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Revision A

Required Data/Guidelines for Payload/Shuttle Electromagnetic Compatibility Analysis

Space Shuttle Integration and Operations Office
Payload Engineering Integration Office

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National Aeronautics and
Space Administration

Lyndon B. Johnson Space Center
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REQUIRED DATA/GUIDELINES FOR PAYLOAD/SHUTTLE ELECTROMAGNETIC COMPATIBILITY ANALYSIS

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REQUIRED DATA/GUIDELINES

FOR

PAYLOAD/SHUTTLE

ELECTROMAGNETIC COMPATIBILITY ANALYSIS

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PREFACE

This document defines the format and content of the payload electromagnetic data required for the Space Shuttle to integrate a payload into the flight and ground operations. It includes the data requirements for preparation of a Payload's Electromagnetic Data Report, consisting of Radio Frequency (RF) Data, Electromagnetic Compatibility (EMC) Test Data and Thermal Blanket Data. The requirements specified in this document are written for a general payload. Requirements applicable or not applicable to a specific payload will only be added or deleted by mutual agreement.

The customer is requested to provide, on schedule, the defined data and the signed title sheet to the Electromagnetic Environmental Effects (E^3) representative of the Engineering Integration Office/MS2. All data submissions made in response to this document are to be reproducible masters and include a signed signature page and a preface page.

The E^3 representative will review the data for Space Shuttle implementation and contact the customer if further review is required for clarification.

CONTENTS

1.0 INTRODUCTION

The data requested and defined in this document is used by the Electromagnetic Environmental Effects (E^3) representative of the Shuttle Engineering Integration Office. Analysis is performed and the results are then used to determine the compatibility of this payload to the Space Shuttle and all comanifested payloads in the cargo bay and/or the middeck/cabin. If the payload is located in the middeck, the analysis will also determine the compatibility with the crewmembers and cabin equipment.

Comments and corrections, notice of equipment design changes affecting required data and requests for explanations or information concerning Electromagnetic Compatibility (EMC) should be directed to the following:

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1.1 Radio Frequency Characteristics

The Radio Frequency (RF) characteristics defined in section 3.0 are used to conduct a worst-case beat frequency analysis to assess the compatibility of all transmitters, receivers and antennas. The locations of Orbiter antennas that are used on-orbit are shown in the ICD 2-19001. The general locations of all Orbiter antennas are provided in figure 3-1.

The payload transmitter/antenna system data is also used to determine the radiated field intensities impinging on the Extravehicular Activity (EVA) crew, other payloads, and the Space

Shuttle. Consideration is given to the geometries between the antennas and the payloads that are berthed, being deployed and retrieved during free flight.

If any marginal incompatibilities are disclosed, experimental verification and clarification of the conflict may be conducted at the JSC Electronic Systems Test Laboratory (ESTL).

RF incompatibilities may result in the generation of proposed mission RF constraints. The constraints may include antenna selection, frequency and channel requirements, power level and other constraints as required. Constraints are coordinated with the mission's Flight Director and the Mission Operations Directorate's (MODs) communications section, before they are inserted into the payload Payload Integration Plan (PIP) (Mission Integration Plan (MIP) for International Space Station (ISS) flights) and referenced in the mission's Flight Requirements Document (FRD). Generic RF constraints for ISS flights are specified in NSTS 21458.

1.2 Unintentional EME Emissions

The payload customer is required to provide a test report providing the payload's and associated Airborne Support Equipment's (ASEs) unintentional conducted and radiated emissions as delineated in section 4.0.

This report is used to certify that the following do not exceed the limits set forth in NSTS 07700, Volume XIV, Appendix 3, Section 12, Electromagnetic Effects and Requirements and ICD 2-19001, Section 10.7.3, Cargo-Produced Interference Environment.

The limits set forth in these documents should be considered prior to and during the design phase of the payload.

1.3 EME Susceptibility

Mission configuration and the Shuttle's electromagnetic environment should also be considered in payload immunity determination. The Shuttle electromagnetic environment is defined in ICD 2-19001, Section 10.7.2, Shuttle Produced Interference Environment.

