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SPACECRAFT PAYLOAD INTEGRATION AND EVOLUTION OFFICE SECONDARY PAYLOAD DEPLOYMENT SYSTEM AVIONICS REQUIREMENTS

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REVISION AND HISTORY PAGE

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1.1 INTRODUCTION

1.2 Purpose

The purpose of this document is to document the performance requirements for the Secondary Payload Deployment System (SPDS) avionics (sequencer and battery). The document identifies the avionics external interfaces, both mechanical and electrical.

1.3 Scope

The SLS SPIE Secondary Payloads Deployment System consists of the deployer, sequencer, battery, and cables for the EM-1 mission. This requirements document addresses only the sequencer and battery. These 2 components comprise the avionics and may be combined or separate. There will be 2 types of avionics: flight and qualification. The flight unit conforms to this document to the fullest extent. The qualification unit is a flight unit designated for qualification testing purposes and will not be used as a flight unit due to overstressing.

1.4 Change Authority/Responsibility

The NASA Office of Primary Responsibility (OPR) for this document is FP30.

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

2.1 DOCUMENTS

2.2 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.

MSFC-STD-3012	EEE Parts Management and Control
SLS-PLAN-008	SLS Program Configuration Management Plan
NASA-STD-4003	Electrical Bonding for NASA Launch Vehicles, Spacecraft, and Flight Equipment
SLS-RQMT-040	SLS Program Electromagnetic Environmental Effects (E3)
NASA-STD-5019	Fracture Control Requirements
SLS-SPEC-028	SLS Structural Design and Verification Requirements
NASA-STD-5001	Structural Design And Test Factors Of Safety For Spaceflight Hardware
NASA-STD-5003	Fracture Control Requirements For Payloads Using The Space Shuttle
MIL-S-8879	Screw Threads, Controlled Radius Root With Increased Minor Diameter, General Specification For
MSFC-HDBK-527/JSC 09604	Materials Selection List For Space Hardware Systems
MSFC-STD-3029	Guidelines For The Selection Of Metallic Materials For Stress Corrosion Cracking Resistance In Sodium Chloride Environments Materials, Processes, And Manufacturing Department Metallic Materials And Processes Group
NASA-STD-6016	Standard Materials and Processes Requirements for Spacecraft
JSC 29353	Flammability Configuration Analysis For Spacecraft Applications

NASA-STD-6012	Corrosion Protection for Space Flight Hardware
MIL-STD-130	Identification Marking of U.S. Military Property
NASA-STD-8739.1, .4, & .5	NASA Workmanship Standards
J-STD-001DS	Space Applications Electronic Hardware Addendum
IPC J-STD-001ES	Joint Industry Standard, Space Applications Electronic Hardware Addendum
IPC-6012B	Qualification & Performance Specification for Rigid Printed Wiring Boards
MSFC-STD-3425	Design Requirements for Rigid Printed Circuit Boards & Assemblies
D-27777	SLS Environmental Qualification and Acceptance Testing Requirements Document
SN-C-0005	Contamination Control Requirements
SLS-PLAN-013A	SLS SMA Plan
SLS-RQMT-014	SLS SMA Requirements
MWI 8730.2	Temporarily - Installed Hardware Control
MPD 1280.1	MSFC Quality Management System Policy
MIL-DTL-38999	Detail Specification: Connectors, Electrical, Circular, Miniature, High Density, Quick Disconnect (Bayonet, Threaded, And Breech Coupling), Environment Resistant, Removable Crimp And Hermetic Solder Contacts, General Specification For
SLS-SPIO-SPEC-001	SPIO ISPE Design Environment
NPR 6000.1	Requirements for Packaging, Handling, and Transportation for Aeronautical and Space Systems, Equipment, and Associated Components

2.3 Reference Documents

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

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
ASME Y14.5M-1994	Dimensioning & Tolerancing

3.0 AVIONICS REQUIREMENTS

3.1 Description

The Space Launch System (SLS) Secondary Payload Deployment System (SPDS) avionics enables payload deployment by providing a battery for power and a sequencer for managing timed signals to the deployer. The avionics will reside in an adapter ring located between the vehicle's second stage and primary payload. The avionics sequencer receives an activation signal from the vehicle's second stage; it does not provide SPDS feedback or status to the vehicle second stage. There is no feedback to the avionics from the deployers or payloads as to any status (stowed or deployed).

The sequencer and battery (the avionics system) is not to be used in launch decision or real-time ascent contingency decisions. Loss of functionality of the sequencer or battery will not affect launch decision; therefore, the sequencer and battery is classified as a Criticality 3 subsystem and does not require redundancy for payload mission success. The criticality of inadvertent activation is unknown because the credibility of the failure and the failure consequences cannot been adequately determined, based on the design maturity. Since the sequencer is the unit that signals the deployers to open and jettison their payloads, the sequencer will provide a signal discrete to each deployer. The signal will be sufficient to activate the deployer. In order to protect the vehicle and its primary payload from inadvertent payload deployment, the sequencer will not be powered until completion of the ICPS disposal maneuver.

Provider of the SPDS's avionics has the option of providing a combined sequencer / battery unit or two separate units, as long as the units work together and meet the joint requirements within this document. Use of existing military or Commercial Off-The-Shelf (COTS) hardware qualified to commercial levels is encouraged.

3.2 Sequencer Functions

Upon sequencer receipt of a "wake-up" signal (discrete) from the vehicle second stage, the sequencer:

1. Initiates counting
2. Sends a signal discrete to each deployer, releasing each payload
3. Shuts the system down once all payloads have been deployed

Prior to flight, "mission skits" will be loaded into the sequencer. These skits determine the delay from the "wake-up" signal to deployment, the proper deployer, and in what order deployment will occur. Neither the deployers nor payloads provide feedback to the avionics system pertaining to status (stowed or deployed).

3.3 Battery Function

The avionics is powered by its own battery. The avionics battery is charged prior to flight. The battery will be able to power the avionics for the period of 10 days. During charging, battery cell health will be monitored externally by GSE for voltage and amperage and read a thermistor in the battery, see Figure 3.3-1.

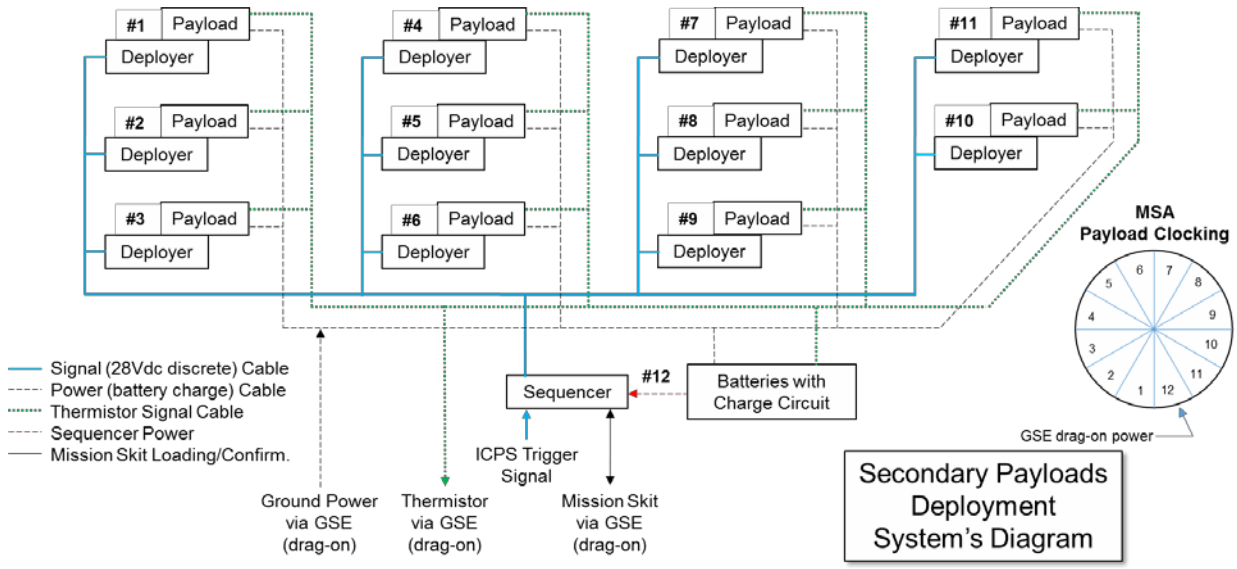


Figure 3.3-1 System Interface Diagram

3.4 Avionics Design and Construction Characteristics

3.4.1 Electrical Design

3.4.1.1 EEE Parts

The avionics shall meet the requirements of MSFC-STD-3012 grade 3 or 4, EEE Parts Management and Control for MSFC Space Flight Hardware.

Rationale: This requirement meets the selection and control of the electrical, electronic, and electromechanical parts to assure the reliability of avionics components commensurate with those components' criticality.

3.4.1.2 Lightning Protection

If circuit upset, due to a lightning strike, could result in a catastrophic hazard (one which would cause premature deployment) to the SLS, the circuit design shall be hardened against the environment or insensitive devices (relays) shall be added to control the hazard.

Rationale: The avionics system must not result in a catastrophic hazard after a lightning strike to the vehicle itself or to nearby structures.

3.4.1.3 Bonding

The avionics shall comply with the electrical bonding requirements of NASA-STD-4003, Electrical Bonding for NASA Launch Vehicles, Spacecraft, and Flight Equipment for a class S bond.

Rationale: All systems and components must be bonded properly in order to comply with electromagnetic compatibility for functional and safe performance.

3.4.1.4 Electrical Grounding

Electrical systems shall be designed to incorporate a distributed single point ground (SPG).

Rationale: The grounding requirement mitigates safety concerns.

3.4.1.5 Circuit Classification

The avionics shall meet the electrical circuit classification requirements of SLS Program Electromagnetic Environmental Effects (E3) Requirements SLS-RQMT-040 Document.

Rationale: Required for proper selection of wire and/or cabling to minimize the effects of EMI.

3.4.1.6 Electromagnetic Interference (EMI)

The avionics shall meet the electromagnetic interference requirements of the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment, as specified in SLS Program Electromagnetic Environmental Effects (E3) Requirements, SLS-RQMT-040 Document.

Rationale: To ensure immunity to EMI and to minimize interference from the device to the vehicle.

3.4.1.7 Ignition Source Avoidance

The avionics electrical components and wiring shall be conformally coated, or otherwise ignition-proofed to prevent ignition of potentially flammable or explosive gases/fluids existing in the vehicle MSA volume.

Rationale: Required for safe operation.

3.4.2 Structural and Mechanical

3.4.2.1 Fracture Control

The avionics shall comply with the requirements of NASA-STD-5019 Fracture Control requirements for manned space flight systems.

Rationale: This document establishes the fracture control requirements for all human-rated spaceflight systems including payloads, propulsion systems, orbital support equipment, and planetary habitats.

