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Space Administration

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CONSTELLATION PROGRAM ELECTROMAGNETIC ENVIRONMENTAL EFFECTS (E3) REQUIREMENTS DOCUMENT ANNEX 1: CREW LAUNCH VEHICLE (CLV) E3 REQUIREMENTS FINAL DRAFT

The electronic version is the official approved document.
Verify this is the correct version before use.

REVISION AND HISTORY PAGE

Status	Revision No.	Change No.	Description	Release Date
Draft	-		Draft Maturity XX%	XX/XX/XX
Baseline	-		Baseline (Reference CxCBD CXXXXXX/X-X, dated XX/XX/XX)	XX/XX/XX
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Revision	A		Revision A (Reference CxCBD CXXXXXX/X-X, dated XX/XX/XX) also includes CxCBD CXXXXXXRX/X-X dated XX/XX/XX	XX/XX/XX

NOTE: Updates to this document, as released by numbered changes (Change XXX), are identified by a black bar on the right margin.

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1.0 INTRODUCTION

CxP 70080, Constellation Program Electromagnetic Environmental Effects (E3) Requirements Document, contains E3 requirements that are applicable to the Constellation Architecture. This document, the Crew Launch Vehicle (CLV) Annex to CxP 70080, contains the E3 requirements for the CLV.

1.1 PURPOSE

The purpose of this document is to define the Constellation Program E3 requirements that are applicable, either directly or in modified form, to the CLV. These requirements will be used in the development and operation of the various elements that will compose the overall CLV system.

1.2 SCOPE

This document provides detailed E3 requirements applicable to the CLV and its elements (First Stage, Upper Stage, Upper Stage Engine). The CLV and CLV element developers are responsible for passing the pertinent requirements on to the subsystem and component level in order to produce a compatible CLV.

1.3 CHANGE AUTHORITY/RESPONSIBILITY

Proposed changes to this document shall be submitted by a Constellation Program Change Request (CR) to the appropriate Constellation Control Board for consideration and disposition.

The CR must include a complete description of the change and the rationale to justify its consideration. All such requests will be processed in accordance with CxP 70073-01, Constellation Program Management Systems Requirements, Volume 1: Configuration Management Requirements.

The appropriate NASA Office of Primary Responsibility (OPR) identified for this document is XXXX.

2.0 DOCUMENTS

2.1 APPLICABLE DOCUMENTS

The following documents include specifications, models, standards, guidelines, handbooks, and other special publications. The documents listed in this paragraph are applicable to the extent specified herein.

CxP 70000 Constellation Architecture Requirements Document (CARD)

CxP 70023 Constellation Design Specification for Natural Environments (DSNE)

CxP 70024	Constellation Program Human Systems Interface Requirements (HSIR)
CxP 70050 Vol 1	Constellation Program Electrical Power System Specification Volume 1: Electrical Power Quality Performance for 28VDC
CxP 70050 Vol 2	Constellation Program Electrical Power System Specification Volume 2: User Electrical Power Quality Performance for 28VDC
CxP 70080	Constellation Program Electromagnetic Environmental Effects (E3) Requirements Document
CxP 70038	Constellation Program Hazard Analysis Methodology
NASA-STD-4003	Electrical Bonding for NASA Launch Vehicles, Spacecraft, Payloads, and Flight Equipment
MIL-STD-461E	Requirements for the Control of Electromagnetic Interference Characteristics of subsystems and Equipment
MIL-STD-1576 (USAF)	Electroexplosive Subsystem Safety Requirements and Test Methods for Space Systems
SAE ARP5412A	Aircraft Lightning Environment and Related Test Waveforms
SAE ARP5413	Certification of Aircraft Electrical/Electronic Systems for the Indirect Effects of Lightning
ANSI/ESD S20.20-1999	ESD Association Standard for the Development of an Electrostatic Discharge Control Program for Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices)
SAE ARP5414A	Aircraft Lightning Zoning
SAE ARP5415A	User’s Manual for Certification of Aircraft Electrical/Electronic Systems for the Indirect Effects of Lightning

SAE ARP5416	Aircraft Lightning Test Methods
SAE ARP5577	Aircraft Lightning Direct Effects Certification

2.2 REFERENCE DOCUMENTS

The following documents contain supplemental information to guide the user in the application of this document.

MIL-STD-464A	Electromagnetic Environmental Effects Requirements for Systems
RTCA DO-160E	Environmental Conditions and Test Procedures for Airborne Equipment, Section 22, Lightning Induced Transient Susceptibility and Section 23, Lightning Direct Effects

3.0 GENERAL

The Constellation Architecture shall be electromagnetically compatible among all systems, subsystems and equipment within the Constellation Architecture and with environments caused by electromagnetic effects external to the Constellation Architecture. Examples of external sources of electromagnetic effects include, but are not limited to, RF fields from range radars, electrostatic charging, direct effects from lightning attachments to the vehicle or launch pad, and indirect electromagnetic effects from lightning attachments to the launch pad protection system or nearby structures and facilities.

APPLICABILITY: As written

3.1 MARGINS

Margins shall be provided based on Constellation operational performance requirements, tolerances in Constellation hardware, and uncertainties involved in verification of Constellation system-level design requirements.

APPLICABILITY: As written

3.1.1 Pyrotechnic Margins

Electrically initiated pyrotechnic devices shall have a demonstrated margin of 16.5 decibels (dB) above the maximum no-fire stimulus.

APPLICABILITY: As defined.

3.2 INTRA-SYSTEM ELECTROMAGNETIC COMPATIBILITY (EMC)

Each Constellation system shall be electromagnetically compatible within itself such that system operational performance requirements are met. This includes ground operations as well as launch, on-orbit, landing, and recovery.

APPLICABILITY: As modified. The requirement applies to the CLV system as well as the individual CLV elements (First Stage, Upper Stage, Upper Stage Engine).

3.2.1 MOBILE LAUNCHER PLATFORM, LAUNCH PAD, AND SIMILAR STRUCTURE INTERNAL ELECTROMAGNETIC ENVIRONMENT (EME)

For steel structures on a comparable scale to that of the test, assembly and checkout facilities, the mobile launcher platform, the launch pad, or larger, electric fields in enclosed volumes resulting from exposure to intentional transmitters shall be no greater than 10 V/m above 200 MHz, up to 18 GHz.

APPLICABILITY: TBD

3.2.2 MULTIPACTION

Equipment and subsystems shall be free of multipaction effects.

APPLICABILITY: As written

3.3 EXTERNAL RF EME

The system shall be electromagnetically compatible with the external radio frequency (RF) electromagnetic environment (EME) defined in Table 1 and Figures 1 through 4 such that operational performance requirements are met.

APPLICABILITY: As modified. The Launch Processing and Launch RF EME is applicable to all CLV elements. The First Stage Recovery Operations RF EME is applicable to CLV First Stage only. Note: The CEV Recovery EME portions of Table 1 and Figure 3 are included in this document only for completeness. These are not applicable to CLV.

TABLE 1 EXTERNAL RF ELECTROMAGNETIC ENVIRONMENT

Launch Processing and Launch Electromagnetic Environment

Frequency (MHz)	Peak (V/m)	Average (V/m)
49	6	5
437 - 447	7	5
2040	8	8
2106	7	7
2865	17	5
3100 - 3500	9	5
4440	9	9
4560	9	9
4640	9	9
4740	9	9
5400 - 5650	113	5
5650 - 5850	189	11
5850 - 5900	113	21
5900 - 5925	21	21
9370 - 9500	17	5
9500 - 9800	40	7
9800 - 9990	17	5
13750 - 14000	32	32

On-Orbit Electromagnetic Environment

Frequency (MHz)	Peak (V/m)	Average (V/m)
11 - 12	27	27
108.00	17	17
404 - 420	11	5
420 - 437	14	14
437 - 447	23	14
447 - 450	14	14
1175 - 1375	30	8
1550 - 1787	14	5
1787	43	43
1787 - 2091	14	5
2091	30	30
2091 - 2110	14	5
2110 - 2120	30	30
2120 - 2145	14	5
2145	93	5
2145 - 2380	14	5
2380	189	189
2380 - 2840	14	7
2840	24	6
2840 - 2870	14	6

2870	24	6
2840 - 2951	14	6
2951	22	5
2951 - 4000	14	6
4000	85	85
4000 - 5400	15	5
5400 - 5660	27	5
5660	27	11
5660 - 5850	27	5
5850 - 5925	27	25
5925 - 6425	9	9
7155 - 7189	24	24
7209	6	6
8500 - 8560	7	5
8560	117	117
8560 - 9355	7	5
9355	142	5
9355 - 10000	7	5
10000	48	5
10593	10	10
14000 - 14500	10	10
16700	17	10
23530 - 23575	24	24
34316	7	7
34500 - 35200	11	11

CEV Recovery Electromagnetic Environment

Frequency (MHz)	Peak (V/m)	Average (V/m)
127	19	19.0
170	60	60
1270 - 1349	37	5
2042	22	22
2061 - 2086	7	7
2091	68	68
2091 - 2095	7	7
2098	9	9
2106	22	22
2110	68	68
2110 - 2115	60	60
2320	54	54
2708	18	5
2712	145	5
2717 - 2745	18	5
2750	9	5
2765 - 2780	11	5
2780	145	5

2780 - 2840	18	5
2860	63	5
2865	7	5
2885	21	5
2890	7	5
2905	9	5
2905	12	12
2922	73	5
2934	10	5
3080	6	5
3100	32	5
3206 - 3386	6	5
4950	55	5
5400	208	5
5450 - 5660	155	5
5660	614	13
5660 - 5740	155	5
5748	268	5
5750	164	5
5765	71	5
5765 - 5800	155	5
5840	14	5
6500	98	5
6619	47	47
7145 - 7300	54	54
7930	107	5
8560	261	261
9000 - 9200	7	7
9220 - 9255	57	5
9265 - 9290	10	5
9310 - 9375	44	5
9455	55	5
9500	151	5
9800 - 10020	44	5
15250	7	7
22000	19	5
34200	6	6
34316	6	6

First Stage Recovery Electromagnetic Environment

Frequency (MHz)	Peak (V/m)	Average (V/m)
437 - 447	7	5
2865	7	5
3100 - 3500	9	5
5640.00	6	5
5650 - 5850	43	5

