National Aeronautics and
Space Administration

SLS-SPIE-RQMT-018

BASELINE

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SPACECRAFT PAYLOAD INTEGRATION AND EVOLUTION OFFICE
SECONDARY PAYLOAD INTERFACE DEFINITION AND REQUIREMENTS DOCUMENT (IDRD)

REVISION AND HISTORY PAGE

Status	Revision No.	Change No.	Description	Effective Date
Baseline			Reference (SPIE ECBD SV3-03-0357, dated 03/03/15), CR SPIE-0124, PCN SP00820	03/16/15

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1.0 INTRODUCTION

1.1 Purpose

The purpose of this document is to provide the generic interface definitions and interface and safety requirements that the Space Launch System (SLS) secondary payloads must meet. Verification methods for the requirements are included. This information will be used to develop Interface Control Documents (ICDs) specific to individual secondary payloads.

1.2 Scope

The Secondary Payloads Interface Definitions and Requirements Document (IDRD) scope is the secondary payloads accommodated by SLS. The IDRD defines interfaces that the secondary payloads must meet, and it levies interface and safety requirements from SLS to the secondary payloads. For purposes of this document, a secondary payload is defined as the integrated dispenser secondary payload unit and is used henceforth**.**

1.3 Change Authority/Responsibility

The NASA Office of Primary Responsibility (OPR) for this document is ES13.

Proposed changes to this document shall be submitted by a SLS Project Change Request (CR) to the Spacecraft Payload Integration and Evolution (SPIE) Engineering Review Board (ERB) and the SPIE Element Control Board (ECB) for disposition. All such requests shall adhere to the SLS-PLAN-008, Configuration Management Plan for SLS Program/Project.

2.0 APPLICABLE AND REFERENCE DOCUMENTS

2.1 Applicable Documents

The specifications, standards, and handbooks in the Applicable Documents table below form a part of this document to the extent specified herein. The user shall refer to SLS-SPIO-RPT-039, "SPIO Element Baseline and Applicable Documents List," for the version incorporated into the SPIO baselines, which defines the requirements for the design, development, test, and evaluation of ISPE hardware. In most cases, the latest revision is used, unless otherwise stated in the SPIO Element Baseline and Applicable Documents List.

ANSI/AIAA S-081	Space Systems – Composite Overwrapped Pressure Vessels
ANSI-Z-136.1	American National Standard for Safe Use of Lasers
GSDO1080	Cross-Program Contamination Control Requirements document for visibly clean standard level
GSFC-STD-7000	General Environmental Verification Standard (GEVS) Elements Interfaces
JSC 20793	Revision C, Crewed Space Vehicle Battery Safety Requirements
KNPR 8715.3	NASA KSC Payload and Cargo Ground Safety Requirements
MIL-STD-130	Identification Marking of U.S. Military Property
MIL-STD-1522A	Revision A, Standard General Requirements for Safe Design and Operation of Pressurized Missile and Space Systems
MIL-STD-1576	Electro-Explosive Subsystem Safety Requirements and Test Methods for Space Systems
MSFC-STD-3029	Revision A, MSFC Technical Standard: Guidelines for the Selection of Metallic Materials for Stress Corrosion Cracking Resistance in Sodium Chloride Environments
MSFC-HDBK-527 / JSC 09604	Materials Selection List for Space Hardware Systems
NASA-STD-4003	NASA Technical Electrical Bonding
NASA-STD-5001	Structural Design and Test Factors of Safety for Spaceflight Hardware

NASA-STD-5019	Fracture Control Requirements for Spaceflight Hardware
NASA-STD-5020	Requirements for Threaded Fastening in Systems in Spaceflight Hardware
NASA-STD-6001	Flammability, Odor, Off-Gassing, and Compatibility Requirements and Test Procedures for Materials in Environments that Support Combustion
NASA-STD-6016	Standard Materials and Processes Requirements for Spacecraft
NASM 33540	Revision 1, General Practices for Safety Wiring, Safety Cabling, Cotter Pinning
NPR 6000.1	Requirements for Packaging, Handling, and Transportation for Aeronautical and Space Systems, Equipment, and Associated Components
SLS-SPIE-RQMT-021	SLS Secondary Payload Deployment System, Dispenser Requirements Document
SLS-PLAN-008	Configuration Management Plan for SLS Program/Project
SLS-PLAN-217	SLS Secondary Payload Safety Process Review Process
SLS-RQMT-216	Safety Requirements for Secondary Payload Hardware Baseline Draft
SLS-SPIO-SPEC-001	Integrated Spacecraft and Payload Integration Element (ISPE) Design Environments Document

2.2 Reference Documents

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

SLS-PLAN-009	SLS Verification and Validation Plan
MSFC-STD-3676	Development Of Vibroacoustic And Shock Design And Test Criteria
SLS-PLAN-170	SLS Contamination and FOD Control Plan
SLS-SPIE-HDBK-005	Secondary Payloads User's Guide (SPUG)
SLS-SPIO-PLAN-020	SLS Program Spacecraft/Payload Integration and Evolution (SPIE) Integrated Spacecraft & Payload Element (ISPE) Contamination and Foreign Object Debris (FOD) Control Plan

3.0 INTERFACE DEFINITIONS AND REQUIREMENTS

3.1 Secondary Payload-to-SLS Interface Definition

Section 3.1 defines the interfaces between the secondary payload and the SLS vehicle. Section 3.2 and Section 3.4 define the interface and safety requirements, respectively. Verification details for interface and safety requirements compliance are identified in Section 4.0.

Secondary payloads are integrated to the SLS vehicle via the Multi-Purpose Crew Vehicle (MPCV) Stage Adapter (MSA). The secondary payloads interface with the MSA, the Secondary Payload Deployment System (SPDS) avionics, and ground operations.

Interfaces between the secondary payload and MSA are:

- Structural via a wall bracket
- Physical interfaces for secondary payload unit size, mass, and center of gravity allocations inside the MSA
- Environmental interfaces for thermal, bonding/grounding, electromagnetic compatibility, venting, shock, random vibration, and load conditions of the secondary payload while in the MSA
- Ground handling interfaces for physical integration of the secondary payload into the MSA

The MSA also interfaces with the SPDS avionics unit components (i.e., sequencer, battery, cabling) via a wall bracket. Up to eleven locations for secondary payloads and one location for the SPDS avionics are distributed radially within the MSA as shown pictorially in Figure 3-1 and clocked approximately as shown in Figure 3-2.

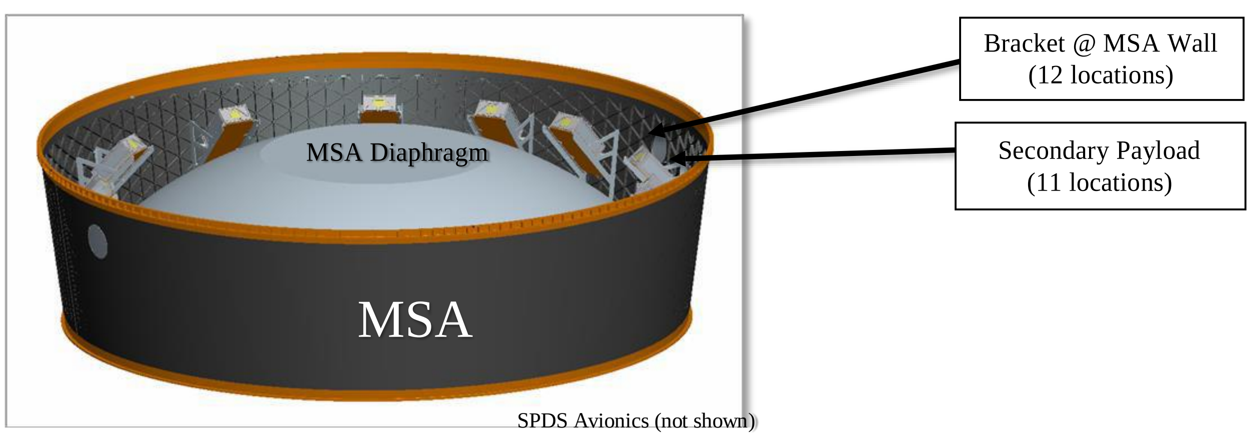


Figure 3-1 MSA to Secondary Payload Interface

The secondary payload to SPDS avionics interface is an electrical interface, depicted in Figure 3-2. This interface initiates the payload deployment sequence (i.e., mission skit) via a discrete cable connection between the SPDS avionics sequencer and each secondary payload located within the MSA. While in the Vehicle Assembly Building (VAB) and prior to roll-out, the deployment sequence is loaded into the SPDS avionics sequencer via a Ground Support Equipment (GSE) drag-on cable connection on the MSA exterior.

The ground operations interface provides the capability to charge the secondary payload and SPDS avionics battery prior to launch. The charge for both is through a GSE drag-on cable connection on the MSA exterior and would occur in the VAB prior to roll-out to the launch pad. The GSE connections are depicted below in Figure 3-2.

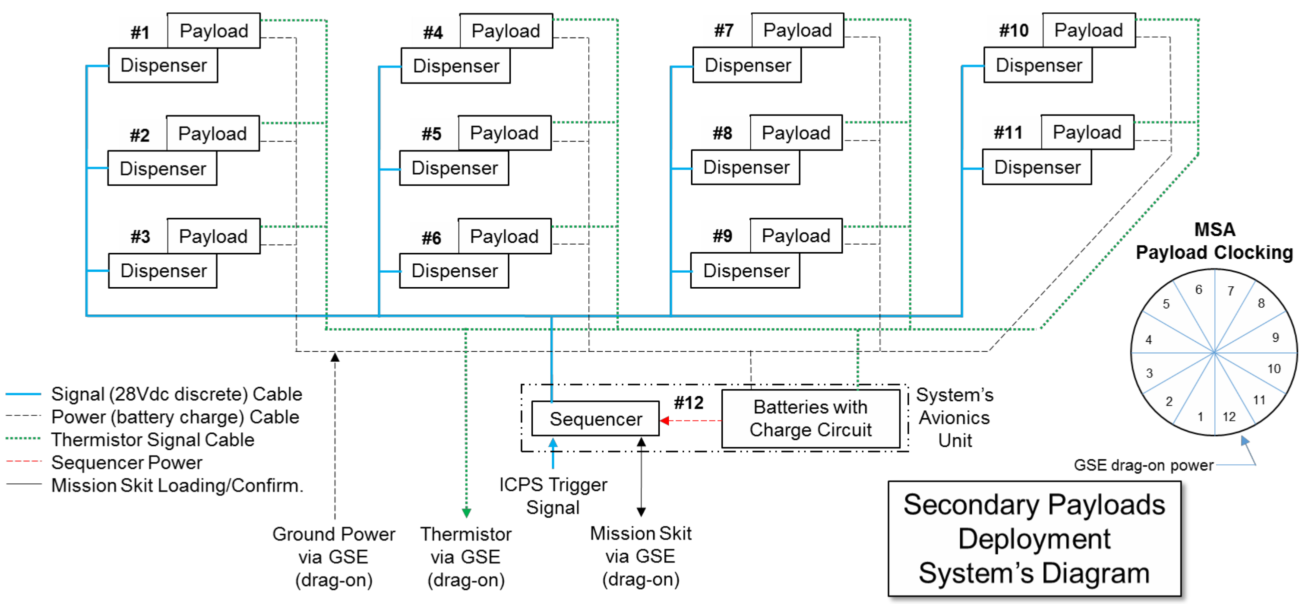


Figure 3-2 SPDS Avionics to Secondary Payload Interface Architecture

3.2 Technical Interfaces Requirements

Payloads will be deployed prior to SPDS battery life depletion, currently sized for 10 days. The deployment window for a secondary payload will start after the ICPS disposal maneuver (approximately 4 to 5 hours after launch). Deployment opportunities continue until the SPDS battery is no longer able to support system power needs. The SPDS battery is sized for a 10-day mission. Figure 3-3 illustrates the mission flow and payload deployment for SLS EM-1.