All safety-critical payloads must establish electromagnetic environment susceptibility margins as defined in the payload's unique Interface Control Document (ICD).

1.4 Thermal Blanket Electrostatic Discharge

The Thermal Blanket Design and Test Data delineated in section 5.0 shall demonstrate that the thermal blankets do not constitute an Electrostatic Discharge (ESD) threat in the closed payload
bay. ESD has the potential to ignite residual explosive gas mixtures that may exist in the payload bay during ascent and descent.

Significant electrostatic charging mechanisms, if any exist, during any mission phase, must be identified and shown to nonhazardous.

In the event that the payload will not utilize any thermal blanketing, a statement from the customer stating this condition must be provided no later than delineated in section 6.0.

2.0 APPLICABLE DOCUMENTS

The current issue of the following documents form a part of this document to the extent specified herein.

a.	ICD 2-19001	Shuttle Orbiter/Cargo Standard Interface Control Document
b.	NSTS 07700, Vol. XIV	Space Shuttle System Payload Accommodations
c.	SL-E-0002	Specification Electromagnetic Interference Characteristics, Requirements for Equipment
d.	MIL-STD-462	Measurement of Electromagnetic Interference Characteristics

2.1 Reference Only Documents

The following documents contain useful reference information.

a.	NSTS 21458	Standard Integration Agreement For All Space Shuttle Program And International Space Program Missions

b. NSTS 37333 — The Electromagnetic Compatibility Frequency Analysis Computer Program EMCFAB1

3.0 RF DATA REQUIRED FOR THE JSC EMC FREQUENCY ANALYSIS

The payload is to supply the following transmitter, receiver and antenna system data. For reference purposes, the locations of all Orbiter antennas that are used on-orbit are defined in document ICD 2-19001. Information for Orbiter antenna locations and payload antenna pointing angles can be seen in figure 3-1 and figure 3-2, respectively. Information is also available upon request from the USA.

All Beat Frequency Analysis (BFA) parameters can be referenced in NSTS 37333.

3.1 Transmitter System Data

3.1.1 Input Data for Beat Frequency Analysis.-

a. Transmitter system name

b. Modulation type: Continuous Wave (CW), Amplitude (AM), Frequency (FM), Phase (PM), CW, Pulse (PU)

c. Center Frequency (MHz)

d. Modulation frequency OR pulse width (MHz or μsec)

e. Transmitter Output + OR – frequency swing (MHz)

f. Pulse repetition frequency (Pulses/Second)

g. Transmitter output peak power, not including cable or waveguide loss to antenna(s) (W)

h. Number of associated antennas

i. Cable or waveguide loss between the transmitter and each associated antenna(s) (dB)

3.1.2 Input Data For Field Intensity Analysis.-

a. Power distribution and selection scheme, if any

b. Identify transmitter turn on, turn off and power level selection scenario in relation to checkout, deployment, station-keeping, maneuvers and retrieval, as applicable

3.2 Receiver System Data

3.2.1 Input Data For Beat Frequency.-

a. System name

b. Center frequency (MHz)

c. Maximum sensitivity (dBm)

d. 3 dB bandwidth at final Intermediate Frequency (IF) stage (MHz)

e. 60 dB bandwidth at final IF stage (MHz)

f. 3 dB bandwidth with autotrack (MHz)

g. Preselector filter type (BESS, BUTT, C.01, GAUS, LEGR, MDER, SYNC, TRAN)

h. Number of poles in preselector filter

i. Preselector filter maximum attenuation (dB)

j. Preselector filter 3 dB bandwidth (MHz)

k. Preselector filter 60 dB bandwidth (MHz)

l. RF gain into 1^{st} mixer

m. Attenuation between receiver and transmitter (dB)

n. Receiver LO frequency (MHz)

o. 1^{st} low order amplitude into 1^{st} mixer (V)

p. 1^{st} IF 3 dB bandwidth (MHz)

q. 1st IF 60 dB bandwidth (MHz)

r. 2nd IF frequency (MHz)