3.4.2.2 Structural Design and Verification

The avionics shall comply with SLS Structural Design and Verification Requirements SLS-SPEC-028 Document.

Rationale: SLS presents common structural design and verification requirements to ensure consistent design, development, and verification of hardware. This document describes general design requirements, design loads, factors of safety and margins of safety, design and stress analysis requirements, structural materials criteria and discusses secondary structure accommodation for human interface and nonstandard fasteners.

3.4.2.3 Fasteners

Fasteners that are used in the avionics system shall meet the structural requirements of NASA-STD-5001, MIL-S-8879, and the fracture control requirements of NASA-STD-5003, paragraph 4.2.3.4.

Rationale: The harsh operational environment will dislodge systems not properly fastened, causing fatal errors.

3.4.2.4 Stress Corrosion

Materials used in the design of the avionics system shall be rated for resistance to Stress Corrosion Cracking in accordance with tables in MSFC-HDBK-527/JSC 09604 and MSFC-STD-3029.

Rationale: This is a safety-driven requirement to protect the vehicle.

3.4.3 Materials

3.4.3.1 Flammability

The avionics shall meet the requirements for flammability as specified in NASA-STD-6016, paragraph 4.2.1.1, as assessed in accordance with JSC 29353, Flammability Configuration Analysis for Spacecraft Applications.

Rationale: This requirement is needed to ensure non-flammable materials are used.

3.4.3.2 Incompatible Materials

The avionics shall be protected against galvanic corrosion by connecting only compatible metals unless protective coatings, sealants, and insulation are used per NASA-STD-6012.

Rationale: The contact of different metals can cause galvanic corrosion.

3.4.3.3 Surface Finish

All parts, assemblies, and equipment comprising the battery and sequencer shall have finish per NASA-STD-6012.

Rationale: This is to provide protection from corrosion and galvanic couples, which reduces the structural integrity of the metals leading to critical failures.

3.4.3.4 Dimensioning and Tolerancing

The avionics shall comply with ASME Y14.5M-1994, Dimensioning and Tolerancing.

Rationale: The avionics needs to establish uniform practices for stating and interpreting dimensioning, tolerancing, and related requirements for use on engineering drawings and in related documents.

3.4.4 Product Marking

3.4.4.1 Part Marking

The avionics shall comply with the requirements of MIL-STD-130 for part marking.

Rationale: This requirement is needed in order to identify and levy the necessary requirements for part marking and to ensure a consistent and acceptable approach is used across the project. The requirement defines the standard to be applied for part marking.

3.4.4.2 Marking Label Readability

The avionics shall comply with the requirements of Human Factors Engineering Design Criteria for Labeling, MIL-STD-130.

Rationale: Specifying common labeling characteristics is required so that a common set of labels can be developed (including, symbols, text, phrases, colors, etc.) for use in all applications of ground crew and flight crew access to the hardware.

3.4.4.3 Units of Measure

The avionics shall be documented using English units, with SI units in parenthesis.

Rationale: The avionics system must be designed for consistency with SLS.

3.4.5 Workmanship

3.4.5.1 OTS Workmanship

The avionics shall comply with the commercial workmanship standards for (Off-The-Shelf) OTS assemblies for the Manufacture and Inspection of Electrical, Electromechanical Hardware for Aerospace and High Performance Spaceflight, and Mission Essential Support Equipment Applications for OTS assemblies.

Rationale: NASA-STD-8739 and J-STD-001DS do not apply to OTS assemblies; and as a rule commercial vendors may not follow NASA-STD-8739 or J-STD-001DS and application of those standards to OTS assemblies is not practical.

3.4.5.2 Staking and Conformal Coating of Printed Wiring Boards

The custom or modified assemblies in the avionics shall be in accordance with NASA-STD-8739.1, Workmanship Standard for Staking and Conformal Coating of Printed Wiring Boards and Electronic Assemblies.

Rationale: This satisfies the requirement for staking and conformal coating of printed wiring boards and electronic assemblies. Staking provides protection and support for parts that may be

damaged by vibration, shock or handling. Conformal coating provides electrical insulation and environmental protection for electronic printed wiring assemblies from humidity, handling, debris, and contamination. Conformal coating inhibits ignition sources and EMI from arching and sparking.

3.4.5.3 Surface Mount Technology

The custom or modified assemblies in the avionics Surface Mount Technology shall be in accordance IPC J-STD-001ES, Joint Industry Standard, Space Applications Electronic Hardware Addendum to J-STD-001E Requirements for Soldered Electrical and Electronic Assemblies.
Rationale: This satisfies the requirements for hand and machine soldering of surface mount electrical connections and to ensure proper workmanship for surface mount area array packages. Reference the Surface Mount Area Array Packages section of J-STD-001ES for the supplemental requirements.

3.4.5.4 Soldered Electrical Connections

The custom or modified assemblies in the avionics shall be in accordance with IPC J-STD001ES, Joint Industry Standard, Space Applications Electronic Hardware Addendum to J-STD-001E Requirements for Soldered Electrical and Electronic Assemblies.
Rationale: This satisfies the requirements for hand and wave soldering to obtain reliable electrical connections.

3.4.5.5 Crimping, Interconnecting Cables, Harness, and Wiring

The custom or modified assemblies within the avionics shall be in accordance with NASA-STD-8739.4, Crimping, Interconnecting Cables, Harness, and Wiring for custom or modified components.
Rationale: This satisfies the requirements for crimping, interconnecting cable, harness assemblies and wiring that connect electrical/electronic and electromechanical components.

3.4.5.6 Rigid Printed Wiring Board Products

The custom or modified assemblies within the avionics shall be in accordance with IPC-6012B, Class 3A, Qualification and Performance Specification for Rigid Printed Wiring Boards.
Rationale: This satisfies the requirements for printed wiring board products intended for use in aircraft, spacecraft, launch vehicles, and mission-essential support equipment. The requirements are to be invoked by design documentation for flight hardware and critical support equipment.

3.4.5.7 Printed Wiring Board Design

The custom or modified assemblies within the avionics shall be in accordance with rigid printed wiring boards design requirements of MSFC-STD-3425, Design Requirements for Rigid Printed Circuit Boards and Assemblies.
Rationale: This requirement will assure that printed wiring board designs will meet the high reliability required for Class 3 hardware and survive the harsh environments imposed by space flight.

3.4.5.8 Electrostatic Discharge Controls

The avionics shall be produced, manufactured, and handled using ESD controls 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).

Rationale: This requirement will assure that hardware sensitive to ESD will be protected/undamaged.

3.4.6 Interchangeability

N/A

3.4.7 Software Safety

3.4.7.1 Software Signal Redundancy

The sequencer software/firmware shall be configured so that two parallel signals will be required to initiate deployment of a payload.

Rationale: To protect the vehicle from damage by an accidental deployment of a payload too early into the flight, two signals from the system's sequencer will be required. In this way a single, errant signal cannot cause an early deployment.

3.4.7.2 Software Architecture

The sequencer software/firmware shall accept, via ground loading, the mission skit defining the timing and order of each payload's deployment in RS422 format and mirror back to the ground equipment the skit for verification purposes.

Rationale: Specific mission deployment sequence and timing will be loaded at the Vehicle Assembly Building (VAB) via a GSE drag-on cable. This will allow for last minute changes to deployment order while the vehicle is being stacked/checked-out prior to roll out.

3.4.8 Human Engineering

3.4.8.1 Ground Crew Interfaces

The avionics shall provide/identify GSE lifting points, for crane operations, to aid the ground crew in handling and installing the avionics system into the Multi-Purpose Crew Vehicle Stage Adapter (MSA).

Rationale: The avionics weight may exceed the limits of a single ground person to lift/carry the unit. Crane operations will be needed to aid in the installation of the unit onto the MSA frame.

3.4.9 Communications

N/A

3.4.10 Other

3.4.10.1 Environmental Qualification and Acceptance Testing

The avionics shall comply with the requirements of SLS Environmental Qualification and Acceptance Testing Requirements Document D-27777, for environmental qualification and acceptance testing.

Rationale: This requirement is necessary to ensure that the qualification and acceptance of flight hardware, systems, and major assemblies are designed and verified in accordance with the approved requirements.

3.4.10.2 Cleanliness Requirements

The avionics shall comply with the SLS vehicle Contamination Control Plan, SN-C-0005 VC level sensitive.

Rationale: This requirement is needed to provide a consistent and acceptable approach across the project. The vehicle requires cleanliness program for safety and mission success.

3.4.10.3 System SR&QA

The avionics shall comply with the requirements specified in SLS SMA Plan SLS-PLAN-013A and section 3.8 of SLS SMA Requirements SLS-RQMT-014.

Rationale: The plan contains system SR&QA top-level requirements, roles, and responsibilities that provide a systematic and objective approach for all launch projects, including lower level project elements, during all phases of the life cycle from launch vehicle design, development, testing, and to the design of all processes from manufacturing to final disposal and/or disposition.

3.4.10.4 Temporary Installed Hardware Identification

All temporarily installed devices shall be marked in accordance with MWI 8730.2, MPD 1280.1 (Remove Before Flight).

Rationale: The color draws attention to any test or temporarily installed hardware (i.e. safety pins or other such items). This includes but is not limited to; test equipment, caps, plugs, covers, support brackets, protective plates, etc.

3.4.10.5 Cross Connection Prevention

The avionics shall prevent miss mating of connectors in close proximity by utilizing clear labeling, connector sizing and insert arrangements, or physical routing for those connectors.

Rationale: The accidental connection of incompatible cables or the disconnections of cables during flight are safety concerns. It is expected that cable slack will be limited, which will prevent many possible misconnections (thus not all connectors need to be unique). For other components, use of differing connectors should help avoid misrouting of cables.

3.4.10.6 Mounting Interface

The avionics shall provide a mounting interface pattern as identified in Figure 3.4.10.6-1.

Rationale: Must ensure that components are built to accept the specified fasteners.