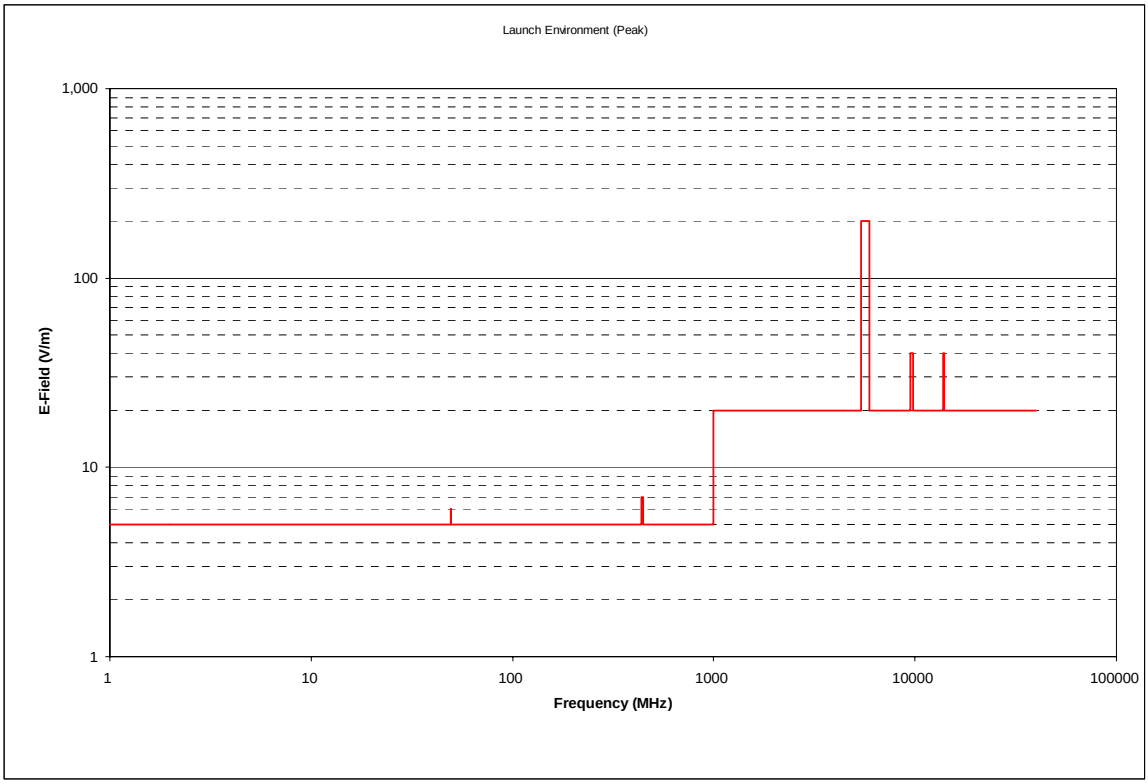


FIGURE 1 LAUNCH PROCESSING AND LAUNCH RF EME (PEAK ENVIRONMENT)

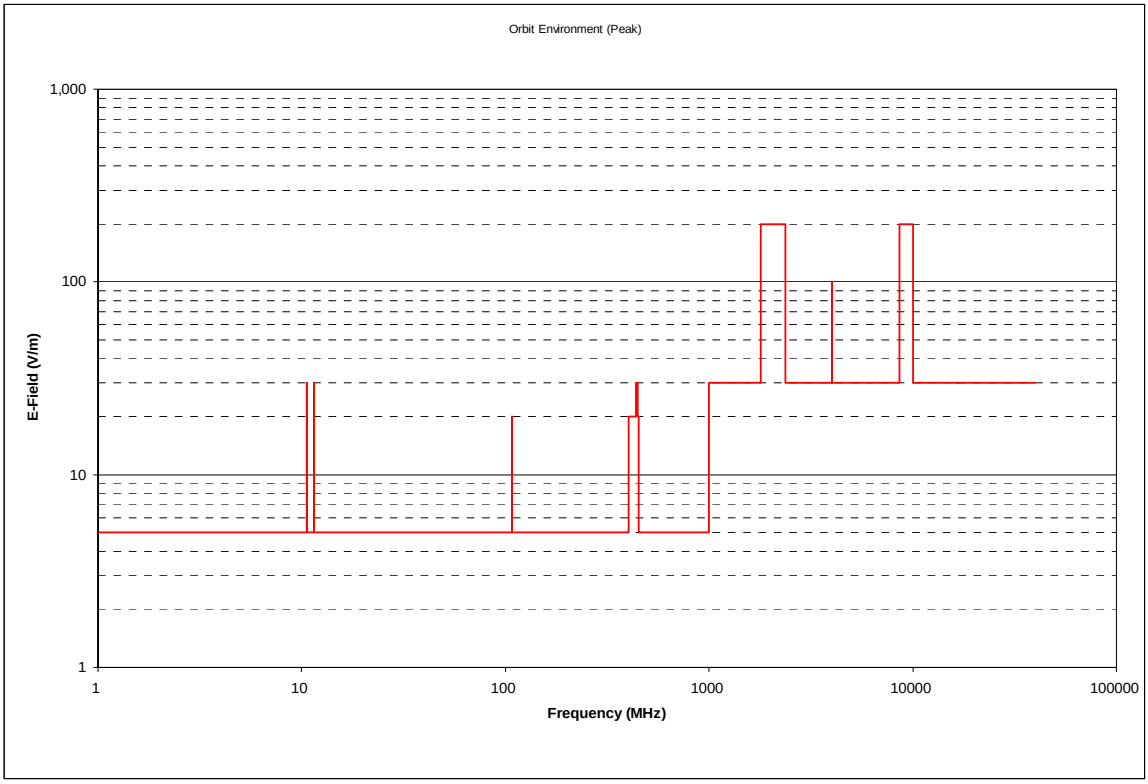


FIGURE 2 ON-ORBIT RF EME

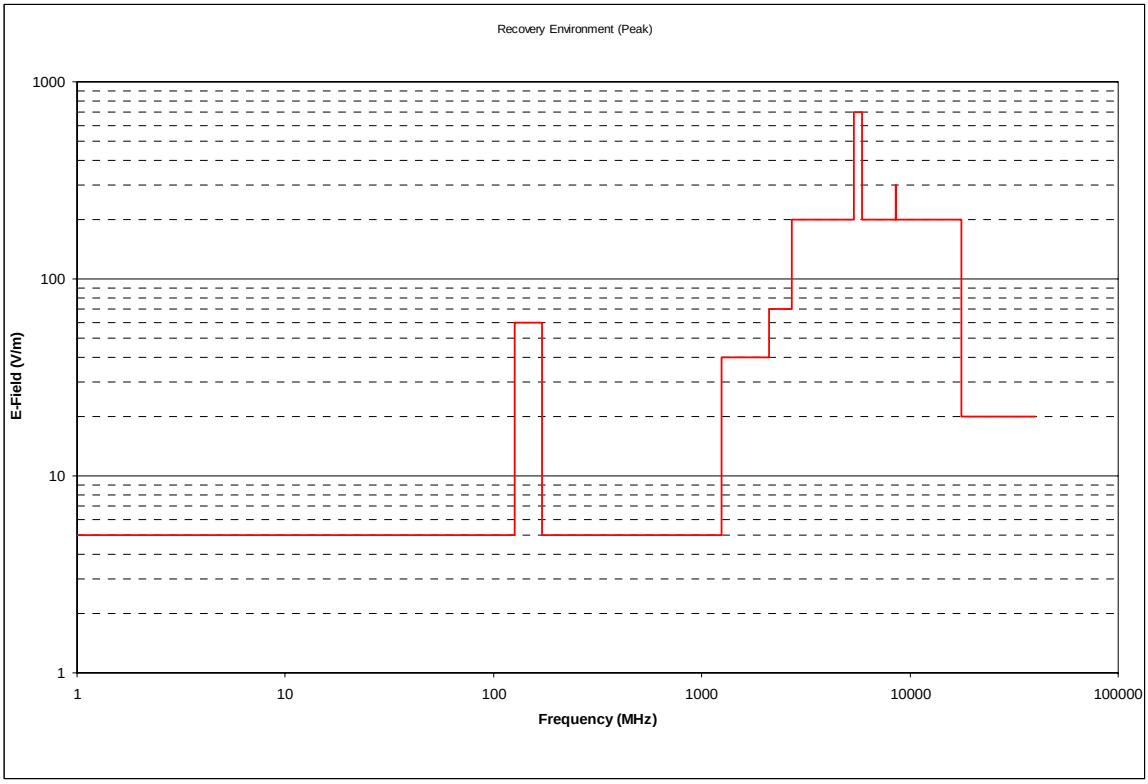


FIGURE 3 CEV RECOVERY OPERATIONS RF EME

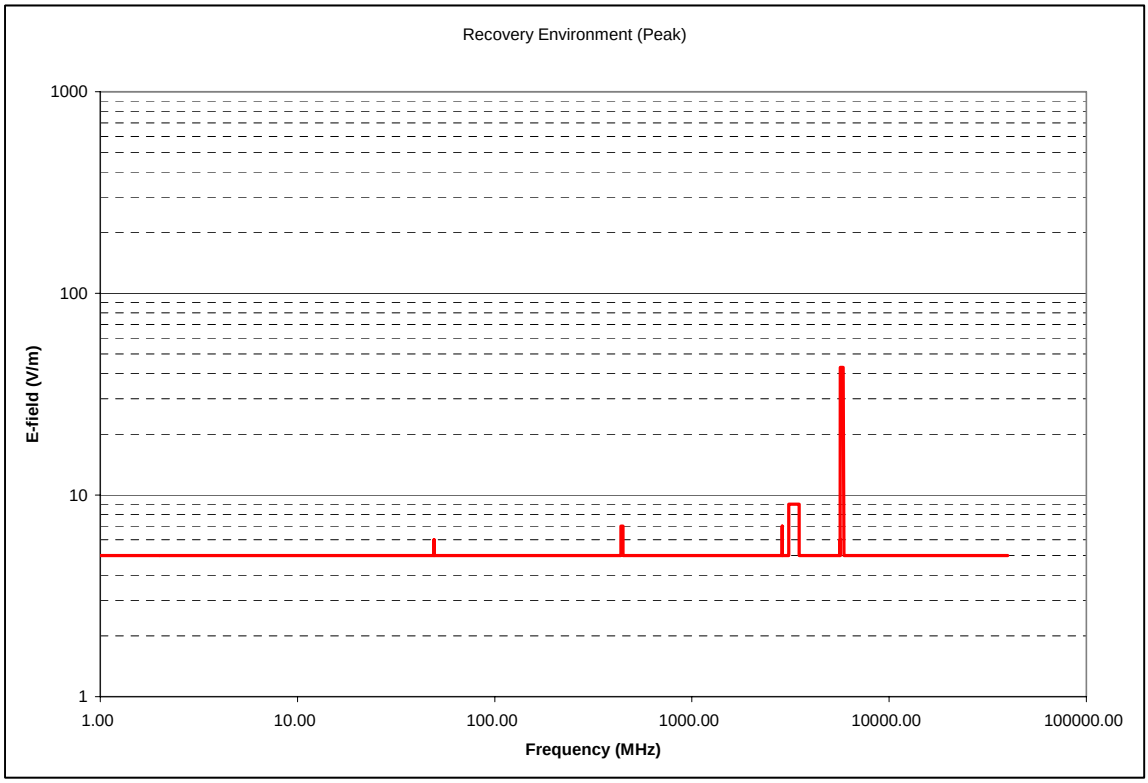


FIGURE 4 FIRST STAGE RECOVERY OPERATIONS RF EME

3.4 EXTERNAL COMPATIBILITY

The Constellation systems and associated subsystems shall be electromagnetically compatible with all equipment and interfaces external to the Constellation Architecture.

APPLICABILITY: As written. Primary external interfaces identified for CLV include the Communications and Tracking (C&T) Network, the Eastern Range, and Recovery Forces (First Stage only).

3.5 LIGHTNING

The Constellation systems shall meet their operational performance requirements in the event of a lightning direct attachment or nearby lightning events, or other atmospheric electrical environments, as described in CXP 70023 Exploration Architecture Design Specification for Natural Environments (DSNE) Paragraphs 3.1.11, Lightning During On-pad Operations; 3.2.12, Natural and Triggered Lightning During Launch and Ascent; 3.5.3, Lightning During Normal Landing Operations; 3.6.3, Lightning During Abort Landing Operations; and 3.7.3, Lightning During Post-Flight and Recovery Operations in the Normal Landing Area.