s. 2nd IF 3 dB bandwidth (MHz)

t. 2nd IF 60 dB bandwidth (MHz)

u. Number of associated antennas

v. Cable or waveguide loss between the receiver and each associated antenna (dB)

w. Number of transmitters operating simultaneously

x. Number of terms in power series for mixing

y. Cable or waveguide loss between the transmitter and each associated antenna(s)

z. Number of antennas connected to the receiver

3.2.2 Input Data For Field Intensity Analysis.-

a. Antenna selection scheme

b. Diplexer, Triplexer, or Quadriplexer insertion loss, as applicable

c. External low noise amplifier gain characteristics, if applicable

d. Image rejection filter attenuation (dB)

e. Maximum “in band” power for proper receiver operation (dBm)

f. Identify turn on, turn off scenario in relation to checkout, deployment, station-keeping, maneuvers and retrieval, as applicable

g. Power threshold to damage receiver at receiver terminals (dBm)

h. Worst case isolation between receiver and associated transmitter

3.3 Antenna System Data

3.3.1 Input Data For Beat Frequency Analysis.-

a. System name associated with antenna

b. Antenna locations in Orbiter Xo, Yo, Zo reference coordinates

   1. For dish antennas, give the feed location.

   2. Mechanical drawings shall be submitted to identify all the payload antennas describing the specific locations and Fields of View (FOV) in the payload bay.

   3. If applicable, the drawings should also describe the specific relocation of payload antennas that are extended, retracted, rotated or swung to a new FOV during payload deployment and retrieval (if applicable) by Remote Manipulator Systems (RMS) or other means.

   4. Identify the Payload Axis System (PAS) and location of the PAS origin.

   5. Locations of receiving antennas shall be provided even if the associated receiver is not activated until the payload is at great range before turn on. (Concern is for inactivated receiver front-end burnout when exposed to high field intensities).

c. List associated antennas (other antennas feeding from or to the same system).

d. Antenna on axis gain (dB)

e. Nonlinear element location in Orbiter Xo, Yo, Zo reference coordinates

f. Antenna pointing angle from the radial and azimuth (deg) as seen in figure 3-2.

g. Antenna field polarization (RHC, LHC,LIN)

h. Antenna effective diameter (m)

i. Antenna efficiency

j. Antenna pattern axial ratio

k. Antenna horizontal polarization tilt angle (deg)

l. Antenna front to back ratio (dB)

3.3.2 Input Data For Field Intensity Analysis.-

a. Provide one of the following for the antenna radiation plot:

    1. Polar Plot

    2. Radiation Distribution Plot

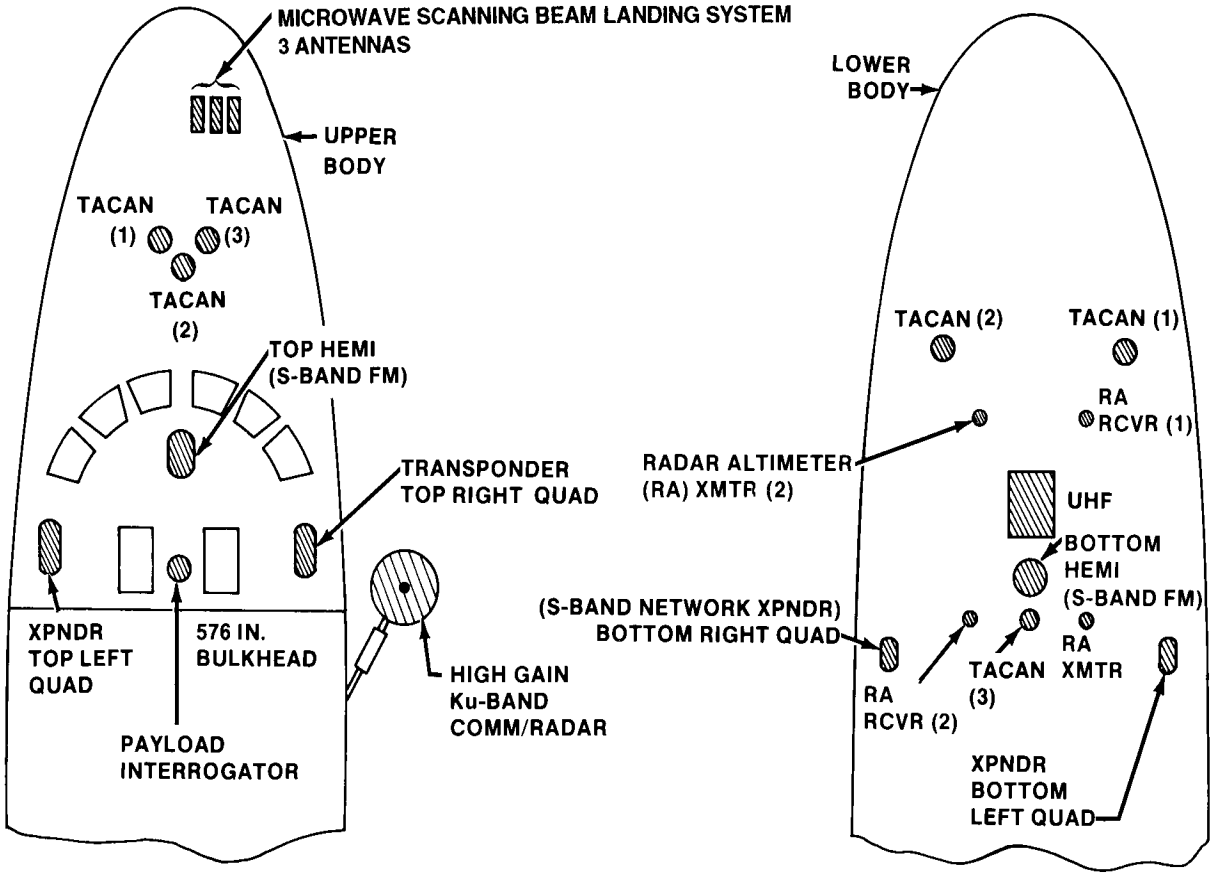

Figure 3-1.- Orbiter antennas.

