National Aeronautics and
Space Administration

SLS-RQMT-040

REVISION A

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SPACE LAUNCH SYSTEM PROGRAM (SLSP) ELECTROMAGNETIC ENVIRONMENTAL EFFECTS (E3) REQUIREMENTS

REVISION AND HISTORY PAGE

Status	Revision No.	Change No.	Description	Effective Date
Baseline			Initial baseline per PCBD SV2-01-0017, dated 1/5/2012; (CR SLS-00014); PCN SV00018	10/05/12
Revision	A		Update to Revision A per CECBD SV2-02-0024, dated 4/10/13; (CR SLS-00098); PCN SV00195	4/10/13

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

1.1 Purpose

This document establishes the Electromagnetic Environmental Effects (E3) Requirements for the Space Launch System (SLS) Program. These requirements will be used in the development and operation of the various elements that will compose the overall SLS vehicle.

1.2 Scope

This document provides detailed E3 requirements and associated verification activities applicable to SLS and its elements. The SLS Program and SLS element developers are responsible for decomposing the pertinent requirements onto the subsystem and component level in order to produce a compatible SLS vehicle.

Electrical bonding, a topic usually discussed in the E3 requirement set, is discussed in SLS-SPEC-032**,** Space Launch System Program (SLSP) System Specification. That specification levies NASA-STD-4003, Electrical Bonding for NASA Launch Vehicles, Spacecraft, Payloads, and Flight Equipment, on the SLS Program.

Further discussion of the requirements contained in this document as well as a detailed requirements flow and verification plan is contained in SLS-PLAN-042, SLSP E3 Control Plan.

1.3 Change Authority/Responsibility

The NASA Office of Primary Responsibility (OPR) for this document is ES42.

Proposed changes to this document shall be submitted by an SLS Program change request (CR) to the SLS Program Control Board (PCB) for disposition. All such requests shall adhere to the SLS-PLAN-008, SLS Program Configuration Management Plan.

2.0 DOCUMENTS

The documents listed in this section are specified in Sections 3.0, 4.0, or 5.0 of this specification. This section does not include documents cited in other sections of this specification or recommended for additional information or as examples. While every effort has been made to ensure the completeness of this list, document users are cautioned that they must meet all specified requirements of documents cited in Sections 3.0 or 4.0 of this specification, whether or not they are listed in Sections 2.1 or 2.2.

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. Unless otherwise stipulated, the most recently approved version of a listed document shall be used. In those situations where the most recently approved version is not to be used, the pertinent version is specified in this list.

MIL-STD-461 Revision F	Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment, December 2007
MIL-STD-1576	Electroexplosive Subsystem Safety Requirements and Test Methods for Space Systems, USAF, July 1984
SAE ARP 5412	Aircraft Lightning Environment and Related Test Waveforms

2.2 Reference Documents

The following documents contain supplemental information to guide the user in the application of this document. These documents, of the exact revision listed below, form a part of this document to the extent specified herein.

A-A-59551	Commercial Item Description: Wire, Electrical, Copper (Uninsulated)
ANSI C63.16-1993	American National Standard Guide for Electrostatic Discharge Test Methodologies and Criteria for Electronic Equipment
ANSI/ESD S20.20	Electrostatic Discharge (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), March 2007
ANSI/ESDA/JEDEC JS-001-2012	For Electrostatic Discharge Sensitivity Testing – Human Body Model (HBM) – Component Level

CISPR:22	Information Technology Equipment – Radio Disturbance Characteristics – Limits and Methods of Measurements, 2006
IEC 61000-4-2	Electromagnetic Compatibility (EMC) – Testing and Measurement Techniques – Electrostatic Discharge Immunity Test
JSC-CR-06-041	Radio Frequency (RF) Environments for Crew Launch Vehicle (CLV) Launch and On-Orbit Spacecraft Scenarios, June 2006
MIL-STD-464 Revision C	Electromagnetic Environmental Effects, Requirements for Systems, December 2010
MPR 7123.1B	MSFC Systems Engineering Processes and Requirements
MWI 8050.1G	Verification and Validation of Hardware, Software, and Ground Support Equipment for MSFC Projects
NASA-STD-4003A	Electrical Bonding for NASA Launch Vehicles, Spacecraft, Payloads, and Flight Equipment
NASA-STD-8739.4	Crimping, Interconnecting Cables, Harnesses, and Wiring
NPR 1800.1C	NASA Occupational Health Program Procedures
RTCA/DO-160 Revision G	Environmental Conditions and Test Procedures for Airborne Equipment, December 2010
SAE ARP 5415A	User’s Manual for Certification of Aircraft Electrical/Electronic Systems for the Indirect Effects of Lightning
SAE ARP 5416A	Aircraft Lightning Test Methods
SLS-PLAN-008	Space Launch System Program (SLSP) Configuration Management Plan
SLS-PLAN-041	Space Launch System Program (SLSP) Radio Frequency (RF) Spectrum Management Plan
SLS-PLAN-042	Space Launch System Program (SLSP) Electromagnetic Environmental Effects (E3) Control Plan
SLS-SPEC-032 Revision D	Space Launch Systems Program (SLSP) System Specification
TOR-2005 (1663)-3790	Cape Canaveral Spaceport Radio Frequency Environment, November 2005

3.0 REQUIREMENTS

The conventions used in this specification, which indicate requirements, goals, and statements of fact, are as follows:

- "Shall" – Used to indicate a requirement that is binding, which must be implemented and its implementation verified in the design.
- "Should" or "May"– Used to indicate a goal which is desirable but not mandatory.
- "Will" – Used to indicate a statement of fact or declaration of purpose on the part of the government that is reflective of decisions or realities that exist and are to be taken as a given and not open to debate or discussion.