These environments include the following:

Lightning electromagnetic effects due to lightning strikes to lightning protection facilities

Nearby lightning strikes while the Constellation vehicle is on the launch pad

Direct lightning strikes to the Constellation system during ground processing, launch, and recovery

The Society of Automotive Engineers (SAE) has published a series of Aerospace Recommended Practices (ARPs) that provide information concerning lightning interactions with aircraft, certification guidance for direct effects and indirect effects, and test methods. These documents, SAE ARP5412, “Aircraft Lightning Environment and Related Test Waveforms,” SAE ARP5413, “Certification of Aircraft Electrical/Electronic Systems for the Indirect Effects of Lightning,” ARP5414, “Aircraft Lightning Zoning,” SAE ARP5415, “User’s Manual for Certification of Aircraft Electrical/Electronic Systems for the Indirect Effects of Lightning,” SAE ARP5416, “Aircraft Lightning Test Methods,” SAE ARP5577, “Aircraft Lightning Direct Effects Certification,” are the source of lightning requirements and test methodologies contained or referred to herein.

The most successful lightning protection design and certification programs (successful means achieving a compliant protection design with minimum weight and cost impact) are achieved when the lightning protection efforts proceed in a logical, stepwise manner.

The basic steps are:

Locate lightning strike zones on the vehicle

Establish the lightning environment

Identify flight critical components or systems

Establish protection criteria

Design lightning protection measures

Verify protection adequacy

APPLICABILITY: As written. CXP 70023 Exploration Architecture Design Specification for Natural Environments (DSNE) Paragraphs 3.1.11, Lightning During On-pad Operations, 3.2.12 and Natural and Triggered Lightning During Launch and Ascent, 3.5.3 are applicable to the CLV and CLV elements. Additionally, paragraph 3.7.3, Lightning During Post-Flight and Recovery Operations in the Normal Landing Area is applicable to the CLV First Stage.

3.5.1 Direct Effects

The Constellation systems, subsystems, or components shall be protected against catastrophic, hazardous/severe-major, or major failures when subjected to direct lightning attachment environments described in SAE ARP5412A, Aircraft Lightning Environment and Related Test Waveforms, Section 6 and CXP 70023 Exploration Architecture Design Specification for Natural Environments (DSNE) Paragraphs 3.1.11, Lightning During On-pad Operations, 3.2.12, Natural and Triggered Lightning During Launch and Ascent, 3.5.3, Lightning During Normal Landing Operations, 3.6.3, Lightning During Abort Landing Operations, 3.7.3, Lightning During Post-Flight and Recovery Operations in the Normal Landing Area.

APPLICABILITY: As written.

Figure 5 is reproduced here for information and shows the basic steps for meeting and verifying CLV lightning direct effects requirements.

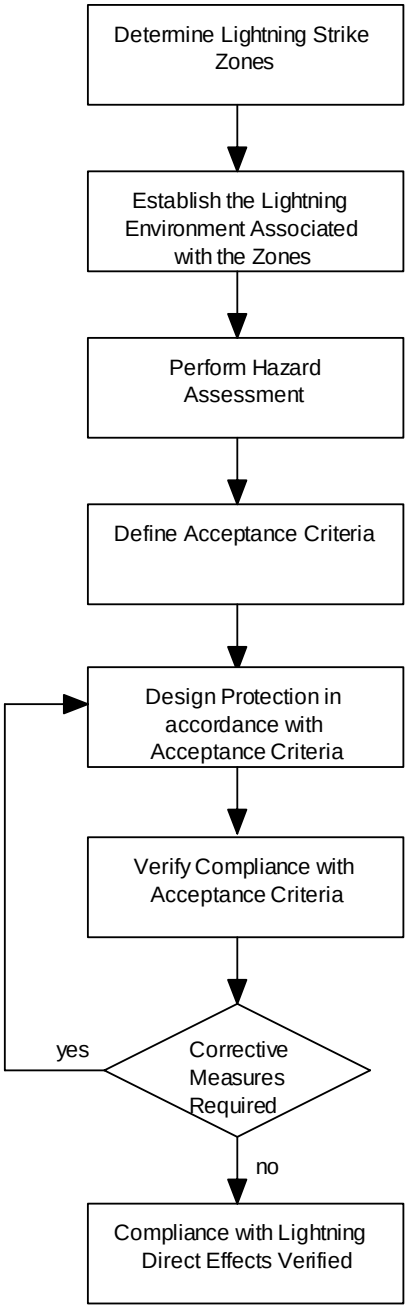


FIGURE 5 STEPS IN LIGHTNING DIRECT EFFECTS PROTECTION

3.5.1.1 Zoning

The lightning attachment zones shall be determined for the integrated Constellation systems using the attachment zone definitions, the zone location process, and initial leader attachment location methods of Sections 5, 7 & 8, respectively, of SAE ARP5414, Aircraft Lightning Zoning.

APPLICABILITY: As modified. The integrated stack will be the configuration primarily exposed to the lightning environment. Therefore, the lightning attachment zones shall be determined for the integrated stack (CEV and CLV).

3.5.1.2 Zone Lightning Environment

The lightning environment associated with the identified lightning zones shall be established using voltage waveforms and current components of Section 6.4 of SAE ARP5412A.

APPLICABILITY: As modified. The integrated stack will be the configuration primarily exposed to the lightning environment. Therefore, the lightning attachment zones environments shall be determined for the integrated stack (CEV and CLV).

3.5.1.3 Hazard Assessment – Direct Effects

The effects of lightning voltage waveforms and current components on all Constellation systems structures, subsystems and components shall be evaluated to determine the possible safety consequences of any lightning damage and to identify element structure, systems and components whose failure or malfunction due to a lightning strike could contribute to or lead to catastrophic effects either immediately or after some delay.

CxP 70038 provides the methodology and guidance for performing various safety analyses for the Constellation Program. The Functional Hazard Assessment (FHA) process described herein supplements the overall Constellation Program safety analysis process by identifying critical functions whose failure or malfunction due to lightning could contribute or lead to catastrophic effects. The FHA process provides for detailed examination of both direct and indirect effects of lightning at the subsystem, equipment or component level. The documented results of the FHA process described herein shall be consistent with the terminology and definitions contained in CxP 70038, Constellation Program Hazard Analysis Methodology.

APPLICABILITY: As written. Typical items that should be analyzed and addressed in the hazard assessment are:

Damage to or loss of aerodynamic fairings and covers

Melting and subsequent loss of fasteners

Melting or other weakening of structural components due to heating

Deformation of structural components

Burn through of tank walls and fuel lines

Damage due to pitting of moveable surfaces such as hydraulics (seal damage) or control surfaces (jack screws, hinges, etc.)

Damage due to melting or welding of components (especially moveable surfaces)

Damage to nonmetallic structures (including punch-through or delamination)

Damage to wiring (either through direct attachment to exposed wiring or attachment to wiring after punch-through of outer surfaces

It should be noted that a loss of redundancy may occur that would not directly lead to a catastrophic hazard or failure. The loss of redundancy should also be evaluated during the hazard assessment.

3.5.1.4 Definition of Acceptance Criteria

As a result of the direct effects hazard assessment, the maximum direct effects acceptance criteria shall be defined. These acceptance criteria will be used in determining compliance to the direct effects requirements herein.

APPLICABILITY: As written. The acceptance criteria are the maximum amount of damage that could be sustained during a lightning event and still maintain safe operations (or prevent a catastrophic event from occurring in the case of operations on the ground).

3.5.1.5 Compliance with Acceptance Criteria

Damage to Constellation systems structures, subsystems and components shall be less than the maximum lightning direct effects acceptance criteria accepted by the procuring agency.

APPLICABILITY: As written.

3.5.2 Indirect Effects

The Constellation systems, subsystems, or components shall be protected against catastrophic, hazardous/severe-major, or major failures when the vehicle is subjected to the indirect lightning environment described in SAE ARP5412A, Aircraft Lightning Environment and Related Test Waveforms, Section 6 and CXP 70023 Exploration Architecture Design Specification for Natural Environments (DSNE) Paragraphs 3.1.11, Lightning During On-pad Operations, 3.2.12, Natural and Triggered Lightning During Launch and Ascent, 3.5.3, Lightning During Normal Landing Operations, 3.6.3,

Lightning During Abort Landing Operations, 3.7.3, Lightning During Post-Flight and Recovery Operations in the Normal Landing Area.

A menu of typical lightning-induced transient waveforms and amplitudes is provided for use in formulating system and equipment test requirements in Section 7 of SAE ARP5412A. Constellation contractors must do the engineering analyses and/or full system tests in order to determine the appropriate transient waveforms and amplitudes that are applicable to specific wire harnesses and associated systems/equipment within the Constellation systems.

APPLICABILITY: As modified. In addition to the flight configuration, the CLV shall meet the indirect effects requirements of the following paragraphs during prelaunch conditions when umbilicals are connected during ground operations.

Figure 6 is reproduced here for information and shows the basic steps for meeting and verifying Constellation lightning indirect effects requirements.

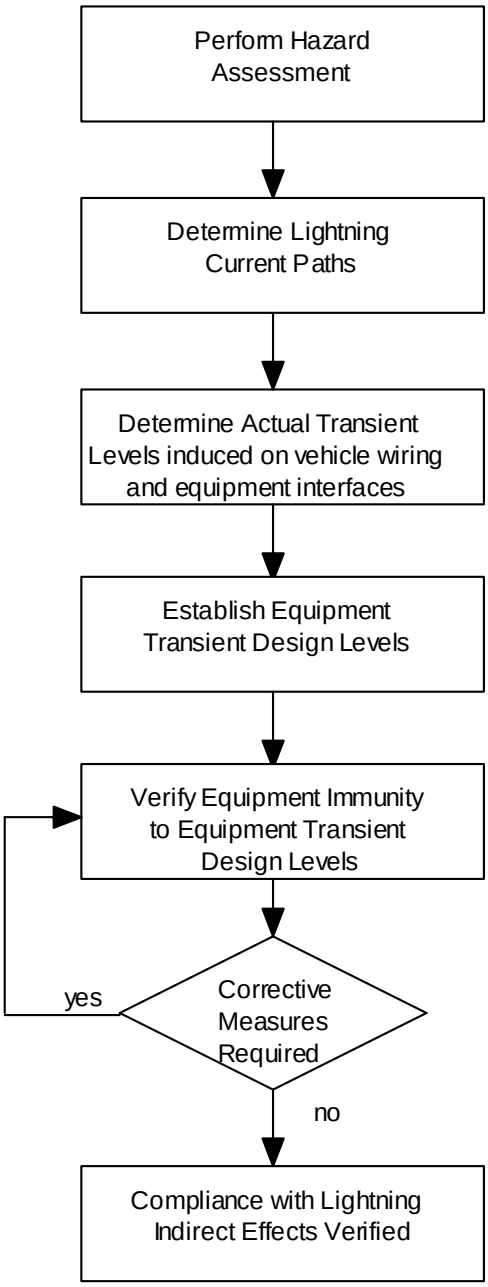


FIGURE 6 STEPS IN LIGHTNING INDIRECT EFFECTS PROTECTION

3.5.2.1 Hazard Assessment– Indirect Effects

The effects of lightning voltage waveforms and current components on all Constellation systems subsystems and equipment shall be evaluated to determine the possible safety consequences of any lightning effects and to identify element subsystems and equipment whose failure or malfunction due to a lightning strike could contribute to or lead to catastrophic effects either immediately or after some delay.