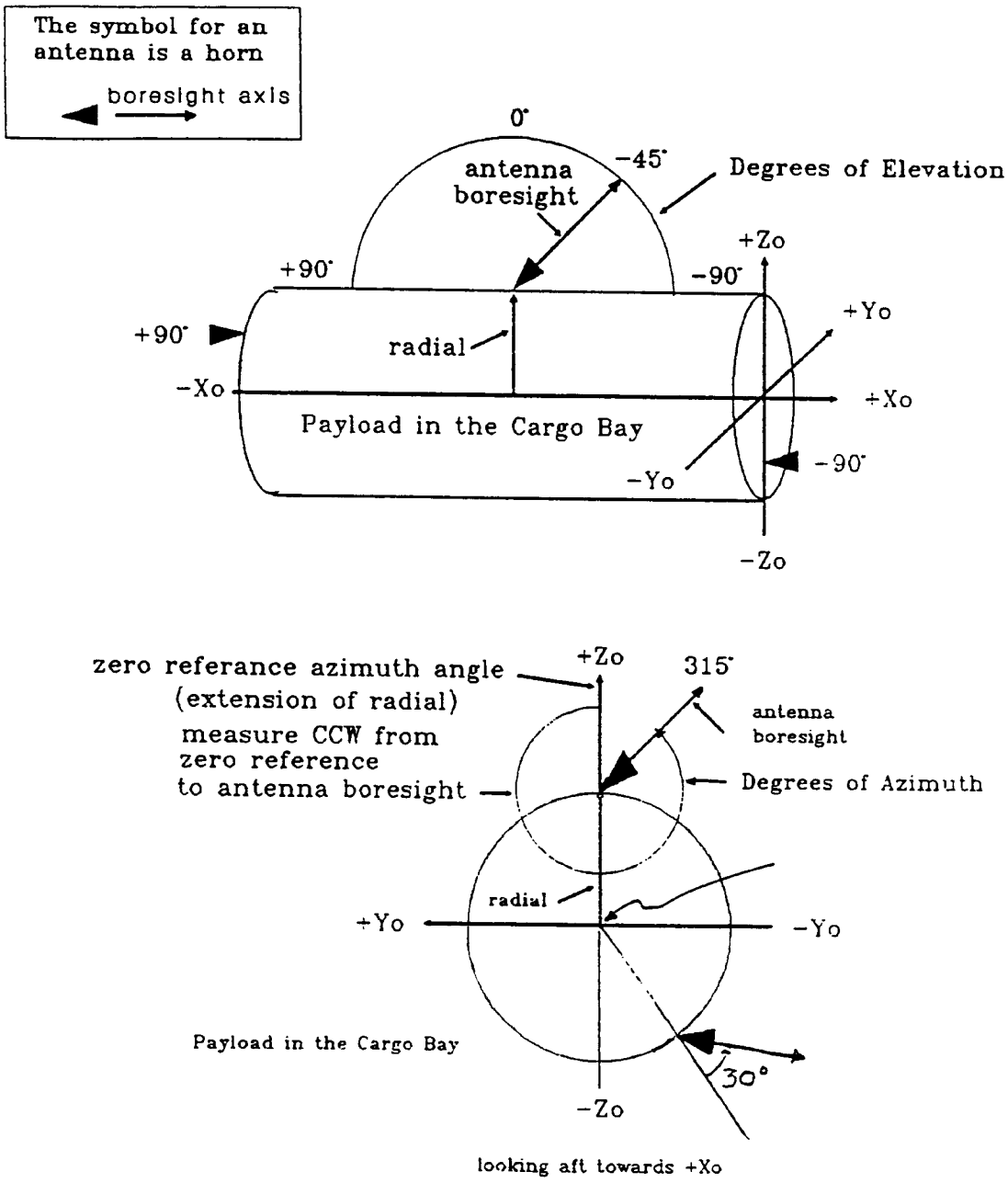

Figure 3-2.- Payload antenna pointing: azimuth and elevation.

4.0 PAYLOAD EMC TEST DATA

4.1 Test Data Delivery

The following test data is required to be delivered to the Space Shuttle Program (SSP) when applicable, and should be delineated in a formal report. The report will be reviewed by the E^3 group at JSC/MS2 to determine compliance with the Unintentional Radiated Emissions Limits and Conducted Emission Limits defined in either ICD 2-19001 or the payload-unique ICD.

The payload customer may request to limit the customary range of radiated and/or conducted frequencies tested due to some unique characteristics of the payload or mission configuration. The request should be made to JSC/MS2 no later than 1 month prior to start of payload EMC testing.

4.2 Unintentional Emissions

4.2.1 Radiated Emissions.- Electric field intensity in dBμV/m vs. frequency in MHz are less than the limits described in figure 10.7.3.2.2.1.1-1 or 10.7.3.2.2.1.1-2 in the ICD 2-19001 for equipment installed internal to the Space Shuttle Vehicle (SSV).

Electric field intensity in dBμV/m vs. frequency in MHz are less than the limits described in figure 10.7.3.2.2.1.2-1 in the ICD 2-19001 for equipment installed external to the crew compartment.

Alternating Current (AC) magnetic flux density in dBpT vs. frequency (30 Hz to 50 KHz) are less than the limits described in paragraph 10.7.3.2.1.1 in the ICD 2-19001.

Direct Current (DC) magnetic fields are less than the limits described in paragraph 10.7.3.2.1.2 in the ICD 2-19001. The source(s) of dc (static) magnetic flux densities greater than 170 dBpT shall be identified and tabulated. The location of each identified electromagnet and/or permanent magnet shall also be tabulated, in Orbiter body coordinates.

4.2.2 Conducted Emissions.- DC ripple current in dBμA vs. frequency in Hz are less than the limits described in paragraph 10.7.3.1.1 in the ICD 2-19001.