Rationales, included for many of the requirements, are intended to provide clarification, justification, purpose, and/or the source of a requirement. In the event that there is an inconsistency between a requirement and its rationale, the requirement always takes precedence.

3.1 SLS Integrated Vehicle Intra-System Electromagnetic Compatibility (EMC)

The SLS integrated vehicle shall be electromagnetically compatible between all elements and systems.

Rationale: This overarching requirement is designed to verify that the various elements that comprise the SLS architecture are electromagnetically compatible with each other.

3.2 SLS Element Intra-System Electromagnetic Compatibility

Individual elements of the SLS vehicle shall be electromagnetically compatible between all systems, subsystems, and equipment.

Rationale: This overarching requirement is designed to verify that the various elements that comprise the SLS architecture are electromagnetically compatible within themselves.

3.3 External Interface Compatibility

The SLS integrated vehicle shall be electromagnetically compatible with external interfaces to the SLS vehicle.

Rationale: This overarching requirement is designed to verify that the SLS vehicle is electromagnetically compatible with external interfaces. External interfaces include the Orion Multi-Purpose Crew Vehicle (MPCV), Ground Systems Development and Operations (GSDO), the Communications and Tracking Network, etc.

3.4 Multipaction

Equipment and subsystems shall be free of multipaction effects.

Rationale: Multipaction is a resonant radio frequency (RF) effect that occurs in a high vacuum. An RF field accelerates free electrons resulting in collisions with surfaces, thus liberating secondary electrons. In the case where the frequency of the signal is such that the RF field changes polarity in concert with the liberation of secondary electrons, an effect similar to an avalanche process results. This effect can lead to strong electrical discharges that can easily disrupt communications and navigation subsystems, and can, under severe conditions, lead to permanent equipment damage. It is therefore essential within SLS systems that RF transmitting equipment and signals not be degraded by the action of multipaction. It is also essential that multipaction effects not result in spurious signals that interfere with receivers.

3.5 RF Electromagnetic Environment (EME)

The SLS integrated vehicle shall be electromagnetically compatible with the RF EME defined in Figures 3-1 and 3-2 and Tables 3-1 and 3-2.

Rationale: The use of RF emitters is constantly increasing. On-board emitters as well as tracking, range safety, and other launch site emitters will illuminate the SLS. Many of these emitters generate very high intensity RF fields, and can cause correspondingly high levels of degradation to SLS's performance if proper shielding and related mitigation techniques are not implanted.

Figure 3-1 is an envelope of the specific emitter sources listed in SLS-PLAN-042. Figure 3-1 was created by combining environments from several sources, including JSC-CR-06-041, RF Environments for CLV Launch and On-Orbit Spacecraft Scenarios, and TOR-2005 (1663)-3790, Cape Canaveral Spaceport Radio Frequency Environment.

Figure 3-1 does not contain data for environments created by SLS transmitters. Elements with on-board transmitters should consider the effects to their system.

RF Environments depicted in Table 3-2 and Figure 3-2 are applicable only to those elements that reach orbit.

Table 3-1. Launch Processing and Launch RF EME

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
5650.01–5850	189	11
5850.01–5900	113	21
5900.01–5925	21	21
9370–9500	17	5
9500.01–9800	40	7
9800.01–9990	17	5
13750–14000	32	32

