NASA

Science Mission Directorate (SMD)

Launch Vehicle Secondary Payload Adapter

Rideshare Users Guide with Do No Harm

(2021 SMD SPA RUG with DNH)

GENERIC VERSION (Sample): Used for pre-planning purposes ONLY.

Proposers must use the specific "RUG" released with the solicitation

to which they are submitting a proposal.

Color coding: **red/bold = requirement**, *blue/italic = guideline for maximum flight opportunity*

Revision 0
Effective Date: December 15, 2021

RECORD OF REVISIONS		
REV	**DESCRIPTION**	**DATE**
0	Replaces previous SMD ESPA RUG 1. Added Do No Harm requirements 2. Multiple edits and updates throughout whole document 3. Updated launch vehicle environments	October 1, 2021

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1 Introduction

1.1 Purpose

This document defines requirements and guidelines for preliminary spacecraft design, launch vehicle integration, and mission planning for a Rideshare Payload (RPL) to follow for proposals submitted to the Science Mission Directorate solicitations that will utilize an Evolved Launch Vehicle (EELV) Secondary Payload Adapter (SPA). These requirements and guidelines also apply to ESPA-class payload accommodations on other launch vehicle carrier rings and secondary payload adapters that aren't named "ESPA", such as the Airbus Hub dispenser, the SHERPA, the SpaceX Rideshare dispenser ring, the USSF ROOSTER, etc. The NASA Rideshare Users Guide (RUG) focuses on payloads that integrate to a SPA ring, including: 1) CubeSats (when their deployer/plate integrates to an SPA port); 2) ESPA-class payloads; and 3) ESPA Grande-class payloads.

This document was developed by the NASA Science Mission Directorate (SMD) Rideshare Office and the NASA Launch Services Program.

This NASA SMD RUG supports RPL developers, including Principal Investigators, concept development teams, and project teams. The RUG specifies acceptable analyses and test methodologies required to assure each Rideshare Payload (RPL) is adequately qualified for the launch environments and operations with the primary payload, as well as with other RPL(s) selected for the launch. Additionally, an RPL must follow the NASA do-no-harm (DNH) process so it does not impact the primary mission or other rideshare payloads.

The RUG also defines rideshare standard services and outlines the specific services provided by the Launch Vehicle Contractor (LVC) under contracts administered by NASA's Launch Service Program (LSP) organization. Any services requested by the RPL beyond those specified in the NASA RUG are by definition "non-standard" or "mission unique" and require additional funding beyond the standard rideshare services funding. All costs resulting from non-standard or mission unique rideshare related activities are funded by the RPL provider.

1.2 Scope

This document provides ground rules and assumptions for RPLs intended to launch on a Secondary Payload Adapter (SPA). **These cannot be exhaustive.** Since the primary payload and the launch vehicle will not be known at the time of proposal submittal, and neither the type of SPA ring nor the SPA integrator will be known, specific interface requirements and generic environment definitions will not be formalized until the launch vehicle contractor and primary observatory have been selected and the primary mission integration cycle has begun. **It is critical that secondary payloads carry additional margins** to account for any associated applicable uncertainty.

"Should" statements and *Guidelines for Maximum Flight Opportunity* are provided to assist proposers looking to maximize their opportunity for rideshare. Violating these guidelines does not make a payload ineligible for inclusion as a rideshare but may limit the number of missions that are compatible with the RPL's launch requirements and may increase integration and launch costs. "**Shall**" statements refer to requirements.

This document also includes Rideshare Mission Assurance (RMA) and Do No Harm (DNH) process guidelines that focus on ensuring safety of flight for the primary mission and other rideshare payloads.

An Accommodation Study will be conducted as part of the selection process. To aid in this process, proposers are asked to document additional RPL requirements that must be accommodated using the mission specific or mission unique hardware processes, or services as specified by the Launch Vehicle to Payload Interface Control Document.

NOTE: For this document, the SPA and the SPA Integrator contractor are considered part of the Launch Vehicle (LV)/Launch Vehicle Contractor (LVC) and/or Government.

1.3 Configuration Control

The NASA RUG is a NASA SMD-owned guide for RPL users. Revisions to this document are coordinated with key stakeholders, suppliers, industry, etc., and are publicly released with each SMD RPL solicitation.

Changes to the NASA RUG can be driven by changes in the LVC-controlled interfaces, environments, services, etc.; therefore, users should contact the SMD Rideshare Office for the most up to date information, such as launch environments.

2 Definitions and Acronyms

2.1 Acronyms:

- ATP – Authority to Proceed
- CB – Craig Bampton
- CCAMs – Contamination Control Avoidance Maneuvers
- CG – Center of Gravity
- CLA – Couple Loads Analysis
- DNH – Do No Harm
- DOT – Department of Transportation
- EMI – Electromagnetic Interference
- ESPA – Evolved Launch Vehicle Secondary Payload Adapter
- FEM – Finite Element Model
- GN2 – Gaseous Nitrogen
- GSE – Ground Support Equipment
- ICD – Interface Control Document
- IFD – In Flight Disconnect
- I&T – Integration and Test
- IPS – Integrated Payload Stack – Fully integrated ESPA with mated RPL
- LSIRD – Launch Service Interface Requirements Document
- LSP – Launch Services Program
- LSTO – Launch Service Task Order
- LV – Launch Vehicle
- LVC – Launch Vehicle Contractor
- MPE – Maximum Predicted Environment
- PGAA – Performance and Guidance Accuracy Analysis
- PSWG – Payload Safety Working Group
- RF – Radio Frequency
- RPL – Rideshare Payload(s)
- RMA – Rideshare Mission Assurance
- RUG – Rideshare Users Guide
- SC or S/C – Spacecraft
- SMD – Science Mission Directorate
- SPA – Secondary Payload Adapter
- TBD – To Be Determined
- TBR – To Be Resolved
- TBS – To Be Supplied
- VLC – Verification Loads Cycle

2.2 Definitions:

- Primary Payload or Spacecraft refers to the spacecraft bus and its associated instruments. The primary spacecraft, or payload, is the spacecraft for which the launch service is initially procured. The primary payload typically dictates launch requirements including launch schedule, time of launch, orbit inclination and destination, and orbit insertion accuracy. (Per NPD 8610.12: A payload that justifies its own launch. Specific characteristics: A primary payload typically defines the orbital placement/trajectory, flight design, critical path of the mission integration, including launch preparation process, and mission operations.)
- Rideshare Payloads (RPL) are those payloads that will have no authority to impact mission integration cycle for the primary mission. This includes, but is not limited to, integration analyses timing, primary payload go-no-go call for launch and driving environmental conditions within the fairing. Rideshare Payloads are synonymous with Secondary Payloads.
- Secondary Payloads – Payloads that will be carried by a Secondary Payload Adapter. A secondary payload utilizes excess capability of a launch after the primary payload requirements are satisfied. A secondary payload can be an experiment, sensor, instrument, or fully integrated spacecraft whose mission objective is different than that of the primary payload mission. See NASA NPD 8610.12H for further definition and specific characteristics.
- Secondary Payload Adapter (SPA) is a generic term for a flight-proven qualified Launch Vehicle adapter carrier/ring enabling deployment of secondary payloads. (ex. Evolved Secondary Payload Adapter (ESPA), Cosmic Deployer Ring, ESPAStar, ESPA Grande, Hub, Sherpa, ROOSTER, etc.)
- DNH – Do No Harm - A set of criteria and requirements to ensure no harm is inflicted on the primary payload, the launch vehicle, or any other payloads. DNH requirements were developed to minimize and mitigate any risks to the stack of payloads and the launch vehicle.
- RMA – Rideshare Mission Assurance (RMA) is the process developed by DoD with the objective to provide all mission partners with a degree of certainty that all payloads included on a mission will do no harm (DNH) to each other, or to any operational aspect of the launch through spacecraft separation.
- Mission Unique: All non-standard, first flight, and any services provided that are newly performed or developed specifically to meet the requirements of a specific rideshare payload, which are not included as part of the standard rideshare integration service. Also known as mission specific.
- Spacecraft bus essential power: Ability for spacecraft to be powered on at launch in order to power survival heaters and enable detection of spacecraft separation as a mission unique service.
- Partners – In this document Rideshare partners refers to all stakeholders for the mission, including Launch Vehicle Contractor, RPLs, and Primary Spacecraft.