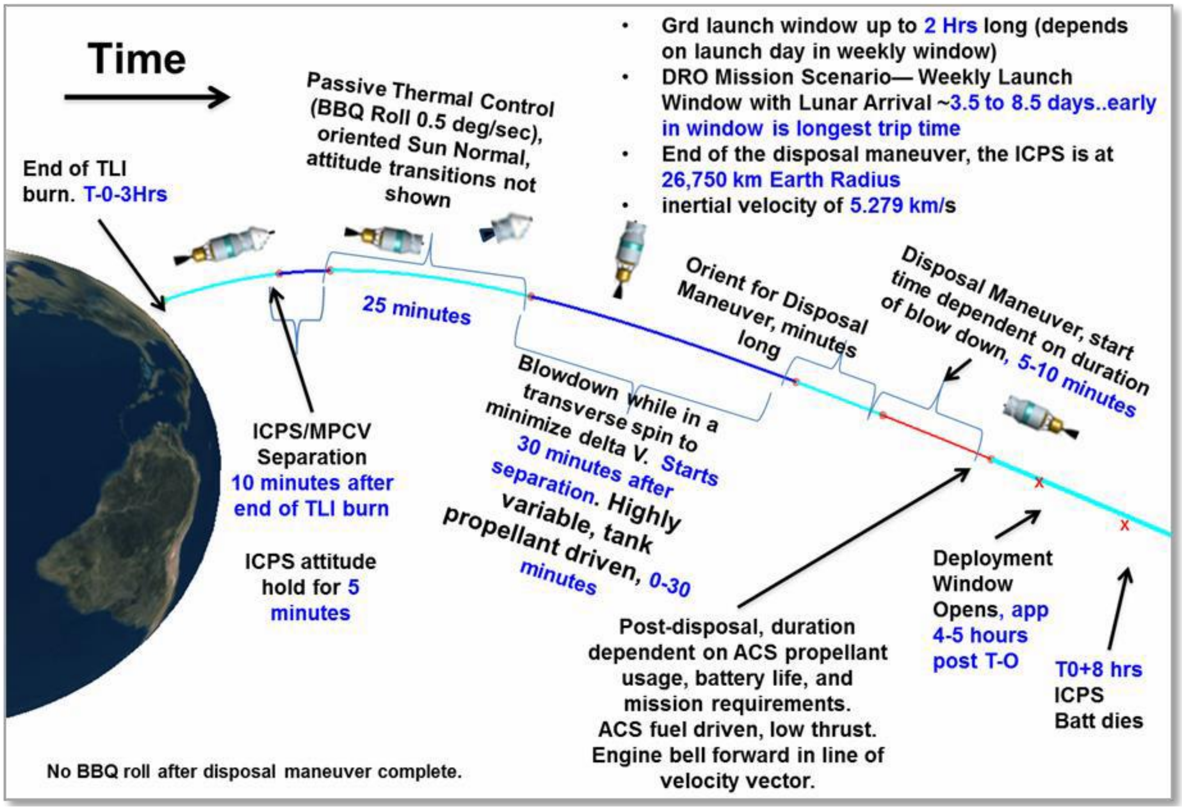


Figure 3-3 Deployment Sequence for EM-1

[SPS.SPL.001] Ejection Rate

Payloads shall be compatible with a minimum ejection rate of 4.6 feet/sec (1.4 m/sec) <TBR-003> based on the maximum allowable payload mass from either a 6U or 12U configuration.

Rationale: The ejection rate for payloads aligns with the NASA qualified dispenser accommodations. The ejection rate is used in analysis to confirm MSA clearance.

[SPS.SPL.002] Payload Providing Other Dispenser

A payload provider with a dispenser other than the NASA certified dispenser shall meet all requirements identified in the SLS-SPIE-RQMT-021, Secondary Payload Deployment System Dispenser Requirements Document.

Rationale: The payload provider is responsible for providing the dispenser that will interface with the secondary payload deployment system avionics. NASA will identify and certify a standard dispenser a provider may purchase for flight. Should a provider supply a different dispenser than the NASA certified dispenser, then the provider must met additional requirements identified in the Dispenser Requirements Document.

[SPS.SPL.003] Dispenser/Payload to MSA Mass

Payloads shall not exceed a combined dispenser/payload (including any thermal protection and vibration isolation) mass of 60 lbs (27.22 kg) for either a 6U or 12U configuration.

Rationale: The overall mass on the MSA bracket must be 60 lbs. or less. Results of the MSA loads analysis showed the max mass capacity on the bracket MSA wall to be 60 lbs for the combined dispenser /payload unit and for features such as vibration isolation and thermal protection. Anything over the mass limit would require redesign of the MSA structure.

[SPS.SPL.004] Dispenser/Payload Center of Gravity

Payloads shall maintain a combined dispenser/payload CG within the 6U or 12U enveloped in Table 3-1and depicted in Figure 3-4.

Rationale: If a payload provider is using a dispenser other than the NASA certified dispenser, then the provider must meet this requirement.

Table 3-1 Combined Dispenser/Payload C.G. Envelope

Parameters	Units	6U		12U	
		Min.	Max.	Min.	Max.
Center of Mass, X	in. (mm	-1.57 (-40)	+1.57 (+40)	-1.57 (-40)	+1.57 (+40)
Center of Mass Y	in. (mm	+0.39 (+10)	+2.76 (+70)	+2.17 (+55)	+4.92 (+125)
Center of Mass Z	in. (mm	+5.24 (+133)	+9.17 (+233)	+5.24 (+133)	+9.17 (+233)

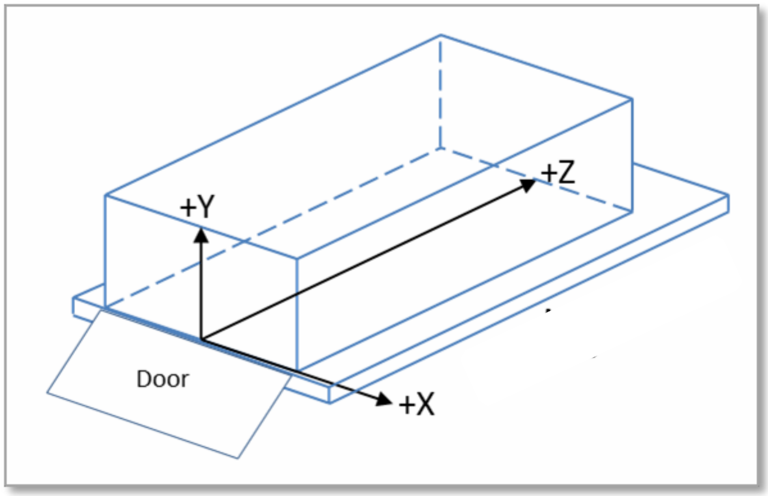


Figure 3-4 Combined Dispenser/Payload CG Envelope

[SPS.SPL.005] Dispenser/Payload Cleanliness

Payloads shall comply with the GSDO-RQMT-1080, Cross-Program Contamination Control Requirements document for visibly clean standard level.

Rationale: This aligns with the ISPERD and MSA requirements documents both in VC level and documentation reference. This is a flowdown from MPCV where the vehicle requires cleanliness and Foreign Object Debris (FOD) control guidance for safety and mission success. For more information about the contamination control, see SLS-PLAN-170 and SLS-SPIO-PLAN-020.

[SPS.SPL.006] Payload Storage

Payloads shall be storable up to 6 months under conditions listed in Table 3-2.

Rationale: Storable is defined as a 6-month period starting at the handover of integrated unit to GSDO under DD1149 through to the point of deployment in flight. Storage of the 15approx.1515d dispenser/payload unit may last as long as six months under KSC environments.

[SPS.SPL.007] Payload Prelaunch

Payloads shall meet all safety and interface requirements defined in this document during and after exposure to the range of environmental conditions specified in Table 3.2.

Rationale: Payloads may experience a range of environmental conditions specified in Table 3-2 while at KSC. Stay time in the VAB could be one to two months and pad time is planned to be no greater than a month. However, in the case of EM-1, there are two planned pad exercises; therefore, payloads will be exposed up to two months.

Table 3-2 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.

[SPS.SPL.008] Random Vibration and Shock

Payloads shall meet all safety and interface requirements defined in this document during and after exposure to vibration and shock environments as defined in Tables 3-3 <TBR-004>, 3-4, 3-5 and 3-6 and in Figures 3-5 and 3-6.

Rationale: This is an allocated requirement. The random vibration criteria represent input at the bracket to dispenser interface. The random vibration criteria are provided in the *radial, axial and lateral directions as shown in Figure 3-5. 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. The vibration environments shown in Table 3.3 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; therefore, it is addressed in Table 3-6.*

Table 3-3 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	0.2 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	