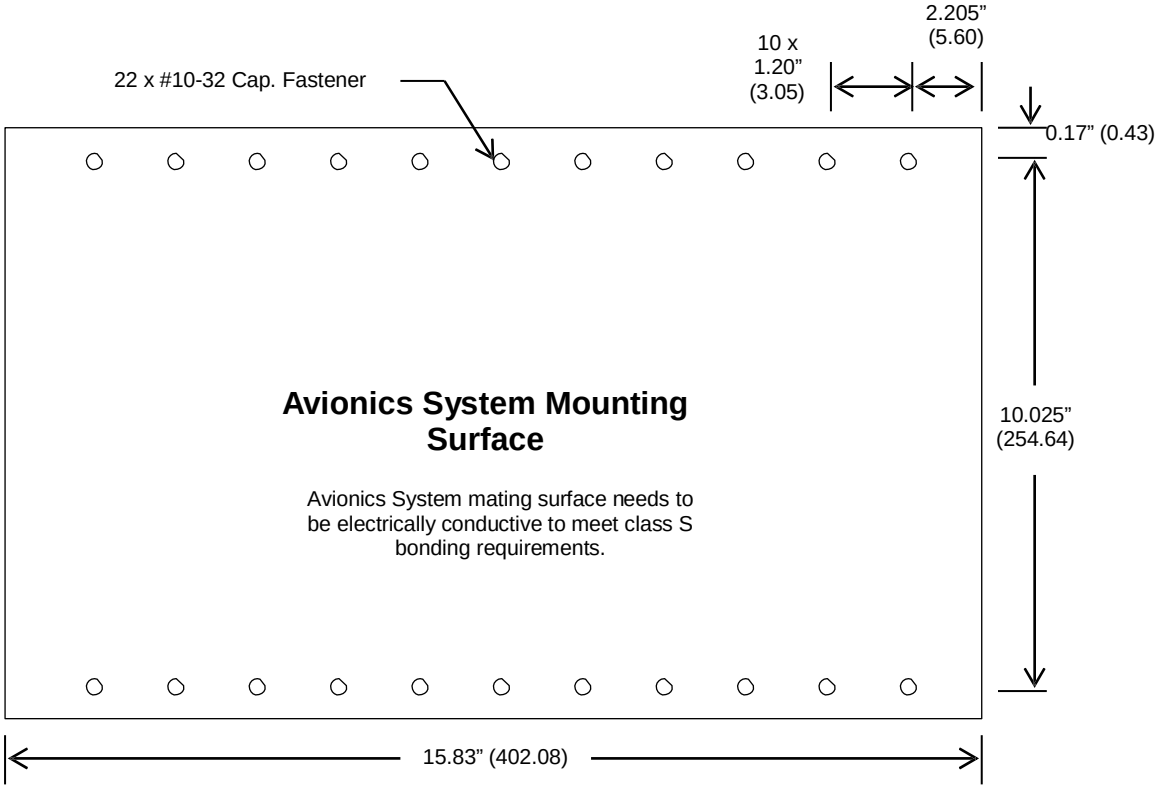


Figure 3.4.10.6-1 Avionics System Mounting Hole Pattern

3.4.10.7 Captive Fasteners

The avionics shall provide captive fasteners with all components requiring any disassembly to aid in installation into the MSA.

Rationale: Protects loose fasteners from falling down into the vehicle during avionics installation.

3.4.10.8 Activation Circuit

The activation circuit shall require two series activation actions to complete the battery-sequencer circuit.

Rationale: Two series of actions are needed to activate the sequencer in order to protect the vehicle from inadvertent payload deployment.

3.4.10.9 Physical Isolation

Electro-mechanical switches (relays or solenoid-switches) used to perform the battery – sequencer circuit closure shall be physically isolated from one another, not be in the same compartment of the sequencer.

Rationale: The purpose of this requirement is to prevent failure propagation due to a part failure or contamination encroachment from a common source.

3.4.10.10 Covered Relays

Relays shall be covered.

Rationale: The purpose of this requirement is to prevent failures due to contamination from manufacturing, transportation, and handling of the relays and to reduce contamination during the assembling and testing of the sequencer.

3.4.10.11 Device Manufacturer

If relays or solenoids-switches are used as the sole switching actuator to the sequencer they shall not be from the same manufacturer.

Rationale: The purpose of this requirement is to prevent defects common to a single manufactured product. The defects common to identical products are defects in: design, assembly, material, and quality.

3.4.10.12 Mortality Testing

Relays and solenoid-switches shall undergo infant mortality cycle testing while limiting the current through the contacts to no more than what is expected during sequencer start up. (Note, accelerated testing may require higher current values and/or fast cycle times. Separate, independent supplies of current are to be used when testing the relays / solenoid switches.)

Rationale: The purpose of this requirement is to catch gross manufacturing defects in material or assembly of the flight article without reducing the cycle life expectancy of the flight article. Separate, independent power supplies are needed to prevent inductive current transients from adding to the duty cycle life of the contacts.

3.4.10.13 Replacement Articles

A replacement article shall pass infant mortality testing.

Rationale: If the article under test fails infant mortality testing an identical replacement article from the same manufacture may be used but the replacement article must come from a different lot number.

3.4.10.14 Actuator Orientation

If relays or solenoids-switches are used as the sole switching actuator to the sequencer, the axis on which the coil of a relay or solenoid is wound shall be perpendicular to axis of the coil of the other solenoid or relay.

Rationale: The purpose of this requirement is to minimalize the g force effects on items that may have similar mass and mass moments of inertia.

3.4.10.15 Use of Barriers

Mechanisms that use a barrier or insulation-circuit blocking scheme to keep the battery circuit open shall satisfy the two series activation action, with use of a barrier method listed below.

- Devices that use translation of the blocking insulator mechanism to keep the circuit open must have a second activation method that prevents the blocking mechanism from undergoing premature movement.
- Devices that use rotation of an insulator and rotation of the insulator to a final conductor to complete the circuit closure must have a secondary method of preventing angular rotation of the insulating disk (or mechanism).

Rationale: Removal of the secondary translational or rotational circuit blocking mechanism by an activation action signal and translation of the primary insulator to a conduction path by the action of another activation action signal satisfies the two series activation action in requirement 3.4.10.8.

3.4.11 Interface Requirements

3.4.11.1 Vibration Isolation Interface

If the avionics needs vibration isolation, then the vibration isolation devices shall be between the avionics and the MSA mounting bracket.

Rationale: Vibration isolation may be needed to survive SLS vehicle launch environments.

3.4.11.2 Alternate System Bonding to MSA

If vibration isolation devices are used, the system shall provide an alternate bonding/grounding class S path to the MSA bracket per NASA-STD-4003.

Rationale: Avionics must be grounded / bonded to the vehicle through the MSA mounting bracket to meet SLS vehicle requirements.

3.4.11.3 Thermal Protection Interface

If the avionics needs thermal protection, then the thermal protection shall be on the system's external surfaces.

Rationale: Thermal protection may be needed to survive SLS vehicle and space environments while mounted in the MSA.

3.4.11.4 System Mass

The overall mass of the battery, sequencer system plus any additional thermal protection or vibration isolation features shall not exceed 60 lbs.

Rationale: The avionics bracket in the MSA is designed to withstand a maximum weight of 60 lbs.

3.4.11.5 System Envelope

The overall envelope of the battery, sequencer system plus any additional thermal protection or vibration isolation features shall not exceed 7.5” (190.5 mm) high x 10.5” (266.7 mm) wide x 15.75” (400.5 mm) long.

3.4.11.6 Avionics System Vent Rate

The avionics shall vent atmosphere at a minimum rate of 0.15 psi/sec during vehicle accent.
Rationale: During ascent, the avionics will need to depressurize with the rise of the vehicle during launch.

3.4.12 Battery Specific Requirements

3.4.12.1 Battery Power for Deployment

The battery shall deliver 28 Vdc ± 4Vdc at 1.5 Amps ± 0.1 Amp for a period of 0.1 ± 0.03 sec. power for each deployment. <TBR-001>
Rationale: The system sequencer needs power to perform mission counting and to manage the deployment skit. The voltage and amperage is the maximum draw to perform a deployment.

3.4.12.2 Battery Duty Power

The battery shall provide the sequencer with an average of 240 Watt-Hour for the duration of the mission.
Rationale: The battery will supply the power, which allows the sequencer to perform its functions. The power level and duration of power to perform the mission skit must not exceed required levels due to system battery size & mission duration. This power consumption does not include payload triggers to the deployers.

3.4.12.3 Battery Mission Time

The battery shall operate for a minimum period of 10 days starting at the time of activation by the second stage.
Rationale: The battery will provide power to the sequencer, which will provide the trigger signal to the deployer for payload deployment over a ten day period.

3.4.12.4 Battery Charging

The battery shall contain its own charging circuit.
Rationale: Prior to vehicle rollout to the pad a drag-on power cable will be available to the deployment system for battery charging. The drag-on power will be adjusted to accommodate the system’s battery trickle charge circuit. For safety purposes each cell needs to be monitored to assure no over-voltages occur and promote a hazard.

3.4.12.5 Battery Wire Connector to Ground Charging Power

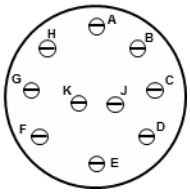
The battery shall use a series III, MIL-DTL-38999 mil standard connector (10 contacts size 20) for taper power while in the VAB.

Rationale: The use of a MIL-DTL-38999 mil standard socket connector satisfies the standard set by ground services.

3.4.12.6 Battery to Ground Connector Pin-Out

The battery shall use a series III, MIL-DTL-38999 mil standard pin connector pin-out as shown in Figure 3.4.12.6-1.

Rationale: The pin-out needs to be standardized for system wiring and battery pin-out design considerations. Pin-out shows optional functions that may be used in future configurations.



C98

Pin	Function
A	RDA(-) – RS422
B	RDA(+) – RS422
C	TDA(-) – RS422
D	TDA (+) – RS422
E	Ground – RS422
F	Power +
G	Spare
H	Power -
J	Spare
K	Spare

Figure 3.4.12.6-1 Battery to Ground Pin-Out Interface Configuration

3.4.12.7 Reverse Polarity Protection

The avionics shall contain a diode on the positive leg of the charging circuit to the battery. *Rationale: The battery will be charged while mounted in the vehicle, prior to flight. The diode protects the battery and ground charging system from reverse polarity when charging. The diode also limits battery bleed-off when not being charged.*

3.4.12.8 Battery Temperature Monitoring

The battery shall provide temperature data during recharging and discharging activities, when mounted in the MSA.

Rationale: Battery temperature is one of the safety monitor parameters to protect the vehicle.

3.4.12.9 Battery Thermistor Type

The avionics shall contain a 10K thermistor with the battery pack with the leads made available to an external connector.

Rationale: The ground system needs the signal from a 10K thermistor to read the temperature of the battery to guard against overheating and fire.

3.4.12.10 Charging Circuit Isolation

The avionics battery charging circuit shall be separate from the avionics circuit.

Rationale: The avionics system cannot power up its main systems when being charged, due to safety concerns (i.e. premature deployment)

3.4.12.11 Smart Batteries

The avionics battery shall use Li-ion 18650 rechargeable batteries with built in protection listed below:

- Overcharge (activated at 4.35V)
- Overdischarge (activated at 2.5V)
- Overcurrent (activated at 7A – 8A)
- Overheating, and dual short circuit protection (external & internal)

Rationale: The charging system is tailored to Li-ion batteries. The built in protections are added safety features to protect the vehicle and ground crew.

3.4.12.12 Failure Containment

The battery enclosure shall contain any possible battery over-pressure failure, gas seepage, or fluid leakage generated from the contents of the battery.
Rationale: Since the battery is an energy storage device it has to contain itself so as to not propagate any failure within the battery to the vehicle.