3 Documents

3.1 Applicable Documents:

- NASA-STD-8719.24 — NASA Expendable Launch Vehicle Payload Safety Requirements. (Base + Annex)
- NPR 8715.6B NASA — Procedural Requirements for Limiting Orbital Debris
- NPR 8715.7B NASA — NASA Payload Safety Program
- NASA-STD-6016 — Standard Materials and Processes Requirements for Spacecraft
- IEST-STD-CC1246 — Product Cleanliness Levels and Contamination Control Program
- ASTM E2900 — Standard Practice for Spacecraft Hardware Thermal Vacuum Bakeout
- LSP-REQ-317.01B — Launch Services Program (LSP) Program Level Dispenser and CubeSat Requirements Document
- NPD 8610.12H — Orbital Space Transportation Services
- ELVL-2016-0044292 — Thermal Analysis Report LSP Flight Analysis Division Thermal Analysis Group Payload Thermal Model Submittal Guideline
- AFSPCMAN 91-710 — Air Force Space Command Manual 91-710, Range Safety User Requirements Manual, 1 July 2004
- MIL-STD-461G — Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment, December 2015
- NASA-HDBK-7004C — Force Limited Vibration Testing
- SPD-32 — SMD Rideshare Policy (EELV Secondary Payload Adapter Secondary Payloads Rideshare)

3.2 Reference Documents:

- EELV RUG — 2016 Evolved Expendable Launch Vehicle Rideshare User's Guide - USSF Space and Missile Systems Center/Launch Systems Enterprise Directorate (SMC/LE)
- TOR-2016-02946 — Rideshare Mission Assurance and the Do No Harm Process – Aerospace Report
- GSFC-STD-7000 — General Environmental Verification Standard (GEVS) for GSFC Flight Program and Projects
- MMPDS — Metallic Materials Properties Development and Standardization
- MIL-HDBK-5 — Military Handbook 5, Metallic Materials and Elements for Aerospace Vehicle Structures
- MIL-STD-1540C — Military Standard Test Requirements for Launch, Upper-Stage, and Space Vehicles
- SMC-S-004 — AFSC Space and Missile Systems Center Standard: Independent Structural Loads Analysis

4 Ground Rules and Assumption

4.1 The Government and/or LVC will do or provide the following:

4.1.1 In a case where a RPL is not able to meet the required mass properties or milestone schedule or is determined by NASA to be unfit to launch, then NASA has the right to replace the RPL with an equivalent mass simulator or with a backup RPL if available. Note, mass simulators will be hard mounted to the SPA Port (non-separating).

4.1.2 Per Rideshare policy, LVC will build and provide mass simulators for each SPA port.

4.1.3 LVC will provide the separation system for each ESPA-class RPL per section 6.3.3

4.1.3.1 For missions that have prior commitments with SMD to provide their separation systems, 4.1.3 does not apply.

4.1.4 LVC will provide In Flight Disconnect (IFD) to each ESPA-class RPL per section 6.4.2.

4.1.5 LVC will perform a separation analysis to validate no contact between RPLs, upper stage and primary payload and demonstrate no impediment to the upper stage Contamination Control Avoidance Maneuvers (CCAMs).

4.1.6 LVC will coordinate RPL deployment time and sequencing with all invested stakeholders.

4.1.7 LVC will provide the RPL separation signal (primary and redundant) to each RPL or to an LVC-provided SPA sequencer.

4.1.8 LVC will provide confirmation of RPL separation/deployment for non-CubeSat dispensers.

4.1.9 LVC will provide Orbital Parameter Message within 30 minutes of RPL separation.

4.1.10 LVC will provide accommodations for RPL GN2 purge systems as a mission unique service*. Any requirement for RPL GN2 purge systems from RPL arrival at integration facility through launch must be noted on the Accommodation Worksheet. Max flight opportunity: no purge requirement.*

4.1.11 Purge interruptions will be inherent for all LV's due to standard launch vehicle processing, therefore RPL missions **shall** ensure they can handle interruptions and have plans in place to mitigate interruption effects. The plans should include the maximum time the RPL can be off purge and the accumulative time.

4.1.12 Facility space will be provided by the LVC for integration onto the SPA at the launch site. It can be used by RPLs for receiving, unpacking, functional checks, battery charging, and facility power.

4.1.12.1 If standalone processing time or spacecraft fueling is required by the RPL prior to delivery to the LVC, NASA will contract a Payload Processing Facility as a RPL mission unique service. *Any requirements to use this space for fueling or pressurization of a propulsion system must be* *specified on the Accommodation Worksheet.* Max flight opportunity: no hydrazine or other hazardous fuel requirement.

4.1.12.2 LVC integration facility's temperature and humidity will typically be controlled to the following levels and will be driven by the primary mission's requirements:

Temperature: 55° – 85° Fahrenheit (12.8° - 29.4°Celsius)
Relative humidity: < 65%

4.1.12.3 LVC will provide a clean room environment at the integration facility for integrated contamination control environments to meet contamination requirement for primary mission.

4.2 RPLs will/will not:

4.2.1 RPLs will not have the authority to make a GO, No-GO call on day of launch.

4.2.2 RPLs will not have the authority to change the launch readiness date of the primary mission.

4.2.3 RPLs will not have physical access post-fairing encapsulation; this includes launch delays/scrubs. RPLs must plan for removal of non-flight covers, safety plugs, etc. to occur prior to encapsulation. *Any requirements for access to the RPL after delivery for integration must be noted on the Accommodation Worksheet. Max flight opportunity: no requirement for post encapsulation access to RPL.*

4.2.4 RPLs will not receive down range telemetry support for RPL deployments. *Any requirement for down range telemetry support for RPL deployments may be assessed as a RPL mission unique service by LSP and must be noted on the Accommodation Worksheet. Max flight opportunity: no requirement for down range telemetry for RPL deployment.*

4.2.5 RPLs will be deployed after the primary mission separation. Deployment time can be a minimum of 120 minutes post-launch. Some primary missions have a longer coast period.