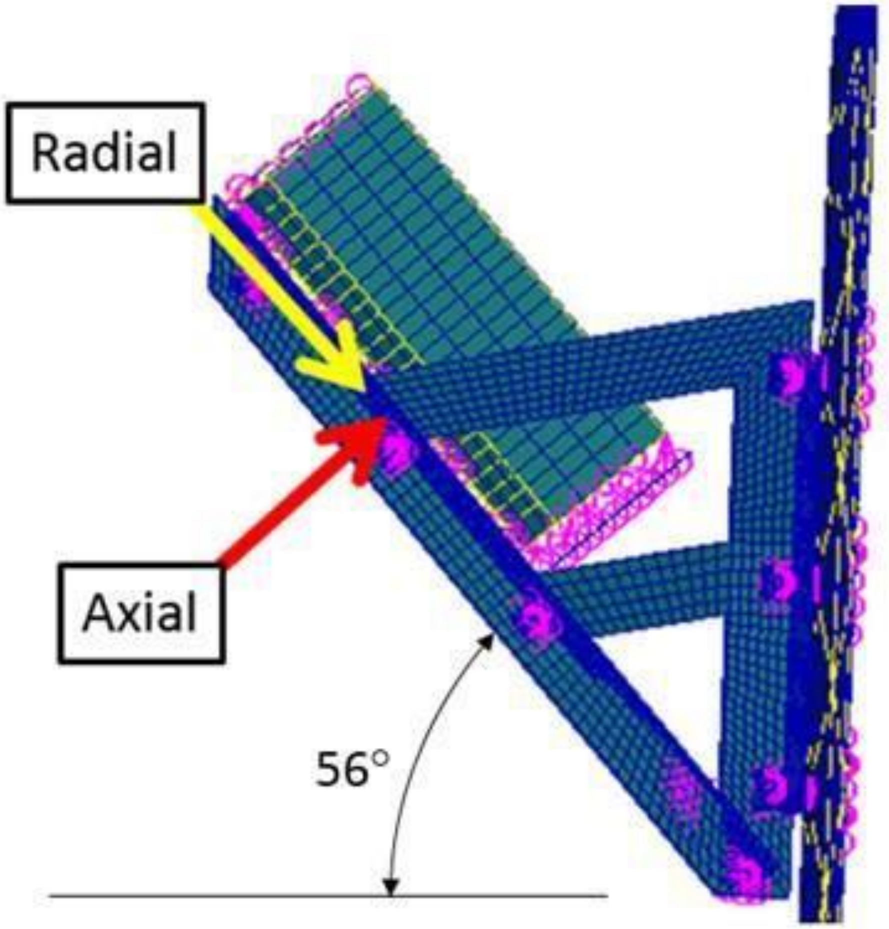


Figure 3-5 Dispenser Local Coordinate System

Table 3.4 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

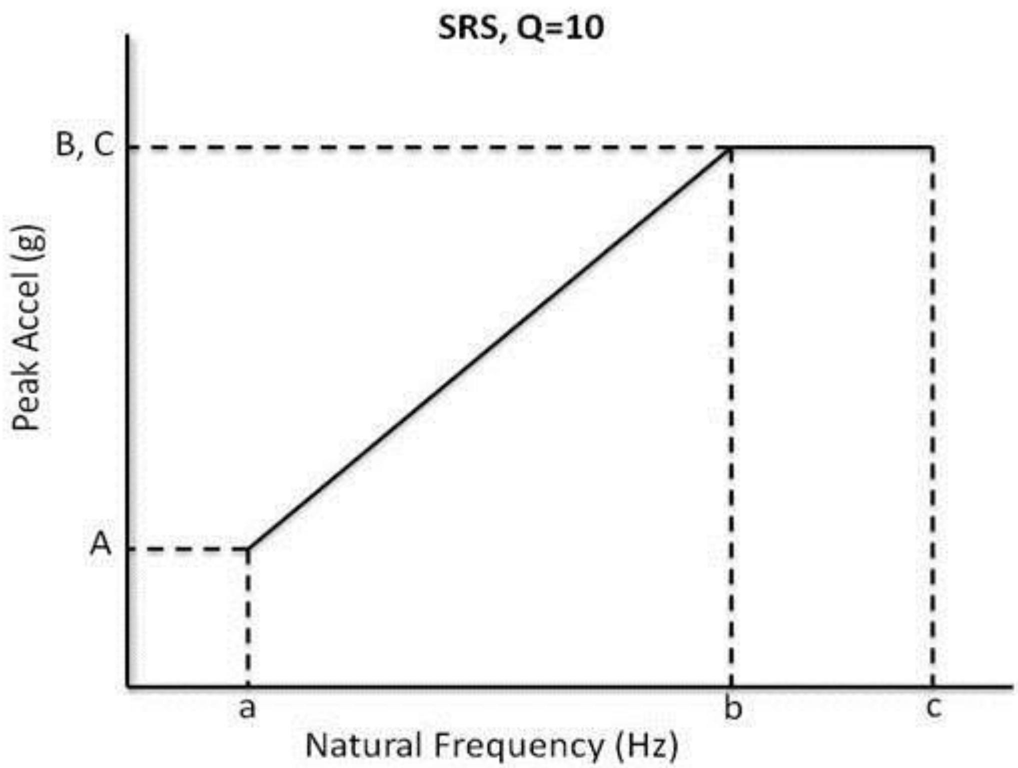


Figure 3-6 Pyrotechnic Shock Spectrum

Table 3-5 Test Shock Environment due to 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 3-6 with this table. Note 2: The shock environment presented should be treated as "test to" environment and not "analyze to" environment					

Table 3.6 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

[SPS.SPL.009] Design Loads

Payloads shall meet all safety and interface requirements defined in this document during and after exposure to the low frequency and random vibration load factors as defined in Tables 3-7 and 3-8.

Rationale: This is an allocated requirement. The load factors shown in Tables 3-7 and 3-8 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. See Figure 3-5 for the axes. The random vibration loads are in the local coordinate system and the low frequency loads are in the vehicle coordinate system.

Table 3-7 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 3-8 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

[SPS.SPL.010] In-Space Temperatures

Payloads shall meet all safety and interface requirements defined in this document during and after exposure to the thermal environments range -143°F to +200°F < TBR-001> inside the MSA volume during the 10-day mission life.

Rationale: A thermal analysis for the 10 day deployment window was conducted reflecting payloads experiencing in-space temperatures ranging from 200°F <TBR-001> (direct sun) to -143°F <TBR-001> (shaded & viewing deep space). The temperatures will be primarily dependent on final orientation of the ICPS and payload position within the MSA.

[SPS.SPL.011] In-Space Radiation

Payloads shall meet all safety and interface requirements defined in this document during and after exposure to the in-space radiation environments range identified in Figure 3-7.

Rationale: Radiations will greatly range due to solar affects to the Van Allen belt and other cosmic radiation. Figure 3-7 shows the best range of anticipated radiation environments.

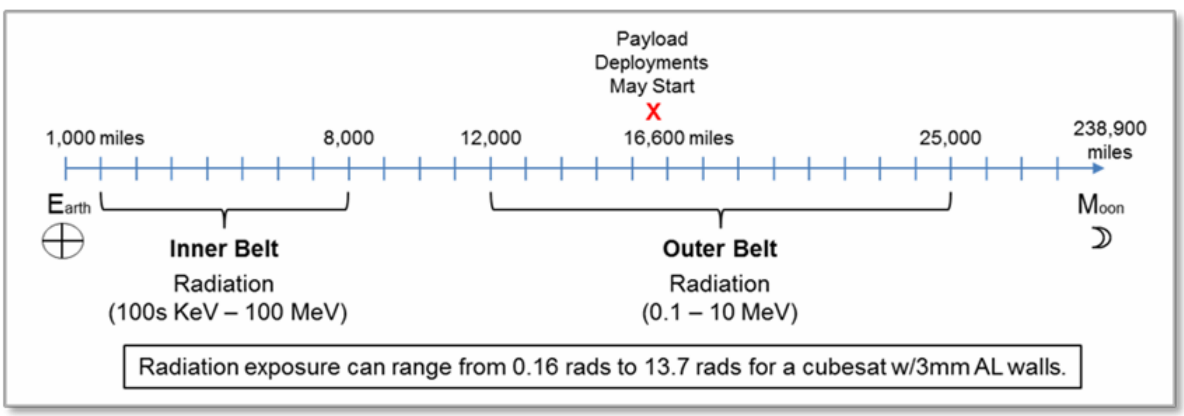


Figure 3-7 Van Allen Belt Radiation Mapping

[SPS.SPL.012] Payload Configuration

Payloads shall restrict payload volume expansion of its launch configuration, which expands its size beyond three times its launch envelope, for a minimum of 15 seconds following deployment.

> *Rationale: This is a derived requirement based on geometrics of the MSA, MPCV Spacecraft Adapter, mounting platform and jettison rate to ensure clearance during deployment. Three times a payload's launch envelope is defined as 40" X 40" X 40" envelope centered on the volumetric center of the cubesat."*

[SPS.SPL.013] Payload Co-Deployments

Payloads needing co-deployment from different dispensers shall be restricted to a 5-second delay between dispenser activation.

> *Rationale: This is a derived requirement based on geometrics of the MSA, MPCV Spacecraft Adapter, mounting platform and jettison rate to prevent collision.*

[SPS.SPL.014] Dispenser Labeling <TBR-002>

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

> *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 access to the hardware Ref. Figure 3-8 is an example of dispenser labeling.*

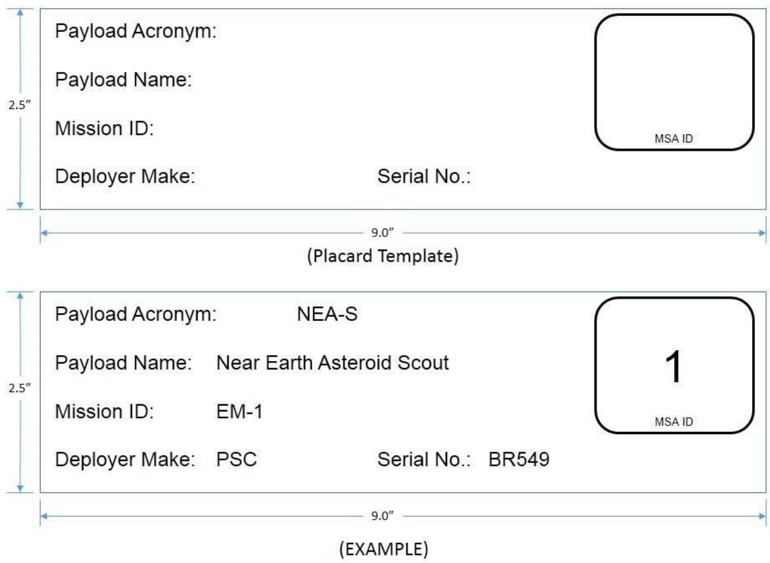


Figure 3-8 Dispenser Label Example <TBR-002>

[SPS.SPL.015] Dispenser Mounting Interface

The payload shall provide a mounting interface pattern as identified in Figure 3-9.

Rationale: To ensure that payloads are built to accept the specified mounting interface pattern and fasteners.

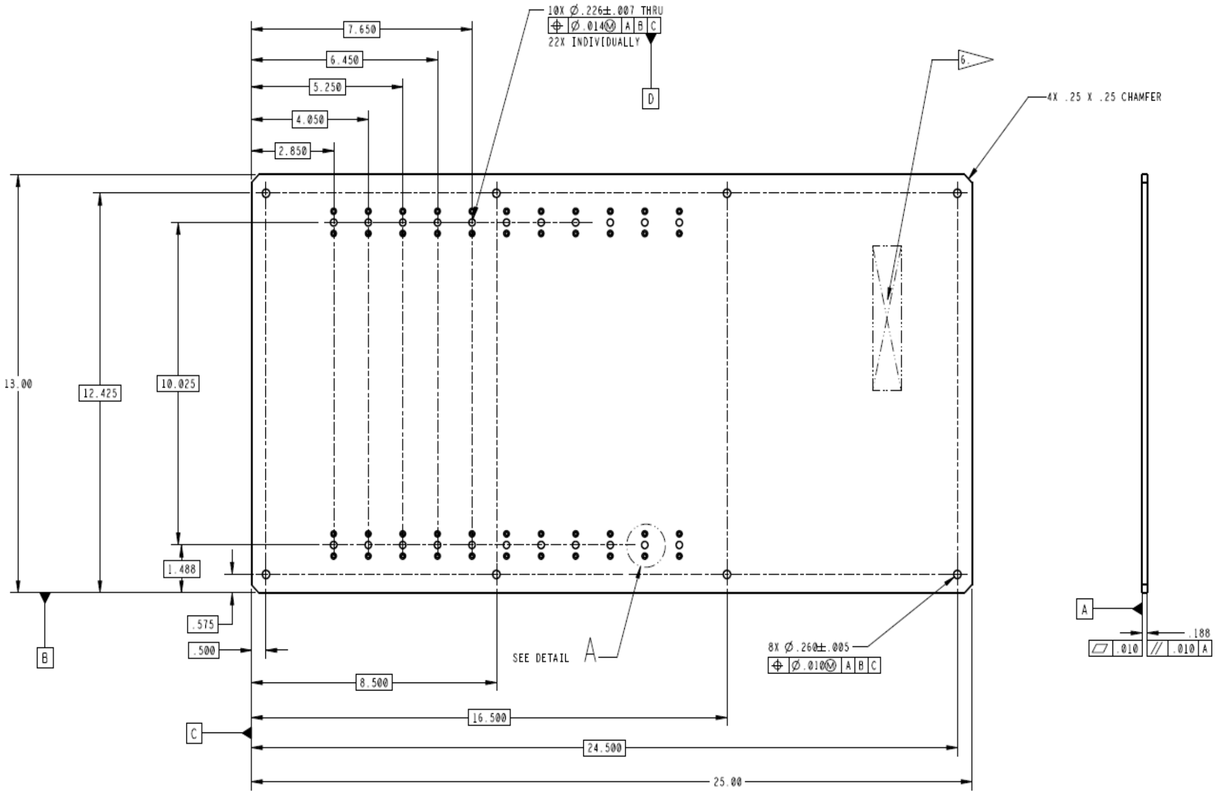


Figure 3-9 MSA Secondary Payload Bracket Interface Pattern

[SPS.SPL.016] Deployment Connector Pin-Out

The payload shall provide a DB-9 socket connector pin-out as shown in Figure 3-10.