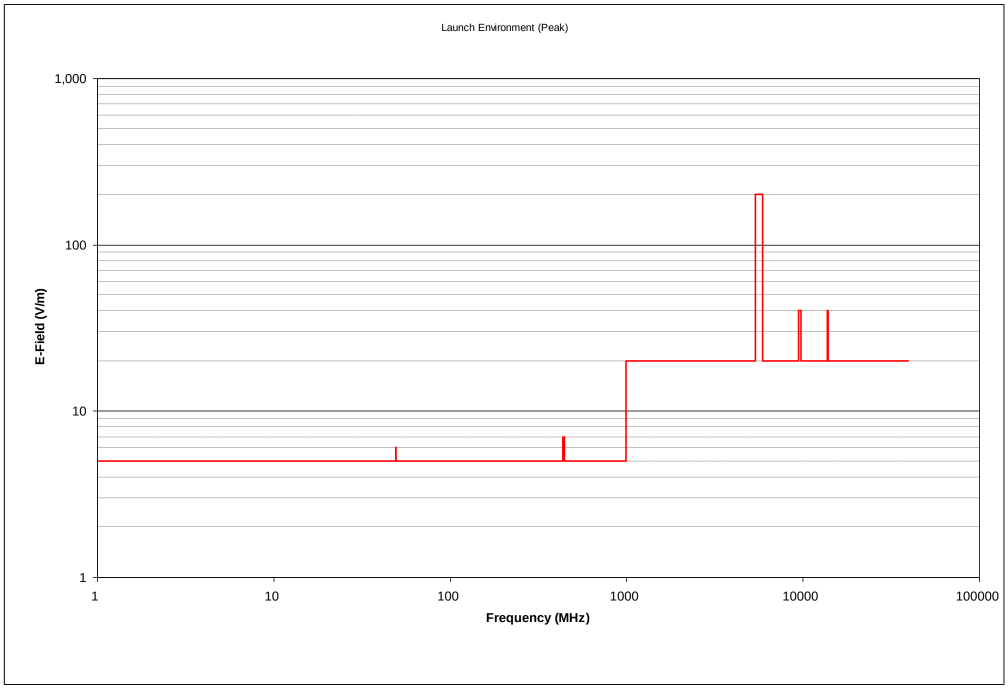

Figure 3-1. Launch Processing and Launch RF EME (Peak Environment)

Table 3-2. On-Orbit RF EME

Frequency (MHz)	Peak (V/m)	Average (V/m)
11–12	27	27
108.00	17	17
404–420.00	11	5
420.01–437.00	14	14
437.01–447.00	23	14
447.01–450.00	14	14
1175–1375	30	8
1550–1786.99	14	5
1787.00	43	43
1787.1–2090.99	14	5
2091.00	30	30
2091.1–2110.00	14	5
2110.01–2120.00	30	30
2120.01–2144.99	14	5

Frequency (MHz)	Peak (V/m)	Average (V/m)
2145.00	93	5
2145.10–2379.99	14	5
2380.00	189	189
2380.1–2839.99	14	7
2840.00	24	6
2840.1–2869.99	14	6
2870.00	24	6
2870.1–2950.99	14	6
2951.00	22	5
2951.1–3999.99	14	6
4000.00	85	85
4000.1–5399.99	15	5
5400.00–5659.99	27	5
5660.00	27	11
5660.1–5850.00	27	5
5850.01–5925.00	27	25
5925.01–6425	9	9
7155–7189	24	24
7209	6	6
8500–8559.99	7	5
8560.00	117	117
8560.10–9354.99	7	5
9355.00	142	5
9355.1–9999.99	7	5
10000.00	48	5
10593.00	10	10
14000–14500	10	10
16700	17	10
23530–23575	24	24
34316	7	7
34500–35200	11	11

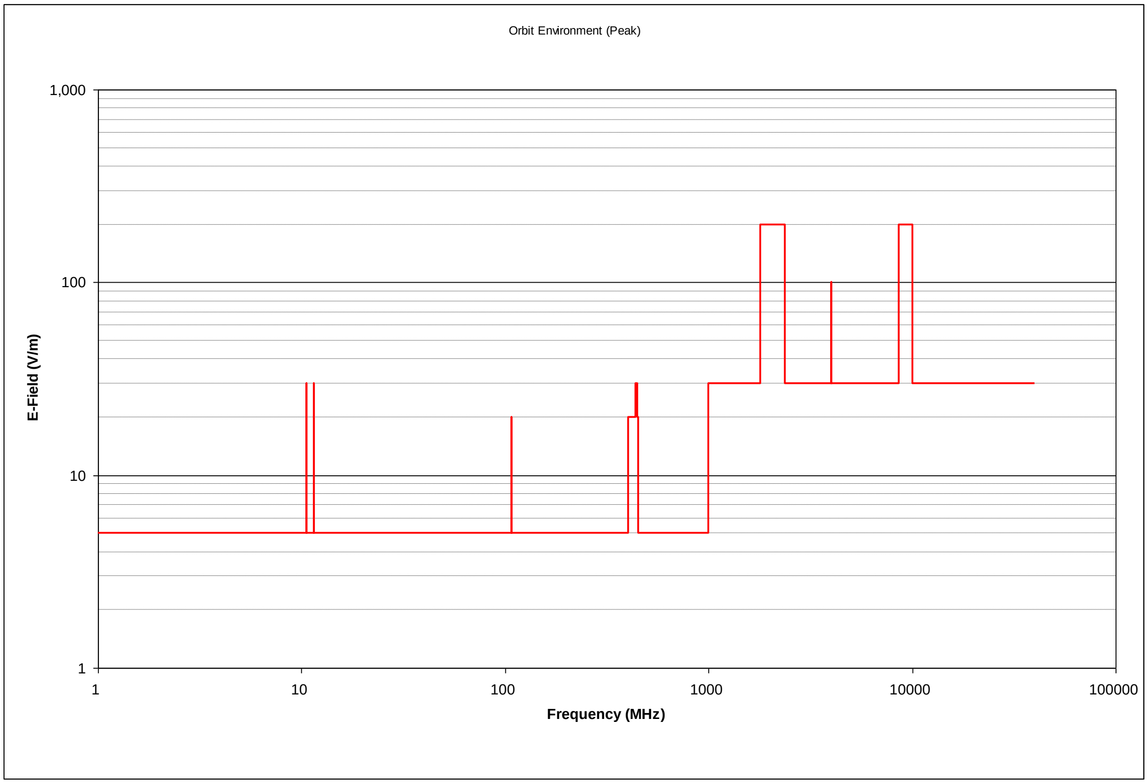

Figure 3-2. On-Orbit RF EME (Peak Environment –57° Inclination)

3.6 Lightning Indirect Effects

Individual subsystems and equipment shall meet their operational performance requirements after exposure to a nearby lightning strike as defined by SAE ARP 5412, Aircraft Lightning Environment and Related Test Waveforms, with a peak current amplitude of 200 kA that terminates to ground 157 meters away from the pad centerline.