3.4.12.13 Battery Lot Testing Criteria

The battery cells used in the avionics battery shall meet the criteria identified in appendix D of this document.
Rationale: Battery cell selection must be made in order to assure safe operation of the avionics.

3.4.13 Sequencer Specific Requirements

3.4.13.1 Trigger Signal from Sequencer

The sequencer shall transmit 80 ± 5 watts at 28Vdc for a period of 0.10 ± 0.03 seconds for each of up to 11 payloads to initiate full deployment of a payload by a deployer. <TBR-002>
Rationale: The sequencer will provide two trigger signals, on two paths, to each deployer for payload deployment. The power level and duration of power to open the door and push the payload out of the deployer must not exceed required levels due to system battery size & mission duration.

3.4.13.2 Trigger Signal from SLS Second Stage

The sequencer shall receive a redundant 28 Vdc command discrete from the SLS second stage with a voltage from 23Vdc to 33Vdc with a maximum current of 500 mA for a period of 200 ±20 milliseconds to initiate the system's deployment skit.
Rationale: The vehicle upper stage will provide the trigger signal for the sequencer to start the countdown to those deployments.

3.4.13.3 Sequencer Trigger Power

The sequencer shall receive 28 Vdc at a maximum of 2.8 Amps power from the system's battery.
Rationale: The sequencer needs power to perform mission counting and to manage the deployment skit. The voltage and amperage is the maximum draw to perform a deployment. Counting/skit operations will have much lower power consumption.

3.4.13.4 Sequencer Duty Power

Once activated by the SLS Second Stage the sequencer shall draw an average of < 1Watt-Hour for the duration of the mission.
Rationale: The sequencer will provide the trigger signal to the deployer for payload deployment. The power level and duration of power to perform the s/w skit must not exceed required levels due to the battery size & mission duration. This power consumption does not include payload triggers to the deployers.

3.4.13.5 Sequencer Mission Time

The sequencer shall operate, once activated for a minimum period of at least 10 days.
Rationale: The sequencer will provide the trigger signal to each deployer for payload deployment over a ten day period.

3.4.13.6 Sequencer Skit Capacity

The sequencer shall be able to hold up to 3 mission skits, totaling 11 deployments per skit.
Rationale: The sequencer needs to hold a skit for a 3.5 day mission, a 6.5 day mission, and a 9.5 day mission to accommodate different lunar launch windows.

3.4.13.7 Sequencer Skit Selection

The sequencer shall select one of three mission skits based on SLS second stage trigger signal (one 20 msec. pulse for skit #1, two 20 msec. pulses for skit #2, and three 20 msec. pulses for skit #3 with a 10msec. delay between pulses).
Rationale: Based on which launch window the vehicle departs Earth will determine which skit the sequencer performs. Ground control can command the SLS second stage to instruct the sequencer to operate the proper skit.

3.4.13.8 Sequencer Clock Accuracy

The sequencer clock shall be accurate within ±0.1sec. per day, over the life of the mission.
Rationale: The sequencer will need to maintain its clock's accuracy in order to make deployments at their proper time, per mission skits.

3.4.13.9 Sequencer to Deployers Interfaces

The sequencer shall have the ability to command up to eleven separate deployers of a 6U or 12U class.

Rationale: The total deployment capability of the secondary payload system will be 11. The deployers can either be a 6U or 12U class. A mission can be a mixture of 6U and 12U deployers up to a maximum of 11 deployers.

3.4.13.10 Sequencer to Deployers Connector Pin-Out

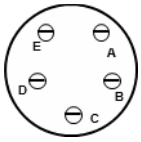
The sequencer shall use a connector with a minimum of 4 pins per deployer.
Rationale: The sequencer sends two parallel discretes to each deployer which when added together is sufficient to open the deployer door. Each discrete will have a return and a positive component.

3.4.13.11 Sequencer Connector to SLS Second Stage Trigger Signal Connector

The sequencer shall use a series III, MIL-DTL38999 mil standard connector (5 contacts size 20).
Rationale: The use of a series III, MIL-DTL-38999 mil standard connector is mandated by the SLS second stage vehicle for serial data transfer, in this case the trigger for sequencer initiation. The discrete from the SLS second stage will come on a twisted shielded pair. An adapter jumper cable may be used if SLS second stage is incompatible with OTS sequencer.

3.4.13.12 Sequencer to SLS Second Stage Connector Pin-Out

The sequencer shall use a series III, MIL-DTL-38999 pin connector pin-out as shown in Figure 3.4.13.12-1.
Rationale: The pin-out needs to match the SLS vehicle's existing interface.



B5

Pin	Function
A	Discrete +
B	Spare
C	Discrete -
D	Spare
E	Ground

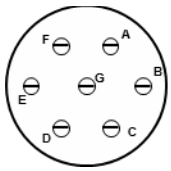
Figure 3.4.13.12-1 Sequencer to SLS Second Stage Pin-Out Interface Configuration

3.4.13.13 Sequencer Wire Connector to Ground Connector

The sequencer shall use a series III, MIL-DTL-38999 mil standard connector (7 contacts size 20).
Rationale: The connector is wired for a RS422 interface with the Ground for skit loading.

3.4.13.14 Sequencer to Ground Connector Pin-Out

The sequencer shall use a series III, MIL-DTL-38999 pin connector pin-out as shown in Figure 3.4.13.14-1.
Rationale: The pin-out needs to match the system to ground interface for skit loading.



B99

Pin	Function
A	RDA(-) – RS422
B	RDA(+) – RS422
C	TDA(-) – RS422
D	TDA (+) – RS422
E	Ground – RS422
F	Spare
G	Spare

Figure 3.4.13.14-1 Sequencer to System Ground Pin-Out Interface Configuration

3.4.14 Maintainability and Supportability

3.4.14.1 Service Life

The avionics shall meet its performance and functional requirements for a period of at least 4 years after acceptance.

Rationale: Requirement provides maximum flexibility for hardware utilization taking into account rework, launch delays, and manifest changes. Consumable products, such as batteries, are not included under service life requirements but are covered as part of normal launch operations processing.

3.4.14.2 Mean Time To Failure

The avionics Mean Time To Failure (MTTF) shall be at least 1,000 hours.

Rationale: Requirement provides minimum the avionics must work. The time is based on roughly four times the length of the expected mission of 10 days.

3.4.15 Natural Environmental Conditions

3.4.15.1 Natural Environments

The avionics shall meet all functional and performance requirements within the range of environmental conditions specified in SLS Program Design Specification for Natural Environments SLS-SPIO-SPEC-001, Table 3.4.15-1.

Rationale: This is an allocated requirement.

Table 3.4.15-1 Natural Environments

Operational Phase	Ground Interface Name	GSDO Baseline	Media	Mass Flow Rate[5]	Max Back Pressure @ Max Flow Rate[9] (psig)	Temperature[3, 4] (°F)	Maximum Humidity Ratio (gr/lb DA)[6]	Maximum Hydrocarbons (ppm)	Airborne Particle Specification	Comments

Integrated and Stacked	ICPS/FWD (MSA)[10]	Y	Conditioned Air[1]	12	0.7	65 - 85	37	15	ISO 14644-1, Class 8	
Rollout	ICPS/FWD (MSA)	N	---	---	---	---	---	---	---	No ECS during Rollout required for Block 1 MPCV configuration.
On the Launch Pad	ICPS/FWD (MSA)[10]	Y	Conditioned Air[1]	12	0.7	65-85	37	15	ISO 14644-1, Class 8	
		Y	Gaseous Nitrogen[2,7]	14	0.8	65-150	1			

Notes:

1. LVSA, MSA and Equip Shelf I/F will get air of the same selected temperature
2. LVSA and MSA I/F will get GN2 of the same selected temperature
3. ICPS I/F set point accuracy ±5°F for GN2. Set point accuracy is 15°F for first 15 minutes after air to GN2, GN2 to air and flow rate adjustments.
4. ICPS I/F set point accuracy +10° / -5° F for air only.
5. Flow rate to be adjustable over the range specified and controllable within ±5% of the set point.
6. gr/lbm DGN2
7. GN2 moisture content remains at the air moisture level and decreases following air to GN2 changeover.
8. Temperature, pressure, and humidity sensor will not be located on umbilical arms or at the end of flexible duct connecting to the flight hardware.
9. Max back pressure@ max flow rate at the vehicle I/F.
10. ICPS environment requirements stipulate that ICPS is capable of withstanding up to 95% relative humidity (without dry inert gas purge or desiccation) for temperatures up to 95° F, and up to dew point of 91° F for temperatures above 95° F, for cumulative period of up to 24 hours within any 72 hour period.

3.4.16 Induced Environmental Conditions

3.4.16.1 Thermal Environments

The avionics shall meet the thermal environments range -143°F to +200°F <TBR-003> in the MSA volume during the 10 day mission life.

Rationale: The avionics must be able to operate within the induced environments present in the MSA, using thermal protection as needed.

3.4.16.2 Random Vibration and Shock

The avionics shall satisfy all flight performance requirements during and after exposure to vibration and shock environments as defined in Tables 3.4.16.2-1, 3.4.16.2-2, 3.4.16.2-3, and 3.4.16.2-4. The random vibration criteria represent input at the Deployer interface. The random vibration criteria are provided in the radial, axial and lateral directions as shown in Figure 3.4.16.2-1. Qualification testing is concluded at levels derived at the maximum predicted environment with tolerances as specified in MSFC-STD-3676 section 6.3 and 7.6.

Rationale: This is an allocated requirement. The vibration environments shown in table 3.4.16.2-1 do not include vibration isolation. While the current predicted flight shock environments are low, the transportation and handling shock environments may pose more of a risk to the payload, so it is addressed in Table 3.4.16.2-4.