DC transient data in voltage excursions vs. time in seconds are less than the limits described in paragraph 10.7.3.1.1 in the ICD 2-19001.

AC ripple current in dBμA vs. frequency in Hz are less than the limits described in paragraph 10.7.3.1.2 in the ICD 2-19001.

AC transient data in voltage excursions vs. time in seconds are less than the limits described in paragraph 10.7.3.1.2 in the ICD 2-19001.

4.3 Radiated and Conducted Susceptibilities (Noise Immunity)

Susceptibility tests are required for payloads designated as Safety Critical. This data shall indicate that the payload's immunity levels are greater than the Shuttle's environmental emission levels, as defined in ICD 2-19001 and/or the payload-unique ICD. The payload customer's EMC Test Plan should employ the test methods in MIL-STD-462 and/or SL-E-0002 as defined by the SSP for Radiated and Conducted Susceptibility testing.

Provision of susceptibility data for nonsafety critical payloads is optional, but recommended. This data is desirable and will provide more evidence for analysis to assure mission success.

5.0 THERMAL BLANKET ESD

5.1 Thermal Blanket Design

ICD 2-19001, section 10.7.4.2.3.5.1 defines the specifications for the following:

a. Bonding of thermal blankets constructed of metalized multilayer construction and metalized surfaces.

b. Number of bond tabs and associated bond straps as determined by the blanket area.

c. Test tabs function as resistance test points between different areas of a blanket or between different areas of two adjacent blankets.

d. Bond tabs function as connection points for static electrical bonding to cargo structure or between different areas of two adjacently connected blankets.

5.2 Thermal Blanket Test Data

The payload customer shall provide data or drawings that describe the payload's exterior thermal blanket(s) design including the following:

a. Type or build-up of the insulation layers and the details on the method of bonding of the layers to each other.

b. Dimensions of each blanket section. (Sections of blankets physically connected to each other, but electrically isolated from each other shall be considered to be individual blankets for bonding purposes).

c. Location of bonding tabs and test tabs on each blanket section.

d. The measured dc resistance in Ohms from all bond tabs to structure.

e. The measured dc resistance, in Ohms, from all blankets, test tab to test tab.

6.0 DATA DELIVERY SCHEDULE

The schedule for each payload to submit the required data is also defined in paragraph 6.3 and in section 15.0 of the individual PIP. The schedule for all payloads is as follows:

Payload Type	RF Data (Transmitters, Receivers, and Antennas)	EMC Test Report	Thermal Blanket Design to Preclude ESD
Spacehabs	90 days prior to CIR	5 months prior to launch	3 months prior to launch
Attached Payloads – ATT	90 days prior to CIR	5 months prior to launch	3 months prior to launch
Deployable-type Payloads – DEP	90 days prior to CIR	5 months prior to launch	3 months prior to launch
Deployable/Retrievable Type Payloads – DRP	90 days prior to CIR	5 months prior to launch	3 months prior to launch

Small Payload Accommodation - SML	90 days prior to CIR	5 months prior to launch	3 months prior to launch
Hitchhiker (exception)	90 days prior to CIR	4 months prior to launch	3 months prior to launch
Middeck Payloads – MDK	5 months prior to launch	3 months prior to launch	N/A

APPENDIX A

KEY DEFINITIONS

BOND. Any fixed union existing between two objects that results in electrical conductivity between the two objects. Such union occurs either from physical contact between conducting surfaces of the objects or from the addition of a firm electrical connection between them.

CONDUCTED NOISE. Undesired electromagnetic emissions propagated along a power or signal conductor. It may consist of steady-state noise, usually given as current vs. frequency and transient noise, usually given as voltage excursions vs. time.

ELECTROMAGNETIC COMPATIBILITY (EMC). The capability of electrical and electronic systems, equipment, and devices to operate in their intended electromagnetic environment with a defined margin of safety and at design levels of performance without suffering or causing degradation as a result of electromagnetic interference.

ELECTROMAGNETIC ENVIRONMENT (EME). The totality of electromagnetic phenomena existing at a given location.

