the EEDs shall be designed to prevent stray pickup and eliminate undesired energy. Safety margin requirements for EEDs are defined in the Electromagnetic Interference Safety Margins For Critical Equipment paragraph of this document. Grounding and bonding requirements for EEDs shall meet the requirements of SSP 30240 and SSP 30245. Wiring requirements for EEDs are defined in SSP 30242.

3.2.11 EXTERNAL ENVIRONMENT EFFECTS

System, subsystem, equipment, and component designs shall analyze and document potential failures caused by external electromagnetic environments. The external electromagnetic environments are defined in SSP 30237.

3.2.12 MATERIALS AND PROCESSES

Materials and processes shall conform to the electrical and electronic requirements of SSP 30233 and as supplemented in SSP 30245.

3.2.13 CORONA

Electrical and electronic subsystems, equipment, and systems shall be designed to preclude damaging or destructive corona in any ISS operating environment. An analysis shall be provided to verify the corona shall not create damaging or destructive effects.

3.3 ANALYSIS

3.3.1 ANALYSIS REQUIREMENTS

Subsystems shall be analyzed for EME to support:

— Quantitative evaluation of proposed designs and design changes.

— Specification tailoring and waiver evaluation.

— Test result assessments.

— Verification test planning and critical test point selection.

— Quantitative assessment of the ISS function safety margins for configuration changes.

3.3.2 ANALYTICAL MODELS AND METHODS

3.3.2.1 ANALYTICAL MODELS

Analytical models used to perform and support analyses provided in the Design Analysis Report (DAR) shall be described in sufficient detail in the DAR to support technical evaluation by the EMECB. Use of model software tools such as IEMCAP, SEMCAP, ISEAS which provide integrated system analyses shall be permitted along with analyses performed with general purpose problem solving tools such as MATHEMATICA, MATLAB, MATHCAD and spreadsheets. Appendix D is the methodology used by the EMECB to perform Integration analysis of the Space Station.

3.4 GOVERNMENT FURNISHED EQUIPMENT AND COMMERCIAL OFF–THE–SHELF EQUIPMENT

3.4.1 SELECTION AND USE OF EQUIPMENT

3.4.1.1 COMMERCIAL OFF–THE–SHELF EQUIPMENT

When Commercial Off–the–Shelf (COTS) equipment is considered for use, the following rules shall be used in selecting and utilizing the equipment in the system:

— The equipment shall be considered adequate if emission and susceptibility test data are available to demonstrate compatibility.

— When compliance with interference requirements cannot be substantiated due to unavailability of test reports, then laboratory interference tests shall be performed for qualification of the subsystem as negotiated with the responsible authority for the equipment.

— If it is determined that more stringent requirements are necessary after evaluation of available data, it shall be the responsibility of the procuring authority to direct the supplier to implement these requirements, or to select another equipment with adequate characteristics.

3.4.1.2 GOVERNMENT FURNISHED EQUIPMENT (GFE)

GFE that is required for use in the system shall be acceptable from an EME viewpoint, provided the interference and susceptibility requirements as outlined below are met:

— As a minimum, subsystem and equipment designs must have met the EMI safety margin requirements of this document and be supported by approved qualification test reports.

— When compliance with applicable specifications cannot be substantiated, laboratory tests shall be performed for qualification of systems, subsystems, or equipment to the applicable requirements as negotiated with the responsible flight element, system or subsystem authority.

— GFE which cannot meet the requirements and for which external suppression measures are ineffective shall be modified if approved by the responsible flight element, system, subsystem or equipment procuring authority. If such procedures are not specified, the flight element, system, subsystem, or equipment supplier shall advise the responsible authority by a timely letter of systems, subsystems, or equipment that cannot meet the requirements and of pertinent details concerning the modifications required.

— When GFE is demonstrated to cause interference that cannot be eliminated by proper installation, control of the system electromagnetic environment, or by reasonable modification to the flight element, system, subsystem, or equipment, then NASA shall have the authority to waive the requirement.

3.5 DOCUMENTATION

3.5.1 EME CONTROL PLAN

Each Tier I Contractor, Payload Provider and International Partner shall submit an EME Control Plan to the EMECB. The EME Control Plan shall include details describing element, system, subsystem, and equipment control processes. Verification planning including tests and analysis shall be summarized in the EME Control Plan.