Table 3.4.16.2-1 Random Vibrations (less vibration isolation) <TBR-004>

Acceptance Test (60 seconds / axis)			
Radial Axis		Axial. and Lateral Axes	
20 Hz	0.00025 g^2/Hz	20 Hz	0.0025 g^2/Hz
20 – 60 Hz	+20 dB/oct	20 – 40 Hz	+19 dB/oct
60 – 300 Hz	0.45 g^2/Hz	40 – 200 Hz	0.02 g^2/Hz
300 – 600 Hz	- 12 dB/oct	200 – 400 Hz	- 12 dB/oct
600 – 1000 Hz	0.03 g^2/Hz	400 – 1400 Hz	0.013 g^2/Hz
1000 – 2000 Hz	- 5 dB/oct	1400 – 2000 Hz	- 14 dB/oct
2000 Hz	0.01 g^2/Hz	2000 Hz	0.0025 g^2/Hz
Composite = 13.4 grms		Composite = 7.8 grms	

Qualification Test (130 seconds / axis)			
Radial Axis		Axial. and Lateral Axes	
20 Hz	0.001 g^2/Hz	20 Hz	0.01 g^2/Hz
20 – 60 Hz	+20 dB/oct	20 – 40 Hz	+19 dB/oct
60 – 300 Hz	1.8 g^2/Hz	40 – 200 Hz	0.8 g^2/Hz
300 – 600 Hz	- 12 dB/oct	200 – 400 Hz	- 12 dB/oct
600 – 1000 Hz	0.12 g^2/Hz	400 – 1400 Hz	0.05 g^2/Hz
1000 – 2000 Hz	- 5 dB/oct	1400 – 2000 Hz	- 14 dB/oct
2000 Hz	0.04 g^2/Hz	2000 Hz	0.01 g^2/Hz
Composite = 26.9 grms		Composite = 15.6 grms	

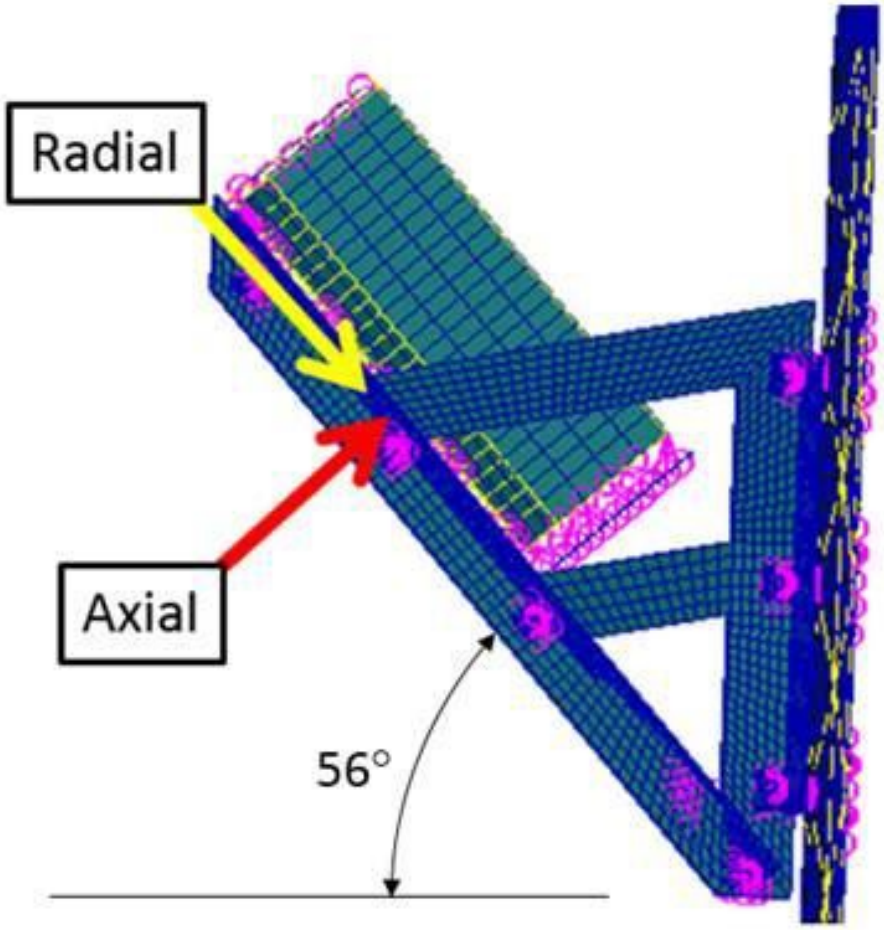


Figure 3.4.16.2-1 Deployer Local Coordinate System

Table 3.4.16.2-2 Envelope of Test Internal Acoustic Levels for the MSA/ICPS Compartment

Frequency (Hz)	Sound Pressure Level (dB re: 20µPa)
20	121.0
25	124.0
31.5	126.4
40	129.4
50	131.4
63	133.4
80	135.3
100	136.9
125	137.8

160	138.1
200	138.4
250	138.4
315	138.1
400	137.6
500	137.0
630	136.5
800	135.5
1000	134.6
1250	133.5
1600	132.0
2000	130.5
2500	128.5
3150	126.7
4000	124.2
5000	121.0
6300	116.5
8000	110.5
10000	106.0
Overall Sound Pressure Level	149.0
Test Duration (sec)	130

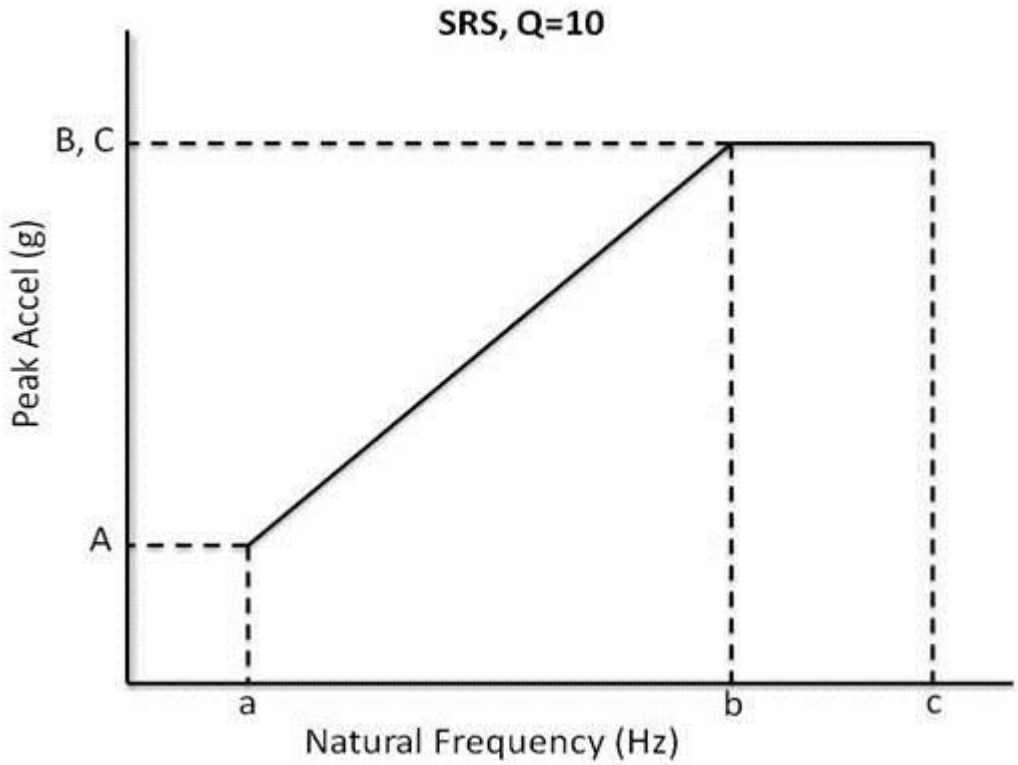


Figure 3.4.16.2-2 Pyrotechnic Shock Spectrum

Table 3.4.16.2-3 Shock (from spacecraft separation)

Spectrum Amplitude (G)			Frequency Points (Hz)		
A	B	C	a	b	c
55	2,000	2,000	100	2,500	10,000
Note 1: Use Figure 3.4.16.2-2 with this table. Note 2: The shock environment presented should be treated as "test to" environment and not "analyze to" environment					

Table 3.4.16.2-4 Procedure for Shock Environments

Type of Shock	Procedure
Transit Drop	MIL-STD-810G Method 516.6 Procedure IV
Bench Handling	MIL-STD-810G Method 516.6 Procedure VI

3.4.16.3 Load Factors

The avionics system shall satisfy all flight performance requirements during and after exposure to the low frequency and random vibration load factors as defined in Tables 3.4.16.3-1 and 3.4.16.3-2. The load factors shall be combined per MSFC-STD-3676. See Figure 3.4.16.2-1 for the axes. The random vibration loads are in the local coordinate system and the low frequency loads are in the vehicle coordinate system.

Rationale: This is an allocated requirement. The load factors shown in Tables 3.4.16.3-1 and 3.4.16.3-2 do not include vibration isolation. The random vibration loads should be combined with the low frequency loads per MSFC-STD-3676 where the random vibration loads are applied one axis at a time in combination with the low frequency loads applied to every axis simultaneously.

Table 3.4.16.3-1 Secondary Payload Component Loads due to Random Vibration

Configuration 1a – 41lb Payload		
Axial	**Lateral**	**Radial**
±28.2g	±15.6g	±18.0g
Configuration 1b – 60lb Payload		
Axial	**Lateral**	**Radial**
±18.0	±14.3	±18.0
Configuration 2 - Sequencer		
Axial	**Lateral**	**Radial**
±28.2g	±15.6g	±18.0g

Table 3.4.16.3-2 Secondary Payload Component Loads due to Low Frequency Loads

	Vehicle Axial	**Vehicle Lateral and Radial**
Liftoff and Ascent Envelope	+0.6, -3.5g	±3.0g

3.4.17 Ground Support Equipment (GSE)

3.4.17.1 Prelaunch GSE

The avionics shall provide a set of Ground Support Equipment (GSE) to support prelaunch operations. The GSE will provide:

1) Taper charging to the SPDS battery,
2) Monitoring of SPDS battery charging (per cell), and
3) Loading of mission skits into the SPDS sequencer.

Rationale: Figure 3.4.17.1-1 depicts the system layout for the GSE. GSE will include a variable, programmable power supply, laptop computer containing necessary LabVIEW software, and a cable harness.

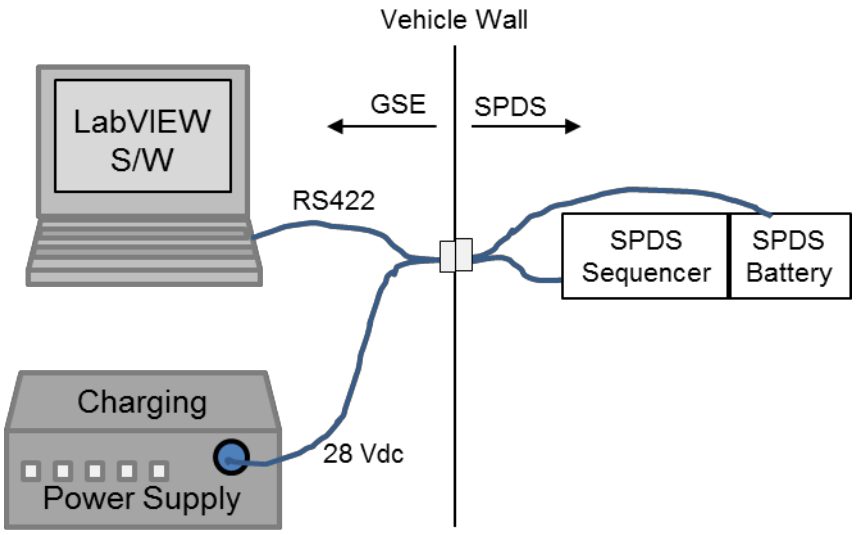


Figure 3.4.17.1-1: SPDS GSE Layout Diagram

3.4.17.2 GSE Charging Power Supply

The power supply shall be variable power output and programmable with the following parameters:

1) 8 to 34 Vdc voltage range in increments of 1 volt minimum
2) 500 mA to 8 A in increments of 100 mA minimum

3.4.17.3 Charger Power

The power supply shall operate off of standard 120Vac 10amp facility power.