CxP 70038 provides the methodology and guidance for performing various safety analyses for the Constellation Program. The Functional Hazard Assessment (FHA) process described herein supplements the overall Constellation Program safety analysis process by identifying critical functions whose failure or malfunction due to lightning could contribute or lead to catastrophic effects. The FHA process provides for detailed examination of both direct and indirect effects of lightning at the subsystem, equipment or component level. The documented results of the FHA process described herein shall be consistent with the terminology and definitions contained in CxP 70038, Constellation Program Hazard Analysis Methodology.

APPLICABILITY: As written. Indirect effects manifest in either component damage or system functional upset. The damage mechanisms for electronic components include dielectric breakdown due to voltage overstress and thermal effects due transient current flow.

System functional upset is an impairment of system operation, either permanent or temporary. Upset may take the form of state change, system reinitialization, or some other anomalous behavior. The hazard assessment should asses the complete system architecture, including hardware, interconnects, and software. It should also??

NOTE: In this context, *system* refers to an assemblage of equipment working together to perform a function or functions and is used in the generic sense.

3.5.2.2 Lightning Current Paths

The possible vehicle lightning current paths through the Constellation Architecture shall be identified using the previously defined lightning zones to identify possible lightning entry and exit locations.

The paths taken by lightning currents if the Constellation hardware is directly struck by lightning while on the pad (where currents in electrical umbilical, fuel and crew access facilities may be applicable), during launch, and during recovery are to be determined based upon the applicable lightning strike zones. These current paths must be identified so that appropriate measures can be designed to prevent associated hazards

APPLICABILITY: As modified. The integrated stack will be the configuration primarily exposed to the lightning environment. Therefore, the lightning current paths shall be determined for the integrated stack (CEV and CLV).

3.5.2.3 Internal Environment

The effects of the internal lightning environment shall be defined by establishing:

a) Actual Transient Levels (ATL's) that can be induced in interconnecting wiring and appear at electrical/electronic equipment interfaces. *Note:* The induced transients will be defined, in most cases, in terms of open circuit voltage (V_{oc}) and short circuit current (I_{sc}) appearing at equipment interfaces. The voltage and current will be related by the source or loop impedances of the interconnecting wire. There may be different ATLs for different circuit functions, locations, amount of shielding, or operating voltages.

b) Equipment Transient Design Levels (ETDL's) that represent the amplitudes of voltage and/or current that the Constellation Architecture subsystems or equipment are required to withstand and remain operational (e.g., no damage or system functional upset). Note: The difference between ETDL and ATL is the margin discussed in Section 3.1. The Equipment Transient Susceptibility Level (ETSL) is a level at which some damage or upset occurs in equipment or systems and is higher than the ETDL.

APPLICABILITY: As written.

3.5.2.3.1 Actual Transient Level Determination

ATLs shall be determined by test and/or analysis using methods found in SAE ARP5415, User's Manual for Certification of Aircraft Electrical/Electronic Systems for the Indirect Effects of Lightning, Section 4 for analysis, and SAE ARP5416, Aircraft Lightning Test Methods, Section 6.1, Aircraft Tests.

APPLICABILITY: As written.

3.5.2.3.2 Equipment Transient Design Level Determination

ETDLs shall have, as a minimum, a 6 dB (2:1) margin over the previously determined ATLs.

APPLICABILITY: As written

3.5.2.4 Compliance with Equipment Transient Design Levels

Equipment and subsystems shall be immune from damage or upset when subjected to the established ETDLs in accordance with Sections 4 and 6 of SAE ARP5416, Aircraft Lightning Test Methods and RTCA/DO-160 (latest version), Environmental Conditions,

and Test Procedures for Airborne Equipment, Section 22, Lightning Induced Transient Susceptibility.

APPLICABILITY: As written.

3.5.3 Lightning Protection of Individual Elements

The individual Constellation systems, when not integrated into the integrated Constellation Architecture, shall be protected against catastrophic or hazardous/severe-major failures from direct and indirect lightning environments described in SAE ARP5412A, Aircraft Lightning Environment and Related Test Waveforms, Section 6, and CXP 70023 Exploration Architecture Design Specification for Natural Environments (DSNE) Paragraphs 3.1.7, Lightning During On-pad Operations, during ground operations, shipping and transportation, refurbishment, and/or other related operations.

APPLICABILITY: As written.

3.6 SUBSYSTEMS AND EQUIPMENT ELECTROMAGNETIC INTERFERENCE (EMI)

Individual subsystems and equipment shall meet electromagnetic interference (EMI) control requirements of MIL-STD-461E, as modified for the various Constellation systems and locations in the attached annexes, so that the Constellation architecture complies with all applicable requirements of this document.

APPLICABILITY: As modified. CLV subsystems and equipment, as well as special test equipment (STE), ground support equipment (GSE), servicing GSE, and core avionics test set (CATS) shall meet the EMI requirements of CxP 72047, Crew Launch Vehicle (CLV) Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment.

3.6.1 Non-developmental items (NDI) and commercial items

Non-developmental items (NDI) and commercial items shall meet EMI interface control requirements so that Constellation Systems' operational performance requirements are met. These EMI interface control requirements are outlined in the following paragraphs and are based on the use of the NDI or commercial item..

APPLICABILITY: As modified. NDI and commercial items used in CLV subsystems and equipment, including STE, GSE, servicing GSE, and CATS shall meet the EMI requirements of CxP 72047, Crew Launch Vehicle (CLV) Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment.

3.6.1.1 NDI and Commercial Information Technology Equipment

NDI and commercial Information Technology Equipment (ITE) used in non-critical, office building or laboratory settings shall meet either the Class B emissions requirements of CISPR 22: 2006, Information Technology Equipment – Radio

Disturbance Characteristics – Limits and Methods of Measurements, or the Class B emissions requirements of Title 47, Code of Federal Regulations, Part 15 – Radio Frequency Devices.

APPLICABILITY:

3.6.1.2 NDI/Commercial Items used as Flight Hardware

NDI and commercial items that are used as flight hardware shall meet EMI control requirements of MIL-STD-461E as modified for the various Constellation Systems and locations in which the items are used.

APPLICABILITY:

3.6.1.3 NDI/Commercial Items used in Electrical Ground Support Equipment

NDI/Commercial items used in electrical ground support equipment (EGSE) and core avionics test set (CATS) equipment shall meet EMI control requirements of MIL-STD-461E, as modified for the various Constellation systems and locations in which the items are used. EGSE is defined as all non-flight hardware designed to functionally test, checkout, or operate the electrical system of Constellation subassemblies, assemblies, or elements during system-level ground testing. CATS is defined as the core complement of EGSE components need to provide power, data, and RF interfaces to the System, elements, or subsystems.

APPLICABILITY:

3.7 ELECTROSTATIC CHARGE CONTROL

The system shall control and dissipate the build-up of electrostatic charges caused by precipitation static (p-static) effects, fluid flow, air flow, exhaust gases flow, personnel charging, charging of launch vehicles (including pre-launch conditions) and space vehicles (post deployment), and other charge generating mechanisms to avoid fuel ignition and ordnance hazards, to protect personnel from shock hazards, and to prevent performance degradation or damage to electronics.

APPLICABILITY: As modified. The build-up of electrostatic charges caused by fluid flow, air flow, exhaust gases flow, charging of launch vehicles (including pre-launch conditions), and other charge generating mechanisms shall be controlled by meeting the Class H and Class S requirements of NASA-STD-4003 as required in paragraph 3.10 of this document.

Unpowered electronic equipment and components shall not be damaged by electrostatic discharges (ESD) equal to or less than 4000 Volts to the case of the equipment or to any pin on external connectors. Equipment sensitive to ESD events at

levels between 4000 Volts and 15000 Volts shall be labeled as ESD sensitive. Equipment labeled as ESD sensitive shall be handled to prevent damage to equipment or latent failures using procedures and processes developed in accordance with ANSI/ESD S20.20-1999, ESD Association Standard for the Development of an Electrostatic Discharge Control Program for Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices).

3.7.1 Precipitation static (p-static)

The system shall control p-static interference to antenna connected receivers onboard the system such that system operational performance requirements are met. The system shall protect against puncture of materials and finishes and shock hazards from charge accumulation.

APPLICABILITY: As written.

3.7.2 Ordnance subsystems

Ordnance subsystems shall not be inadvertently initiated or duded by a 25 kilovolt electrostatic discharge caused by personnel handling.

APPLICABILITY: As written.

3.8 ELECTROMAGNETIC RADIATION HAZARDS (EMRADHAZ)

The system design shall protect personnel, fuels, and ordnance from hazardous effects of electromagnetic radiation.

APPLICABILITY: As written.

3.8.1 Hazards of electromagnetic radiation to personnel (HERP)

The system shall comply with Human-Systems Integration Requirements (HSIR) criteria for the protection of personnel against the hazardous effects of electromagnetic radiation.

APPLICABILITY: As written.

3.8.2 Hazards of electromagnetic radiation to fuel (HERF)

The system shall protect against the inadvertent ignition of fuels and propellants caused by the exposure to radio frequency electromagnetic energy.

APPLICABILITY: As written.

3.8.3 Hazards of electromagnetic radiation to ordnance (HERO)

Electrically initiated devices (EIDs) in ordnance shall not be inadvertently actuated during or experience degraded performance characteristics after exposure to the

defined external electromagnetic environment, for both direct RF induced actuation of the EID and inadvertent activation of an electrically powered firing circuit.

APPLICABILITY: As written.

3.9 LIFE CYCLE AND MAINTAINABILITY

The Constellation Systems shall meet the E3 requirements of this document throughout its life cycle including: assembly, storage, handling, packaging, transportation, checkout, integration with other elements, launch, normal in-flight operation, emergency and planned contingency operations, re-entry, landing, recovery, processing, and the processes associated with each aspect.

APPLICABILITY: As written.

3.10 ELECTRICAL BONDING

The Constellation systems, elements, subsystems, and equipment shall meet the electrical bonding requirements of NASA-STD-4003.

APPLICABILITY: As modified. Because of single point ground requirements, the Class C bond of NASA-STD-4003 is not applicable to CLV subsystems and equipment.

3.11 GROUNDING

Constellation electrical systems shall be designed to incorporate a distributed single point ground to prevent intentional dc or low frequency electrical current from flowing in ground references except under fault conditions. Figure 3.7 illustrates the distributed single point ground concept.

APPLICABILITY: As written.

3.11.1 Power Isolation

Each primary electrical power system shall be DC isolated from secondary power systems by a minimum of one megohm.