Rationale: Lightning indirect effects may result when the electromagnetic fields and structural voltage rises produced by a strike near the vehicle induce voltages and current transients into electrical and electronic equipment. The purpose of this requirement is to assure that the vehicle has some level of immunity to those transients so that "go/no-go" decisions can be made in a timely fashion after the vehicle experiences a lightning event and prevent costly "roll-back" scenarios. This requirement is based on a lightning attachment to the LC-39 water tower, a distance of 157 meters from the pad center line. The magnetic field that the vehicle will be exposed to is based on the distance of the lightning event from the vehicle, and is not specific to pad 39. Further discussion of the basis and limitations of this requirement can be found in SLS-PLAN-042. Lightning waveform information can be found in SAE ARP 5412. Information detailing *requirement decomposition processes for lightning indirect effects can be found in SAE ARP 5415, User's Manual for Certification of Aircraft Electrical/Electronic Systems for the Indirect Effects of Lightning. SAE ARP 5416, Aircraft Lightning Test Methods, describes tests that should be considered for a verification approach.*

3.7 Subsystems and Equipment Electromagnetic Interference (EMI)

Individual subsystems and equipment shall meet the EMI control requirements of MIL-STD-461F, Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment.

Rationale: Individual equipment and system EMI characteristics, such as conducted and radiated emissions, and conducted and radiated susceptibility, must be controlled to obtain a high degree of assurance that these items will function in their intended installations without unintentional electromagnetic interactions between other equipment, subsystems, or external environments.

3.7.1 NDIs and Commercial ITE Used As or That Interface with Flight Hardware

The non-developmental items (NDIs) and commercial items that are used as flight hardware or that interface with flight hardware shall meet EMI control requirements of MIL-STD-461F.

Rationale: Information technology equipment (ITE) includes, for example, data processing equipment, office machines, electronic business equipment, and telecommunications equipment. NDI includes, for example, commercial off-the-shelf (COTS) equipment and subassemblies. NDI and commercial items that are used as flight hardware or that interface with flight hardware are subject to the same equipment and subsystem EMI specifications at the interface as other hardware developed for that system.

3.8 Electrostatic Discharge Hazards

3.8.1 Electrostatic Charge Control

The SLS integrated vehicle shall control and dissipate the buildup of electrostatic charges to avoid fuel ignition and pyrotechnic hazards, to protect personnel from shock hazards, to protect against puncture of materials and finishes, to prevent performance degradation or damage to electronics, and to mitigate the effects of spacecraft charging.

Rationale: Voltages associated with static charging and energy released during discharges are potentially hazardous to personnel, pyrotechnics, and electronics, and may ignite fuel vapors. Dust, rain, and other airborne particulate matter can impart an electrostatic charge buildup on the SLS vehicle either in situ on the launch pad or in flight during launch, caused by charge separation and the phenomenon known as triboelectric charging. Fluid and gaseous flow in lines can deposit *electrostatic charges leading to potentially hazardous voltage levels. During maintenance and servicing, contact of personnel with the structure and various materials can create a charge buildup on both the personnel and the structure, particularly on poorly conductive or nonconductive surfaces. P-static environments can be found in MIL-STD-464C Section A.5.8.2, under the Requirement Guidance paragraph.*

Additionally, the space plasma environment can produce voltage differentials either on the surface of the spacecraft (i.e., surface charging) or in the outside material itself (i.e., dielectric charging), which if it exceeds the local breakdown strength of the material can produce electrostatic discharges. These discharges can cause degradation in surface thermal properties, transient currents and malfunction of critical electronics, electromagnetic interference in radio receivers and avionics sections, and solar array degradation, among other phenomenon.

3.8.2 Electrostatic Discharge Immunity – Electronic Equipment

Electrical and electronic equipment shall be immune to ESDs equal to or less than 4000 volts (V), as defined by the Human Body Model (HBM), to the case of the equipment and to pins on external connectors in an unpowered state.

Rationale: Potentially susceptible items include electronic microcircuits, discrete semiconductors, and integrated circuits. Since 1980, several different types of ESD waveforms and categories have been identified. Of these, the HBM is the most applicable for hardware concerns at the equipment level. Also, the HBM has had three divisions of susceptibility. These divisions are Class 1 (0 V to 1999 V); Class 2 (2000 V to 3999 V); and Class 3 (upward from 4000 V). Hardware in the first two classes is considered to be the most susceptible, and thus requires the greatest level of protection.