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

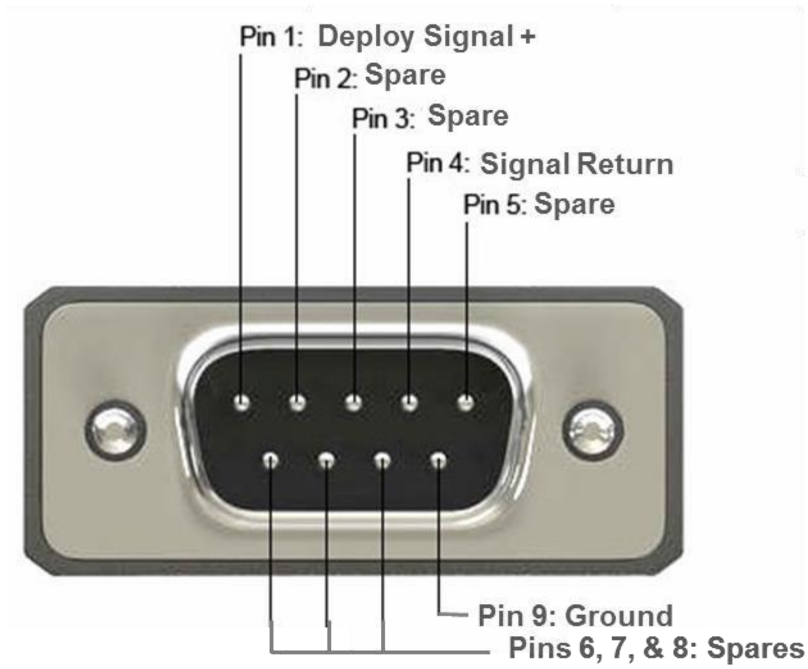


Figure 3-10 Dispenser Pin-Out Interface Configuration

3.3 Payload Battery Charging Requirements

A payload that requires battery charging prior to launch, in the VAB, must meet the following conditions.

[SPS.SPL.017] Payload Battery Diode

The payload shall contain a diode on the positive leg of the charging circuit to the battery.

> *Rationale: The diode is needed to prevent charge reversal and reduce power bleed when ground charging is withdrawn. The battery will be charged while mounted in the vehicle.*

[SPS.SPL.018] Payload Thermistor

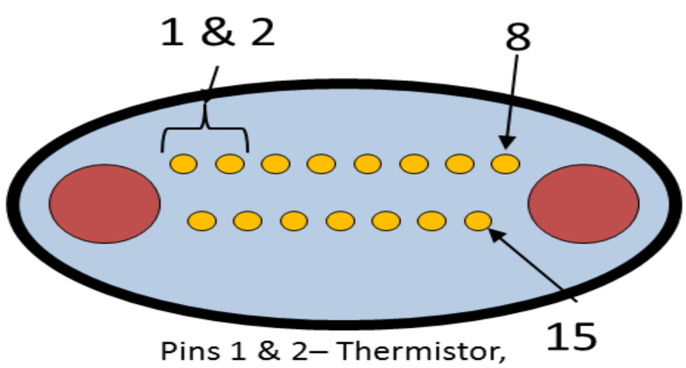
The payload shall contain a 10K thermistor within the battery pack with the leads made available to an external connector.

Rationale: The battery pack temperature must be monitored during charging operations in the VAB. If a battery cells are distributed (not located in a single battery enclosure), then multiple thermistors will be required. A 10K thermistor must be imbedded in the battery with the thermistor leads connected to pins #1 and #2 on the separation connector as illustrated in Figure 3-11.

[SPS.SPL.019] Payload Separation Connector Pin-Out

The payload shall use a separation connector pin-out as shown in Figure 3-11.

Rationale: The pin-out needs to be standardized for system wiring and GSE pin-out design considerations. Per Figure 3-11, pin #8 (+ voltage) and pin #15 (- voltage, return) on the separation connector will be used for payload battery charging. Pin-out shows optional functions that may be used in future configurations.



Pins 1 & 2– Thermistor,
Pin 8 – Voltage +, Pin 15 – Voltage –
All other pins (3 thru 7, & 9 thru 14) are
spares (for payload use).

Figure 3-11 Separation Connector Pin-Out Interface Configuration

[SPS.SPL.020] Payload Charging Circuit

The payload shall have the charging circuit separate from the payload system's circuit.

Rationale: The battery charging circuit will need to be separate from the rest of the payload circuitry so that the payload does not need to be active while charging occurs. Safety issues may occur (i.e. premature deployment, activation of propulsion system, etc.).

[SPS.SPL.021]Payload Li-ion 18650 Rechargeable Batteries

The payload shall use Li-ion 18650 rechargeable batteries with built-in protection for overcharge, over-discharge, over-current, over-heating, and dual short circuit protection.

Rationale: The charging system is tailored for Li-ion batteries. The battery industry refers to batteries with this type of protection as "smart batteries." The built-in protections are added safety features to protect the vehicle and ground crew.

[SPS.SPL.022] Failure Containment

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 operations of the avionics.

3.4 Safety Interface Requirements <FWD-001>

This section contains verbatim safety requirements from SLS-RQMT-216, SLS Exploration Mission 1 (EM-1) Safety Requirements for Secondary Payload Hardware that are applicable to secondary payload. These requirements are repeated here for completeness. In the event of conflict between the IDRD and SLS-RQMT-216, the contents of SLS-RQMT-216 shall take precedence over requirements stated in this section.

3.4.1 System Program Requirements

3.4.1.1 Safety Analysis

A safety analysis shall be performed in a systematic manner on each SLS EM-1 secondary payload to identify hazardous subsystems and functions in accordance with SLS-PLAN-217.

3.4.1.2 Hazard Reduction

Action for reducing hazards will be conducted in the following order of precedence:

Eliminate Hazards By Design	Hazards identified in the relevant hazard analyses will be eliminated by design where possible.
Minimize Likelihood and/or Severity	If a hazard cannot be eliminated by design, the goal of the design will be to insure inherent safety through the selection of appropriate design features. Damage control, containment, and isolation of potential hazards will be included in design considerations.
Safety Devices	Hazards which cannot be eliminated through design selection will be reduced and made controllable through the use of automatic safety devices as part of the system, subsystem, or equipment.

Warning Devices	When it is not practical to preclude the existence or occurrence of known hazards or to use automatic safety devices, devices will be employed for the timely detection of the condition and the generation of an adequate warning signal, coupled with emergency controls of corrective action for operating personnel to safe or shut down the affected subsystem. Warning signals and their application will be designed to minimize the probability of wrong signals or of improper reaction to the signal.
Special Procedures	Where it is not possible to reduce the magnitude of an existing or potential hazard through design or the use of safety and warning devices, special procedures will be developed to counter hazardous conditions for enhancement of personnel safety.

For SLS secondary payloads on EM-1, hazard reduction shall preclude the use of “Warning Devices” and “Special Procedures” for risk reduction of flight hazards.

3.4.1.3 Mishap/Incident/Mission Failures Investigation and Reporting

Mishap/incident/mission failures investigation and reporting for post- government acceptance SLS EM-1 secondary payloads will be handled under the provisions of NASA Headquarters policy documents NPR 8621.1 and NPG 8621.1 as part of the SLS and GSDO procedures.

3.4.2 Technical Requirements

3.4.2.1 General

The following requirements are applicable to all EM-1 secondary payloads launched on the SLS MSA. Compliance is either through design for failure tolerance or through design for minimum risk. When a safety requirement cannot be met, a waiver shall be submitted in accordance with SLS-PLAN-217.

3.4.2.1.1 Failure Tolerance

Failure tolerance is the basic safety requirement that will be used to control most secondary payload hazards. The secondary payload shall tolerate a minimum number of credible failures determined by the hazard level. This criterion applies when the loss of a function or the inadvertent occurrence of a function results in a hazardous event.

3.4.2.1.1.1 Critical Hazards

Critical hazards, as defined in Appendix D, shall be one failure tolerant and incorporate two inhibits.

3.4.2.1.2 Catastrophic Hazards

Catastrophic hazards, as defined in Appendix D shall be two failure tolerant and incorporate three inhibits.

3.4.2.2 Design for Minimum Risk

Secondary payload hazards may also be controlled through a process in which approved standards and margins are implemented that account for the absence of failure tolerance; this process is known as "Design for Minimum Risk." Design for minimum risk are areas where hazards are controlled by specification requirements that specify safety related properties and characteristics of the design that have been baselined by program requirements rather than failure tolerance criteria. For example, a pressure vessel shall be certified safe based upon its inherent properties to withstand pressure loading that have been verified by analysis and qualification and acceptance testing; however, failure tolerance must be imposed upon an external system that might affect the vessel, such as a tank heater, to assure that failures of the heater do not cause the pressure to exceed the maximum design pressure of the pressure vessel. This process is used in areas where failure tolerance is impractical or impossible due to design constraints. Failure of primary structure, structural failure of pressure vessel walls, and failure of pressurized lines are excepted from the failure tolerance requirement, provided failures are controlled through a defined process in which approved standards and margins are implemented that account for the absence of failure tolerance. Other areas where failure tolerance is impractical may be excepted from the above failure tolerance requirements with the concurrence of the PSRP. Final approval of the compliance to failure tolerance requirements and use of DFMR is documented via hazard analysis and approved as described in SLS-PLAN-217. Hazard controls related to these areas are extremely critical and warrant careful attention to the details of verification of compliance on the part of the payload developer and the SLS Program. Minimum supporting data requirements and approval for these areas of design have been identified in SLS-PLAN-217.

3.4.2.3 Environmental Compatibility

A payload shall be certified safe in the applicable worst case natural and induced environments as defined for the MSA portion of the SLS. See SLS-SPIO-SPEC-001 "ISPE Design Environments Document."

3.4.2.4 Safe Without SLS Services

Secondary payloads shall be designed to maintain failure tolerance or safety margins consistent with the hazard potential without ground crew intervention. In the event of a sudden loss or temporary interruption of provided ground services, the vehicle needs to remain safe.

3.4.3 Control of Hazardous Functions

3.4.3.1 General

Hazardous functions are operational events (e.g., motor firings, appendage deployments, stage separations, and active thermal control) whose inadvertent operations or loss may result in a hazard.