3.5.2 EMC TEST PLAN/PROCEDURE/REPORT

Each Tier I Contractor, Payload Provider and International Partner, shall submit an EMC Test Plan/Procedure/Report to the EMECB. The EMC Test Plan shall include details as defined in the International Technical Agreements and PG Supplier Data Requirements Lists.

3.5.3 EME DESIGN ANALYSIS REPORT

Each Tier I Contractor, Payload Provider and International Partner shall submit an EME DAR. The EME Design Analysis Report shall include details and conditions for the element, system, subsystem, and equipment included in the deliverable end item. In addition to the DAR, each HWP shall provide configuration data, analysis data and test results data to the prime contractor in the detail and format as defined for the EME Configuration, Analysis and Test Data Base (appendix D). For international partners detail and format of these data exchanges are defined in the Bilateral Data Exchange Agreements.

3.5.4 EMI TEST PLANS, PROCEDURES AND REPORTS

HWPs shall provide EMI test plans/procedures and reports.

3.6 VERIFICATION

3.6.1 VERIFICATION METHODS

Flight element, systems, subsystems, and equipment compatibility shall be verified by a combination of tests, demonstrations, analyses, and inspections.

3.6.2 INTEGRATION TESTS

3.6.2.1 DELIVERABLE END ITEM COMPATIBILITY TEST

Tier I Contractors, Payload Providers, and International Partners, shall perform a system EMC test on the highest level deliverable end item package. The test shall include:

— A functional compatibility demonstration to verify that the deliverable end item equipment is self–compatible.

— An interface test with simulated sources and loads to show that circuits interfacing with the next highest level of assembly function compatibly with the interface (including grounding and bonding).

— Safety margin tests where margins have not been previously determined by equipment–level tests or analyses.

3.6.2.1.1 CONDITIONS TO START SYSTEM–LEVEL TESTING

Outstanding approved engineering orders, engineering change proposals, modifications, and configuration changes applicable to the end item components shall have been incorporated and installed prior to test. Requests for exceptions shall contain supporting rationale for tests of substandard configurations, and shall be submitted to the EMECB for approval.

3.6.2.1.2 COMPLIANCE

Equipment components of the end item shall have complied with applicable equipment–level EMI/EMC specifications (SSP 30237, SSP 30238, SSP 30240, SSP 30242, and SSP 30245) or have approved waivers allowing the specification exceptions.

3.6.2.1.3 TEST PLAN

Tests shall not be conducted without an approved test plan.

3.6.2.1.4 POWER QUALITY

External electrical power supplied to the flight element, system, or subsystem, under test shall simulate the power quality requirements and interface (including dynamic impedance) requirements of SSP 30482. The end item compatibility test will be performed with its input power set, to the worst case input voltage levels (i.e, the high limit, nominal level, or low limit) called out in SSP 30482.

3.6.2.1.5 TEST LOCATION APPROVAL

Tests shall not be conducted where the electromagnetic environment at the test site would affect the validity of the tests. The location and environment of the test site shall be included in the test plan and submitted for approval to the EMECB.

3.6.2.1.6 TEST ITEM OPERATING ADJUSTMENTS

During tests, all electronic flight elements, systems, subsystems, and equipment under control of crew or ground operations personnel shall be adjusted within the limits of the test article specifications(s) for nominal operating conditions (i.e., a receiver squelch circuit shall be set to it’s normal operating position and not to extreme positions) so as to provide indication of interference or susceptibility consistent with planned operation.

3.6.2.1.7 COMPATIBILITY

Tests shall be performed to indicate compatible operation, undesirable responses, unacceptable responses, or malfunctions while all flight elements, systems, subsystems and equipment are

operated. It shall be the responsibility of the supplier to determine conclusively and correctly the causes of non–compatibility (i.e., the source(s), coupling paths, and susceptible components) in order to support hardware/software fixes, operational workarounds, or preparation of waiver requests.

3.6.2.1.8 INSTRUMENTATION

Each EME test shall be monitored by appropriate means to assure adequate recording of measured data used to evaluate the effects of test article operation and demonstrate the required safety margins. Instrumentation to be used shall be specified in the test plan.