APPLICABILITY: As written. Primary refers to vehicle power (e.g. 28V vehicle power) and secondary refers to conditioned power (e.g. 15Vdc power)

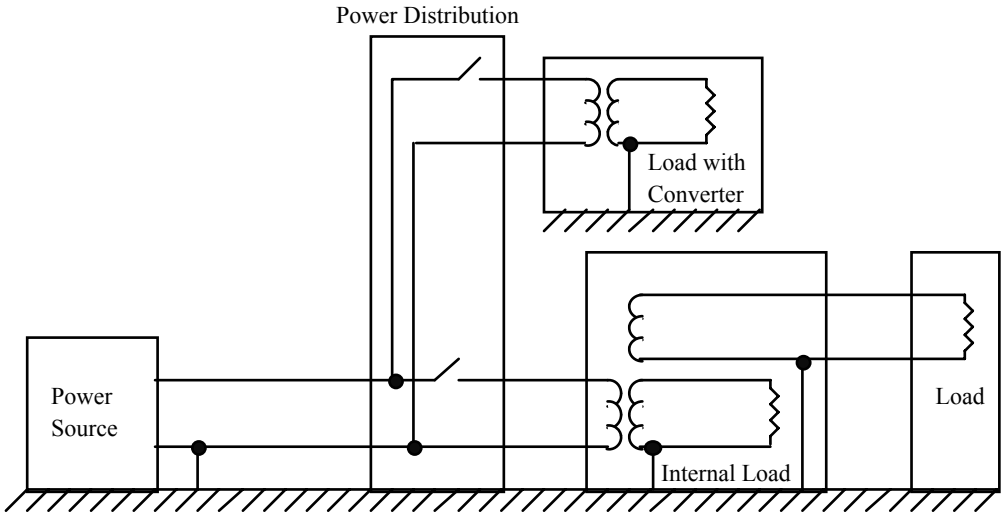


FIGURE 7 DISTRIBUTED SINGLE POINT GROUND CONCEPT

3.11.2 Equipment Isolation

Equipment power inputs shall be DC isolated from chassis/structure by a minimum resistance of 1 Megohm.

APPLICABILITY: As written.

3.11.3 Grounding for Electrical Fault Clearing

Each power source that contains circuit protection devices (fuses, circuit breakers, etc.) shall have the power return line connected to chassis/structure at one and only one point to provide a fault current return path.

APPLICABILITY: As written.

3.11.4 Signal Grounding

Signal returns external to a subsystem or equipment shall be isolated from chassis/structure by at least one megohm except at their single reference to structure. Balanced differential circuitry is given special considerations and is addressed in paragraph 3.11.4.3 below. Circuitry utilizing coaxial cabling is given special considerations and is addressed in paragraph 3.12.3, below.

APPLICABILITY: As written.

3.11.4.1 Signal Returns

Each signal, command, control, and power circuit routed externally to the equipment shall employ a separate return and shall be isolated from harness shields by a minimum resistance of 1 Megohm.

APPLICABILITY: As written.

3.11.4.2 Signal Return Isolation

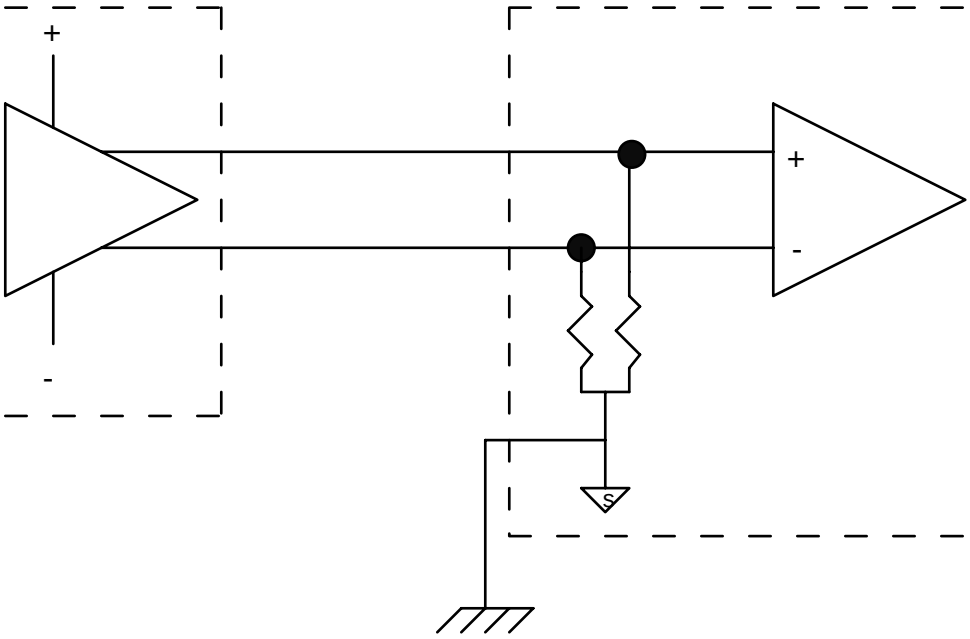
Signal returns using separate derived power sources shall be isolated from other returns by a minimum resistance of 1 Megohm.

APPLICABILITY: As written.

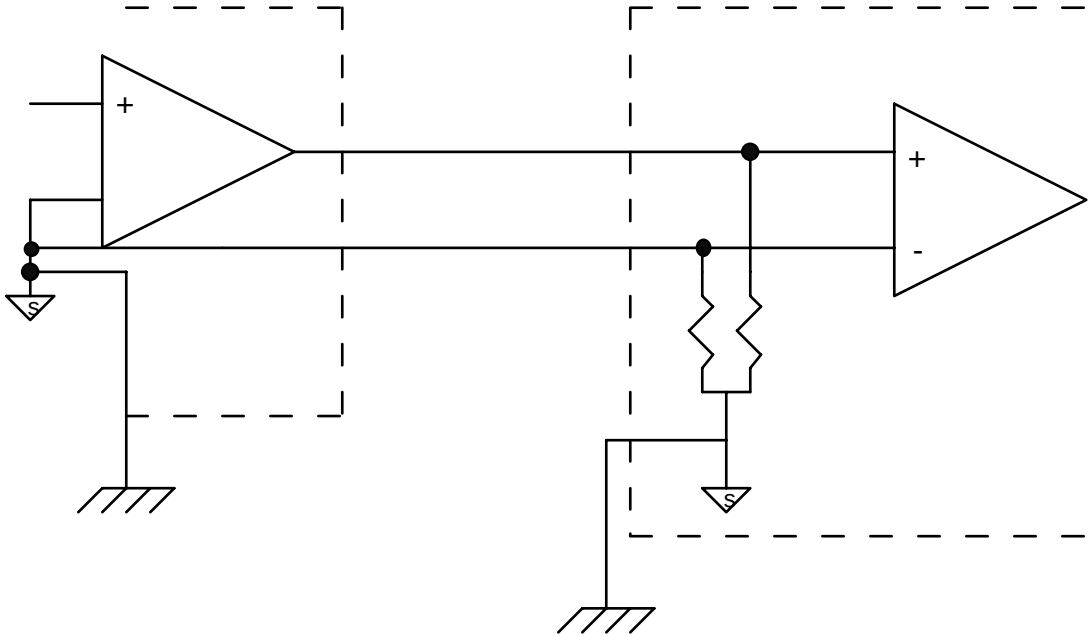
3.11.4.3 Balanced Differential Circuit Isolation

Balanced differential circuits external to equipment shall be isolated from structure by 6 kilohms or greater. Line drivers and receivers having balanced receivers and low impedance drivers are considered balanced circuits even though the source is referenced to ground. See Figure 8 for generic examples of balanced differential circuitry.

APPLICABILITY: As written.



Balanced Differential Line Driver and Receiver



Single-ended Line Driver and Balanced Differential Receiver

FIGURE 8 BALANCED DIFFERENTIAL LINE DRIVER AND RECEIVER EXAMPLES

3.12 CABLE AND WIRE DESIGN FOR ELECTROMAGNETIC COMPATIBILITY

The Constellation systems shall allocate cables and wiring into similar classes of voltage, frequency, and susceptibility levels as shown in Table 2.

APPLICABILITY: As written.

3.12.1 Circuit Classification

The wiring and cabling shall be classified according to the frequency or rise/fall time of the signal, the circuit impedance, the circuit voltage, and circuit sensitivity. Table 2. shows the circuit classifications for Constellation systems.

APPLICABILITY: As written.

3.12.2 Wire and Cabling Bundling and Routing

Wiring and cabling of similar classifications shall be labeled with its circuit class and bundled and routed together and isolated from wiring and cabling of other classifications through mechanical means such as physical separation, routing in cable trays, or shielding.

APPLICABILITY: As written.

TABLE 2 CIRCUIT CLASSIFICATION

Frequency f: Rise, Fall Time (μs) t_r, t_f	Voltage or Sensitivity	Source Impedance (ohms)	Load Impedance (ohms)	Circuit Class	Minimum[4] Wire Type	Shield[1,2]
Analog (ac, dc) f ≤ 50kHz t_r, t_f ≥ 10 μs	≤ 100 mV	All	< 600 k	ML	TWS	MPG
	≤ 100 mV	All	≥ 600 k	ML	TWDS	MPG
	< 6 V	All	All	ML	TWS	MPG
	6 – 40 V	All	All	HO	TW	None
	> 40 V	All	All	EO	TW	None
50 kHz < f < 1 MHz; t_r, t_f ≤ 10 μs	< 100mV	All	All	RF	TWDS	MPG
	≥ 100mV	All	All	RF	TWS	MPG
f ≥ 1 MHz[1,3]	All	All	All	RF	TWS, Twin-ax, Coax	MPG
BWAD	All	All	All	MO	TWS	MPG

Acronyms And Abbreviations

ML	Low-level analog or sensitive circuit designation
HO	Control, and high-level discrete signal circuit designation
EO	Power and High voltage (> 40V) circuit designation
MO	Pyrotechnic Circuit designation
MPG	Multiple Point Ground
RF	Radio Frequency
TW	Twisted
TWDS	Twisted Double Shielded
TWS	Twisted Shielded

NOTES:

1. Shield architecture shall be compatible with the circuit application.
2. The length of shield termination to chassis/structure for all circuits should be the minimum length practical. The preferred method is to connect the shield peripherally to the back shell of the connector with a continuous impedance electrical bond path through both halves of the connector shell and the connector to mounting surface interface. Overall shield terminations shall not be carried through connector pins. No shield terminations shall be carried into the interior of the electrical equipment or enclosure. The use of direct wire or "pigtail" terminations limits the effectiveness of cable shields above 10 MHz and is highly discouraged.
3. Digital signals shall be classified as RF and routed as wire type per this table.
4 Solar array interconnects may use loop minimization methods that do not require twisting of leads

3.12.3 Coax Cabling

Coax cabling shall be permitted only when all frequency components of the signal are equal to or greater than 1 MHz. Coax shall not be used as interconnects between equipment utilizing different power sources unless electrical isolation is provided (opto-isolators, transformers, etc.) to prevent violation of single point ground architecture.

APPLICABILITY: As written.

3.12.4 Cable Shield Termination

Cable shields shall be terminated at both ends and at intermediate break points (such as bulkhead feed-throughs)directly to structure or chassis through connector backshells.

APPLICABILITY: As written.

3.12.5 Overall Cable Shield Termination

Overall cable shields and coaxial outer conductors shall be terminated peripherally (360º) through connector backshells.

APPLICABILITY: As written.

3.13 EM SPECTRUM COMPATIBILITY

The Constellation RF systems shall be developed in compliance with radio frequency (RF) spectrum management procedures and policies defined in NPD 2570.5D, NASA Electromagnetic Spectrum Management, and National Telecommunications and Information Administration (NTIA) Manual of Regulations & Procedures for Federal Radio Frequency Management (May 2003 Edition, January 2006 Revisions), Chapter 10.

APPLICABILITY: As written.