3.8.3 Electrostatic Discharge Immunity – Insensitive Electronic Equipment

Electrical and electronic equipment without an ESD label shall be immune to ESDs equal to or less than 15,000 V to the case of the equipment and to pins on external connectors in an unpowered state.

Rationale: Equipment that does not receive a sensitivity label will need to ensure that discharges up to 15,000 volts to the equipment will not damage the equipment.

3.8.4 Electrostatic Discharge Sensitivity Labeling

Equipment sensitive to ESD events at levels below 15,000 V shall be labeled as ESD sensitive, in accordance with any variant of the JESD471 ESD symbol.

Rationale: Equipment labeled as ESD sensitive will be handled to prevent damage to equipment or latent failures using procedures and processes developed in accordance with ANSI/ESD S20.20-2007, 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).

3.8.5 Precipitation Static (p-static)

The SLS integrated vehicle shall control p-static interference to antenna-connected receivers on board the system such that system operational performance requirements are met.

Rationale: As systems in motion encounter dust, rain, snow, ice, and other particulate matter, an electrostatic charge buildup on the structure results from triboelectric charging. This buildup of static electricity causes significant voltages to be present, which can result in interference to antenna-connected equipment. P-static environments can be found in MIL-STD-464C Section A.5.8.2, under the Requirement Guidance paragraph.

3.9 Electromagnetic Radiation Hazards (EMRADHAZ)

3.9.1 Hazards of Electromagnetic Radiation to Personnel (HERP)

The SLS integrated vehicle will include RF transmitters which are capable of generating hazardous electromagnetic radiation. RF transmitter characteristics will be included in the SLS-PLAN-041, SLSP RF Spectrum Management Plan. This information should be used to comply with NPR 1800.1, NASA Occupational Health Program Procedures, non-ionizing radiation regulations.

Rationale: Radar and electronic countermeasure (ECM) systems usually present the greatest potential personnel hazard due to high transmitter output powers, antenna characteristics, and possible exposure of ground support and astronaut personnel.

Ground support personnel have a higher potential for being overexposed because of the variety of tasks, the proximity to radiating elements, and the pressures for rapid maintenance response.

3.9.2 Hazards of Electromagnetic Radiation to Fuel (HERF)

The SLS integrated vehicle shall protect against the inadvertent ignition of fuels and propellants caused by exposure to the defined RF electromagnetic environment.

Rationale: RF energy can induce currents into any metal object. The amount of current, and thus the strength of an arc or spark produced between two electrical conductors *(or heating of small filaments), depends on both the field intensity of the RF energy and how well each conducting element acts as a receiving antenna. Many parts of a system, a refueling vehicle, and static grounding conductors can act as receiving antennas. The induced current depends mainly on the conductor length in relation to the wavelength of the RF energy and the orientation in the radiated field. It is not feasible to predict or control these factors. The hazard criteria must then be based on the assumption that an ideal receiving antenna could be inadvertently created with the conductors.*

3.9.3 Hazards of Electromagnetic Radiation to Ordnance (HERO) – Performance Degradation

Electrically initiated pyrotechnic devices and systems shall meet their operational performance requirements after and during exposure to the defined RF electromagnetic environment.

Rationale: RF energy of sufficient magnitude to degrade electrically initiated pyrotechnics systems can be coupled from the RF electromagnetic environment into the electroexplosive device (EED) or firing circuit via wiring, or capacitively coupled from nearby radiated objects. The possible consequences include both hazards to safety and performance degradation.

3.10 Life Cycle and Maintainability

The system operational performance and E3 requirements of this document shall be met throughout its life cycle.

Rationale: It is essential that life cycle considerations be included in the tradeoffs used to develop E3 protection. For example, corrosion control is an important issue in maintaining EMC throughout the system's life cycle. It is important that protection provisions that require maintenance be accessible and not be degraded due to maintenance actions on these provisions.

3.11 Grounding and Isolation

SLS electrical systems shall be designed to incorporate a distributed single point ground (SPG). Figure 3-2 illustrates the distributed SPG concept.

Rationale: An electrical system is grounded for three reasons: safety, enhanced operability of the circuit, and EMI control. Some electrical circuits require grounding to a common reference plane ("ground" plane) in order to operate efficiently. A single reference to structure prevents unwanted direct current (DC) and noise currents from circulating through the structure, thereby mitigating potential EMI problems.

In order to establish a distributed SPG for the electrical power system (EPS), it is necessary to define isolation requirements at the equipment interface.

Guidance for equipment-level isolation requirements is discussed in SLS-PLAN-042. It is also necessary to ensure that secondary electrical power systems and electrical signals routed externally to equipment meet the isolation requirements to prevent multiple references to structure (ground loops).