3.6.2.1.8.1 INSTRUMENTATION MEASUREMENT STANDARDS

Instrumentation shall meet or exceed measurement standards traceable to standards maintained by the National Institute of Standards and Technology or other value(s) derived from a controlled measurement process utilizing a fundamental constant of nature.

3.6.2.1.9 OPERATING MODES

The overall system shall be operated in representative modes of operation as defined in the test plan. Representative modes including programmed missions, flight, and stage assembly shall be used. Known “Worst–Case” modes as determined by analysis shall be included in the test plan.

3.6.2.1.10 SIMULATED INTERFACES

When test articles require simulation of interfaces with equipment not the responsibility of the supplier, or where special inputs are required, the means of simulating these interfaces shall be described in the test plan.

3.6.2.1.11 GENERAL CONDITIONS

The EMC tests shall demonstrate required compatibility when flight elements, systems, subsystems, and equipment, including GSE, and simulators are individually or collectively operated in representative modes of operation. Transmitters and receivers shall be operated at those critical frequencies identified during system analysis and laboratory tests. Multichannel transmitters and receivers shall be tested at a representative number of frequencies, usually not less than 20. If the system uses special frequencies for command channels, distress messages, or other purposes, then they shall be given special attention.

3.6.2.1.12 ACCEPTANCE CRITERIA

Compliance with this requirements document shall have been achieved when compatible operation of the test item is demonstrated along with the existence of the required safety margins at designated critical circuits.

3.6.2.1.13 TEST SITE AMBIENT ELECTROMAGNETIC ENVIRONMENT

The electromagnetic ambient environment at the end item test site shall be measured, recorded and analyzed to ensure that the ambient environment does not degrade test results or mask interference from the test article. The environment shall be monitored periodically during the test, and shall be controlled to the extent necessary to prevent test degradation (i.e., by shutting off local external sources or conducting the test during times when the local external sources are not present). Ambient signals (both steady–state and transient) shall be considered as a possible source of interference and will be measured when end item functions cannot be positively identified as interference sources.

3.6.3 TEST ANALYSIS

Test analyses shall be performed as necessary to utilize the end item, equipment, subsystem, and equipment test data in support of verification of the EMC requirements.

4.0 QUALITY ASSURANCE PROVISIONS

4.1 RESPONSIBILITY FOR INSPECTION

Unless otherwise specified, the supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified, the supplier may use his own facilities or any other commercial laboratory acceptable to the Prime Contractor.

4.2 WAIVERS

Either one of two courses of action may be taken when an ISS flight element or launch package does not meet its EME requirements:

— The discrepancy shall be corrected such that the equipment complies with the requirements.

— An analysis shall be performed to assure that system EMC is not degraded, including the flight element itself or any other part of the Space Station or launch package.

Requests for waivers shall be prepared for submittal to the EMECB for approval. Preparation and execution of the waiver requests shall be in accordance with the ISS waiver request format and procedure. Waiver requests shall be accompanied by technical analysis, and process rationale relative to granting the waiver. The analyses supporting waiver requests shall also 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.

APPENDIX A ABBREVIATIONS AND ACRONYMS

AIT	Analysis Integration Team
BWAD	Bridge Wire Actuated Device
CAT	Configuration, Analysis & Test
CATD	Configuration, Analysis & Test Data
CATDB	Configuration, Analysis & Test Database
CDR	Critical Design Review
COTS	Commercial Off the Shelf (equipment)
CSA	Canadian Space Agency
DAR	Design Analysis Report
dB	Decibel
DBM	Database Manager (software)
EED	Electroexplosive Device
EIPT	Environments Integration Product Team
EMC	Electromagnetic Compatibility
EMCAB	EMC Advisory Board
EME	Electromagnetic Effects
EMECB	Electromagnetic Effects Control Board
EMEC	Electromagnetic Effects Compatibility
EMI	Electromagnetic Interference
EMI/EMC	Electromagnetic Interference/Electromagnetic Compatibility
ESA	European Space Agency
ESD	Electrostatic Discharge
FSE	Flight Support Equipment
GFE	Government–Furnished Equipment
GSE	Ground Support Equipment
GSS	Ground System Segment
GUI	Graphics User Interface
HWP	Hardware Provider (any provider of hardware to the ISS program)
IEMCAP	Software for computer aided analysis of EM compatibility
INFORMEX	Database Manager (software)
ISEAS	Integrated Space Station Electromagnetic Compatibility Analysis System (analysis software)
ISS	International Space Station
MATHEMATICA	General Purpose Mathematical analysis software
MATLAB	General Purpose Mathematical analysis software
MATHCAD	General Purpose Mathematical analysis software
MOU	Memorandum of Understanding
NASA	National Aeronautics and Space Administration
NASDA	National Space Development Agency of Japan
NSTS	National Space Transportation System
ORACLE	Database Management Software