3.14 PYROTECHNIC CIRCUITRY

The Constellation pyrotechnic circuitries shall comply with the electromagnetic compatibility requirements of MIL-STD-1576, Electroexplosive Subsystem Safety Requirements and Test Methods for Space Systems, as stipulated in paragraphs 4.3, 4.4.1 (except the level is to be 16.5 dB below the maximum no fire stimulus), 4.4.2, 5.2, 5.3, 5.4, 5.5, 5.7.1, 5.7.2, 5.7.3, 5.7.4,5.7.5, 5.7.6, 5.8.1, 5.8.2, 5.11.1.1, 5.12.1.2, and 6.10.

APPLICABILITY: As written.

3.15 CORONA

The Constellation Architecture hardware which utilizes or produces electrical voltages in excess of 190V and are required to operate during ascent/descent or during a depressurization/repressurization event shall prevent corona/arcing from occurring in unsealed electrical/electronic components. Electrical/electronic components utilizing a sealed chassis design or components which are powered under space vacuum conditions only do not require corona/arcing testing.

APPLICABILITY: Applicability limited to CLV subsystems and equipment which produce or utilize voltages with peak amplitudes in excess of 190V.

4.0 GENERAL

Verification: Electromagnetic compatibility of Constellation systems shall be verified by a combination of inspection, analysis and test of systems, subsystems, and equipment. Tests shall verify that electromagnetic compatibility for all planned simultaneous operations occurring during all life cycle aspects has been achieved successfully, and can be maintained at certification levels over the design life cycle. Analysis shall be used to bridge the gap of lower level test data and the integrated vehicle testing that uses simulators or lower testing level to insure that the overall architecture is compliant with the requirements. Inspection shall verify that all systems comply with requirements as detailed in the following paragraphs, and that equipment and systems are ready for test. Verification is considered successful when three items are satisfied: 1) During the tests all systems successfully complete functional and operational performance requirements; 2) The analysis indicates that the integrated vehicle testing shows lower level assumptions and data adequately demonstrate compliance with the requirements; 3) Inspection of verification submittal information demonstrates compliance.

APPLICABILITY: As written.

4.1 MARGINS

Verification: Margins shall be verified by test, analysis, or a combination thereof. Verification shall be considered successful when 1) test has verified through physical demonstration that an equipment or a system design can withstand or tolerate the required electromagnetic stress and remain operational, or 2) in cases where test is determined to be not possible, analysis has verified that the design thresholds of susceptibility of the system, subsystems, and equipment are above the maximum stress level allowed to occur within the equipment or system, and are equal to or greater than the electromagnetic stress levels the equipment or system is required to withstand or tolerate.

APPLICABILITY: As written.

4.1.1 Pyrotechnic Margins

Margins shall be verified by test, analysis, or a combination thereof. Verification shall be considered successful when 1) tests have verified through physical demonstration that the levels induced in the pyrotechnic device is 15% or less of the maximum no-fire current, or 2) in cases where test is determined to be not possible, analysis has verified that the levels induced in the pyrotechnic device is 15% or less of the maximum no-fire current.

APPLICABILITY:

4.2 INTRA-SYSTEM ELECTROMAGNETIC COMPATIBILITY (EMC)

Verification: Intra-system electromagnetic compatibility between Constellation systems shall be verified through test and analysis. The test shall verify that electromagnetic compatibility has been achieved successfully for all planned simultaneous subsystem operations, and can be maintained at certification levels over the design life cycle. Analysis shall verify that electromagnetic compatibility has been achieved successfully, and can be maintained at certification levels over the design life cycle, for operational conditions that are impractical to test on the ground. Verification is considered successful when analyses and tests show that the system successfully complies with design, functional and operational performance requirements.

APPLICABILITY: As written.

4.2.1 Mobile Launcher Platform, Launch Pad, and similar structure internal electromagnetic environment (EME)

Verification: Immunity to a 10 V/m electric field strength above 200 MHz shall be verified through test and analysis. Verification is considered successful when tests demonstrate the equipment is immune to exposure to a 10 V/m electric field above 200 MHz up to 18 GHz.

APPLICABILITY: Not Applicable.

4.2.2 Multipaction

Verification: Freedom from multipaction effects shall be verified through test and analysis. Analysis shall verify that sufficient margin can be demonstrated through test, and how that demonstration is to be shown. Based on the completed analysis results, the test shall verify that multipaction effects do not occur under high vacuum conditions. Verification is considered successful when analyses and tests show that the equipment or subsystem is free of multipaction effects in high vacuum conditions.

APPLICABILITY: As written.

4.3 EXTERNAL RF EME

Verification: Compatibility with the external electromagnetic environment shall be verified by test and analysis. The test shall verify that the vehicle meets functional and performance requirements without degradation in the presence of the electromagnetic environment. The analysis shall verify that the vehicle operates without degradation in the presence of the electromagnetic environment for operational conditions that are impractical to test on ground, such as: ascent, on-orbit and descent. Verification is considered successful when the analysis and test results verify that the vehicle is compatible with the external electromagnetic environment.

APPLICABILITY: As written.

4.4 EXTERNAL COMPATIBILITY

Verification: Electromagnetic compatibility between Constellation Systems and external interfaces shall be verified through test, analysis, and inspection. The test shall verify that electromagnetic compatibility for all planned simultaneous operations with external interfaces including transportation systems, recovery systems, RF systems (e.g. TDRSS, Range Safety), and other vehicles (e.g. International Space Station (ISS)) has been achieved successfully for all planned simultaneous subsystem operations, and can be maintained at certification levels over the design life cycle. The analysis shall verify that electromagnetic compatibility for all planned simultaneous operations with external interfaces has been achieved successfully for all planned simultaneous subsystem operations, and can be maintained at certification levels over the design life cycle, in cases where testing is impractical. Inspection shall verify that all Constellation Systems comply with all requirements contained herein. Verification is considered successful when three items are satisfied: 1) During the test all systems successfully comply with design, functional and operational performance requirements when exposed to the defined external RF environment. 2) Analysis results show all systems successfully comply with design, functional and operational performance requirements when exposed to the defined external RF environment. 3) Inspection of the Constellation E3 Requirements Document verification submittal information demonstrates compliance.

APPLICABILITY: As written.

4.5 LIGHTNING

Verification: Operational performance of Constellation systems after exposure to lightning direct or indirect effects shall be verified by a combination of inspection, analysis and test of systems, subsystems, and equipment. Tests shall verify that Constellation systems can meet operational performance requirements during and after exposure to lightning environments. Inspection shall verify that all systems comply with the detailed lightning requirements in the following paragraphs. Verification is

considered successful when three items are satisfied: 1) During the tests all systems successfully complete functional and operational performance requirements; 2) Analysis shows that all configurations demonstrate compliance; and 3) Inspection of verification submittal information demonstrates compliance.

APPLICABILITY: As written.

4.5.1 Direct Effects

Verification: Protection against catastrophic, hazardous/sever-major, or major failures due to lightning direct attachments shall be verified by a combination of test and inspection. Inspection shall verify that all systems comply with the detailed lightning direct effects requirements in the following paragraphs. Testing shall verify that Constellation Architecture structures, subsystems and components that are subject to conducted lightning, as well as direct lightning attachment, do not experience catastrophic loss of structural integrity, loss of function, or loss of protection for underlying subsystems. Verification is considered successful when two items are satisfied: 1) During testing all structures, subsystems, and components successfully demonstrate that structural integrity, function, and protection of underlying subsystems is maintained 2) Inspection of verification submittal information demonstrates compliance.

APPLICABILITY: As written.

4.5.1.1 Zoning

Verification: Lightning attachment zone determination shall be verified by analysis. The analysis shall verify the identification of lightning attachment zones for the integrated Constellation systems. Verification shall be considered successful when the analysis defines lightning channel attachment zones and areas of the vehicles situated between such zones. Scale model testing may be required to identify potential attachment points and support lightning zone analysis

APPLICABILITY: As written.

4.5.1.2 Zone Lightning Environment

Verification: The established lightning environment shall be verified by inspection and analysis. The inspection shall verify compliance with the lightning attachment zone determination requirement. The analysis shall verify that the proper voltage waveforms and current components have been identified for the various lightning zones of the vehicle. Verification shall be considered successful when two things occur: 1) Inspection of verification submittal shows compliance with the lightning attachment zone determination requirement; and 2) The analysis shows that the proper voltage waveforms and current components have been established for the identified lightning strike zones.

APPLICABILITY: As written.

4.5.1.3 Hazard Assessment – Direct Effects

Verification: The hazard assessment shall be verified by analysis. The analysis shall verify that structures, subsystems, and components whose failure or malfunction due to lightning direct effects could contribute or lead to a catastrophic failure have been evaluated and identified. The verification is considered successful when a detailed list of structures, subsystems, and components whose failure or malfunction due to lightning direct effects could contribute or lead to a catastrophic failure has been identified.

APPLICABILITY: As written.

4.5.1.4 Definition of Acceptance Criteria

Verification: Definition of the acceptance criteria shall be verified by test and analysis. The test shall verify that the maximum amount of damage, interference, or other effects allowed by the acceptance criteria does not contribute to failure or malfunction of each item identified in the hazard assessment. Analysis shall verify that the maximum amount of damage, interference, or other effects allowed by the acceptance criteria does not contribute to failure or malfunction of each item identified in the hazard assessment for cases where testing is impractical. Verification shall be considered successful when test and analysis results show that the items identified in the hazard assessment do not fail or malfunction when subjected to the maximum amount of damage, interference, or other effects allowed by the acceptance criteria.

APPLICABILITY: As written.

4.5.1.5 Compliance with Acceptance Criteria

Verification: Damage to Constellation systems structures, subsystems and components shall be verified by test and analysis. The testing, using procedures and methodology found in Sections 4, 5, and 7 of SAE ARP5416, Aircraft Lightning Test Methods and RTCA/DO-160E, Environmental Conditions and Test Procedures for Airborne Equipment, Section 23, Lightning Direct Effects, shall verify that maximum damage or other effects is less than that defined in the acceptance criteria. The analysis, using results from developmental or qualification testing on sub-scale or component test samples, shall verify that maximum damage or other effects is less than that defined in the acceptance criteria. The verification shall be considered successful when analysis and test results show that maximum damage or other effects sustained is less than that defined in the acceptance criteria.

APPLICABILITY: As written.

4.5.2 Indirect Effects

Verification: Protection against catastrophic, hazardous/sever-major, or major failures due to lightning indirect effects shall be verified by a combination of test, analysis and inspection. Inspection shall verify that all systems comply with the detailed lightning indirect effects requirements in the following paragraphs. Testing shall verify that Constellation Architecture subsystems and equipment do not experience catastrophic loss of function or loss of protection for underlying subsystems. Verification is considered successful when three items are satisfied: 1) During testing all subsystems and equipment successfully demonstrate that function, and protection of underlying subsystems is maintained; 2) Inspection of verification submittal information demonstrates compliance; and 3) The test data correlates with the current path data and demonstrates system integration did not alter the current path assumptions

APPLICABILITY: As written.

4.5.2.1 Hazard Assessment– Indirect Effects

Verification: The hazard assessment shall be verified by analysis. The analysis shall verify that subsystems and equipment whose failure or malfunction due to lightning indirect effects could contribute or lead to a catastrophic failure have been evaluated and identified. The verification is considered successful when a detailed list of subsystems and equipment whose failure or malfunction due to lightning indirect effects could contribute or lead to a catastrophic failure has been identified.