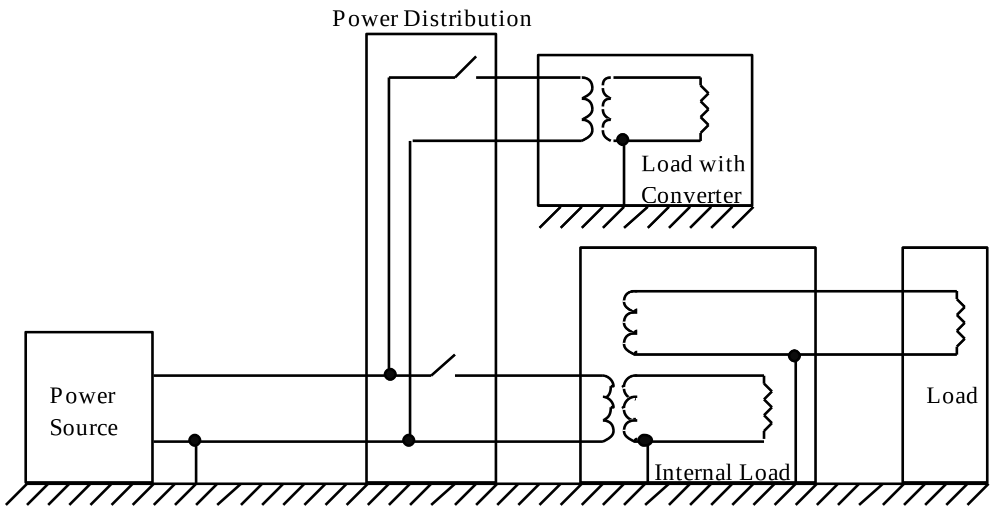

Figure 3-3. Distributed Single Point Ground Concept

3.11.1 Grounding for Electrical Fault Clearing

Each power system that contains circuit protection devices shall have the power return line connected to the chassis/structure at one and only one point to provide a fault current return path.

Rationale: Grounding an electrical power circuit provides a current return path during an electrical fault, allowing the fuse or circuit breaker to operate properly and to prevent shock hazards to personnel. It is important to maintain isolation to avoid SPG violations. These violations result in ground loops that radiate noise or pick up noise from outside sources. Circuit protection devices include fuses, circuit breakers, etc.

3.11.2 Signal Grounding

Signal returns shall be referenced to structure at a maximum of one point. This requirement is not applicable to circuits that use a coaxial shield for signal return in which all frequency components of the signal are greater than or equal to 1 MHz.

Rationale: It is important to maintain signal isolation to avoid SPG violations. These violations result in ground loops that radiate noise or pick up noise from outside sources. Signal returns include but are not limited to analog, digital, discrete, and control signals.

3.12 Cable/Harness Design and Routing for Electromagnetic Compatibility

3.12.1 Circuit Classification

Circuits or cables shall be categorized according to their interference and susceptibility characteristics.

Rationale: The determination of wiring and cabling treatment (cable shielding, twisting, controlled impedance, routing, etc.) is based on frequency, sensitivity, operating voltage, and impedance so that noisy circuits can be routed or separated away from sensitive circuits. Example circuit classification strategies are provided in SLS-PLAN-042.

3.12.2 Cable-to-Cable Crosstalk Control

Cables and harnesses shall be designed and routed to control cable-to-cable crosstalk such that the system operational performance requirements are met.

Rationale: Use of power and signal cables is prevalent on all spacecraft and payloads. These cables may act as both transmitting and receiving antennas for radiated EMI and conduits for conducted EMI. Because cables are usually routed to accommodate practical routing paths and equipment location, it is almost impossible to predict and quantify the EMI environment associated with these cables. Wire separation, shielding, routing, and bundling techniques have long been used by NASA and Department of Defense (DoD) programs/projects and are effective measures to control EMI due to cable-to-cable coupling. Proven signal separation and cable shielding strategies are discussed in SLS-PLAN-042.

3.12.3 Cable Shield Termination

Individual cable shields shall be terminated at both ends and at intermediate break points through connector backshells unless contained in an overall harness shield that meets the requirements of 3.12.4.

Rationale: Cable shields should be terminated at both ends to maximize shielding effectiveness. Peripheral terminations provide the lowest impedance termination. Direct wire or "pigtail" terminations severely impact shielding effectiveness of cable shields at frequencies above 10 MHz and should be avoided.

3.12.4 Overall Harness Shield Termination

Overall harness shields and coaxial outer conductors shall be terminated peripherally (360 degrees) through connector backshells at both ends and at intermediate break points.

Rationale: Peripheral terminations provide the lowest impedance termination. Direct wire or "pigtail" terminations severely impact shielding effectiveness of cable shields at frequencies above 10 MHz and should be avoided.

3.13 SLS Integrated Vehicle Radiated Emissions

The SLS integrated vehicle shall control unintentional radiated electromagnetic fields to be compatible with the on-board, antenna-connected RF systems.

Rationale: Verification of system compatibility with radiated emissions is a basic element of demonstrating that E3 design efforts have been successful.

Equipment test limits will be agreed upon by affected parties and documented in the element-to-element and program-to-program interface control documents (ICDs).

3.14 Electroexplosive Subsystem

The SLS electroexplosive subsystems shall comply with the electromagnetic compatibility requirements of MIL-STD-1576, Electroexplosive Subsystem Safety Requirements and Test Methods for Space Systems, as tailored for the SLS Program in Table 3-1 below.