ELECTROMAGNETIC ENVIRONMENTAL EFFECTS (E^3). The totality of electromagnetic phenomena for an overall system in all operational locations.

ELECTROMAGNETIC INTERFERENCE (EMI). Any electromagnetic disturbance, conducted or radiated, whether intentional or not, which interrupts, obstructs, or otherwise degrades or limits the effective performance of electronic/electrical equipment.

ELECTROSTATIC DISCHARGE (ESD). A transfer of charge between bodies at different electrical potentials caused by direct contact or induced by an electrostatic field.

GROUNDING. The bonding of an equipment case, frame, or chassis to an object or vehicle structure to ensure a common potential. The connection of an electric circuit or equipment to Earth or to some conducting body of relatively large extent which serves in place of Earth.

MARGINS. The difference between the equipment threshold of susceptibility and the environment stress to which the equipment is exposed.

RADIATED NOISE: Undesired electromagnetic emissions that are radiated from any unit, antenna, cable or interconnecting wiring. It may consist of electric field intensity vs. frequency or magnetic flux density vs. frequency.

RADIO FREQUENCY (RF) COMPATIBILITY. The ability of the various antenna-connected RF receiver and transmitter subsystems contained within a system to function properly without performance degradation caused by antenna-to-antenna coupling between any two subsystems.

STATIC ELECTRICITY. Stationary electrical charge produced and accumulated or stored on the surface of materials through triboelectric (charge deposition and/or separation by friction, neutral particle impingement, or separation of materials), exogenous (charge inducement by proximity to external electric field effects), or ionic (deposition of charge by a stream of charged particles, such as an engine exhaust) charging processes.

TAILORING. Tailoring is the process by which the requirements of a standard are adapted (that is, modified, deleted, or supplemented) to the characteristics or operational requirements of the item under development. The tailoring process does not constitute a waiver or deviation.

APPENDIX B

ACRONYMS AND ABBREVIATIONS

AC	Alternating Current
AM	Amplitude Modulation
ASE	Airborne Support Equipment
ATT	Attached Payloads
BFA	Beat Frequency Analysis
CCW	Counter Clock Wise
CIR	Cargo Integration Review
CW	Continuous Wave
dB	decibel
dBm	decibels above one milliwatt (power)
dBpT	decibels above one picoTesla (magnetic flux density)
dBμA	decibels above one microampere (current)
dBμV/m	decibels above one microvolt per meter (electric field intensity)
DC	Direct Current
DEG	Degree (angular)
DEP	Deployable Type Payload
DRP	Deployable/Retrievable Type Payload
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
E^3	Electromagnetic Environmental Effects
EMU	Extravehicular Mobility Unit
ESD	Electrostatic Discharge
ESTL	Electronic Systems Test Laboratory
EVA	Extravehicular Activity
FM	Frequency Modulation
FOV	Field of View
FRD	Flight Requirements Document
GFE	Government-Furnished Equipment
HEMI	Hemispherical
Hz	Hertz
ICD	Interface Control Document
IF	Intermediate Frequency
JSC	Lyndon B. Johnson Space Center

KHz	Kilohertz
KSC	John F. Kennedy Space Center
LHCP	Left Hand Circularly Polarized (antenna)
LIN	Linearly Polarized (antenna)
LOS	Line of Sight
MHz	Megahertz
MMU	Manned Maneuvering Unit
MOD	Mission Operations Directorate
MSFC	George C. Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
PAS	Payload Axis System
PIP	Payload Integration Plan
PM	Phase Modulation
RF	Radio Frequency
RHCP	Right Hand Circularly Polarized
RMS	Remote Manipulator System
SAFER	Simplified Aid for EVA Rescue
SLB	Spacelab (Non-MSFC Managed)
SLM	Spacelab (MSFC Managed)
SML	Small Payload Accommodation
μsec	microseconds
V	Volts
vs	versus
W	Watts
Xo	Orbiter X Structural axis (nose -, tail +)
Yo	Orbiter Y Structural axis (port [left] -, starboard [right] +)
Zo	Orbiter Z Structural axis (down -, up +)

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