3.4.17.4 Laptop Computer

The laptop computer shall operate with Windows 7 software.

3.4.17.5 Support Software

LabVIEW software shall be used for battery monitoring and sequencer mission skit loading activities.

3.4.17.6 Software Monitoring

GSE software shall record the battery current, temperature, and cell voltage at least every minute. For charge rates that exceed the battery capacity (i.e., if capacity is 1 Amp-Hour and charger is supplying greater than 1 Amp of current), record voltages every 10 seconds for charge

rates between 1 and 2 times battery capacity and every second for charge rates that exceed 2 times battery capacity.
Rationale: Data will be reviewed for anomalies and verification of voltage limits real-time throughout charging or discharging activities.

3.4.18 Transportability

3.4.18.1 Packaging and Packing

The avionics shall comply with the requirements of NPR 6000.1 for packaging and packing for shipment to the launch site or to any facility from the contractor's site.
Rationale: The requirement is needed to establish packaging requirements for shipment, which are adequate to maintain the reliability of NASA items and to achieve their damage-free delivery to the place and time of ultimate use.

4.1 VERIFICATION

The verification program shall ensure that the deployer will conform to the design and performance requirements specified in Section 3. For each Section 3 requirement, there shall be a corresponding Section 4 verification requirement that contains the requirements necessary to show compliance with each "shall" statement. The verification requirement must have three parts: the method of verification, a description of the verification work to be performed, and success criteria that determines when the verification is complete. Non- "shall" statements will not have a verification requirement for compliance.

This following section identifies the how, what, and when the requirements will be verified and the various organizations and personnel that will conduct and support verification.

4.2 Description

4.2.1 Verification Methods

Verification methods are the methods by which the requirements in Section 3.4 are to be verified. One or more of the following methods will be used:

1. Test—Verification by test is the actual operation of equipment during ambient conditions or when hardware is subjected to specified environments to evaluate performance.

1a. Functional Test—Functional testing is an individual test or series of electrical or mechanical performance tests conducted on-flight or flight-configured hardware and/or software at conditions equal to or less than design specifications. Its purpose is to establish that the system performs satisfactorily in accordance with design and performance specifications. Functional testing generally is performed at ambient conditions. Functional testing is performed before and after each environmental test or major move in order to verify system performance prior to the next test/operation.

1b. Environmental Test—Environmental testing is an individual test or series of tests conducted on-flight or flight-configured hardware and/or software to assure the hardware will perform satisfactorily in its flight environment. Environmental tests include vibration, acoustic and thermal vacuum and may or may not be combined with functional testing depending on the objectives of the test.

2. Analysis—Verification by analysis is a process used in lieu of or in addition to testing to verify compliance to requirements. The selected techniques may include systems engineering analysis, statistics and qualitative analysis, computer and hardware simulations, analog modeling, similarity assessment, and verification of records.

3. Demonstration—Verification by demonstration is the use of actual demonstration techniques in conjunction with requirements such as operational performance, serviceability, accessibility, transportability, human engineering features, and display data.

4. Inspection—Verification by inspection is the physical evaluation of hardware and/or documentation/drawings to verify design features. Inspection is used to verify construction features, workmanship, dimension and physical condition, such as cleanliness, surface finish, and locking hardware.

4.2.2 Verification Cross Reference Matrix

A Verification Cross Reference Matrix (VCRM) is generated to show the requirement trace and closure methods. The VCRM is an appendix to this document.

4.2.3 Test Equipment and Facilities

Unit Tester - Portable, self-contained hardware and software necessary to functionally test both the requirements and the design of a standard deployer in a stand-alone configuration.

4.2.4 Acceptance and Rejection Criteria

The standard deployer which has passed all of the inspections shall be accepted. Assemblies which are not accepted will be considered rejected. The full particulars concerning rejection and the necessary action taken to correct the defect will be made available to the Government inspector before resubmittal of the assembly for retest.

4.2.5 Requests for Deviation or Waiver

Requests for deviation or waiver from this specification, applicable drawings, specifications, publications, and materials or processes herein, shall be submitted to the procuring activity for approval.

4.2.6 Government Acceptance Inspections

The Government acceptance inspection shall be conducted in accordance with the provisions of the contract.

4.2.7 Acceptance Tests

Each assembly submitted for acceptance under the contract shall successfully comply with acceptance test requirements in by the test methods in Acceptance Test Procedure for the assembly.

4.2.8 Preproduction and Periodic Production Tests

Preproduction and periodic production tests shall be performed at a test activity designated by the Government when the frequency and quantity are in the contract. Preproduction tests will be conducted after the award of the contract. Failure of a periodic production sample will result in the rejection of the lot represented by the sample or the cessation of production as determined by the procuring activity.

4.2.9 Production Tests and Inspections

Production tests and inspections shall be conducted in accordance with the production, test, and inspection plan.

APPENDIX A
ACRONYMS AND ABBREVIATIONS AND GLOSSARY OF TERMS

A1.0 ACRONYMS AND ABBREVIATIONS

AWG	American Wire Gage
CEI	Component End Item
dB	decibel
E3	Electromagnetic Environmental Effects
ECS	Environmental Control System
EEE	electrical, electronic, and electromechanical
ESD	Electro Static Discharge
EMC	Electro Magnetic Compatibility
EMI	Electromagnetic Interference
etc.	Etcetera
F°	Fahrenheit
FDIR	Fault Detection, Isolation, and Recovery
ft.	feet
FU	Flight Units
g	gravity
GN2	Gaseous Nitrogen
gr	grains
GSDO	Ground Systems Development Organization
GSE	Ground Support Equipment
HSIR	Human-Systems Integration Requirements
Hz	Hertz
I/F	interface
Kg	kilograms
Lb	pounds
ICPS	Interim Cryogenic Propulsion Stage
LRU	Line Replaceable Unit
LVSA	Launch Vehicle Stage Adapter
m	meter
ML	Mobile Launcher
mm	millimeter
MPCV	Multi-Purpose Crew Vehicle
MSA	MPCV Spacecraft Adapter
MSFC	Marshall Space Flight Center
MTTF	Mean Time To Failure
NASA	National Aeronautics and Space Agency

NEDD	Natural Environments Design Document
OA	Organic Acid
OTS	Off-The-Shelf
ppm	parts per million
psi	pounds per square inch
psig	pounds per square inch, gage
QU	Qualification Unit
RMS	Root Mean Square
Rqmt.	Requirement
SCC	Stress Corrosion Conditions
sec.	second
SI	International System of Units
SLS	Space Launch System
SR&QA	System Reliability & Quality Assurance
SRU	Shop Replaceable Unit
TBD	To Be Determined
TBR	To Be Reviewed
U	Unit (1U is ~10mm x ~10mm x ~10mm)
VAB	Vehicle Assembly Building
VC	Visibly Clean
VCRM	Verification Cross Reference Matrix
VDC	Volts Direct Current

A2.0 GLOSSARY OF TERMS

Term	Description
Avionics	An electronics package which performs electrical operations and controls the mechanical systems.
Battery	A device for generating an electric current by chemical reaction.
Deployer	A spring loaded device for holding and releasing small satellites.
Mission Skit	A table of times and deployer designations. This is used by the sequencer to determine when to activate a specific deployer to release a payload.
Sequencer	An electrical device which counts in seconds and energizes deployers per the mission skit.
Trigger Signal	A signal (a discrete) from one system to another to start the receiving system's operations.

APPENDIX B
VERIFICATION CROSS REFERENCE MATRIX 3.4 REQUIREMENTS

Section No.	Section / Requirement Title	Method				
		N/A	A	T	D	I
3.0	Avionics Requirements	X				
3.1	Description	X				
3.2	Sequencer Functions	X				
3.3	Battery Functions	X				
3.4	Avionics Design and Construction Characteristics	X				
3.4.1	Electrical Design	X				
3.4.1.1	EEE Parts		X			
3.4.1.2	Lightning Protection		X			
3.4.1.3	Bonding			X		
3.4.1.4	Electrical Grounding		X			X
3.4.1.5	Circuit Classification		X			
3.4.1.6	Electromagnetic Interference (EMI)			X		
3.4.1.7	Ignition Source Avoidance		X			X
3.4.2	Structural and Mechanical	X				
3.4.2.1	Fracture Control		X			
3.4.2.2	Structural Design and Verification		X			
3.4.2.3	Fasteners		X			
3.4.2.4	Stress Corrosion		X			
3.4.3	Materials	X				
3.4.3.1	Flammability		X			
3.4.3.2	Incompatible Materials		X			
3.4.3.3	Surface Finish					X
3.4.3.4	Dimensioning and Tolerancing		X			
3.4.4	Product Marking	X				
3.4.4.1	Part Marking					X
3.4.4.2	Marking Label Readability					X
3.4.4.3	Units of Measure					X
3.4.5	Workmanship	X				
3.4.5.1	OTS Workmanship					X
3.4.5.2	Staking and Conformal Coating of Printed Wiring Boards					X
3.4.5.3	Surface Mount Technology					X
3.4.5.4	Soldered Electrical Connections					X
3.4.5.5	Crimping, Interconnecting Cables, Harness, and Wiring					X
3.4.5.6	Rigid Printed Wiring Board Products					X
3.4.5.7	Printed Wiring Board Design					X

Section No.	Section / Requirement Title	Method				
		N/A	A	T	D	I
3.4.5.8	Electrostatic Discharge Controls					X
3.4.6	Interchangeability	X				
3.4.7	Software Safety	X				
3.4.7.1	Software Signal Redundancy			X		
3.4.7.2	Software Architecture			X		
3.4.8	Human Engineering	X				
3.4.8.1	Ground Crew Interfaces					X
3.4.9	Communications	X				
3.4.10	Other	X				
3.4.10.1	Environmental Qualification and Acceptance Testing		X	X		
3.4.10.2	Cleanliness Requirements					X
3.4.10.3	System SR&QA		X			
3.4.10.4	Temporary Installed Hardware Identification					X
3.4.10.5	Cross Connection Prevention					X
3.4.10.6	Mounting Interface					X
3.4.10.7	Provide Captive Fasteners					X
3.4.10.8	Activation Circuit					X
3.4.10.9	Physical Isolation					X
3.4.10.10	Covered Relays					X
3.4.10.11	Device Manufacturer					X
3.4.10.12	Mortality Testing			X		
3.4.10.13	Replacement Articles			X		
3.4.10.14	Actuator Orientation					X
3.4.10.15	Use of Barriers					X
3.4.11	Interface Requirements	X				
3.4.11.1	Vibration Isolation Interface					X
3.4.11.2	Alternate System Bonding to MSA					X
3.4.11.3	Thermal Protection Interface					X
3.4.11.4	System Mass		X	X		
3.4.11.5	System Envelope		X	X		
3.4.11.6	Avionics System Vent Rate		X			
3.4.12	Battery Specific Requirements	X				
3.4.12.1	Battery Power for Deployment		X	X		
3.4.12.2	Battery Duty Power		X	X		
3.4.12.3	Battery Mission Time		X			
3.4.12.4	Battery Charging					X
3.4.12.5	Battery Wire Connector to Ground Charging Power					X
3.4.12.6	Battery to Ground Connector Pin-Out					X
3.4.12.7	Reverse Polarity Protection			X		
3.4.12.8	Battery Temperature Monitoring			X		
3.4.12.9	Battery Thermistor Type			X		X
3.4.12.10	Charging Circuit Isolation		X	X		
3.4.12.11	Smart Batteries					X