Table 3-3. SLS Program Tailoring of MIL-STD-1576

MIL-STD-1576 Applicable Paragraph	SLS Tailored Requirement
4.4.1a	The level is to be 16.5 dB below the RF Maximum No-Fire Stimulus (MNFS) and include both the pin-to-pin firing mode and pins-to-case firing mode,
4.4.1b	No tailoring required.
5.2	A-A-59551 can be used to verify the optical shield coverage requirement.
5.3	No tailoring required.
5.4	No tailoring required.
5.5	Insulation resistance testing per NASA-STD-8739.4, Crimping, Interconnecting Cables, Harnesses, and Wiring, may be used in place of MIL-STD-1576 requirement 5.5.
5.7.1	No tailoring required.
5.7.2	The level is to be 16.5 dB below the RF MNFS.
5.7.3	No tailoring required.
5.7.4	No tailoring required.
5.7.5a	No tailoring required.
5.7.5b	The level is to be 16.5 dB below the RF MNFS.
5.7.5c	No tailoring required.
5.7.5d	SLS-SPEC-032 defines fault tolerance.

MIL-STD-1576 Applicable Paragraph	SLS Tailored Requirement
5.7.6	No tailoring required.
5.8.1	No tailoring required.
5.8.2a	The level is to be 16.5 dB below the RF MNFS.
5.8.2b	No tailoring required.
5.8.2c	No tailoring required.
5.11.1.1a	Bruceton and Neyer statistical methods may be utilized.
5.11.1.1b	No tailoring required.
5.12.1.2	No tailoring required.

Rationale: This standard establishes the general requirements and test methods for the design and development of pyrotechnic subsystems to preclude hazards from unintentional initiation and from failure to fire. The requirements apply to all subsystems utilizing explosive or pyrotechnic components, particularly those that are electrically initiated.

3.15 Corona

Equipment that utilizes or produces voltages above 150 V shall be designed to prevent corona/arcing due to the ionization of gases.

Rationale: Corona/arcing can cause EMI problems and/or contribute to hardware failures.

4.0 VERIFICATION PROVISIONS

4.1 General

This section identifies activities required to verify that the requirements of Section 3.0 have been satisfied.

4.2 Verification Methods

The SLS vehicle shall be verified by analysis, demonstration, inspection, test, validation of records, or similarity (or a combination thereof) as specified herein to assure compliance with Section 3.0. Definitions of verification methods are from Marshall Work Instruction (MWI) 8050.1, Verification and Validation of Hardware, Software, and Ground Support Equipment for MSFC Projects.

4.2.1 Analysis

Analysis involves the use of engineering analysis, qualitative assessment, computer modeling, and/or simulations to ensure compliance to the requirement(s). Analysis is a method used in lieu of, or in addition to, testing.

4.2.2 Inspection

Inspection is the physical evaluation to ensure that the requirement(s) has been incorporated or met. Inspection is used as the method on the product to satisfy such requirements as construction features, workmanship, dimensions, and physical conditions identified on the engineering documentation (e.g., drawings, Engineering Parts List).

4.2.3 Demonstration

Demonstration is the “acting out” to ensure the requirement(s) has been incorporated or met. Demonstration is used as the method on the product to satisfy such requirements as accessibility, replace-ability, and human factors.

4.2.4 Test

Test (e.g., functional, environmental) is the actual operation to ensure that the performance is in accordance with the requirement(s).

4.2.5 Validation of Records

Validation of records is the use of vendor-furnished/supplied manufacturing or processing records to ensure the requirement(s) has been incorporated or met. Validation of records is used as the method to satisfy incorporation of requirements for such items as commercial off-the-shelf products and products purchased to standards.

4.2.6 Similarity

Similarity is the process of assessing prior data, configurations, processes, or applications and concluding that the item under assessment is similar or identical to another item that has previously been verified to equivalent or more stringent specifications or validated to an equivalent use or function.

Similarity shall only be used when each of the following criteria is met:

1. Engineering evaluation(s) reveals that design configurations between the item under assessment and the similar item would produce the same results if the verification/validation activity was performed on the item under assessment.
2. The similar item was designed for and verified/validated to equal or higher environmental (e.g., thermal, stress) levels than those required for the item under assessment.
3. The item under assessment was built by the same manufacturer using the same manufacturing processes and the same quality control procedures as the similar item.
4. Similarity assessment shall undergo an independent evaluation by a technically qualified person or group other than the person(s) performing the assessment.

Similarity shall not be used when either of the following conditions exists:

1. The similar item used in the assessment was itself verified/validated using similarity as the method.
2. The item has a criticality of 1 or 1R (i.e., items whose failure or malfunction could result in loss of vehicle, life, or serious injury).

Table 4-1. Verification Methods

Requirement	Title	Method A	I	D	T	VR	S	Verification Method Comments
3.1	SLS Integrated Vehicle Intra-System Electromagnetic Compatibility (EMC)	●			●			Verification will include a combination of methods.
3.2	SLS Element Intra-System Electromagnetic Compatibility	●			●			Verification will include both methods.
3.3	External Physical Interface Compatibility	●			●			Verification will include a combination of methods.
3.4	Multipaction	●			●			Verification will include both methods.
3.5	RF Electromagnetic Environment (EME)	●			●			Verification will include both methods.