3.4.3.1.1 Monitors

SLS EM-1 Secondary Payloads shall be designed such that monitoring for safety is not required.

3.4.3.1.2 Use of Timers

When timers are used on deployable secondary payloads to control inhibits to hazardous functions, deployment of the payload from the SLS MSA shall be achieved prior to the initiation of the timer. Premature activation of a secondary payload is a catastrophic hazard to the vehicle unless it is shown otherwise.

3.4.3.2 Functions Resulting in Critical Hazards

1. A function whose inadvertent operation could result in a critical hazard shall be controlled by two independent inhibits, whenever the hazard potential exists.
2. Where loss of a function could result in a critical hazard, no single credible failure shall cause loss of that function.

3.4.3.3 Functions Resulting in Catastrophic Hazards

1. A function whose inadvertent operation could result in a catastrophic hazard shall be controlled by a minimum of three independent inhibits, whenever the hazard potential exists.
2. The return path for the function circuit shall be interrupted by one of the required inhibits if the design of the function circuit without the return path inhibit in place is such that a single credible failure between the last power side inhibit and the function, (e.g., a single short to power) can result in inadvertent operation of the catastrophic hazardous function.
3. If loss of a function could cause a catastrophic hazard, no two credible failures shall cause loss of that function.

3.4.4 Specific Catastrophic Hazardous Functions

In the following subparagraphs, specific requirements related to inhibits and operations are defined for several identified potentially catastrophic hazardous functions.

3.4.4.1 Deployable Payloads

Premature deployment or activation of a secondary payload is a catastrophic hazard unless it is shown otherwise. The general inhibit and monitoring requirements of Section 3.4.3 shall apply. Nominal deployment of a payload is not considered a hazard.

3.4.4.2 Radio Frequency Transmitters

Payloads will remain powered off from the time of hand over for integration at KSC until deployment. The following requirements are in place to ensure that the payload transmitter will not be a hazard to the vehicle.

1. Payloads shall have one Radio Frequency (RF) inhibit for power output that is less than 1.5Watt (W). Payloads shall have two independent RF inhibits for power output equal to or greater than 1.5W.
2. Payloads shall delay any signal transmissions for a minimum of 15 seconds after deployment.

Rationale: Two inhibits provide protection to the ICPS and other components from secondary payload RF transmissions. Potential RF transmissions from secondary payloads during ascent prior to MPCV separation could result in reflective RF effects.

3.4.4.3 Fluid Release from a Pressurized System Inside of a Closed Volume

A secondary payload containing either gas or fluid shall show the following:

1. The gas or fluid is contained or
2. The gas or fluid cannot damage the adjacent structure due to either over-pressurization or damage from fluid contact.

As a general rule, pressurized systems that are two fault tolerant to the release of fluid through controlled release devices do not require additional analysis beyond the analysis done for pressure system requirements. Also, pressurized systems that are two failure tolerant or designed for minimum risk to prevent leakage do not require additional analysis. The design will be assessed by the SLS EM-1 PSRP as part of a safety review. Reference section 3.4.8.8, Chemical Releases, and sections 3.4.8.10, Flammable Materials for material requirements in the event there is a fluid release.

3.4.5 Hazard Detection and Safing

There is no capability for flight controller hazard detection and safing actions for SLS EM-1 Secondary Payloads.

3.4.6 Failure Propagation

The design shall preclude propagation of failures from the SLS EM-1secondary payload to SLS systems or adjacent secondary payloads that could in turn create a hazard for adjacent SLS systems.

3.4.7 Redundancy Separation

Safety-critical redundant subsystems shall be separated by the maximum practical distance, or otherwise protected, to ensure that an unexpected event that damages one will not prevent the others from performing the safety critical function. All redundant functions that are required to prevent a catastrophic or critical hazard shall be routed through separate connectors.

3.4.8 Structures

3.4.8.1 Structural Design

The structural design of the payload and the payload dispenser shall provide ultimate factors of safety equal to or greater than 1.4 for primary structure for all applicable SLS mission phases. Design and testing of primary structure shall be in accordance with NASA-STD-5001 “Structural Design and Test Factors of Safety for Spaceflight Hardware.”

When failure of structure can result in a catastrophic event, the design shall be based on fracture control procedures to prevent structural failure arising from the initiation or propagation of flaws or crack-like defects during fabrication, testing, and service life. Requirements for fracture control are specified in NASA-STD-5019 “Fracture Control Requirements for Spaceflight Hardware.”

The use of safety critical fasteners for payload and dispenser primary structures shall be in accordance with NASA-STD-5020 “Requirements for Threaded Fastening in Systems in Spaceflight Hardware.”

Any glass or ceramics that are used in structural applications shall be in accordance with NASA-STD-5018, Strength, Design and Verification Criteria for Glass, Ceramics, and Windows in Human Space Flight Applications.

3.4.8.1.1 Safety Critical Fasteners

Locking refers to the locking devices and/or methods used to prevent fastener loosening. This requirement applies to any fastener or group of fasteners when loosening could create a catastrophic hazard due to loss of structural integrity of the fastened joint or by release of mass or debris.

1. All safety critical fasteners shall have two separate and verifiable locking features. Preload may be used as one of the features. Locking devices shall be either prevailing torque self-locking device or non-friction locking device.
2. Threaded fasteners used in joints subject to rotation shall use at least one non-friction locking device.

3. The design, installation, and inspection of non-friction locking devices such as lockwire (safety wire), safety cable, and cotter pins shall meet the requirements of NASM 33540.
4. Installation procedures shall include verification of the function of the locking feature. For prevailing torque self-locking devices, verify during each installation that the running torque falls between the minimum and maximum torques specified in the appropriate fastener procurement specification. For non-friction locking devices, verify the integrity of the locking devices by visual inspection.
5. Fastener installation (preload) torque shall be specified on the engineering drawing or on an installation procedure referenced on the engineering drawing. Running torque shall be similarly specified when prevailing torque self-locking devices are used.
6. Thread locking compounds, such as Loctite and Vibratite, may be used on safety critical fasteners with prior approval of the SLS EM-1 PSRP provided the requirements of NASA-STD-5020 are met.
7. Staking compounds may be used on safety critical fasteners with prior approval of the EM-1 PSRP provided the requirements of NASA-STD-5020 are met. These compounds, such as epoxy or other adhesives, rely on an adhesive bond to prevent rotation of the fastener head or nut.

3.4.8.2 Corrosion

Materials used in the design of payload dispenser: structures, support bracketry, and mounting hardware shall be rated for resistance to Stress Corrosion Cracking (SCC) in accordance with the tables in MSFC-STD-3029, and the ratings of MAPTIS. Payload provided dispenser shall utilize alloys with high resistance to SCC, unless documented in a MUA. Provider shall obtain concurrence from PSRP on alloys.

Material and process shall be in accordance with NASA-STD- 6016.

When failure of a part made from a moderate or low resistance alloy could result in a critical or catastrophic hazard, a Material Usage Agreement (MUA), which includes an assessment of the potential for a stress corrosion failure per NASA-STD-6016, shall be attached to the applicable stress corrosion hazard report contained in the safety assessment report.

When failure of a part made from a moderate or low resistance alloy would not result in a hazard, rationale to support the non-hazard assessment shall be included in the stress corrosion hazard report.

Controls that are required to prevent SCC of components after manufacturing shall be identified in the hazard report and closure shall be documented in the verification log prior to flight.

All concerns pertaining to general corrosion, pitting corrosion, and galvanic corrosion control, prevention and protection shall conform to the guidelines provided in MSFC-SPEC-250A. In addition, Tables 1 and 2 provide specific criteria regarding the required test methods for qualification in various environments and compatibility limits for mixed material systems.

3.4.8.3 Mechanisms

Mechanisms (movable mechanical systems) used in systems with the potential to result in either a critical or catastrophic hazard shall be designed to NASA-STD-5017 "Design and Development Requirements for Mechanisms." It addresses the functionality (the ability to operate or the ability to retain configuration) of mechanical systems rather than their strength as a structural element or the electrical aspects of an electromechanical system.

3.4.8.4 Pressure Systems / Pressure Vessels

The Maximum Design Pressure (MDP) for a pressurized system shall be the highest pressure defined by maximum relief pressure, maximum regulator pressure, or maximum temperature. Transient pressures shall be considered. Design Factors of Safety (FoS) shall apply to MDP. Where pressure regulators, relief devices, and/or a thermal control system (e.g., heaters) are used to control pressure, collectively they shall be two-failure tolerant from causing the pressure to exceed the MDP of the system. Pressure integrity will be verified at the system level. Table 3-9 provides the overall FoS for the design for pressure systems. The following paragraphs refer back to this table and provide additional detail.

Table 3-9. Factors of Safety for Design of Pressure Systems

FoS for Pressure		
1. Pressurized Systems	**Proof[1]**	**Ultimate**
a. Lines and fittings less than 1.5 inches diameter (OD)	1.5 x MDP	4.0 x MDP
b. Lines and fittings, 1.5 inches dia. (OD) or greater	1.5 x MDP	2.5 x MDP
c. Reservoirs/Pressure vessels	1.5 x MDP	2.0 x MDP
d. Other components and their internal parts which are exposed to system pressure	1.5 x MDP	2.5 x MDP
e. Flex hoses, all diameters	2.0 x MDP	4.0 x MDP
(1) Proof Factor determined from fracture mechanics service life analysis must be used if greater than minimum factor.		

3.4.8.4.1 Pressure Relief Capability

For pressurized system/vessels which may be connected to a higher pressure source where pressure regulation is used to control the MDP of the lower pressure system, at least one pressure relief device shall be provided. The pressure relief device may be a part of the two-failure tolerant design establishing MDP for the lower pressure system/vessel.

3.4.8.4.2 Pressure Vessels

Safety requirements for payload pressure vessels are listed in the paragraphs below with FoS as specified in Table 3-9. Pressure vessel materials shall be compatible with fluids used in cleaning, test, and operation. MDP, as defined Appendix A, will be substituted for all references to Maximum Expected Operating Pressure (MEOP) in the pressure vessel standards (ANSI/AIAA S-080 and ANSI/AIAA S-081). Data requirements for pressure vessels are listed in SLS-PLAN-217.

3.4.8.4.2.1 Metallic Pressure Vessels

Metallic Pressure Vessels shall meet applicable sections of the pressure vessel requirements in ANSI/AIAA S-080 based on the payload design.

3.4.8.4.2.2 Composite Overwrapped Pressure Vessels (COPVs)

COPVs shall meet applicable sections of the pressure vessel requirements in ANSI/AIAA S-081 based on the payload design. A damage control plan and stress rupture life assessment are required for each COPV.

3.4.8.4.3 Pressure Stabilized Vessels

Pressure Stabilized Vessels shall not be used on SLS EM-1 Secondary Payloads.

3.4.8.4.4 Pressurized Lines, Fittings, and Components

1. Pressurized Lines, Fittings, and Components shall have an ultimate FoS as defined in section “2” of Table 3-9. Factors of Safety for Design of Pressure Systems.
2. Secondary compartments or volumes that are integral or attached by design to the above parts and which can become pressurized as a result of a credible single barrier failure shall be designed for safety consistent with structural requirements. These compartments shall have a minimum FoS as defined in section “2d” o

3. Table 3-. If external leakage would not present a catastrophic hazard to the SLS, the secondary volume shall either be vented or equipped with a relief provision in lieu of designing for system pressure.