OSE	Orbital Support Equipment
RF, rf	Radio Frequency
SEMCAP	System EM Compatibility Analysis Program
TBD	To Be Determined
V	Volt
VMDB	Vehicle Master Database

APPENDIX B GLOSSARY

ELECTROMAGNETIC COMPATIBILITY

The capability of systems and all associated subsystems/equipment to perform within design limits without degradation due to the Electromagnetic Effect encountered during accomplishment of the assigned mission.

ELECTROMAGNETIC EMISSIONS

Electromagnetic energy radiated or conducted from an electrical or electronic component, equipment, subsystem, system or flight element.

ELECTROMAGNETIC ENVIRONMENT

The composite natural and induced sum of the electric and magnetic fields at any point due to man–made and natural sources, to which a system or subsystem/equipment will be exposed during a mission.

ELECTROMAGNETIC INTERFERENCE

Any electromagnetic disturbance, phenomenon, signal, or emission (man–made or natural) which causes equipment performance outside of the equipment's design limits.

ELECTROMAGNETIC SUSCEPTIBILITY

Equipment capability for impaired performance due to electric or magnetic environments (radiated or conducted).

EMI MALFUNCTION

A failure of a system or associated subsystem/equipment due to electromagnetic interference or susceptibility that results in a loss of function, mishap, a mission abort, or failure to accomplish mission.

RECEIVER AREA NOISE LEVEL

The receiver area electrical noise level at a particular frequency is that receiver output obtained with all controls at standard settings, all other subsystems/equipment turned off, the receiver antenna connected, and the intended signal is not present.

SUBSYSTEM

A collection of equipment designed to work together. The subsystem contributes to the system functionality and does not stand alone.

SYSTEM

A collection of equipment, subsystems, skills, and techniques capable of performing or supporting an operational role. A complete system includes related facilities, equipment, subsystems, materials, services, and personnel required for operation to the degree that the system can be considered autonomous within the operational environment.

UNACCEPTABLE RESPONSE

An unacceptable response is an abnormality in the operation or output of a subsystem or equipment due to electromagnetic interference.

UNDESIRABLE RESPONSE

A recognized distortion or perturbation of normal output of equipment, subsystem or system which is considered tolerable by the procuring activity.

APPENDIX C ELECTROMAGNETICS EFFECTS CONTROL BOARD

C.1 PURPOSE

This document establishes the Electromagnetic Effects Control Board (EMECB) that serves as the technical forum for maintenance of EME requirements, plans and reports and for resolving issues relative to EME environmental effects on the Space Station system. This charter defines details necessary for the EMECB to support the design review and integration of technical activities associated with the electromagnetic effect. The Prime Contractor Lead for EME is designated as Chairperson.

C.2 SCOPE

The EMECB is responsible for the technical guidance and timely resolution of technical issues related to environmental electromagnetic effects and EME requirements maintenance and compliance verification of the International Space Station. The primary focus of the team is on resolution of electromagnetics issues and achievement of the required systems performance. This includes the evaluation of waiver requests for relaxation of EME requirements and data exchange between appropriate elements and disciplines to ensure that the optimum overall Station–level, system–level, and user accommodation requirements related to this environment are incorporated in the design.

C.3 AUTHORITY

The EMECB is the counterpart of the EMC Advisory Board (EMCAB) defined in MIL–E–6051D, the electromagnetic effect control process used in other government programs. It will obtain the benefit of skills available across the program to provide specific expertise for coordinating integration of the electromagnetic effect. The EMECB provides the mechanism by which the Prime Contractor assures the active participation of supporting organizations in EME matters. The EMECB is responsible for activities of working groups it establishes.

C.4 RESPONSIBILITIES

C.4.1 EMECB RESPONSIBILITIES

Certain specific responsibilities of the EMECB are identified in the following paragraphs:

C.4.1.1 Provide technical evaluation of the Electromagnetic Effects Compatibility (EMEC) process status and the EME concerns.