4.2.6 RPLs should assume that the launch vehicle upper stage will act as a 3-axis-stabilized inertial platform and no launch vehicle delta-v will be available to the RPL. *Any requirement for the launch vehicle to be pointed in a particular direction at the moment an RPL is released must be noted on the Accommodation Worksheet. Max flight opportunity: no requirement for specific direction or upper stage maneuver requirement.*

4.2.7 RPLs should anticipate that they will be required to remain "dormant" (with no RF transmission and no appendages deployed) for some period following their release. (see 6.4.1.5)

4.2.8 Per Rideshare policy, RPLs are responsible for the cost(s) for their mission unique item(s). RPLs should carry mission unique funds to cover mission unique requirements that may come up during mission integration.

5 Rideshare Mission Assurance and Do-No-Harm

For Rideshare missions, there is a need to mitigate risks from the RPLs to the primary mission, all payloads on the mission and to the launch vehicle. The Department of Defense (DoD) Space Test Program (STP) implemented a hybrid system of risk mitigation called Rideshare Mission Assurance (RMA). The objective of the DOD RMA process is to provide all mission partners with a degree of certainty that all payloads included on a mission will Do No Harm (DNH) to each other, or to any operational aspect of the launch. In 2016, the DoD STP developed a Rideshare Mission Assurance Do-No-Harm (TOR-2016-02946) guideline document. This document is only releasable to Government and Government contractors and will not be in the NASA SMD program library for SMD solicitations. NASA has established a similar process and a tailored set of Do-No-Harm criteria in support of NASA SMD rideshare missions and the relevant requirements from the STP TOR are embedded within this document.

The DoD and NASA RMA and DNH process mitigates risks by assessing each payload flying on a mission against a tailored set of criteria, known as "Do No Harm" criteria. The primary concern of the RMA process is to ensure that the payloads are robust enough to survive the environments experienced during launch and/or will not inadvertently power on and perform functions that could be harmful to other missions. Other areas also assessed includes any co-use of facilities during the launch campaign and the critical function inhibit scheme utilized by the payload. The focus of this process is to ensure safety of flight for all mission partners and is not to ensure mission success for individual RPLs. It is the responsibility of the RPLs to ensure their own mission success.

This document incorporates key elements of the DoD STP and NASA RMA process for this early procurement and concept development phase. Following the guidelines and requirements in this document allows NASA payloads to be compatible with Space Force rideshare opportunities and Space Force payloads to compatible with primary NASA missions.

5.1 Program Management Insight

For the RMA process to work efficiently, sufficient insight into the RPL design, integration, and in particular, the test process, is required by NASA program management. This insight is not limited to the individual program's management authority but must include the overall mission program management whenever safety of flight risks are involved. Integration and test methods must be understood by the overall NASA mission management team to ensure that the methods and procedures implemented are sufficient to demonstrate DNH, and do not compromise otherwise sound designs. Furthermore, any post testing changes to the RPL must be vetted by the overall NASA mission program management prior to the implementation of the changes, in order to ensure that there is no additional risk caused by the late stage changes.

High risk tolerance with respect to public, personnel, and facility safety, does not apply and protections for those areas are the same for high risk-tolerant missions and low risk-tolerant missions.

All NASA and NASA-sponsored payloads **shall** be designed to meet NASA-STD-8719.24 or AFSPCMAN 91-710 to ensure hazards are appropriately controlled as documented in section 6.

5.2 Do No Harm Management

The Rideshare DNH and Mission Assurance process provides a framework for performing mission assurance on multi-payload missions that is commonly used in the multi-payload industry. The NASA SMD DNH management process is actively managed by a team of stakeholders consisting of the NASA Primary Mission Program Office (PgO), the Primary Mission Project, NASA Launch Services Program (LSP), the Launch Service Contractor (LSC), and the RPL programs and projects.

Early programmatic discussion and agreement from all mission partners is essential to ensuring that DNH baselines are understood, that DNH risks are evaluated properly, and that DNH verification is conducted in an acceptable manner. Once the LSC is on contract, this process will be formalized, and a detailed mission specific set of Do-No-Harm criteria will be developed and validated as part of the overall mission integration cycle. The communications and authority protocol, and the process for non-conformances or exceptions, will be specified by NASA after launch vehicle selection.

The Rideshare Mission Assurance process may allow for limited exceptions to the DNH requirements. All parties on a rideshare mission must understand the process for requesting such exceptions. More importantly, all rideshare partners must understand that such requests need to be made, and approved, before they are implemented.

6 Requirements:

6.1 Mission Integration

6.1.1 RPLs **shall** meet the data input timelines for the Primary Mission Integration Cycle (e.g., PGAA-1, 2, 3, and Verification Load Cycle (VLC)). See Appendix A for an example of expected timelines for RPL data product deliverables for rideshare integration.

6.1.2 RPLs **shall** provide all data products listed in Appendix A to meet the Primary Mission Integration Cycle Schedule.

6.2 Mission Trajectory

6.2.1 The RPL orbit insertion **shall** be designed to not make physical contact with the primary spacecraft, or LV performing end of mission operations. The RPL's trajectory insertion, including C3, will be dependent on excess capability of the launch vehicle after inserting the primary spacecraft and after considering additional resources needed by the LV for end of mission disposal.

6.2.2 RPLs consisting of constellations (or that otherwise separate into multiple free-flying components), including CubeSats, **shall** provide analysis showing no re-contact between the CubeSat constellation members.

6.2.3 RPLs should be designed to survive for a minimum of 120 minutes between launch and spacecraft deployment.

6.2.4 The LVC will perform conjunction analysis for initial protection of the primary spacecraft and the LV upper stage. The RPL is responsible for any motion analyses relative to other secondaries from LV separation through either their first RPL maneuver or a period of time that will be determined during mission integration.

6.2.5 RPLs **shall** meet NPR 8715.6B, NASA Procedural Requirements for Limiting Orbital Debris, for orbital debris and end of mission requirements.

6.3 Mechanical

6.3.1 ESPA/SPA Ring Reference Coordinates and Origin:

6.3.1.1 RPLs will use the coordinate system specified in Figure 6.1. The origin of the coordinate system is at the center of the -X face of the spacecraft (the center of the SPA port). The X-dimension is measured from the SPA port interface plane, and the dimension in the table includes the width of the separation system.

Figure 6.1 SPA and RPL Coordinate System

6.3.2 ESPA-Class Payloads Interface Requirements

6.3.2.1 RPLs **shall not** exceed the mass and volume requirements as specified in Table 6.1; RPLs with lower mass will be easier to accommodate. If your design requires protrusion outside the cube volume, please provide rationale for evaluation and consideration in the Accommodation Worksheet. *Max flight opportunity: x-dimension < 38" would be compatible with 4-m and 5-m fairing launch vehicles.*

Table 6.1 ESPA/SPA RPL Mass, Volume Interface Requirements for 4-meter Fairing

ESPA	Port Mass Capacity[4]	Allowable RPL Volume[1, 2, 3,5]	RPL Interface
ESPA Grande 4 Port	465 kg	42"x46"x38" Y, Z, X	24" circular
ESPA 6 Port	220 kg	24"x28"x38" Y,Z,X	15" circular

(1) X-dimension assumes a 4-meter fairing; ESPA Grande on 5-meter fairing allows 56".
(2) The RPL X-axes starts at the ESPA port interface plane.
(3) The RPL X-axis dimension includes the separation system width. This means separation system width will be subtracted from the 38" allowable dimension.
(4) The flyaway portion of the separation system shall be considered as part of the RPL total mass.
(5) Separation system tip-off must be accounted for to ensure any RPL structure that extends into the internal volume of the ring will exit the volume upon RPL deployment without contacting the port inner diameter.