Requirement	Title	Method A	I	D	T	VR	S	Verification Method Comments
3.6	Lightning Indirect Effects	●			●			Verification will include both methods. RTCA/DO-160G, Environmental Conditions and Test Procedures for Airborne Equipment, shall be used as the test specification.
3.7	Subsystems and Equipment Electromagnetic Interference (EMI)	●			●			Verification will include both methods. MIL-STD-461F shall be used as the test specification.
3.7.1	NDIs and Commercial ITE Used As or That Interface with Flight Hardware	●			●			Verification will include both methods.
3.8.1	Electrostatic Charge Control	●			●			Verification will include either method or a combination.
3.8.2	Electrostatic Discharge Immunity – Electronic Equipment				●			Test procedures from ANSI C.63.16-1993, American National Standard Guide for Electrostatic Discharge Test Methodologies and Criteria for Electronic Equipment, or IEC 61000-4-2, Electromagnetic Compatibility (EMC) –Testing and Measurement Techniques – Electrostatic Discharge Immunity Test, with a 4 kV transient waveform from ANSI/ESDA/JEDEC JS-001-2012 shall be used as the test specification.
3.8.3	Electrostatic Discharge Immunity – Insensitive Electronic Equipment				●			Verification will be considered complete if inspection of test results from 3.8.2 confirm 3.8.3 requirement.
3.8.4	Electrostatic Discharge Sensitivity Labeling		●					
3.8.5	Precipitation Static (p-static)	●			●			Verification will include either method or a combination.
3.9.2	Hazards of Electromagnetic Radiation of Fuel (HERF)	●	●		●			Verification will include a combination of prescribed methods.

Requirement	Title	A	I	D	T	VR	S	Verification Method Comments
		Method						
3.9.3	Hazards of Electromagnetic Radiation to Ordnance (HERO) – Performance Degradation	●			●			Verification will include both methods.
3.10	Life Cycle and Maintainability	●	●		●			Verification will include a combination of prescribed methods.
3.11	Grounding and Isolation	●	●		●			Verification may include a combination of prescribed methods.
3.11.1	Grounding for Electrical Fault Clearing		●					
3.11.2	Signal Grounding	●	●					Verification will include both methods.
3.12.1	Circuit Classification	●	●					Verification will include either method or a combination.
3.12.2	Cable-to-Cable Crosstalk Control	●	●					Verification may include both methods.
3.12.3	Cable Shield Termination		●					
3.12.4	Overall Harness Shield Termination		●					
3.13	SLS Integrated Vehicle Radiated Emissions	●			●			Verification will include both methods.
3.14	Electroexplosive Subsystem	●	●		●			Verification will include a combination of prescribed methods.
3.15	Corona	●			●			Verification will include either method or a combination.

APPENDIX A
ACRONYMS AND ABBREVIATIONS

ANSI	American National Standards Institute
ARP	Aerospace Recommended Practice
CECBD	Chief Engineer's Control Board Directive
CISPR	International Special Committee on Radio Interference
CLV	Crew Launch Vehicle
COTS	Commercial Off-the-Shelf
CR	Change Request
dB	Decibel
DC	Direct Current
DoD	Department of Defense
E3	Electromagnetic Environmental Effects
ECM	Electronic Countermeasure
EED	Electroexplosive Device
EMC	Electromagnetic Compatibility
EME	Electromagnetic Environment
EMI	Electromagnetic Interference
EMRADHAZ	Electromagnetic Radiation Hazard
EPS	Electrical Power System
ESD	Electrostatic Discharge
GSDO	Ground Systems Development and Operations
HBM	Human Body Model
HERF	Hazards of Electromagnetic Radiation to Fuel
HERO	Hazards of Electromagnetic Radiation to Ordnance
HERP	Hazards of Electromagnetic Radiation to Personnel
ICD	Interface Control Document
IEC	International Electrotechnical Commission
ITE	Information Technology Equipment
JEDEC	Joint Electron Device Engineering Council
JSC	Joint Spectrum Center
kA	Kiloamperes
LC	Launch Complex
MHz	Megahertz
MIL	Military

MNFS	Maximum No-Fire Stimulus
MPCV	Multi-Purpose Crew Vehicle
MPR	Marshall Procedural Requirement
MSFC	Marshall Space Flight Center
MWI	Marshall Work Instruction
NASA	National Aeronautics and Space Administration
NDI	Non-Developmental Item
OPR	Office of Primary Responsibility
PCB	Program Control Board
PCBD	Program Control Board Directive
p-static	Precipitation Static
RF	Radio Frequency
RQMT	Requirement
RTCA	Radio Technical Commission for Aeronautics
SAE	Society of Automotive Engineers
SLS	Space Launch System
SLSP	Space Launch System Program
SPG	Single Point Ground
SRR	System Requirements Review
STD	Standard
TOR	Technical Operating Report
USAF	United States Air Force
V	Volts
V/m	Volts per Meter