C.4.1.2 Participate in Program Reviews for EME disciplines. Facilitate communications among team members and their organizations.

C.4.1.3 Coordinate assessments of Tier I subcontractor EME control plans, test and analysis plans and test and analysis reports.

C.4.1.4 Modify and update the program specific environmental discipline requirements documents and specifications when necessary. Evaluate and recommend disposition of EME waiver requests.

C.4.1.5 Coordinate prime contractor assessment of EME verification documentation and implement processing of the recommended actions by the proper management channels.

C.4.1.6 Ensure that legal requirements related to electromagnetics effects are addressed.

C.4.1.7 Support development of user accommodation requirements for specific environments disciplines. Review, update and evaluate the Space Station Radio Frequency (rf) environment.

C.4.1.8 Coordinate follow–up oversight to ensure timely and appropriate implementation of EMECB action items. Review and evaluate the electromagnetic effects of the interactions with the Space Shuttle and review Shuttle requirements for compliance. Recommended changes to the Space Station and Space Shuttle requirements or operations as needed.

C.4.1.9 Review and evaluate EME requirements of other spacecraft that may interface with the Space Station to ensure compliance with Space Station EME requirements.

C.4.1.10 Coordinate the definition of system–level requirements for controlling and monitoring the electromagnetic effect.

C.4.1.11 Conduct studies dealing with issues affecting or effected by the electromagnetic effect.

C.4.1.12 Maintain current definitions of the combined natural and induced electromagnetic effect in the proximity of the Space Station.

C.4.1.13 Evaluate future changes in the electromagnetic effect and define models, tools, and databases required for assessment of the electromagnetic effect and electromagnetic–plasma interactions during the design and operational phases of the ISS.

C.4.1.14 Assure that the electromagnetic effect is adequately defined, consistent with other environments definitions, and is accurately reflected in the appropriate documents and designs.

C.4.1.15 Identify technical issues associated with the electromagnetic effect definition and develop recommendations for resolution of issues to forward to the IMR for subsequent introduction into the Configurations Management process.

C.4.1.16 Provide support to formal design reviews, Space Station Control Board activities, and other panel/working groups as required.

C.4.1.17 Review development status of electromagnetic effect requirements for stages and interfaces to assure adequate coordination and flow of information across technical interfaces.

C.4.1.18 Develop user accommodation requirements related to the electromagnetic effect definition and Space Station design.

C.4.2 RESPONSIBILITIES OF PRESENTERS AT CONTROL BOARD MEETINGS

The presenter of materials is responsible for coordination of issues that affect other program participants prior to presentation. Members are responsible for providing feedback to presenters on significant aspects of the issues.

C.4.3 RESPONSIBILITIES OF THE CHAIRPERSON

A goal of the EMECB is to achieve consensus on each issue. However, the EMECB chairperson will be the final authority for decisions concerning actions items, recommendations to IPTs or AITs on change requests, waiver requests, deviation requests, and for resolution of issues. Decisions will be documented and issued within 48 hours of the decision. Any contractor who believes a contract adjustment is required shall notify their respective project office and the EIT chairperson within five calendar days of receipt of the decision.

Appropriate action shall be taken by pertinent project offices to resolve contractual issues as soon as practicable. If necessary, the EMECB may be used to reconsider issues because of the severity of the impacts.

The chairperson shall present EME discipline issues and status to the AIT's or IPTs as appropriate. The EMECB chairperson shall present requirements changes, deviations and waivers, present EIT for consideration by the Vehicle AIT.

C.5 MEMBERSHIP

Membership of the EMECB board shall consist of the chairperson (EME Prime Lead) and members appointed by the member's parent organization and concurred with the EMECB Chairperson. The following are to support as required:

— NASA EME Technical Lead

— NASA Program Engineering Office Representative
— Tier I Contractors
— EME technical contact as designated by each contractor
— Canadian Space Agency (CSA) Prime Contractor representative
— Canadian Space Agency (CSA) representative
— Electrical Power System representative
— European Space Agency (ESA) Prime Contractor representative
— European Space Agency (ESA) representative
— Italian Space Agency Prime Contractor representative
— Italian Space Agency representative
— Materials and Processes representative
— National Space Development Agency of Japan (NASDA) each contractor representative
— National Space Development Agency of Japan representative (NASDA)
— Safety, Reliability, Maintainability & Quality Assurance representative
— Russian Space Agency Prime Contractor representative
— Russian Space Agency representative
— Other participants on ISS as required

C.6 PROCEDURES

Operating procedures are given in the following paragraphs:

C.6.1 The EMECB will meet as needed but at least semiannually. Meetings may be called on an as–required basis by the EMECB chairperson. Maximum use will be made of teleconferences and video conferences.