APPLICABILITY: As written.

4.5.2.2 Lightning Current Paths

Verification: Lightning current paths shall be verified by inspection and analysis. The inspection shall verify compliance with the lightning attachment zone determination requirement. The analysis shall verify that the proper current paths have been identified for the various lightning zones of the vehicle. Verification shall be considered successful when two things occur: 1) Inspection of verification submittal shows compliance with the lightning attachment zone determination requirement; and 2) The analysis shows that the proper current paths have been established for the identified lightning strike zones.

APPLICABILITY: As written.

4.5.2.3 Internal Environment

Verification: Internal environment determination shall be verified by inspection. Inspection shall show that actual transient level determination and equipment transient design level determination has been completed. Verification shall be considered

successful when inspection of verification submittal information for the ATL and EDTL requirements shows those requirements have been satisfied.

APPLICABILITY: As written.

4.5.2.3.1 Actual Transient Level Determination

Verification: The ATL determination shall be verified by inspection. The inspection shall show that ATL determination has been performed using testing and/or analysis methods found in SAE ARP5415, User's Manual for Certification of Aircraft Electrical/Electronic Systems for the Indirect Effects of Lightning, Section 4 for analysis, and SAE ARP5416, Aircraft Lightning Test Methods, Section 6.1, Aircraft Test and the results are consistent with the expectations of those documents. The verification shall be considered successful when inspection shows that ATLs have been determined.

APPLICABILITY: As written.

4.5.2.3.2 Equipment Transient Design Level Determination

Verification: ETDL levels shall be verified by analysis. The analysis shall verify that ETDL s are 6 dB (factor of 2) above the ATLs measured in the integrated Constellation system. The verification is considered successful when it is shown that ETDLs established for use in equipment and subsystem verification are 6 dB above the ATLs.

APPLICABILITY: As modified. ETDLs shall be verified by testing of flight-like or flight-representative elements to determine that transient levels measured are 6 dB below ETDLs. In practice, ATL determination is a two step process. ATLs will first be identified by analysis early in the design phase so that ETDLs can then be imposed in equipment procurement specifications. Testing on flight-like or flight-representative elements is later performed to verify that ATLs identified earlier are less than transient levels measured. The results of this testing is then used to verify that ETDLs are greater than 6dB above ATLs.

If ATLs are determined by testing of flight-like or flight-representative systems prior to establishment of ATLs, the ETDL determination verification by analysis shall be acceptable.

NOTE: Flight-like implies a high-fidelity qualification or acceptance unit. Flight-representative implies something of lesser fidelity. An example of a flight-representative system would be the forward and aft skirt, the systems tunnel, and structure representing the motor casing of the First Stage. The skirts and systems tunnels could be flight-like while the motor casing would be represented by a semi-cylindrical structure.

4.5.2.4 Compliance with Equipment Transient Design Levels

Verification: Compliance with equipment transient design levels shall be verified by test and analysis. Testing shall verify that equipment and subsystems are immune to damage or upset when subjected to the ETDLs. Analysis shall verify that equipment and subsystems are immune to damage when damage testing is impractical. Verification shall be considered successful when two things occur: 1) test results from equipment and subsystem upset testing show immunity to ETDLs; 2) results from equipment damage tests or analyses show that equipment immunity to damage from ETDLs.

APPLICABILITY: As modified. Test limits and test methods shall be contained in CxP 72047, Crew Launch Vehicle (CLV) Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment.

4.5.3 Lightning Protection of Individual Elements

Verification: The lightning protection shall be verified by test and analysis. The analysis and test shall show the Ground Systems mitigate the risk of direct attachment and indirect effects to Constellation systems and protect against catastrophic or hazardous/severe-major failures. The verification is considered successful when the test and analysis results show that Constellation systems are protected against catastrophic or hazardous failures from direct lightning attachment during ground operations, shipping and transportation, refurbishment, and other related operations.

APPLICABILITY: As written.

4.6 SUBSYSTEMS AND EQUIPMENT ELECTROMAGNETIC INTERFERENCE (EMI)

Verification: Subsystem and equipment compliance with electromagnetic emissions and susceptibility limits shall be verified by tests. Testing shall verify that equipment and subsystems comply with emissions and susceptibility requirements. Verification shall be considered successful when: 1) emissions are below limits and 2) equipment and subsystems are immune to interference when subjected to susceptibility test levels.

APPLICABILITY: As modified. CxP 72047, Crew Launch Vehicle (CLV) Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment contain EMI test methods and test limits.

4.6.1 Non-developmental items (NDI) and commercial items

Verification: The compliance of NDI and commercial items with suitable electromagnetic emissions and susceptibility limits shall be verified by tests, inspection, or a combination thereof. Test shall verify and provide irrefutable evidence that the affected hardware meets or exceeds the applicable Constellation E3 requirements. Inspection shall verify that the NDI and commercial items comply with the detailed requirements of the

following paragraphs. Verification shall be considered successful when tests, inspection of verification submittal information, or a combination of both, demonstrate compliance.

APPLICABILITY: As

4.6.1.1 NDI and Commercial Information Technology equipment

The compliance of NDI and commercial Information Technology Equipment (ITE) with CISPR 22: 2006, Information technology equipment – Radio disturbance characteristics – Limits and methods of measurements or Class B emissions requirements of Title 47, Code of Federal Regulations, Part 15 – Radio Frequency Devices shall be by inspection. Inspection shall verify that the NDI and commercial ITE comply with CISPR 22: 2006, Information technology equipment – Radio disturbance characteristics – Limits and methods of measurements or Class B emissions requirements of Title 47, Code of Federal Regulations, Part 15 – Radio Frequency Devices. Verification shall be considered successful when inspection of CISPR 22 or Title 47, Code of Federal Regulations, Part 15 certification information demonstrates compliance.

APPLICABILITY: As written

4.6.1.2 Flight Hardware Usage of NDI/Commercial Items

The compliance of NDI/Commercial items with electromagnetic emissions and susceptibility limits shall be verified by tests. Testing shall verify that equipment and subsystems comply with emissions and susceptibility requirements. Verification shall be considered successful when: 1) emissions are below limits, and 2) equipment and subsystems are immune to interference when subjected to susceptibility test levels.

APPLICABILITY: As written

4.6.1.3 Electrical Ground Support Equipment Usage of NDI/Commercial Items

The compliance of NDI/Commercial items used in electrical ground support equipment (EGSE) and core avionics test set (CATS) equipment with electromagnetic emissions and susceptibility limits shall be verified by tests. Testing shall verify that equipment and subsystems comply with emissions and susceptibility requirements. Verification shall be considered successful when: 1) emissions are below limits, and 2) equipment and subsystems are immune to interference when subjected to susceptibility test levels.

APPLICABILITY: As written

4.7 ELECTROSTATIC CHARGE CONTROL

Verification: Subsystem and equipment compliance with required control and dissipation of electrostatic charge build-up shall be verified by tests and analysis. Analysis shall verify that adequate control measures have been incorporated into the design, such as transient absorbing devices, series resistance, or proper electrical grounding and

bonding. Testing shall verify compliance with Constellation requirements through exposure to standard electrostatic discharge waveforms, either to pins, case, or a combination thereof. Verification shall be considered successful when the equipment demonstrates compatibility with Constellation systems through satisfaction of the analytical and physical processes.

APPLICABILITY: As written

4.7.1 Precipitation static (p-static)

Verification: Systems, subsystems and equipment must be verified to not pose a hazard when subjected to p-static charging. Verification of pStatic control shall be verified by tests. Testing shall verify compliance with Constellation requirements by demonstrating that deposition of electrostatic charge on the outer mold line of the vehicle shall not cause interference with on-board communications and tracking systems; shall not result in build-up of electrostatic charge to levels hazardous to personnel; and shall not result in build-up of electrostatic charge to levels that could damage the vehicle. Verification shall be considered successful when compatibility has been demonstrated through satisfaction of the physical test process.

APPLICABILITY: TBD

4.7.2 Ordnance subsystems

Verification: Design to prevent inadvertent initiation or dudding of ordnance systems by an electrostatic discharge shall be verified by test. Compliance shall be demonstrated by test, discharging a 500 pF capacitor charged to 25kV through a 5000 ohm resistor to the ordnance subsystem, including electrical interfaces, enclosures, and handling points. Verification shall be considered successful when test results show that inadvertent initiation or dudding of ordnance systems due to electrostatic discharges does not occur.

APPLICABILITY: As written.

4.8 ELECTROMAGNETIC RADIATION HAZARDS (EMRADHAZ)

Verification: Safety regarding RF hazards shall be verified by analysis and tests. Analysis shall verify that adequate control measures have been incorporated into the design such as shielding, cable routing, proper electrical grounding and bonding. Operational considerations also will be included in the analysis, identifying internally and externally generated RF maximum capabilities to system design and Mission Systems personnel for keep out zone establishment and enforcement. Testing shall verify compliance with Constellation requirements by demonstrating system response to level 2 prescribed RF environments is below any interference or damage thresholds. Verification shall be considered successful when compatibility has been demonstrated through satisfaction of the analytical and physical processes.

APPLICABILITY: As written

4.8.1 Hazards of electromagnetic radiation to personnel (HERP)

Verification: Safety regarding RF hazards to personnel shall be verified by analysis and tests. Analysis shall verify that internally and externally generated RF maximum capabilities have been properly identified, and appropriate safe distances have been determined based on human exposure limits in CxP 70024, Constellation Program Human Systems Interface Requirements (HSIR). Testing shall verify compliance with Constellation requirements by demonstrating that internally and externally generated RF capabilities are in compliance with prescribed RF environments. Verification shall be considered successful when compatibility has been demonstrated through satisfaction of the analytical and physical processes.

APPLICABILITY: As written

4.8.2 Hazards of electromagnetic radiation to fuel (HERF)

Verification: Safety regarding RF hazards to fuels shall be verified by inspection and analysis with testing limited to special circumstances. Inspection and analysis shall verify that adequate control measures have been incorporated into the design to preclude fuel ignition, such as shielding and proper electrical grounding and bonding of any conductors in near proximity to fuel containment vessels, fuel hoses, ducts, and so forth. Operational considerations also will be included in the analysis, identifying internally and externally generated RF maximum capabilities to system design and operational personnel for keep out zone establishment and enforcement. When deemed necessary, testing shall verify compliance with Constellation requirements by demonstrating that exposure of fuel samples cannot be ignited by exposure to prescribed RF environments. Verification shall be considered successful when compatibility has been demonstrated through satisfaction of the analytical and physical processes.

APPLICABILITY: As written

4.8.3 Hazards of electromagnetic radiation to ordnance (HERO)

Verification: Safety regarding RF hazards to ordnance shall be verified by analysis and tests. Tests shall be required unless a theoretical assessment positively indicates that the RF-induced energy on EID firing lines or in electronic circuits associated with safety-critical functions is low enough to assure an acceptable safety margin in the specified electromagnetic environment (bearing in mind the possible inaccuracies in the analysis technique). Analysis shall verify that adequate control measures have been incorporated into the design such as shielding, cable routing, proper electrical grounding and bonding. Operational considerations also will be included in the analysis, identifying internally and externally generated RF maximum capabilities to system design and

MOD personnel for keep out zone establishment and enforcement. Testing shall verify compliance with Constellation requirements by demonstrating system response to prescribed RF environments (paragraph 3.3) is below the specified 16.5 dB safety margin with respect to the maximum no-fire stimulus (MNFS). Verification shall be considered successful when compatibility has been demonstrated through satisfaction of the analytical and physical processes.