Note: Leakage in pressurized lines utilizing redundant seals in series which have been acceptance pressure tested individually prior to flight will not be considered a credible single barrier failure. Failures of structural parts such as pressure lines and tanks, and properly designed and tested welded or brazed joints will not be considered single barrier failures. In order to be classified as non-credible failure, the item shall be designed for a safety factor of 2.5 on the MDP, and will be certified for all operating environments including fatigue conditions.

3.4.8.4.5 Burst Discs

When burst discs are used as the second and final control of pressure (2 controls total) to meet the requirements of Section 3.4.8.4, they shall be designed to the following requirements:

1. Burst discs shall incorporate a reversing membrane against a cutting edge to insure rupture.
2. Burst disc design shall not employ sliding parts or surfaces subject to friction and/or galling.
3. Stress corrosion resistant materials shall be used for all parts under continuous load.
4. The burst disc design shall be qualified for the intended application by testing at the intended use conditions including temperature and flow rate.
5. Qualification will be for the specific part number used, and it will be verified that no design or material changes exist between flight assemblies and assemblies making up the qualification database.
6. Each flight assembly shall be verified for membrane actuation pressure either by, (1) use of special tooling or procedures to prevent cutting-edge contact during the test or, (2) demonstration of a rigorous lot screening program approved by the EM-1 PSRP.

Burst disks must be assessed for where they vent to assure they do not impinge on critical hardware or vent to an enclosed container that might overpressurize. When venting outside of the payload container this may require including SLS integration in the effort.

3.4.8.4.5.1 Sealed or Vented Containers

1. Secondary payload sealed containers shall be designed to withstand the maximum pressure differential created by SLS ascent. (15.2 psia for items exposed to directly to vacuum).

2. Vented containers shall size vent flow areas such that structural integrity is maintained with a minimum FoS of 1.4 for a depress rate of 0.15 psi/sec (9 psi/min).

3.4.8.4.5.2 Relief Valves

The relief valve design shall be qualified for the intended application and the verification approach shall be documented in the hazard analysis.

3.4.8.5 Materials

A listing of materials (both metals and nonmetals) with a “rating” indicating acceptability for each materials characteristic is available electronically in the NASA MSFC Materials and Processes Technical Information System (MAPTIS). Materials and processes shall be in accordance with NASA-STD-6016. For materials that create potential hazardous situations as described in the paragraphs below and for which no prior NASA test data or rating exists, the payload developer will present other test results for SLS Program review or request assistance from the MSFC in conducting applicable tests. All concerns pertaining to general corrosion, pitting corrosion, and galvanic corrosion control, prevention and protection shall conform to the guidelines provided in NASA-STD-6012. Tables 1 and 2 provide specific criteria regarding the required test methods for qualification in various environments and compatibility limits for mixed material systems. The payload material requirements for hazardous materials, flammability, and off-gassing are as follows.

3.4.8.6 Hazardous Materials

Hazardous materials shall be contained during ground processing and shall not be released or ejected in or near the SLS, unless such release/ejection has been negotiated with the Program. During exposure to all SLS environments, hazardous fluid systems shall contain the fluids unless the use of the SLS vent/dump provisions has been negotiated with the SLS Program. Toxic or hazardous chemicals/materials shall have failure tolerant containment appropriate with the hazard level or be contained in an approved pressure vessel.

A list of all hazardous materials (including hazardous fluids, chemicals, and biological materials) along with a corresponding Material Safety Data Sheet (MSDS) will be provided to the SLS EM-1 PSRP for review and acceptance of use through the hazard report endorsement. Payloads should expect to provide this information to the GSDO SMA prior to shipment of the hardware to KSC.

3.4.8.7 Fluid Systems

Particular attention will be given to materials used in systems containing hazardous fluids. These hazardous fluids include gaseous oxygen, liquid oxygen, fuels, oxidizers, and other fluids that could chemically or physically degrade the system or cause an exothermic reaction. Those materials within the system exposed to oxygen (liquid and gaseous) or other hazardous fluids, both directly and by a credible single barrier failure, shall meet the requirements of NASA-STD-6001 at MDP and temperature. The payload supplier's compatibility data on hazardous fluids may be used to accept materials in this category if approved by the SLS Program.

3.4.8.8 Chemical Releases

Any chemical whose release would create a toxicity hazard or cause a hazard to SLS hardware shall be contained. Mercury is an example of such a chemical, since it produces toxic vapors and can amalgamate with metals or metal alloys used in spacecraft hardware. Containment shall be provided by an approved pressure vessel as defined in section 3.4.8.4 or the use of two or three redundantly sealed containers, depending on the toxicological hazard for a chemical with a vapor at any positive pressure. The payload developer shall assure that each level of containment will not leak under the maximum use conditions (i.e., vibration, temperature, pressure, etc.). Documentation of chemical usage, along with the containment methods, shall be supplied for review and endorsement.

3.4.8.9 Biological Materials

Any biological material to be flown on a secondary payload shall be limited to Biosafety Level – (BSL-1), will be reviewed and approved by the SLS EM-1 PSRP, and shall be loaded and sealed in its container prior to shipment of the payload hardware to KSC. Containment shall be provided by approved pressure vessel or a container with a certified single level of containment as approved by the SLS EM-1 PSRP.

3.4.8.10 Flammable Materials

A secondary payload shall not constitute an uncontrolled fire hazard to the SLS or other secondary payloads. The minimum use of flammable materials shall be the preferred means of hazard reduction. The determination of flammability shall be in accordance with NASA-STD-6001. Materials used in non-pressurized areas shall be evaluated for flammability in an air environment at 14.7 psi. A flammability assessment shall be documented in accordance with the SLS EM-1 PSRP Process.

3.4.9 Material Offgassing

Non-metallic materials shall be selected in order to avoid producing toxic levels of off-gassed products in order to protect ground personnel during ground processing per NASA-STD-6016. Non-metallic materials with no test data in the MAPTIS database shall either require a Materials Usage Agreement (MUA) or off-gas testing as specified in NASA-STD-6001.

3.4.10 Material Outgassing

Low outgassing materials shall be selected in order to prevent contamination of adjacent payloads and SLS hardware that may be sensitive to outgassing. Materials with no test data in the MAPTIS database will require an MUA, or ASTM-E595 testing. Untested or unidentified materials may use thermal vacuum bake-out of the assembled article per MSFC-Spec-1238 for safety verification.

3.4.11 Pyrotechnics

A list of all pyrotechnic devices, their location, strength, and their proposed use will be provided to SLS EM-1 PSRP. If premature firing or failure to fire will cause a hazard, the pyrotechnic subsystem and devices shall meet the design and test requirements of MSFC-SPEC-3635, Pyrotechnic System Specification.

3.4.12 Radiation

3.4.12.1 Ionizing Radiation

Secondary payloads containing or using radioactive materials or that generate ionizing radiation shall be identified and approval obtained for their use by the SLS EM-1 PSRP. Descriptive data shall be provided in accordance with the SLS EM-1 PSRP Process. Any radioactive materials flown aboard SLS must be reported to the SLS Program in accordance with NPR 8715.3C. Major radioactive sources require approval by the Interagency Nuclear Safety Review Panel through the NASA coordinator for the panel. Radioactive materials shall comply with KSC requirements contained in ANSI-Z-136.1 and KNPR 1860.1.

3.4.12.2 Emissions and Susceptibility

1. Electronic emissions from secondary payloads are controlled by requiring the payload to remain powered off until deployment (see RF transmissions under section 3.4.4.2).
2. Demonstrate that the payload is not susceptible to the electronic emission environment documented in SLS-SPIO-SPEC-001 “ISPE Design Environments Document” and shall not result in inadvertent operation of payload functions.

3.4.12.3 Lasers

A list of all lasers and their proposed use shall be provided to the SLS EM-1 PSRP. Payloads should expect to provide this information to the GSDO SMA prior to shipment of the hardware to KSC. Any lasers that can be accessed during ground processing shall be designed and operated in accordance with American National Standard for Safe Use of Lasers, ANSI-Z-136.1.

3.4.13 Electrical Systems

3.4.13.1 General

Electrical power distribution circuitry shall be designed to include circuit protection devices to protect against circuit damage normally associated with an electrical fault when such a fault could result in damage to the SLS. Bent pins or conductive contamination in an electrical connector will not be considered a credible failure mode if a post mate functional verification is performed to assure that shorts between adjacent connector pins or from pins to connector shell do not exist. If this test cannot be performed, then the electrical design shall insure that any pin if bent prior to or during connector mating cannot invalidate more than one inhibit and that conductive contamination is precluded by proper inspection procedures.

3.4.14 Batteries

Batteries used on secondary payloads shall be designed to control applicable hazards caused by buildup or venting of flammable, corrosive or toxic gasses and reaction products; the expulsion of electrolyte; and by failure modes of over-temperature, shorts, reverse current, cell reversal, leakage, cell grounds, and overpressure. For batteries meeting the criteria of SLS-SPIE-RQMT-018, the payload shall provide lot testing per Appendix D of SLS-SPIE-RQMT-018. All other batteries used on secondary payloads shall be designed in accordance with JSC 20793, Rev C, Crewed Space Vehicle Battery Safety Requirements.

3.4.15 Lightning

Payload electrical circuits may be subjected to the electromagnetic fields due to a lightning strike to the launch pad. If circuit upset could result in a catastrophic hazard to the SLS, the circuit design shall be hardened against the environment or insensitive devices (relays) shall be added to control the hazard.

3.4.16 Verification

Test, analysis, inspection and demonstration, as appropriate, will be the methods used for verification of design features used to control potential hazards. The successful completion of the safety process will require positive feedback of completion results for all verification items associated with a given hazard. Reporting of results by procedure/report number and date is required. See SLS-SPIE-RQMT-018, Secondary Payload Interface Definition and Requirements Document for further details on verification methods.

A payload safety verification tracking log (SVTL) is required to properly status the completion steps associated with hazard report verification items (see SLS-PLAN-217).

3.4.17 Hazardous Operations

The payload developer shall assess all secondary payload flight operations and determine their hazard potential to the SLS. The hazardous operations identified shall be assessed in the applicable flight safety assessment report.

Secondary payloads shall be designed such that any required access to hardware during ground operations can be accomplished with minimum risk to personnel.

3.4.18 Payload Commanding

Commanding of secondary payloads prior to deployment is prohibited.

3.4.19 Flammable Atmospheres

During the ascent phase, secondary payloads shall not cause ignition of a flammable atmosphere that may be present in the MSA. The basic assumption is that there is a flammable atmosphere inside the MSA during ascent and the control philosophy is for payload design to ensure that there is no electrical ignition source due to payload electronics or electrostatic discharge during ascent. The payload design shall meet the following requirements.

1. Payloads shall be powered off from the time of hand over for integration at KSC until deployment.
2. Conductive surfaces (including metalized Multilayer Insulation (MLI) layers) shall be electrostatically bonded per the requirements of a Class S bond as documented in NASA-STD-4003.

4.0 DISPENSER – VERIFICATION

The verification process ensures that the payload conforms to the technical and safety requirements specified in Section 3 of this IDRD. For each Section 3 requirement, there shall be a corresponding Section 4 verification method identified. Verification methods (i.e., analysis, test, demonstration, inspection, and/or validation of records) will be specified for each *shall* requirement statement and serve as the methods by which the requirements are to be verified. (Note: Non- “shall” statements will not have a verification requirement for compliance.) Each verification method will be defined below.