6.3.2.2 RPLs **shall** maintain a center of gravity as follows:

- CG along the RPL X-axis **shall** be less than 20" from the ESPA interface port
- Lateral CG (Y, and Z axis) **shall** be within 1" of the RPL X-axis centerline
- RPL Spacecraft separation tip-off rates & CG offset requirement language

6.3.3 ESPA Class Separation Systems:

6.3.3.1 LVC will provide the appropriate separation system for each RPL, based on the payload design characteristics. Specification for commonly used separation systems are listed below:
https://www.ruag.com
https://www.planetarysystemscorp.com
https://exolaunch.com/carbonix.html

6.3.3.2 RPL Spacecraft should familiarize themselves with standard separation tip-off rate capabilities of the different available separation systems for small spacecraft and appropriately design spacecraft CG offsets. Tip-off rate estimate *(ω_{max})* includes effects from SV mass properties *(ω_{sv})*, launch vehicle initial rate *(ω_{init})*, and separation system dispersions *(ω_{sep})*.

$$\omega_{max} = \omega_{sv} + \omega_{init} + \omega_{sep}$$

In the absence of more detailed modeling, conservation of momentum can be used to provide a first-order estimate of the angular rate the separation system will impart on the space vehicle, ω_{sv}.

$$\omega_{sv} < \frac{m_{sv} v_{rel} r_{sv}}{I_{sv}}$$

Where I_{sv} is lateral mass moment of inertia, r_{sv} is the radial CG offset, m_{sv} is spacecraft mass, and v_{rel} is relative separation velocity between the spacecraft and launch vehicle. Based on experience and currently available separation systems, several assumptions may be employed for determination a preliminary rate budget and subsequently refined during mission integration.

- *min v_{rel} of 0.4 m/s for m_{sv} < 150 kg and 0.3 m/s for $m_{sv} \geq$ 150kg*
- *$\omega_{init} \leq$ 0.5deg/s for the roll axis and $\omega_{init} \leq$ 0.1 deg/s for lateral.*
- *ω_{sep} = 1-3 deg/s as a preliminary estimate for separation system prior to mission specific analysis*

6.3.4 Static Loads

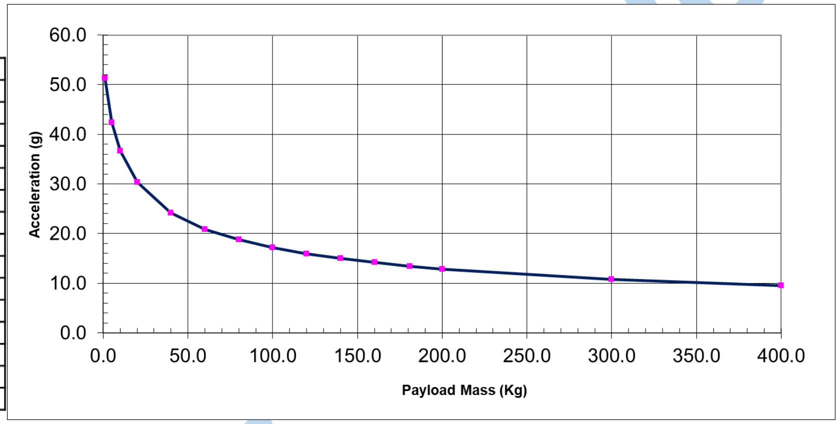
6.3.4.1 The peak line load across the ESPA/RPL interface **shall** not exceed 400 lbs./in. This is defined at the separation plane between the active and passive parts of the separation system. This limit is based on a maximum LV acceleration of 8.5g

6.3.4.2 RPLs should refer to Figure 6.2 for the Mass Acceleration Curve for RPLs.

Figure 6.2 Mass Acceleration Curve for RPLs provided by GSFC

Break Points*

Mass (kg)	Accel (g)
1.0	51.3
5.0	42.4
10.0	36.6
20.0	30.3
40.0	24.2
60.0	20.9
80.0	18.7
100.0	17.2
120.0	15.9
140.0	15.0
160.0	14.2
181.0	13.5
200.0	12.9
300.0	10.8
400.0	9.5



6.3.4.3 Spacecraft **shall** demonstrate the ability to withstand static launch loads to the levels identified by the Interface Control Document (ICD) (or in the relevant appendix of the Rideshare User's Guide). In the absence of existing guidance, Appendix A provides general guidance to rideshare payloads for load levels and testing approaches.

6.3.4.4 RPLs **shall** apply the maximum axial static and lateral loads such that all worst-case combinations and directions of max tension, max compression, max shear, and max bending meet structural design requirements.

6.3.4.5 Structural compliance should be demonstrated by test or analysis using appropriate safety factors. Reference NASA-STD-5001 for guidance.

6.3.5 RPL Stiffness

6.3.5.1 RPLs **shall** have first fixed-free fundamental frequencies above 75 Hz constrained at the separation system interface plane. *A risk may be carried by NASA for RPL's with frequencies below 75Hz. Additional Coupled Loads Analyses will be required to be performed with the selected LV to determine any coupling or adverse CLA response impacts to the primary mission. Unfavorable results may result in the demanifesting of the RPL. Max flight opportunity: First fixed-free fundamental frequencies above 75 Hz constrained at the separation system interface plane.*

6.4 Electrical

6.4.1 Electrical Power

6.4.1.1 RPLs **shall** be powered off during all integrated and hazardous operations and from T-15 minutes through deployment. Once the RPL has been integrated to the ESPA, the RPL can only be powered on for battery charging and hazardous system monitoring. *Requirements for powering on after integration to the ESPA must be detailed in the Accommodation Worksheet. Max flight opportunity: No requirement to be powered on during launch.*

6.4.1.2 The RPL T-0 electrical interface **shall** be dead-faced (electrically isolated) at T-15 minutes prior to launch. This timeframe may be able to be adjusted by a few minutes due to the specific launch vehicle launch configuration and launch day script, but it is not guaranteed to be changed, therefore secondary payloads should plan for T-15 minutes.

6.4.1.3 RPLs **shall** incorporate a Remove Before Flight pin that cuts power to the spacecraft bus. This will be used during transportation and ground processing/integration activities.

6.4.1.4 All inhibits to hazardous operations (such as deployments, pressure system activation, RF transmission, etc.) **shall** have 3 independent inhibits (dual-fault tolerant). Timers are not considered inhibits. These include but are not limited to: propulsion/pressure system activation, any deployable structures such as solar arrays or antennas, and all RF transmitters. Verification of this requirement by analysis only is acceptable (refer to NASA-STD-8719.24 Base +Annex).

6.4.1.5 RPLs **shall** inhibit deployments and transmitter turn-on for minimum of 15 minutes after deployment. Time to be determined during the integration process as part of the mission ICD process.

6.4.1.6 RPLs **shall** require no electrical access after encapsulation. This includes remove before flight pins, battery enable plugs, etc.