APPLICABILITY: As written

4.9 LIFE CYCLE AND MAINTAINABILITY

Verification: Life cycle hardness shall be demonstrated by inspection, analysis, test, or a combination thereof. Inspection and/or analysis shall verify that design features and considerations that have been incorporated into various subsystems and equipment will act together in an integrated sense to guarantee the longevity of electromagnetic hardness characteristics, without unnecessarily driving up parts counts or maintenance costs. Tests shall verify that various combinations of features provide for electromagnetic protection. Verification shall be considered successful when inspection, analysis, and test demonstrate that various design features and techniques can act together to provide a complete electromagnetic protection without incurring unnecessary parts counts or maintenance costs.

APPLICABILITY: As written.

4.10 ELECTRICAL BONDING

Verification: Electrical bonding shall be verified by test, analysis, and inspection. Testing shall verify the adequacy of electrical bonding processes and procedures for each bonding class. Analysis shall verify that correct bond classes have been identified and bonding paths are designed to meet identified bonding class requirements. Inspection shall verify that proper bonding processes, procedures, and classes have been identified in hardware drawings and documentation. Inspection shall also verify that hardware fabrication and installation measurements demonstrate proper electrical bonding has been achieved. Verification shall be considered successful when each bonding joint is shown to have the correct bonding class requirement, the fabrication and installation procedure will result in a proper electrical bond, and the tested bonds meet the identified bond class resistance limits.

APPLICABILITY: As written.

4.11 GROUNDING

Verification: Distributed single point grounding shall be verified by analysis and inspection. Analysis and inspection of drawings and installation records shall verify that the electrical system incorporates a distributed single point ground design.. Verification

shall be considered successful when it can be shown that each electrical system meets the distributed single point ground criteria.

APPLICABILITY: As written.

4.11.1 Power Isolation

Verification: Power isolation shall be verified by analysis and inspection. Analysis and inspection of drawings and installation records shall verify that each primary power system is DC isolated from secondary power systems. Verification shall be considered successful when it can be shown that primary power is DC isolated from secondary power.

APPLICABILITY: As written.

4.11.2 Equipment Isolation

Verification: Equipment input isolation shall be verified by analysis and inspection. Analysis and inspection of drawings and installation records shall verify that each power input is DC isolated from chassis/structure.. Verification shall be considered successful when it can be shown that each power input is isolated from chassis/structure by 1 Megohm.

APPLICABILITY: As written.

4.11.3 Grounding for Electrical Fault Clearing

Verification: Grounding for electrical fault clearing shall be verified by inspection. Inspection shall verify that the design provides a fault current return path to allow circuit protection devices to clear electrical faults. Verification shall be considered successful when it is shown that each power circuit has one path to structure that is capable of carrying any fault current that may occur until a circuit breaker or fuse disconnects the faulty circuit.

APPLICABILITY: As written.

4.11.4 Signal Grounding

Verification: Signal return grounding shall be verified by analysis and inspection. Analysis and inspection of drawings and installation records shall verify that the circuit return design provides DC isolation from chassis/structure except at a single reference to structure. Verification shall be considered successful when each signal circuit is shown to be isolated from chassis or structure by at least one megohm.

APPLICABILITY: As written.

4.11.4.1 Signal Returns

Verification: Signal return routing shall be verified by inspection. Inspection shall verify that each signal employs a separate return. Verification shall be considered successful when inspection of hardware drawings and documentation shows each signal circuit routed externally to the equipment has its own return and is isolated from the harness shields.

APPLICABILITY: As written.

4.11.4.2 Signal Return Isolation

Verification: Signal return isolation shall be verified by analysis and inspection. Analysis and inspection of drawings and installation records shall verify that each signal return is isolated so that separately derived power sources are not interconnected. Verification shall be considered successful when signal returns are shown to be isolated from each other so that independent power sources are not interconnected.

APPLICABILITY: As written.

4.11.4.3 Balanced Differential Circuit Isolation

Verification: Balanced differential circuit isolation shall be verified by analysis and inspection. Analysis and inspection of drawings and installation records shall verify that each balanced differential signal return is isolated from chassis/structure by 6 kilohms. Verification shall be considered successful when analysis and inspection shows that balanced differential signal returns are isolated from structure/chassis by at least six kilohms.

APPLICABILITY: As written.

4.12 CABLE AND WIRE DESIGN FOR ELECTROMAGNETIC COMPATIBILITY

Verification: Cable and wiring allocation into different classes shall be verified by inspection. Inspection shall verify that cable and wiring has been allocated into similar classes. Verification shall be considered successful when inspection of verification submittal information shows compliance for the following requirements: circuit classification, wire and cabling bundling and routing, controlled impedance wiring, shield terminations.

APPLICABILITY: As written.

4.12.1 Circuit Classification

Verification: Wiring and cabling classification shall be verified by analysis. The analysis shall verify that wiring and cabling has been classified according to frequency or rise/fall times, circuit impedance, circuit voltage, and circuit sensitivity. Verification shall be

considered successful when wiring and cabling classifications are found to be in accordance with the circuit classifications of Table 2.

APPLICABILITY: As written.

4.12.2 Wire and Cabling Bundling and Routing

Verification: Wiring and cabling bundling and routed shall be verified by inspection. Inspection shall verify that cabling and wiring are labeled with circuit class and separated and routed in accordance with classification requirements. Verification shall be considered successful when inspection of drawings and installation documentation shows that wiring and cabling are properly labeled with circuit class and separated and routed in accordance with classification requirements.

APPLICABILITY: As written.

4.12.3 Coax Cabling

Verification: Coax cabling usage shall be verified by inspection. Inspection shall verify that all signal frequency components transmitted on coaxial cabling are greater than or equal to 1 MHz. Verification shall be considered successful when inspection of design shows that all signal frequency components transmitted on coaxial cabling are greater than or equal to 1 MHz.

APPLICABILITY: As written.

4.12.4 Cable Shield Termination

Verification: Shield termination shall be verified by inspection. Inspection shall verify that cable shields are terminated at all ends to structure or chassis through connector backshells (including intermediate break points/bulkhead connectors). Verification shall be considered successful when inspection of drawings and installation documentation shows that shields are terminated at all ends of cabling through connector backshells to chassis or structure.

APPLICABILITY: As written.

4.12.5 Overall Cable Shield Termination

Verification: Overall shield termination shall be verified by inspection. Inspection shall verify that overall cable shields are terminated peripherally (360º) through connector backshells. Verification shall be considered successful when inspection of drawings and installation documentation shows that overall shields are terminated peripherally (360º) through connector backshells.

APPLICABILITY: As written.

4.13 EM SPECTRUM COMPATIBILITY

Verification: Spectrum compatibility shall be verified inspection. Inspection shall verify that all Constellation RF systems comply with radio frequency (RF) spectrum management procedures and policies defined in NPD 2570.5D, NASA Electromagnetic Spectrum Management, and National Telecommunications and Information Administration (NTIA) Manual of Regulations & Procedures for Federal Radio Frequency Management (May 2003 Edition, January 2006 Revisions), Chapter 10.. Verification is considered successful when inspection shows that submitted certification request documentation is approved, and Constellation usage of RF spectrum is authorized, by controlling approval agencies.

APPLICABILITY: As written.

4.14 PYROTECHNIC CIRCUITRY

Verification: Constellation pyrotechnic circuitry shall be verified as specified in MIL-STD-1576, Electroexplosive Subsystem Safety Requirements and Test Methods for Space Systems.

APPLICABILITY: As written.

4.15 CORONA

Verification: The prevention of corona/arcing occurrences shall be verified by test. The test shall verify that hardware utilizing or producing voltages in excess of 190V do not produce corona/arcing while operating during ascent/descent or during a depressurization/repressurization event. The test shall be considered successful when operations in partial pressure conditions do not result in corona/arcing occurrences.

APPLICABILITY**: As written.**

APPENDIX A ACRONYMS AND ABBREVIATIONS

AC	Advisory Circular
Ac	Alternating Current
ARP	Aerospace Recommended Practice
ATL	Actual Transient Level
BSL	Baseline
BWAD	Bridge Wire Actuated Device
CARD	Constellation Architecture Requirements Document
CEV	Crew Exploration Vehicle
CLV	Crew Launch Vehicle
Coax	Coaxial Cable
COTS	Commercial-Off-the-Shelf
CR	Change Request
CxCBD	Constellation Control Board Directive
CxP	Constellation Program
dB	Decibel
dc	Direct Current
DoD	Department of Defense
DRM	Design Reference Mission
DSNE	Design Specification for Natural Environments
E3	Electromagnetic Environmental Effects
EM	Electromagnetic
EMC	Electromagnetic Compatibility
EME	Electromagnetic Environment
EMI	Electromagnetic Interference
EMRADHAZ	Electromagnetic Radiation Hazard
EPS	Electrical Power System
ESD	Electrostatic Discharge
ETDL	Equipment Transient Design Level
ETSL	Equipment Transient Susceptibility Level
f	Frequency
FHA	Functional Hazard Assessment
FAA	Federal Aviation Administration
GHz	Gigahertz
HERF	Hazards of Electromagnetic Radiation to Fuel

HERO	Hazards of Electromagnetic Radiation to Ordnance
HERP	Hazards of Electromagnetic Radiation to Personnel
HSIR	Human Systems Interface Requirements
IR	Current times Resistance
I_{sc}	Short Circuit Current
ISS	International Space Station
JSC	Joint Spectrum Center
kHz	Kilohertz
kohm	Kilohm
MHz	Megahertz
ML, HO, EO, MO	Nomenclature to define circuit classification
MPG	Multipoint Ground
mV	Millivolt
NASA	National Aeronautics and Space Administration
NDI	Non-Developmental Item
NPD	NASA Policy Directive
NPR	NASA Procedural Requirements
NTIA	National Telecommunications and Information Administration
OPR	Office of Primary Responsibility
p-static	Precipitation Static
pF	Pico-Farad
RF	Radio Frequency
RTCA	Radio Technical Commission for Aeronautics
SAE	Society of Automotive Engineers
SBU	Sensitive But Unclassified
STD	Standard
TDRSS	Tracking and Data Relay Satellite System
t_f	Falltime
t_r	Risetime
TW	Twisted
TWDS	Twisted Double Shielded
TWS	Twisted Shielded
µs	Microsecond

V	Volts
V/m	Volts per meter
V_{oc}	Open Circuit Voltage

APPENDIX B OPEN WORK

B1.0 OPEN WORK

B1.1 TO BE DETERMINED AND TO BE RESOLVED ITEMS

To Be Determined (TBD) items contained in this document result from TBDs listed in CxP 70080. As those TBDs are solved, this document will be updated to reflect changes to CxP 70080.

To Be Resolved (TBR) items are know issues that currently exist. As the issues are resolved, the document will be updated.

B1.2 CONSTELLATION SYSTEM REQUIREMENTS REVIEW (SRR) ISSUES

Several review item discrepancies (RIDs) were written against CxP 70080 during the Constellation SRR. It is currently unknown how the RID closure and resulting actions from the SRR will affect CxP 70080 and, necessarily, this Annex.