Section No.	Section / Requirement Title	Method				
		N/A	A	T	D	I
3.4.12.12	Failure Containment		X			
3.4.12.13	Battery Lot Testing Criteria			X		
3.4.13	Sequencer Specific Requirements	X				
3.4.13.1	Trigger Signal from Sequencer			X		
3.4.13.2	Trigger Signal from SLS Second Stage			X		
3.4.13.3	Sequencer Trigger Power			X		
3.4.13.4	Sequencer Duty Power			X		
3.4.13.5	Sequencer Mission Time			X		
3.4.13.6	Sequencer Skit Capacity			X		
3.4.13.7	Sequencer Skit Selection			X		
3.4.13.8	Sequencer Clock Accuracy			X		
3.4.13.9	Sequencer to Deployers Interfaces				X	
3.4.13.10	Sequencer to Deployers Connector Pin-Out					X
3.4.13.11	Sequencer Connector to SLS Second Stage Trigger Signal Connector					X
3.4.13.12	Sequencer to SLS Second Stage Connector Pin-Out					X
3.4.13.13	Sequencer Wire Connector to Ground Connector					X
3.4.13.14	Sequencer to Ground Connector Pin-Out					X
3.4.14	Maintainability and Supportability	X				
3.4.14.1	Service Life		X			
3.4.14.2	Mean Time to Failure		X			
3.4.15	Natural Environmental Conditions	X				
3.4.15.1	Natural Environments		X	X		
3.4.16	Induced Environmental Conditions	X				
3.4.16.1	Thermal Environments		X	X		
3.4.16.2	Random Shock and Vibration		X	X		
3.4.16.3	Load Factors		X	X		
3.4.17	Ground Support Equipment					X
3.4.17.1	Prelaunch GSE					X
3.4.17.2	GSE Charging Power Supply					X
3.4.17.3	Charger Power					X
3.4.17.4	Laptop Computer					X
3.4.17.5	Support Software					X
3.4.17.6	Software Monitoring			X		
3.4.18	Transportability	X				
3.4.18.1	Packaging and Packing					X

APPENDIX C
OPEN WORK

All resolved TBDs, TBRs, and forward work items should be listed on the Change Request (CR) the next time the document is updated and submitted for formal review, and that will serve as the formal change record through the configuration management system.

C1.0 TO BE DETERMINED

Table C1-1 lists the specific To Be Determined (TBD) items in the document that are not yet known. The TBD is inserted as a placeholder wherever the required data is needed and is formatted in bold type within carets. The TBD item is sequentially numbered as applicable (i.e., **<TBD-001>** is the first undetermined item assigned in the document). As each TBD is resolved, the updated text is inserted in each place that the TBD appears in the document and the item is removed from this table. As new TBD items are assigned, they will be added to this list in accordance with the above described numbering scheme. Original TBDs will not be renumbered.

Table C1-1. To Be Determined Items

TBD	Section	Description
TBD-001		

C2.0 TO BE RESOLVED

Table C2-1 lists the specific To Be Resolved (TBR) issues in the document that are not yet known. The TBR is inserted as a placeholder wherever the required data is needed and is formatted in bold type within carets. The TBR issue is sequentially numbered as applicable (i.e., **<TBR-001>** is the first unresolved issue assigned in the document). As each TBR is resolved, the updated text is inserted in each place that the TBR appears in the document and the issue is removed from this table. As new TBR issues are assigned, they will be added to this list in accordance with the above described numbering scheme. Original TBRs will not be renumbered.

Table C2-1. To Be Resolved Issues

TBR	Section	Description
TBR-001	3.4.12.1	Battery Power for Deployment
TBR-002	3.4.13.1	Trigger Signal from Sequencer
TBR-003	3.4.16.1	Thermal Environments
TBR-004	3.4.16.2-1	Random Vibrations Table

C3.0 FORWARD WORK

Table C3-1 lists the specific forward work items identified during this document's Change Request (CR) review and evaluation. Each item is given a sequential number using a similar format to that for the TBDs and TBRs. For each item, include the section number(s) of this document that the open work will impact, and in the Description include the specific number of the comment from the Change Evaluation (CE), i.e., CE-10, CE-27. Do not include a placeholder for forward work items in the body of the document; list them only in Table B3-1.

Table C3-1. Forward Work

FWD	Section	Description
FWD-001		

APPENDIX D
BATTERY LOT TESTING CRITERIA

Secondary Payloads Battery Lot Testing/Flight Acceptance Criteria
Based on JSC 20793 Rev. C

The following are the relative testing requirements for Li-ion batteries with respect to Secondary Payload Deployment System (SPDS) and the EM-1 payloads. Areas have been highlighted to point out specific tests and/or conditions which are needed. This information is for lot testing and flight configuration testing. If tests and test data are done properly lot testing will help cover most of flight battery selection tests. The section numbers below come from JSC 20793 rev. C.

4.4.4 Cell Matching

Cell performance matching for selection into batteries is a useful practice in custom battery builds when done in addition to cell acceptance screening specified in Section 4.2.3b.

a. For custom batteries with catastrophic failure modes, cell performance matching prior to battery assembly shall be performed to mitigate state-of-charge (SOC) imbalances that could adversely affect battery performance and/or safety.

b. For custom batteries with catastrophic failure modes, cells shall be matched in a battery based on charge retention, internal resistance and/or AC impedance, and ampere-hour capacity (for rechargeable chemistries).

The requirements above prescribe a matching protocol intended to select from the acceptance screened lot of cells. These requirements are not a remedy for poor lot uniformity. Note that cell matching and the use of balancing circuits should not be rationale for accepting lots with poor cell lot uniformity, which indicates a less controlled manufacturing process and may indicate product with a higher likelihood of rapid degradation of field performance.

4.2.3 Acceptance Testing

This section addresses the acceptance testing of the flight battery.

a. All cell lots intended for custom flight batteries shall undergo 100-percent acceptance screening that includes, at minimum, visual inspection, mass, OCV retention, alternating current (AC) and/or direct current (DC) resistance, and capacity (for rechargeable chemistries) or load check (for primary chemistries).

b. All of the batteries intended for flight shall undergo flight acceptance (nondestructive) testing, which will include an evaluation of OCV, mass, capacity (for rechargeable chemistries) or load check (for primaries), internal resistance, visual inspection, vibration to flight acceptance levels, and thermal/vacuum testing.

As a minimum, the flight acceptance test program should include the following:

1. Functional baseline test (OCV, mass, capacity (for rechargeable chemistries or load check for primaries), internal resistance, and visual inspection).

2. Vibration to flight acceptance levels (see Appendix A for more details).

3. Functional baseline test recheck.
4. Vacuum (approx. 0.1 psi) or equivalent leak checks.
5. Functional baseline test recheck.

For batteries used in a pressurized volume or environment, exposure to a vacuum environment (approximately 0.1 psi) for a minimum of 6 hours.
For batteries used in an unpressurized volume or environment, thermal vacuum cycles must be performed with the deep vacuum levels of 1×10^{-5} Torr (instead of the 0.1 psi used for habitable volume/pressurized environments). Alternatively, the thermal cycles and vacuum environment tests can be performed independently. Details of recommended flight acceptance tests are provided under each battery chemistry section in Section 6 with a detailed example in Section 6's lithium-ion section. For those chemistries not listed in Section 6, early consultation with program technical staff is recommended.
JSC 66548 can be used as an example for the flight certification and acceptance of COTS lithium-ion batteries that details the level of testing required under the engineering, qualification, flight acceptance, and lot sample testing of COTS lithium-ion batteries.

6.4.3.3 Acceptance Testing

a. All flight cells and batteries should undergo acceptance testing that includes, as a minimum, verification of battery performance to mission requirements by charge/discharge cycling, vibration, and vacuum leak checks.

b. Acceptance testing should include a minimum of 10 charge/discharge cycles to screen for latent defects and infant mortalities. The required number of cycles can be achieved using the total of cycles performed at the vendor, during cell acceptance screening, at sub-battery assembly, and at the completed assembly level.

c. The vibration levels and spectrum used to screen the qualification and flight batteries for the occurrence of internal shorts should be higher than what is obtained from the calculation of mission requirements (Appendix A).

d. In the event that cell-level controls are used as safety controls, irrespective of the cell size and design, test data should be provided to prove that these devices are effectively working as designed in the flight lot of cells.

e. For custom battery designs, the flight lot of cells should be 100-percent visually inspected (e.g., corrosion, bulging, scratches, dents and deformations, misaligned seals, electrolyte leakage, contaminants in the seal, etc.).

f. For custom battery designs made of small-capacity, high-volume commercial cells, the flight lot of cells should be acceptance screened to remove ±3-sigma outliers for the following minimum performance parameters: OCV, mass, dimensions, DC internal resistance and/or AC impedance, leak check, charge and discharge capacity, and charge or voltage retention. (For large lot sizes of cells, dimensional screening can be performed using "go/no-go" jigs or gauges.) Cells with temporary discrepancies should be rejected. EP-WI-031 can be used for cell acceptance testing of lots of lithium-ion cells. To ensure only lots with adequate performance uniformity pass, after removing

outlier cells, the resultant ±3*σ range for the following parameters as a percentage of the mean (±3-sigma range/mean) should not exceed the following:

1. OCV (<1%)

2. Mass (<2%)

3. Capacity (<5%)

4. DC and AC resistance (<15%)

If the total number of cells that fail the acceptance screening criteria is greater than 15 percent of the lot, then the lot is rejected.
In the event that large-capacity, lower volume cells are planned for the flight build, a different flow may be more suitable, as generally there are fewer cells to work with at the beginning of the screening. In this case, additional screening iterations may not be possible with the limited number of high-cost cells involved. In addition, cell matching takes a more prominent role.