6.4.2 Connectors:

6.4.2.1 The connector interface varies with the separation system selection and will be coordinated with the RPL after LV selection. LVC will provide one in flight disconnect (IFD) connector and one spare to each of the RPL developers for incorporation into spacecraft build. Pinout assignments and electrical characteristics of the harness will be defined during the interface control document development.

6.4.3 Battery:

Battery charging can be provided through an SPA T-0 connector (LV ground umbilical). Requirements for battery charging and monitoring must be detailed in the Accommodation Worksheet. Battery charging will not be provided during integrated operation or hazardous operations. If battery charging is permitted thru LV ground umbilical, the RPL must control battery power remotely, because no access will be provided to RPLs post encapsulation. LVC will provide RPL telemetry for battery monitoring data up until T-15 minutes before launch.

6.4.3.1 RPLs **shall** utilize Underwriter Laboratory (or-equivalent) approved batteries with no modifications and be compliant with Range Safety requirements (NASA-STD-8719.24).

6.4.3.2 RPLs **shall** incorporate battery circuit protection for charging/discharging to avoid unbalanced cell condition.

6.4.3.3 RPLs **shall** meet battery charge monitoring requirements per NASA-STD-8719.24. RPL monitoring of the charge activity **will be required** to avoid generation of Radio Frequency (RF) emissions that may affect nearby hardware.

6.5 Environments:

This section contains general requirements for early development/design which would be adequate for the launch vehicles currently on NASA LSP contracts, but may change when new launch vehicles become available. Mission specific environments will be defined once the launch vehicle contractor and primary observatory have been selected and the mission integration cycle has begun. These Mission Specific environments will be flowed down to the RPLs from the Launch Vehicle to Primary Payload Interface Control Document (ICD). The environments defined in the LV to Primary Payload ICD will take precedence over the requirement defined in this section.

6.5.1 Thermal

6.5.1.1 RPLs **shall not** impose specific requirements that constrain the environment of the launch vehicle or specify temperature and humidity requirements that would be in conflict with the primary spacecraft requirements.

6.5.1.2 A significant concern for a RPL is ensuring they understand and are able to accommodate the environmental control systems (ECS) being maintained for the primary spacecraft. The LV ECS system is designed to maintain the environment around the primary spacecraft within a specific temperature and relativity humidity band. Since the RPL will be sharing the same ECS gas volume as the primary spacecraft, RPLs must be compatible with the prelaunch ECS requirements established by the primary spacecraft.

6.5.1.3 RPLs should be able to tolerate the ascent and on-orbit thermal environment without the use of spacecraft heaters. *Max flight opportunity: No requirement for heaters.*

6.5.2 Random Vibration

6.5.2.1 RPLs **shall** be designed to the representative composite random vibration environments defined in Appendix B.

6.5.2.2 Random Vibration testing must prove that the populated RPL is capable of surviving the LV-induced random vibration environment with margin and is assessed using a shaker table.

6.5.2.3 RPLs may use force limiting to limit the random vibration levels at resonant frequencies; all other notching methodologies should be avoided, as defined in NASA-HDBK-7004C.

6.5.3 Sine Vibration

6.5.3.1 RPLs **shall** be designed to the representative composite sine vibration environments defined in Appendix B.

6.5.4 Acoustics

While most small RPLs are primarily driven by the LV random vibration environment, many individual design elements remain acoustically sensitive. Deployable solar arrays, large antennas, and other lightweight structures will often remain acoustically driven in certain frequency ranges. Generally, structures should be considered acoustically sensitive if they have an area-to-mass ratio above 150 in2/lbm. If analysis shows that the RPL being assessed does have acoustic sensitivities, then actual testing is required to demonstrate RMA / DNH compliance. This testing can be performed either at the system level (recommended), or on just the sensitive components (allowable only if system level testing is impractical). Like the random vibration tests, acoustic tests should be performed to MPE +3db in order to demonstrate margin, and all structures should be tested in their ascent configuration. Acoustic testing can only be waived if it has been collectively (launch provider and all payloads/program offices/other stakeholders) determined that no components of the RPL are acoustically sensitive, or that the RPL response to structurally-borne vibrations envelope the responses to the acoustic environment at all points across all frequencies.

6.5.4.1 RPLs **shall** be designed to the representative composite acoustic environments defined in Appendix B.

6.5.4.2 RPLs with an area-to-mass ratio greater than 150 in2/lbm **shall** undergo acoustic testing, either as part of system testing (preferred) or as a subsystem.

6.5.4.3 RPLs **shall** test to the acoustic levels identified by the mission ICD (or in the relevant appendix of the Rideshare User's Guide).

6.5.4.4 Programs may assess whether the random vibration environment envelopes the acoustic environment, and if so, use the random vibration test as their acoustics verification.

6.5.4.5 Compliance **shall** be demonstrated by test, at the specified levels +3dB.

6.5.5 Shock

Historically, the driving shock event for any payload has been its own separation from the launch vehicle, and as such, an instrumented separation system test would provide the required insight into the robustness of the RPL. However, with the increasing use of low-shock separation systems this assumption can no longer be made. Analysis of the shock levels imparted onto the payload by LV- or rideshare partner-induced shock events (ignition, lift off, stage cutoffs, stage reignites, fairing separation, rideshare partner deployment) must be assessed against the envelope of instrumented RPL testing. Any exceedances imposed by any rideshare partner must be assessed individually.

6.5.5.1 RPLs **shall** be designed to the representative composite shock environments defined in Appendix B defined at the RPL adaptor port. Shock environment provided is based on LV candidate users guides interface levels for separation of primary spacecraft. The provided level includes 30% attenuation across the LV adapter-to-RPL adapter interface. Distance attenuation was explicitly not accounted for due to the RPL adapter details being unknown.

6.5.6 Pressure

6.5.6.1 RPLs **shall** demonstrate compliance with pressure decay rate during LV ascent.

6.5.6.2 RPLs **shall** freely vent all volumes not designated as a pressure container or pressure vessel.

6.5.6.3 RPLs will be exposed to a free molecular heating environment once the fairing is jettisoned. The payload fairing jettison is driven by the primary mission and can be based on free molecular heating or delta in pressure at separation.

6.5.7 Contamination

The primary mission will drive these requirements, and they may be more restrictive than what is listed below. Often NASA spacecraft have high sensitivity (ISO Level 7 (Class 10,000) contamination control) requirements for both molecular and particulate contamination on all surfaces within the fairing volume. As a result, strict cleanliness requirements that conform to the primary spacecraft requirements may be placed on secondary payloads. Particle redistribution analyses may be required.

6.5.7.1 RPLs **shall** adhere to a **minimum** of ISO Level 8 (Class 100,000) cleanliness requirements.

6.5.7.2 RPLs **shall** be cleaned, certified, and maintained **minimally** to level 500R1 per IEST-STD-CC1246E.

6.5.7.3 RPLs **shall** undergo thermal vacuum bakeout per ASTM E2900.

6.5.7.4 RPLs material selections **shall** be in accordance with NASA-STD-6016 Standard Materials and Processes Requirements for Spacecraft. High outgassing materials may need to comply with ASTM E1559 testing for contamination sensitive surfaces.