C.6.2 The EMECB will normally meet every quarter; however, meeting frequency will be determined by the chairperson. Partial membership meetings may be called on an “as–required” basis by the chairperson. Maximum use of teleconferences will be made.

C.6.3 The meeting agenda will be established by the chairperson, coordinated with appropriate members, and distributed 10 working days in advance of the meeting.

C.6.4 Copies of the presentation materials will be provided before the meeting to individuals that will participate via teleconference or video conference.

C.6.5 Action items resulting from the meeting shall be assigned by the EMECB chairperson with the concurrence of the assignees. These action items will be distributed to actionees within four working days of the meeting date.

C.6.6 Minutes of the meeting will be prepared and distributed with within 10 working days of the meeting's end date. When possible, the minutes will be distributed with the action items.

C.6.7 Copies of the material presented at the meeting will be available at the meeting through the chairperson upon request, but will not be provided with the minutes.

APPENDIX D EME CONFIGURATION, ANALYSIS AND TEST DATABASE

D.1 PURPOSE

An ISS EME Configuration, Analysis and Test DataBase (CATDB) is being developed to allow technical integration of the ISS electromagnetic effect. This analysis will confirm the electromagnetic compatibility of the ISS. The CATDB will provide the formatted outputs that will be used as input data for analytical tools such as ISEAS or IEMCAP. The CATDB will contain ISS EME related equipment and end–item hardware configuration, analysis and test (CAT) data. This data will include wiring and shielding configuration, equipment location and orientation (i.e., for cases, racks, connectors, antennas, sensors, etc.), frequency and amplitude characteristics for emitters and receivers, and other data from the EMC and EMI test reports. The CATDB will allow ad hoc queries from the PGs and IPs through the Vehicle Master DataBase (VMDB).

D.2 DATABASE STRUCTURE

The Prime will assemble and maintain the CATDB with data and support from the PGs, IPs, and providers of GFE and payloads. The CATDB structure will be defined by the Prime and will be revised as necessary to reflect changes in EME technical integration needs. The CATDB will utilize a Relational Model using Structured Query Language to facilitate use and querying of the database by non–database specialists, and to facilitate electronic transfer of data to and from other databases. Data in the CATDB will be updated periodically to reflect EME related details of ISS documentation, configuration, wiring, cabling and equipment. The CATDB will incorporate on–going analysis data and test data regarding emissions, susceptibilities, and safety margins of the equipment and end items as it becomes available.

D.3 VMDB RELATIONSHIP

The CATDB is a tool which draws data from the VMDB. All configuration, analysis, and test data required by the Prime will reside within the VMDB. In addition, the VMDB possesses (or has) a library function and a Graphics User Interface (GUI). The library function will allow the VMDB to store and retrieve additional data that contains useful information about the equipment or end item provided. The GUI is used to view graphics and drawings associated with the data.

D.4 DATA PROVIDERS TASKS

There are several tasks required of the providers to enable the CATDB to be fully useful and effective for the ISS community. These are tasks that provide the collection of the data to populate the different fields of the database.

D.4.1 Data Provider task one is to provide periodic level–of–effort aid and assistance to the Prime in:

D.4.1.1 Identifying and acquiring access to on–line databases used in the description, manufacture, assembly and tracking of the ISS equipment, wiring, and end item installation details.

D.4.1.2 Identifying and providing data from cable schematics, assembly drawings, descriptions, installation locations, and other installation details and acquiring access to on–line utilities providing hard copies of these items, and in some instances, access to selected data in databases supporting the utilities. This data should be provided in a format compatible with the CATDB.