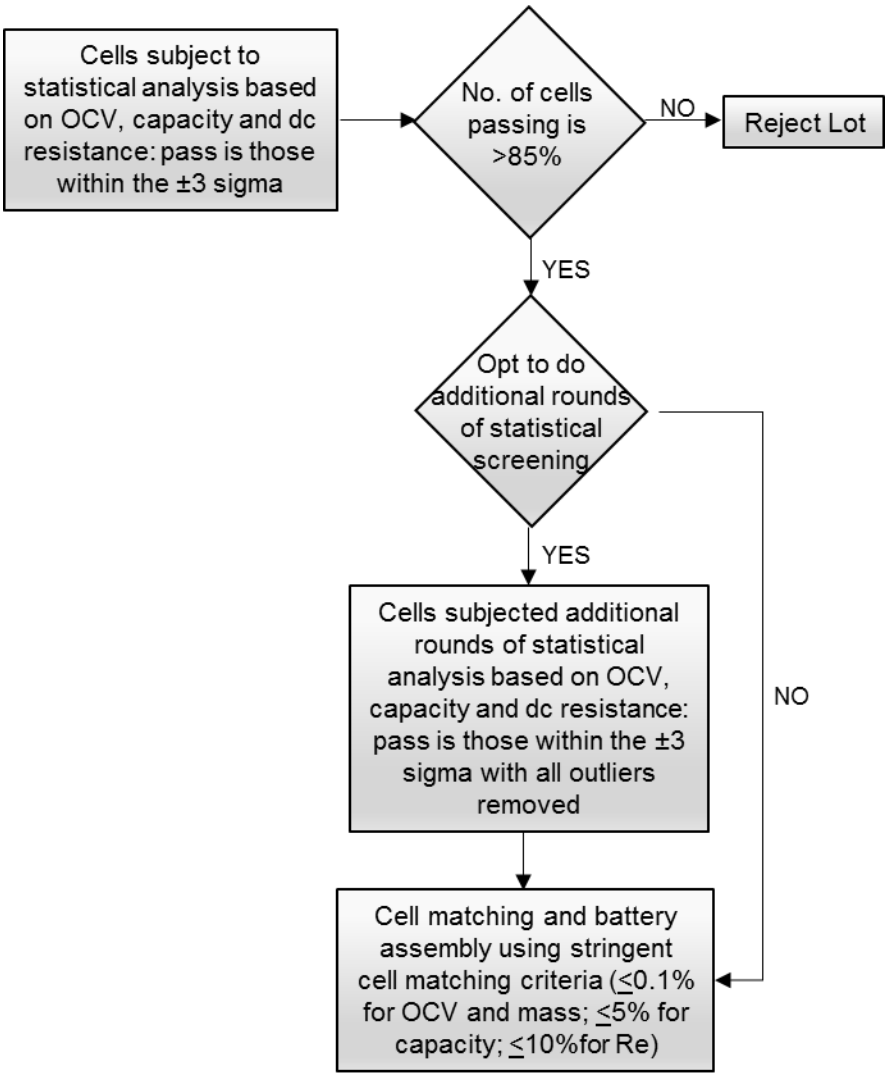


Figure 6.4.3-2. Cell Acceptance Flow with Small Numbers of Larger, Lower Volume Custom Cells

g. Within the cells that fall into the ±3-sigma range, the following parameters may be used for matching cells: OCV, mass, capacity, DC resistance, and AC impedance.

A.3 Flight Cell and Battery Pack Verification Acceptance Testing

The type of acceptance testing required for different battery chemistries is listed in Table A-3 for flight batteries. Note that omission of any cell chemistry from the table does not mean it cannot be used. Cell chemistries not listed in the table can be used with sufficient hazard control verification to warrant battery approval. Off-gassing/out-gassing tests may be required for materials compatibility. Data from the cell and battery pack screening must be recorded and included as part of the acceptance data package. JSC 25159, “Toxicological Hazard Assessments on Batteries Used in Space Shuttle Missions,” is to be used to determine the toxicity of batteries based on their generic chemistry classification.

Table A-3 provides a guideline for the types of acceptance tests that are required to be performed, and a categorical rating for each chemistry is included to offer design guidance. Table A-4 provides a categorical description of batteries based on cell chemistries and their associated amounts of hazard controls. The test levels required must be based on the mission to be performed and the environments expected for the battery. Consultation with the respective NASA Power Systems Office must be conducted to verify that the test levels are adequate. For chemistries not listed in the table, the respective NASA Power Systems Office can be consulted.

Table A-3. Flight Acceptance Tests for Cells or Battery Packs

Battery Cell Chemistry	Battery Category See Table 3.5-2 for descriptions	Conducted on 100% of Flight Cells								
		Visual Inspection	Dimension	Weight	OCV	CCV	Vacuum / Leak	Vibration	Cycle Testing	Thermal Cycle (EVA Only)
Alkaline	1, 2	M	M	M	M	M	M	N/A	N/A	M
Zn-air	1, 2	M	M	M	M	M	N/A	N/A	N/A	N/A
Li iodine	1, 2	M	M	M	M	M	M	N/A	N/A	M
LiCFx	1, 2	M	M	M	M	M	M	N/A	N/A	M
LiFeS2	1, 2	M	M	M	M	M	M	M	N/A	M
AgZn	1 - 3	M	M	M	M	M	M	M	M(s)	M
Li-MnO2	1 - 3	M	M	M	M	M	M	M	N/A	M
NiCd	1 - 3	M	M	M	M	M	M	M	M	M
NiMH	1 - 3	M	M	M	M	M	M	M	M	M
Pb Acid	2 – 4	M	M	M	M	M	M	M	M	M
Li-BCX	4	M	M	M	M	M	M	M	N/A	M
Li-ion/ Li-ion polymer	3	M	M	M	M	M	M	M	M	M
Li-SOCl2	4	M	M	M	M	M	M	M	N/A	M
NiH2	3	M	M	M	M	M	M	M	M	M
Li-SO2	4	M	M	M	M	M	M	M	N/A	M

M = Mandatory for cells (if loose cell application) and battery packs (if battery pack application) for screening (workmanship or internal short depending on the chemistry).
(s)= For secondary (rechargeable) cells and batteries.

Table A-4. Categorical Descriptions for Batteries

Category	Description
1	Small Commonly Used Commercial-Off-The-Shelf (COTS) battery cells that can be used for flight with minimal testing/documentation required. Example: Batteries/Cells covered in the Form 1230.
2	COTS cells available to the public requiring additional testing/documentation. Example: Battery/Cell chemistries covered on the form 1230 but of a large capacity or higher complexity. Sealed Lead Acid (SLA), Li-SOCl2 button cells.
3	Cells available for Original Equipment Manufacturer (OEM) assembly as a pack, but not readily available to the general public as loose cells. Example: Li-ion, Ni-H2.
4	Cells and batteries of any size that cannot be used, stored, or transported in a habitable volume. Example: Li-SO2, sodium sulfur, Li-SOCl2, Li-BCX, Li-SO2CL2.

A.4 AVT for Batteries Tolerant to Internal Shorts

The purpose of the AVT for those batteries tolerant to internal shorts is to detect material and workmanship flaws prior to flight by subjecting the battery to a dynamic vibration environment. The test duration in each of the three orthogonal axes should be no less than 1 minute. The test levels and spectrum are shown in Figure A-3 and Table A-5.

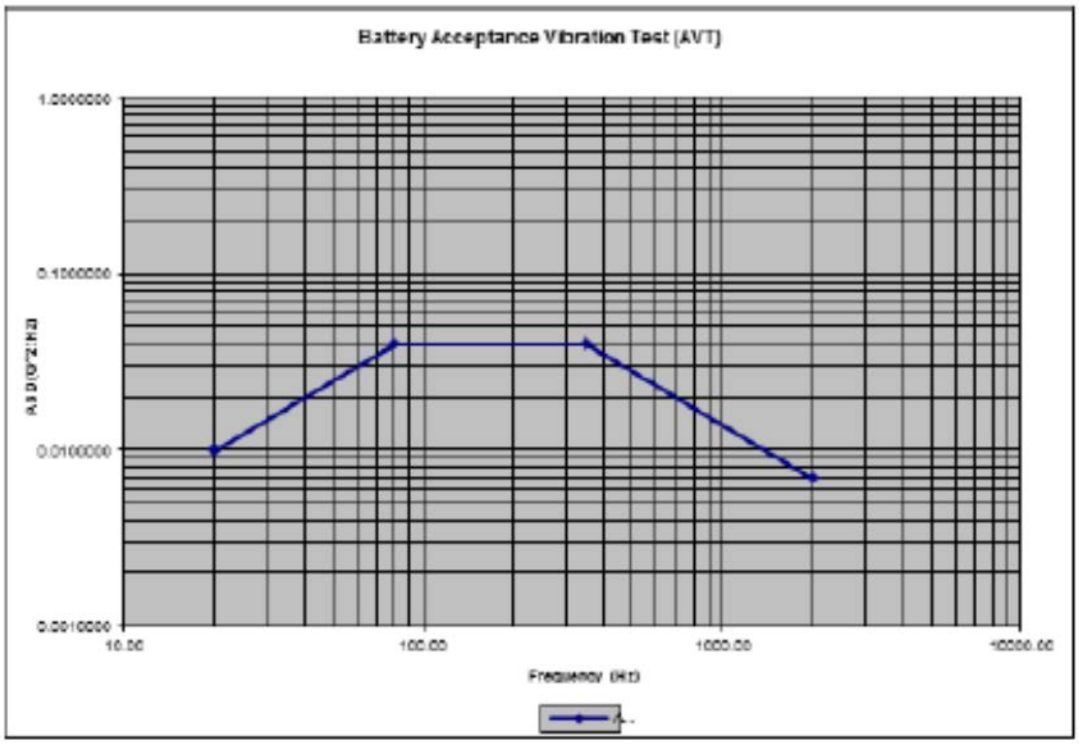


Figure A-3. Flight Acceptance Vibration Spectrum for Batteries Tolerant to Internal Shorts

Table A-5. Flight Acceptance Vibration Spectrum for Batteries Tolerant to Internal Shorts

FREQ (Hz)	ASD (G2/Hz)	dB/COT	Grms
20.00	0.010000	x	x
80.00	0.040000	3.01	1.22
350.00	0.040000	0.00	3.51
2000.00	0.007000	-3.01	6.06

Test condition tolerances should be applied to the nominal values defined in Figure A-3 and Table A-5. A maximum allowable tolerance of +/–1.5 dB should be applied to the power spectral density values. Any aspect of the test not specifically defined in this document should be conducted in accordance with the applicable requirement (e.g., SP-T-0023, SSP-41172, SSP-52005).

4.2.1 Engineering Evaluation

Evaluation testing shall, at a minimum, consist of characterizing the cell and battery safety under abuse conditions of overcharge, over-discharge into reversal, external short circuit and cell internal short circuit, temperature tolerance, vent and burst pressure determination and for custom batteries (greater than 20 Wh), cell destructive physical analysis.

CCV – Closed Circuit Voltage
OCV – Open Circuit Voltage