6.5.7.5 RPLs will be assessed against the risk of contaminating sensitive components of other rideshare partners. The DNH process must ensure that nothing from the RPL being assessed can be re-deposited on critical components of rideshare partners. This includes both particulate matter and volatile compounds. This requirement is assessed by a combination of test (thermal cycle or thermal vacuum) and analysis (materials lists, contamination control plans, line of sight to sensitive components). While thermal vacuum testing is generally considered an electrical stress test, the level and duration of the upper temperature soak can be used to demonstrate that any volatile compounds will have baked out of the system and no longer pose a threat to the mission. Particulate matter mitigation must be addressed prior to the first-time payloads are in the same area or in a co-used clean-room for launch processing.

6.5.7.6 RPLs **shall** be cleaned to a level that will not cause a cleanliness violation for any other mission partner.

6.5.7.7 RPLs should limit the use of uncured silicone to minimize impact to other mission payloads. *Max flight opportunity: No use of silicone on spacecraft.*

6.5.8 Helium Sensitivity

RPLs should be aware that the payload fairing environment may expose the RPL to helium sources and therefore should consider this in spacecraft design in order to avoid damage from potential helium gas exposure.

6.5.9 Electromagnetic Interference/Electromagnetic Compatibility (EMI/EMC)

Because RPLs are launched in a "powered down" state, EMI risks are generally assessed in relation to the RPL processing period. Radiated Emissions (RE) assessments of the RPL are performed to ensure that any functional testing in a co-used processing facility will not damage sensitive components of rideshare partners. In addition to the RE testing, Radiated Susceptibility (RS) assessments of the RPL may also be performed to provide inputs to all other rideshare partners' DNH analysis. These tests should be performed per MIL-STD-461G or equivalent. If incompatibilities are discovered in the RE/RS testing, simple mitigation steps can be implemented to reduce risk. Simple mitigation steps might include using antenna hats to eliminate free radiation and organizing time-sequenced tests between RPL to allow for sensitive electronics to be safe.

6.5.9.1 RPLs **shall** not conduct free radiation during launch processing. "Plugs out" testing may be conducted with antenna hats.

6.5.9.2 RPLs **shall** ensure Underwriter Laboratory (UL) or equivalent certification on all electrical ground support equipment (EGSE). All EGSE **shall** meet NASA-STD-8719.24, NASA Expendable Launch Vehicle Payload Safety Requirements.

6.5.9.3 RPLs radiated emissions at the payload interface plane **shall** not exceed the levels shown in Figure 6.3.

6.5.9.4 RPLs **shall** meet inhibit requirement for RF transmission as per section 6.4.1.4.

6.5.9.5 RPLs **shall** show compliance for electromagnetic compatibility margins per NASA-STD-8719.24 (and/or AFSPCMAN 91-710), MIL-STD-461G and MIL-STD-464A.

6.5.9.6 RPLs **shall** remain powered off from encapsulation through separation on orbit to support the 3 inhibit requirement.

6.5.9.7 RPLs **shall** be compatible with the launch vehicle and range radiated emissions:

- 20 V/m for 2MHz to 18GHz

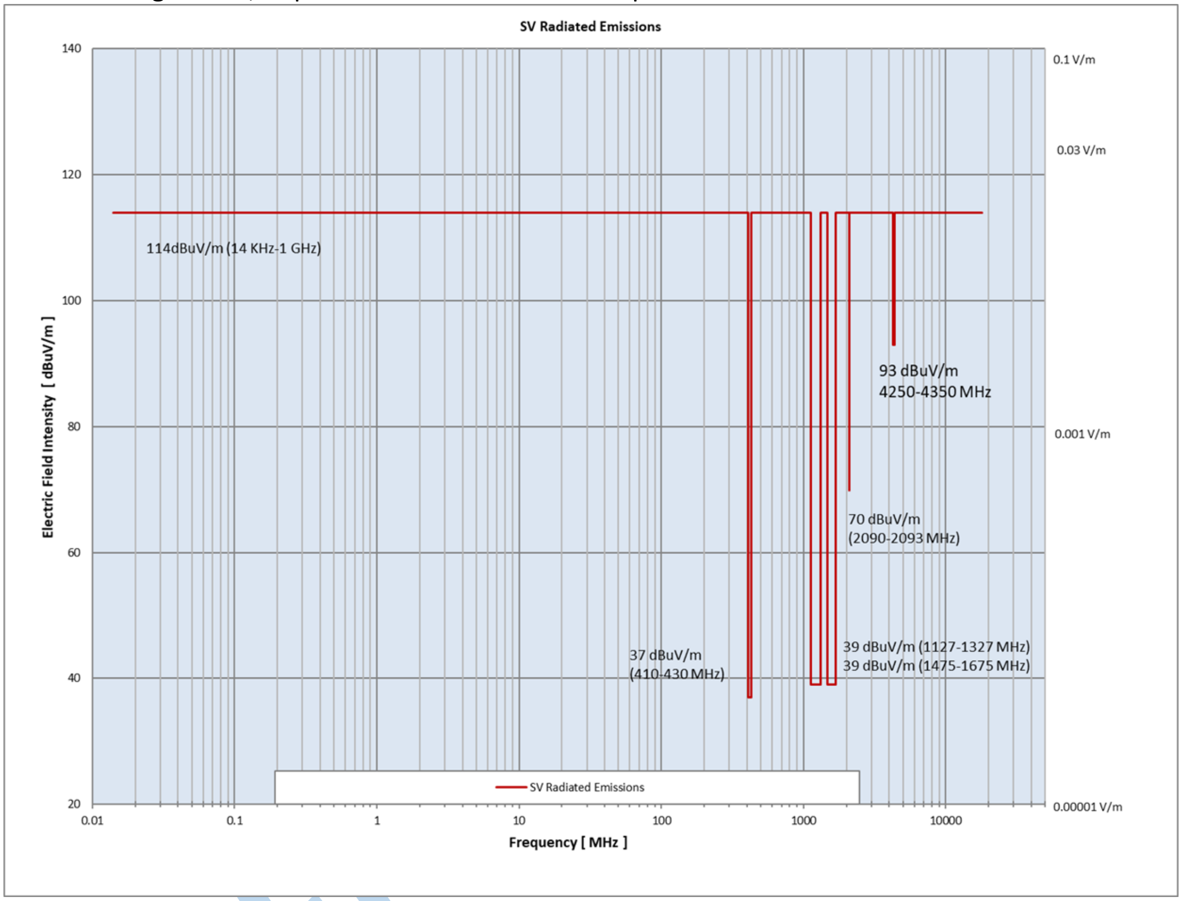
6.5.9.8 The RPLs **shall** meet the following EMI margin requirements:

6.5.9.8.1 Electroexplosive Devices (EED) - The RPLs **shall** demonstrate a 20 dB Electro-Magnetic Interference Safety Margin (EMISM) to the RF environment (vs. dc no-fire threshold) for all firing circuits.

6.5.9.8.2 Safety Critical Circuits - The RPLs **shall** demonstrate a 6 dB EMISM to the RF environment for all safety critical circuits and circuits that could propagate a failure to the launch vehicle.

6.5.9.8.3 RPLs **shall** be magnetically clean from encapsulation through separation on orbit, with magnetic fields less than or equal to 1 Gauss at 1 meter from the RPL and all ground support equipment (GSE).

Figure 6.3, Representative Constraint on Spacecraft Radiated Emissions



6.5.10 Radiation

6.5.10.1 **No** ionizing radiation is **permitted**.