- Test—Verification by test is the actual operation of equipment during ambient conditions or when hardware is subjected to specified environments to evaluate performance. Two types of tests are defined below.
  - 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.
  - 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.
- 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.

- 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.
- 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.
- Similarity—Verification by similarity is the process of assessing prior data, configuration, 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 must not be used when either the similar item used in the assessment was itself verified/validated using similarity as the method, and for items whose criticality is 1 or 1R (i.e., items whose failure or malfunction could result in loss of vehicle, life, or serious injury).
- Validation of Records—Verification by validation of records (VR) is the use of vendor- or interfacing project-supplied verification metadata or furnished/supplied manufacturing or processing records to ensure the requirements have been incorporated or met. Validation of records can be used as the method to satisfy incorporation of requirements for such items as COTS products or closure of allocated requirements (e.g., closure of allocated requirements).
- A Verification Cross Reference Matrix (VCRM) is generated to show the requirement trace and closure methods. The VCRM is in Appendix B of this document.

APPENDIX A
ACRONYMS AND ABBREVIATIONS AND GLOSSORY OF TERMS

A1.0 ACRONYMS AND ABBREVIATIONS

@	At
12U	A 12 unit configuration dispenser with dimensions of 20x20x30 cm
6U	A 6 unit configuration dispenser with dimensions of 10x20x30 cm
ACS	Attitude Control System
AL	Aluminum
app.	Approximately
batt.	Battery
BBQ	Bar-B-Que [roll]
BSL	Bio Safety Level
CDC	Centers for Disease Control and Prevention
CG	Center of Gravity
cm	Centimeter(s)
CoC	Certification of Compliance
CoFR	Certification of Flight Readiness
COPV	Composite Overwrapped Pressure Vessel
COTS	Commercial Off-the-Shelf
DEP	Dispenser
DoD	Department of Defense
DRO	Distant Retrograde Orbit
ECS	Environmental Control System
EM-1	Exploration Mission One
F	Fahrenheit
FOD	Foreign Object Damage/Debris
FOS	Factors of Safety
FWD	Forward
g	Grams

GEVS	General Environmental Verification Standard
GN2	Gaseous Nitrogen
GSDO	Ground Systems Development and Operations
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
HDBK	Handbook
Hz	Hertz(s)
I/F	Interface
ICD	Interface Control Document
ICPS	Interim Cryogenic Propulsion Stage
IDRD	Interface Definitions and Requirements Document
in.	Inch(es)
ISO	International Organization for Standardization
ISPE	Integrated Spacecraft and Payload Element
JSC	Johnson Space Center
KeV	Kilo Electron Volt(s)
kg	Kilogram(s)
KSC	Kennedy Space Center
lbs	Pound(s)
LVSA	Launch Vehicle Spacecraft Adapter
m	Meter(s)
MAWP	Maximum Allowable Working Pressure
Max	Maximum
MCC	Mission Control Center
MDOP	Maximum Design Operating Pressure
MDP	Maximum Design Pressure
MEOP	Maximum Expected Operating Pressure
MeV	Mega Electron Volt(s)
MIL	Military
Min	Minimum or Minute(s)
MIUL	Material Identification and Usage list

MLI	Multi-Layer Insulation
mm	Millimeter(s)
MOP	Maximum Operating Pressure
MPCV	Multi-Purpose Crew Vehicle
MSA	MPCV Spacecraft Adapter
MSFC	Marshall Space Flight Center
MUA	Material Usage Agreement
NASA	National Aeronautics and Space Administration
NDE	Non Destructive Evaluation
NIH	National Institutes of Health
NPR	NASA Procedural Requirement
OD	Outside Diameter
PDI	Payload Integration
PL	Payload
POCC	Payload Operation Control Center
ppm	Parts Per Million
psi	Pounds Per Square Inch (static pressure)
psia	Pounds Per Square Inch Absolute (or Ambient)
psig	Pounds Per Square Inch Gauge
PSRP	Payload Safety Review Panel
rads	Radiation [absorbed] dosage
RF	Radio Frequency
RQMT	Requirement(s)
SCC	Stress Corrosion Cracking
SLS	Space Launch System
SPDS	Secondary Payload Deployment System
SPIE	Spacecraft/Payload Integration and Evolution
SPIM	Secondary Payloads Integration Manager
SPIO	Spacecraft/Payload Integration Office
STD	Standard
TBD	To Be Determined

TBR	To Be Resolved
TLI	Trans-Lunar Injection
TNT	Trinitrotoluene
T-O	Take Off
U	Satellite unit of measure, 1 U = 10 cm x 10 cm x 10 cm (cubic volume)
U.S.	United States
VAB	Vehicle Assembly Building
VR	Validation of Records
VRCM	Verification Cross Reference Matrix
W	Watt

A2.0 GLOSSARY OF TERMS

Dispenser	A rectangular box that fully encapsulates and deploys a small payload.
Mission skit	Payload deployment sequence information that is loaded into the Secondary Payload Deployment System (SPDS) avionics prior to rollout to the launch pad.

APPENDIX B
VERIFICATION MATRIX

Table B-1. Verification Cross Reference Matrix 3.2 thru 3.4 Requirements

Req ID: [SPS.SPL.###]	Section / Requirement Title	Method					
		A	D	I	T	VR	S
TECHNICAL INTERFACE REQUIREMENTS							
001	Deployment Rate	X					
002	Payload Providing Other Dispenser					X	
003	Dispenser/Payload to MSA Mass				X		
004	Dispenser/Payload Center of Gravity	X			X		
005	Dispenser/Payload Cleanliness			X			
006	Payload Storage	X					
007	Payload Prelaunch	X					
008	Random Vibration and Shock	X			X		
009	Design Loads	X			X		
010	In-Space Temperatures	X					
011	In-Space Radiation	X					
012	Payload Activation	X					
013	Payload Co-Deployments	X					
014	Dispenser Labeling			X			
015	Dispenser Mounting Interface			X			
016	Deployment Connector Pin-Out			X			
PAYLOAD BATTERY CHARGING REQUIREMENTS							
017	Payload Battery Diode			X			

Req ID: [SPS.SPL.###]	**Section / Requirement Title**	**Method**					
		A	**D**	**I**	**T**	**VR**	**S**
018	Payload Thermistor			**X**	**X**		
019	Payload Separation Connector Pin-Out			**X**			
020	Payload Charging Circuit			**X**			
021	Payload Li-ion 18650 Rechargeable Batteries			**X**			
022	Failure Containment	**X**					
SAFETY INTERFACE REQUIREMENTS <FWD-001>							

Req ID: [SPS.SPL.###]	**Section / Requirement Title**	**Method**					
		A	**D**	**I**	**T**	**VR**	**S**

APPENDIX C
GLOSSARY OF SAFETY REQUIREMENT TERMS

Term	Description
Brittle Fracture	Brittle fracture is a type of catastrophic failure in structural materials that usually occurs without prior plastic deformation and at extremely high speed. The fracture is usually characterized by a flat fracture surface with little or no shear lips (slant fracture surface) and at average stress levels below those of general yielding.
BSL – 1	Biosafety Level 1 is a designation provided by the Centers for Disease Control and Prevention (CDC) and the National Institutes of Health (NIH) for well-characterized agents not known to consistently cause diseases in healthy adults, and of minimal potential hazard to laboratory personnel and the environment.
Catastrophic Hazard	Personnel: Loss of life or permanently disabling injury. Facilities, Equipment, Assets: Loss of vehicle prior to completing its mission, or loss of essential flight/ground assets
Class B Ordnance	Explosives function by rapid combustion rather than by detonation.
Components	Components for purposes of pressure systems, are all elements of a pressurized system.
Composite Overwrapped Pressure Vessel	A pressure vessel with a composite structure fully or partially encapsulating a metallic or plastic liner. The liner serves as a fluid (gas or liquid) permeation barrier and may or may not carry substantive pressure loads. The composite generally carries pressure and environmental loads.
Controls	A device or function that operates an inhibit is referred to as a control for an inhibit. Controls do not satisfy the inhibit or failure tolerance requirements for hazardous functions.
Critical Hazard	Personnel: Injury or occupational illness requiring definitive/specialty hospital/medical treatment resulting in loss of mission. Facilities, Equipment, Assets: Loss of ESD mission, condition that requires safe-haven, or major damage to essential flight/ground assets
Design for Minimum Risk	Design for minimum risk are areas where hazards are controlled by specification requirements that specify safety related properties and characteristics of the design that have been baselined by program requirements rather than failure tolerance criteria. For example, a pressure vessel shall be certified safe based upon its inherent properties to withstand pressure loading that have been verified by analysis and qualification and acceptance testing; however, failure tolerance must be imposed upon an external system that might affect the vessel, such as a tank heater, to assure that failures of the heater do not cause the pressure to exceed the maximum design pressure of the pressure vessel.

Term	Description
Electromagnetic Emissions	Electromagnetic energy radiated or conducted from an electrical or electronic component, equipment, subsystem, system, or flight element.
Electromagnetic Susceptibility	Equipment capability for impaired performance due to electric or magnetic environments (radiated or conducted).
Factor Of Safety	The factor by which the limit load is multiplied to obtain the ultimate load. The limit load is the maximum anticipated load or combination of loads, which a structure may be expected to experience. Ultimate load is the load that a payload must be able to withstand without failure.
Failure Tolerance	The number of failures that can occur in a system or subsystem without the occurrence of a hazard. Single failure tolerance would require a minimum of two failures for the hazard to occur. Two-failure tolerance would require a minimum of three failures for a hazard to occur
Fittings	In pressure systems, fittings are local elements of a pressurized system utilized to connect lines, components and/or vessels within the system.
Fracture Control	Fracture control is a set of policies and procedures involving the application of analysis and design methodology, manufacturing technology and operating procedures to prevent structural failure due to the initiation of and/or propagation of flaws or crack-like deflects during fabrication, testing, and service life
Fracture Critical Fastener	A fastener is classified as fracture critical when failure of one fastener results in a single-point direct catastrophic failure.
Independent Inhibit	Two or more inhibits are independent if no single credible failure, event, or environment can eliminate more than one inhibit.
Inhibits	An inhibit is a design feature that provides a physical interruption between an energy source and a function (a relay or transistor between a battery and a pyrotechnic initiator, a latch valve in the plumbing line between a propellant tank and a thruster, etc.).
Leak Before Burst	A fracture mechanics design concept in which it is shown that any initial flaw will grow through the wall of a pressure vessel and cause leakage rather than burst (catastrophic failure)
Lines	Lines are tubular elements of a Pressurized system provided as a means for transferring fluids between components of the system. Included in this definition are flex hoses.
Maximum Design Pressure	The MDP for a pressurized system shall be the highest pressure defined by maximum relief pressure, maximum regulator pressure, or maximum temperature. MDP is equivalent to Maximum Expected Operating Pressure (MEOP).