D.4.2 Data Provider task two is to provide files or on–line transmittal in ASCII format for data on graphs of equipment and end item measured test data used in EMC test reports. The units of the data series (i.e., dB/mVolt vs Hz, dB/mVolt/Meter vs MHz, etc.), along with the title and date of the test report and the date of the measurement, if available, shall be included in the header of the file using a format negotiated with the Prime.

D.4.3 The data providers should contact their spectrum–analyzer and instrument suppliers for software/hardware solutions for ASCII outputs of measured data.

D.5 CAT DATA ATTRIBUTES AND TRACEABILITY

CAT data attributes and traceability shall be provided in each data provider submittal. These traceability attributes shall include the data source (i.e., drawing, test report, analysis report, manufacturer, etc.), title, revision number and date. The inclusion of other data attributes which the data providers find useful shall be permitted.

D.6 CAT DATA TRANSMITTAL

CAT data and drawings will be submitted in the following format:

D.6.1 All drawings shall be delivered in a CCIT Group 4 Raster Image per the exchange agreements with the PGs as defined in SDS/SDRL PC–005, Engineering Drawings and Associated Lists. This SDRL defines the format of the file, header information required when sending the file, naming convention of the file, etc.

D.6.2 ”A” size, bookform drawings (e. g. documents) shall be delivered in a PRINTERLEAF compatible format. PRINTERLEAF is a standard file format that is compatible with several applications. MSWord, Interleaf, and ASCII text files are all compatible with PRINTERLEAF.

D.6.3 All test data shall be delivered as an ASCII delimited file. Each column/field must be defined as well as how the file as a whole relates to part numbers, part instance, flight, etc.

D.6.4 Graphs produced for analysis and test reports are typically generated by computer software and digital measurement equipment. It is likely that the same software used to generate graphical data will also produce ASCII formatted outputs. Data providers are encouraged to contact their instrument suppliers for software/hardware solutions. In the event these solutions seem prohibitively expensive, there are manual means for the digitization of hardcopy plots. These methods are typically expensive and seriously degrade the accuracy and resolution of the data.

D.7 CATDB DATA FLOW

Figure D.1, Configuration Analysis and Test Data Flow, describes the flow of CAT data through the program, from HWPs to CATDB end users. The flow is a series of data exchanges.

D.7.1 Exchange 1 is the bulk of raw data and drawings. It contains test results, analyses, wiring diagrams and other information that contributes to assessing the EME.

D.7.2 Exchange 2 contains Exchange 1 information, plus additional analyses and data for GFE and equipment developed by PGs and IPs. This data is formally submitted between Data Management Groups, and will not be loaded into the VMDB until the approval process is complete.

D.7.3 Exchange 3 is via a virtual link. The data resides in the VMDB in tables, or as datasets and drawings in the library. As different end users will require different data formats or contents, the CATDB will be necessary to meet ad hoc needs. The CATDB should retain the VMDB’s library and GUI functions to support the transfer of drawings and additional data sets.

D.7.4 Exchange 4 will vary in content and format to meet the user’s needs. At this time, ISEAS and IEMCAP are the best defined users of this data and their input requirements will drive the design of the associated VMDB tables and content of data exchanges 1 and 2.

D.8 CATDB DATA CONTENT

Configuration data to be submitted should include, but not be limited to; equipment and rack location (X, Y, and Z offsets relative to rack or module origin); cabling attributes including length, routing, and termination; wire attributes including size, description, number of conductors, shield type, thickness, and termination, dielectric type and thickness, resistance, inductance, functional type (from ICD or equivalent), EMC category, length; and cross referencing to match wire components to cable bundles. In addition to the data submitted in tabular form, drawings indicating configuration should be included. Data providers will provide sufficient detail on their coordinate system to support the Prime in development of a common coordinate system.

Test data should include, but not be limited to, the testing indicated in the EMI Test Report as outlined in SDS–VE–0059A or as negotiated with the IPs. Data files should include the tabulation of graphical test data, specification value of parameters, the source of that value, and justification for omission of any required testing. In the case of GFE and IP developed hardware, other tests may be included.

D.9 CATDB DEVELOPMENT

The Prime will develop, along with the CATDB end users, the required structure of the outputs from the CATDB, which will drive the structure of related VMDB tables. The structure of these VMDB tables will be made available to data providers at the HWPs, PGs, IPs and providers of GFE. Data providers will format their data as closely as possible to the VMDB structure, and in the event of incompatibilities, coordinate solutions with the Prime.