6.6 Ground Operations

6.6.1 RPLs **shall** provide GSE lifting fixtures to support mate operations onto the SPA.

6.6.2 RPLs **shall** provide their own GSE for payload operations such as battery charging, monitoring, testing, etc.

6.7 Requirements for U-Class Containerized (CubeSat) RPLs and CubeSat Constellations

6.7.1 RPLs proposing CubeSat payloads **shall** provide their own flight qualified dispenser system that meets the requirement of this specification. The dispenser system will be mounted to the ESPA Port. Only the CubeSats will be deployed.

6.7.2 CubeSat RPLs **shall** meet the requirement of this specification, except for sections 6.3.1, 6.3.2, 6.3.3, 6.3.4, 6.3.5, and 6.4.2.

6.7.3 CubeSat payloads **shall** comply with LSP-REQ-317.01B.

7 Safety

7.1 Fault Tolerance

7.1.1 NASA RPL missions **shall** implement a Payload Safety Working Group (PSWG) per NPR 8715.7B. RPLs **shall** also support and comply with the primary mission Payload Safety Working Group (PSWG). All hazardous operations (such as deployments of deployables, RF transmission and propulsion activation) **shall** be dual fault tolerant.

7.2 Hazard System Activation

7.2.1 RPLs **shall** have the ability to activate hazardous systems based on time limit identified in the LV to Primary Payload ICD. These hazardous systems must be noted in the Accommodation Worksheet. They may consist of, but are not limited to:

- Deployments of solar arrays, booms, and antennas etc. The proposal must show that these will not be deployed inadvertently such as to impact the primary spacecraft, other secondaries, or the launch vehicle.
- RF transmission. The proposal must show RF inhibit architecture such that the spacecraft cannot transmit until after it has separated and achieved a safe distance from the other spacecraft and from the upper stage.
- Propulsion System
- Any other systems

7.3 Propulsion and Pressure vessels

7.3.1 Non-propellant/pressure vessels reaction control system such as reaction wheels and torque bars are preferred.

7.3.2 RPLs with propulsion should use cold gas propulsion or green propellant if possible.

7.3.3 RPLs with pressure vessels **shall** comply with NASA-STD-8719.24, NASA Expendable Launch Vehicle Payload Safety Requirements, at the launch site.

7.3.4 RPLs **shall** comply with NASA-STD-8719.24, NASA Expendable Launch Vehicle Payload Safety Requirements, for loading and offloading of propellants and hazardous commodities.

7.3.5 If RPLs have pressurized systems such as those included in propulsion systems, extensive testing and/or analysis must be performed to ensure that no failures will occur during launch. *Max flight opportunity: no pressure vessels.*

7.4 Hazardous Materials

7.4.1 RPLs hazardous material **shall** conform to NASA-STD-8719.24, NASA Expendable Launch Vehicle Payload Safety Requirements.

7.5 Orbital Debris

7.5.1 RPLs mission design and hardware **shall** be in accordance with NPR 8715.6B NASA Procedural Requirements for Limiting Orbital Debris and Evaluating the Meteoroid and Orbital Debris Environments.

7.6 Ground Processing

7.6.1 DNH - System Configuration and Penalty Testing
Prior to arrival at the launch site RPLs **shall** have completed all their system-level environmental testing in flight configuration and will not break configuration for the remainder of the mission.

System Configuration can be broken for reasons such as:

- Unexpected test anomalies that require the removal of a specific component for additional box level testing.
- To repair or replacement of malfunctioning units, and even
- Last-minute replacement of flight batteries.

If system configuration is broken, penalty testing may be required to ensure the system as a whole has proven its integrity/robustness after the configuration break.

In a majority of cases, these configuration breaks happen near the end of the I&T flow (during thermal vacuum testing or after), and to initiate a full system environmental retest could incur unrecoverable schedule and fiscal costs on a program. However, the DNH risk from a broken configuration without any remediation is difficult to assess and is considered high. In order to reduce this risk without a system workmanship screen (acceptance level testing), the strength of the panels and associated fasteners will be scrutinized. Combinations of augmentation schemes such as locking features, head staking, lubrication of dissimilar mating surfaces, and limited fastener reuse can all provide valid mitigation and potentially avoid penalty testing.

7.6.2 Modifications of hardware that breaks system configuration **shall** not be considered post arrival at the launch site as all I&T work is expected to be complete with the system fully verified.

7.6.3 RPLs **shall** meet Department of Transportation requirements and acquire applicable certification for the transportation of hazardous commodities and/or pressurized system when not at the launch site.

7.6.4 RPLs **shall** be able to be processed in either a horizontal or vertical orientation at the launch site.

Appendix A – Nominal Timeline of Inputs to support Primary Mission Integration Cycle*

***Timelines will be adjusted after the Primary Mission Launch Vehicle has been selected.**

RPL Timeline	S/C Input needed	LVC Timeline To LSP	LVC Deliverable
(1) During Phase A (2) CSR Delivery (3) LSTO start	S/C Questionnaire/LSIRD Mission Support Requirements draft. Final at LSTO start. Assume LSTO start to be ATP need date plus 6-9 M.	LV ATP + 6M for Preliminary; final by contract L-15M	Mission Interface Control Document (ICD) Draft
(1) During Phase A (2) CSR Delivery (3) NLT LV ATP + 4 weeks	S/C drawings and fairing Requirements, CAD models (i.e. Details of mechanical interface, CAD showing outer skin line, location of SC access needs so door locations can be determined)	ATP + 6M for Preliminary; final by contract L-15 M for MICD	Payload Compatibility/Critical Static Clearance Drawing/MICD. Updates as required thru the mission as the SC changes.
LV ATP + 4 weeks	**S/C dynamic model (Craig Bampton (CB) format) (first delivery) and accompanying memo to describe use of model. First CLA date is not set in stone in contract. Most SC desire for it to be done ASAP after ATP.**	Receipt of SC CB model plus 3-4 M with dynamic clearance plus another 1 M	Preliminary Design Loads Cycle and dynamic clearance assessment to LV hardware (i.e. separation system, fairing) ****Feeds Primary S/C CDR (~ L-33M)***
ATP + 1M-6M	S/C Target spec and Mass Properties (first delivery) Most SC desire to kick this effort off ASAP after ATP. Per contract, several LV contractors allow this but SpaceX has first one at ATP + 6M.	SC input +2-3M	Initial Performance and Guidance Accuracy Analysis (PGAA) ****Feeds Primary S/C CDR (~ L-33M)***
LV ATP +4 weeks	S/C flight harnesses requirements	ATP + 6M for Preliminary; final by L-15M	Electrical Interface Control Drawings (or as soon as available; flight hardware is needed sooner than GSE info). Many connectors require long lead times. For connectors, Flight **and GSE**, the LV is providing, need dates for the SC drive procurement. Preferred to understand these need dates ASAP after ATP.
NLT L-24M	Mass Simulator Specifications (updated S/C CAD model, Mass, CG, freq)	L-18 M	Mass Simulator
L-24 M & In conjunction with final	The S/C nutation time constant (if applicable), otherwise, ICD details and trajectory analysis	Initial L-21M Final @ ~L-6M	Spacecraft Separation Analysis: Initial is as required. Final is required but contracts between contractors varies this deliverable from L-6M to L-1M