Term	Description
Monitoring	The ability to ascertain and communicate the status of functions, devices, inhibits and parameters. Monitoring can be either real-time or on a periodic basis.
Non-friction Locking Device	An all-metal mechanical device that is used to prevent the movement of an externally and/or internally threaded part. Examples of these devices are lockwire, safety cable and cotter pins. This device would have to shear before the fastener(s) could unthread. Non-friction locking devices are verifiable by visual inspection.
Pressure Stabilized Vessels	Pressure vessels that are pressure-stabilized and must contain a minimum pressure to maintain the required ultimate factors of safety to insure structural integrity under launch loads.
Pressure Vessel	A pressure vessel is a component of a pressurized system designed primarily as a container that stores pressurized fluids and: a. Contains stored energy of 14,240 foot-pounds (19,310 joules or 0.01 pounds trinitrotoluene (TNT) equivalent) or greater based on adiabatic expansion of a perfect gas; or b. Will experience a design limit pressure greater than 100 psia; or c. Contains a fluid in excess of 15 psia, which will create a hazard if released.
Pressurized System	A pressurized system, as addressed in this document, comprises the pressure vessels or pressurized structure, lines, fittings, valves, etc., that are exposed to and designed by the pressure within these components. It does not include electrical control devices, etc., required to operate the system.
Prevailing Torque Self-Locking Device	A mechanical device that prevents fastener loosening by increasing the friction between the male and female threads. Prevailing torque self-locking devices are verifiable by measurement of running torque during assembly, also called “self-locking device.”
Primary Structure	That part of a flight vehicle or payload that sustains the significant applied loads and provides main load paths for distributing reactions to applied loads. Also, the main structure which is required to sustain the significant applied loads, including pressure and thermal loads, and which if it fails creates a catastrophic hazard. If a component is small enough and in an environment where no serious threat is imposed if it breaks, then it is not primary structure.
Proof Pressure	The proof pressure is the test pressure that pressurized components shall sustain without detrimental deformation. The proof pressure is used to give evidence of satisfactory workmanship and material quality, and/or establish maximum initial flaw sizes. It is equal to the product of MDP and proof pressure design factor.
Pyrotechnic Device	All devices and assemblies containing or actuated by propellants or explosives, with the exception of large rocket motors. Pyrotechnic devices include items such as initiators, igniters, detonators, safe and arm devices, booster cartridges, pressure cartridges,

Term	Description
	separation bolts and nuts, pin pullers, linear separation systems, shaped charges, explosive guillotines, pyro-valves, detonation transfer assemblies (mild detonating fuse, confined detonating cord, confined detonating fuse, shielded mild detonating cord, etc.), thru bulkhead initiators, mortars, thrusters, explosive circuit interrupters, and other similar items.
Running Torque	The torque required to overcome the locking feature when 100 percent of the locking feature is engaged and the fastener is unseated Running torque is dynamic and can be measured in either the loosening or tightening direction, also known as the locking torque or self-locking torque.
Safety Critical	A condition, event, operation, process, function, equipment, or system (including software and firmware) with potential for personnel injury or loss, or with potential for loss or damage to vehicles, equipment or facilities, loss or excessive degradation of the function of critical equipment, or which is necessary to control a hazard.
Safety Critical Fastener	A fastener, or group of fasteners, is considered to be performing a safety critical function if the loss of that fastener, or group of fasteners could result in a catastrophic hazard including the generation of Foreign Object Damage/Debris (FOD).
Sealed Container	A housing or enclosure designed to retain its internal atmosphere and which does not meet the pressure vessel definition (e.g., an electronics housing).
Secondary Structure	The internal or external structure that is used to attach small components, provide storage, and to make either an internal volume or external surface usable. Secondary structure attaches to and is supported by primary structure
Stress-Corrosion Cracking	Stress-corrosion cracking is a mechanical-environmental induced failure process in which sustained tensile stress and chemical attack combine to initiate and propagate a flaw in a metal part.
Structure	all components and assemblies designed to sustain loads or pressures, provide stiffness and stability, or provide support or containment
Vented Container	An enclosure that is not intentionally sealed or is provided with vents such that it will not create a hazard in the event of depressurization or repressurization of the surrounding volume.

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 that 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.

1. 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.
2. 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.

1. 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).
2. 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 (61approx. 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.

    1. 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.
    2. 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).
    3. 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.

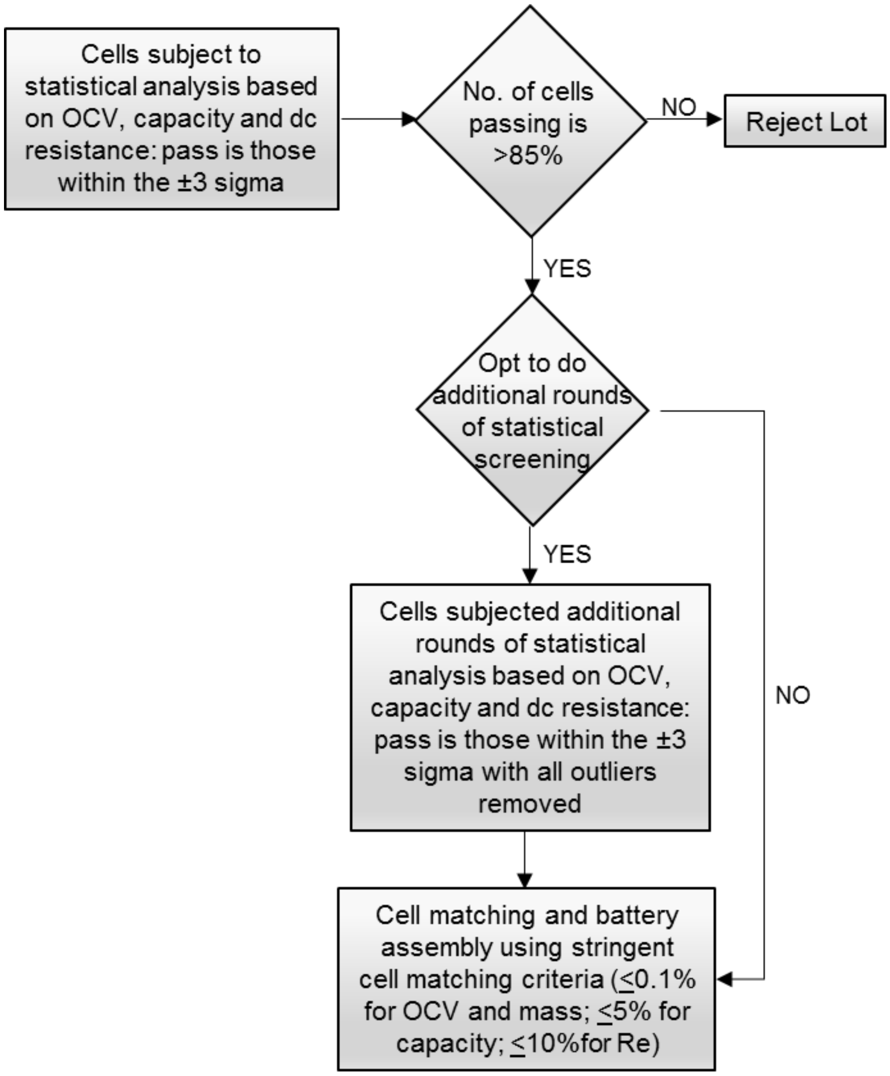


Figure 6.4.3-2. Cell Acceptance Flow with Small Numbers of Larger, Lower Volume Custom Cell

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 Testin	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-	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	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
2	COTS cells available to the public requiring additional testing/documentation. Example: Battery/Cell
3	Cells available for Original Equipment Manufacturer (OEM) assembly as a pack, but not readily
4	Cells and batteries of any size that cannot be used, stored, or transported in a habitable volume.

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.

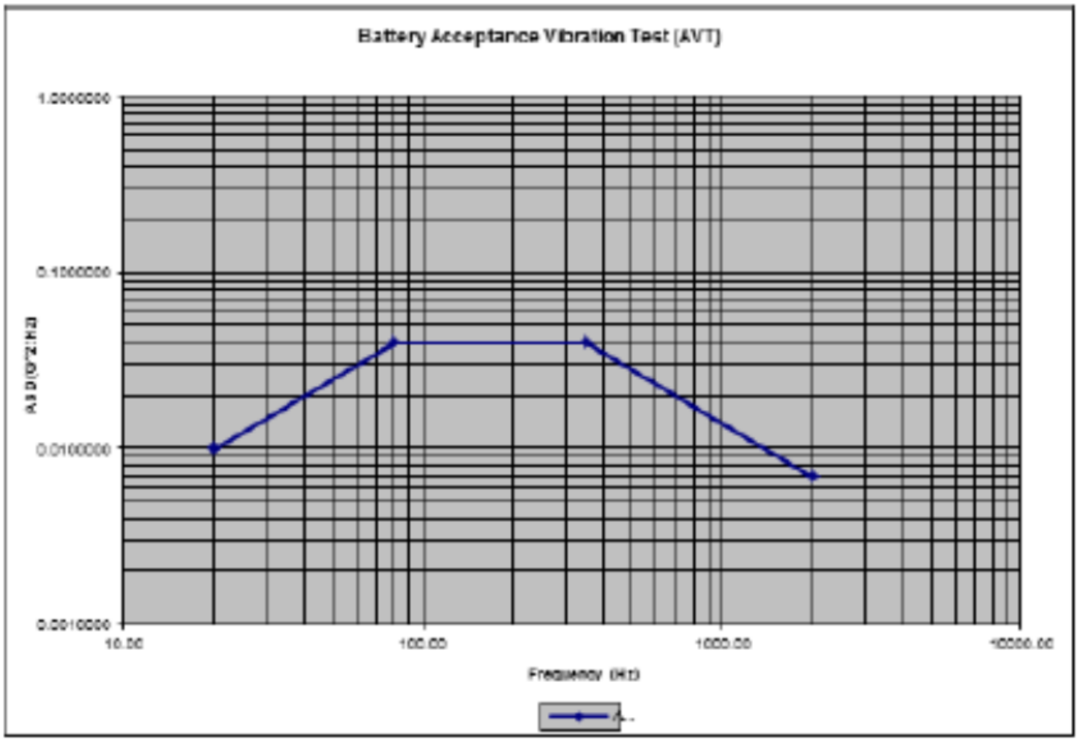


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Figure A-3. Flight Acceptance Vibration Spectrum for Batteries Tolerant to Internal Shorts

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

APPENDIX E
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.

E 1.0 TO BE DETERMINED

Table E1-1 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 E1-1. To Be Determined Items

TBD	Section	Description
TBD-001		

E2.0 TO BE RESOLVED

Table E2-1 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 E2-1. To Be Resolved Issues

TBR	Section	Description
TBR-001	3.2 SPS.SPL.010	In-Space Temperatures

TBR	Section	Description
TBR-002	3.2 SPS.SPL.014	Dispenser labeling Dispenser labeling is being worked with GSDO since using different label method than MIL-STD
TBR-003	3.2 SPS.SPL.001	Payload Ejection Rate
TBR-004	3.2 SPS.SPL.008	Random Vibration data will be updated by CDR.

E 3.0 FORWARD WORK

Table E3-1 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 E3-1.

Table E3-1. Forward Work

FWD	Section	Description
FWD-001	3.4, and Appendix B	Safety requirements will be updated once the RQMT-216 document has been fully baselined. At that time we will revisit how to adequately break apart/ better document the safety requirements for verification, readdress how best to handle the SOW/process related shall statements that might still remain from PCB approval for baseline, and identify verification methods for the safety requirements in the VCRM.