APPENDIX E MODIFICATIONS TO MIL–STD–1576, ELECTROEXPLOSIVE SUBSYSTEM SAFETY REQUIREMENTS AND TEST METHODS FOR SPACE SYSTEMS', 31 JULY 1984 AND NOTICE 01 04, SEPT 92

In the event of conflict, the requirements of this document, SSP 30243, supersede those requirements in MIL–STD–1576 as applied to the ISS. The intent is to provide ISS specific clarification of the requirements of MIL–STD–1576 rather than replacement of those requirements.

E.1 MODIFICATIONS TO SECTION 4.0 OF MIL–STD–1576 ARE SHOWN BELOW. THE PARAGRAPH NUMBER IN THE MIL STD IS TO BE REPLACED BY THE PARAGRAPH AS SHOWN BELOW.

E.1.1 4.3 BONDING – THE BONDING REQUIREMENTS SPECIFIED IN SSP 30245 SHALL BE APPLIED.

E.1.2 4.4 ELECTROEXPLOSIVE SUBSYSTEMS ELECTROMAGNETIC COMPATIBILITY (EMC)

4.4.1 Inadvertent activation

a. The electroexplosive subsystem shall limit the power produced at each EED by the radiated electromagnetic effect, defined in SSP 30237 for RS03, acting on the subsystem to a level at least 20dB below the maximum pin–to–pin DC no–fire power of the EED.

b. Under the same conditions stated in 4.4.1a above, the electroexplosive subsystem shall limit the power produced at each device (exclusive of EEDs) in the firing circuit to a level at least 6dB below the minimum activation power for each of the safety devices.

4.4.2 Direct Coupling to the EED and EES. EEDs shall not fire when the EES is subjected to the test requirements of SSP 30237, CS02.

E.2 MODIFICATIONS TO SECTION 5.0 OF MIL–STD–1576 ARE SHOWN BELOW. THE PARAGRAPH NUMBER IN THE MIL STD IS TO BE REPLACED BY PARAGRAPH AS SHOWN BELOW.

E.2.1 5.2 SHIELDS

a. The firing circuit including the EEDs shall be completely shielded and shall not have RF apertures. Shielding effectiveness shall be demonstrated by test to be 6dB for circuitry excepting EEDs and wiring to EEDs. EEDs and EED wiring shall be demonstrated to have a 20dB margin by test or a 34dB margin by test or a 34dB margin by analysis.

b. Cable shielding shall provide a minimum of 85 percent of optical coverage and shall be a minimum of three skin depths thick at the lowest threat frequency. The method for determining optical coverage shall be in accordance with FED–STD–228 or Federal QQ–B–575.

e. Shields shall not be used as intentional current carrying conductors and shall be multipoint grounded.

f. Not applicable.

5.4 Cables

a. Electroexplosive circuit cables shall be individually shielded when bundled in a common cable and a 20dB isolation requirement shall be applied to coupling between any two or more cables. An overshield of the bundled cable shall be used to provide shielding from external sources where required.

5.7.1 Wiring

b. EED firing sources shall be single point grounded and the firing signal to EEDs shall be balanced with respect to ground.

APPENDIX F APPROVED TAILORING/INTERPRETATION AGREEMENTS

EMECB TIA–0042

3.2.9 STATIC ELECTRICITY

Exception: The PEGH (CI No. 222066A) is allowed to use the RIC chip which is not qualified to the SSP 30243 ESD levels.

Rationale: There is only one manufacturer of the RIC chip used in the PEHG design. The I/O connector pins in question are associated with the AUI interface which is not used on–orbit. The PEHG units currently have ESD labeling, in accordance with MIL–STD–1686, warning of potential damage by electrostatic discharges between 4000 and 15,000 volts.

EMECB TIA–0061

3.2.2 SYSTEM, SUBSYSTEM AND EQUIPMENT REQUESTS

Exception: The Ammonia Servicer (PN GS5–00421–001) is exempt from meeting the MIL–STD–461C limits between the ranges of 190 kHz to 250 kHz and 450 kHz to 600 kHz.

Rationale: The DC power for this equipment is provided by another piece of KSC GSE (PMN GS5–00650–001). The EMI testing was performed using this DC source and no degradation of operation was found.