trajectory analysis	results are input to SC separation analysis.		
L-20M	S/C ventable and non-ventable volumes. Timing can be after L-18 M but can be as late as L-6M	L-15M	Payload Fairing Venting Analysis (initial data in IRD, confirmed as input to venting analysis at this time)
NLT L-19M	S/C dynamic model, CB format and accompanying memo to describe use of model (second delivery)	~L-12 M	Intermediate Design Loads Cycle (AKA FDLC) and dynamic clearance assessment to LV hardware (i.e. separation system, fairing) ***Feeds Primary S/C PER***
L-16M	S/C Target spec and Mass Properties (second delivery)	~L-12M	Performance and Guidance Accuracy and Analysis (PGAA) – Preliminary Mission Analysis (PMA) ***Feeds Primary S/C PER***
L-16M	S/C RF Systems summary	L-12 M and L-3M As required	EMI/EMC and RF Compatibility Study (initial data in IRD, confirmed as input to RF Compat at this time)
L-13M	S/C radio frequency application	L-9M	RF Link Analysis (initial data in IRD/ICD, confirmed as input to RF link at this time). Cannot be performed until PMA complete
L-12M	Simplified S/C geometrical and thermal mathematical models. Format and maximum sizes are negotiated with contractor after award. Potential SC will be required to simplify their existing models used for their on orbit thermal analysis due to size limitations to run the full SC/LV integrated models. Preferred around L-12M	L-8M	Integrated Thermal Analysis. Cannot be performed until PMA but preferred to be done after FMA.
60 days prior to SC CDR	S/C Mission System Prelaunch Safety Package (MSPSP) inputs	>= 30 days prior to SC ship to launch site	Final Spacecraft MSPSP (this is time of final release of MSPSP, inputs would be much earlier)
L-11M	S/C verified dynamic model, CB plus memo (third delivery). This delivery drives final availability of LV input to final flight software validation and timing is critical	L-6M	Verification Loads Cycle (VLC) and dynamic clearance assessment to LV hardware (i.e. separation system, fairing)

L-10M	S/C Target spec, S/C mass properties statement, launch window (third delivery)	~L-6M	Performance and Guidance Accuracy Analysis (PGAA) (some need as early as L-36 weeks)
NLT 30 days prior to use	S/C launch site test plan, S/C launch site standalone test procedures, and S/C integrated test procedure inputs	Final: NLT use – 4 weeks	Integrated and stand-alone Test Procedures at PPF and pad
L-3M	S/C Final Target spec and final s/c mass properties statement. Note this is listed as A/R for all contractors. Timing of this final delivery will be set after award	L-2M	Final Mission Analysis (FMA)
30 days prior to need/use date	Misc. S/C data as needed (e.g. Environmental Test Plans, Procedures and Results)		
		Delivered with each update of the ICD revision	Mission ICD Verification Matrix

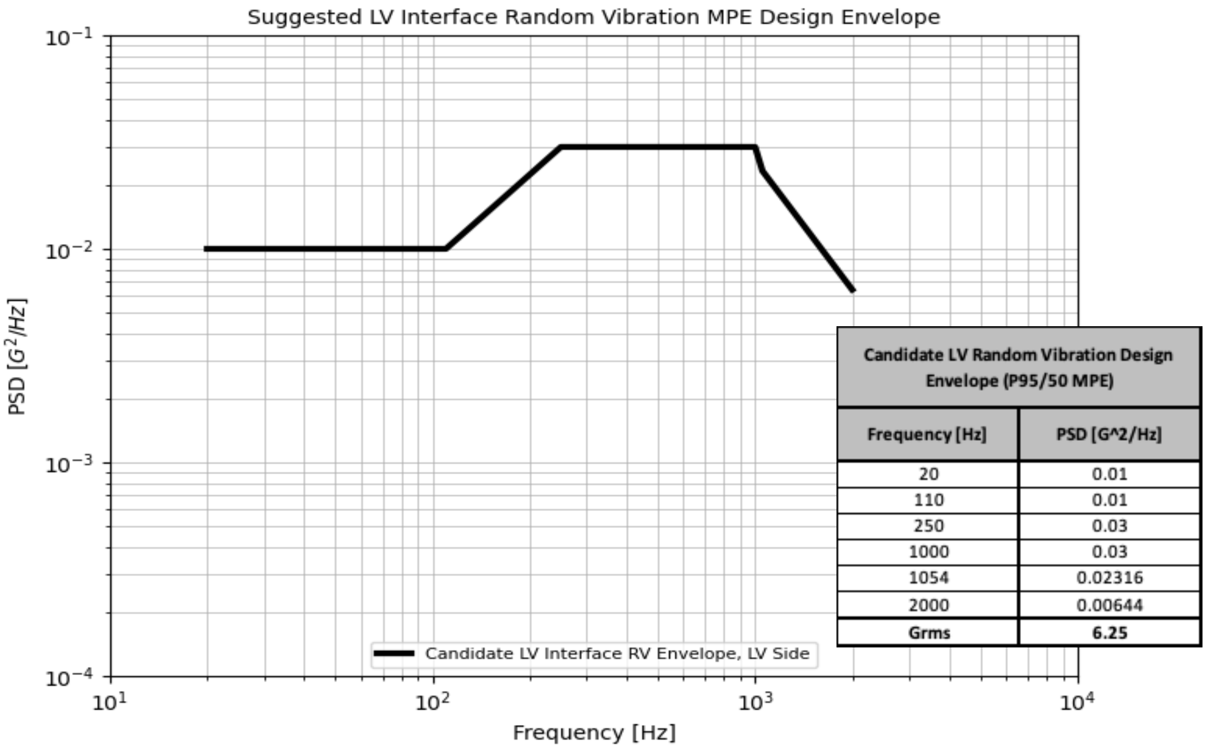
Other SC Inputs needed:

- SC documents/drawings to show compliance with following concerns:
  - SC separation detection methods across the LV-SC interface which initiate mission critical functions shall be electrically and mechanically single fault tolerant.
  - SC separation detection circuits shall provide protection to tolerate open circuit durations of up to 100 µsec on all contacts of all connectors at the same time.
  - The SC transmitter(s) shall be electrically and mechanically dual fault tolerant (3 inhibits) against inadvertent radiation.
  - The SC shall have the capability to prevent erroneous RF signals from inadvertently initiating SC transmitter radiation.
  - The SC timer shall accommodate timing dispersions that encompass the entire launch window and LV 3-sigma / contingency flight time dispersions.
  - During launch operations, the SC shall provide the capability to remotely reset the timer. A timer reset may be required for circumstances including but not limited to a launch recycle or launch abort. Note: timers are not recommended implementation
    - The SC timer reset capability shall be single fault tolerant (2 different methods are required to reset the timer)
  - The SC flight phase detection mechanism shall be tested to a flight like LV simulation to mitigate incorrect determination of LV phase of flight.
  - The SC ground command up-link shall be single fault tolerant against inadvertent commands from being initiated until after SC Separation

Appendix B – Encompassing Launch Vehicle Environments (8/11/2021 update)

* Unless otherwise noted, all environments herein are defined as a P95/50 statistical envelope defined at the rideshare adapter port. With the normal exception of acoustics which is spatially averaged within the payload fairing.

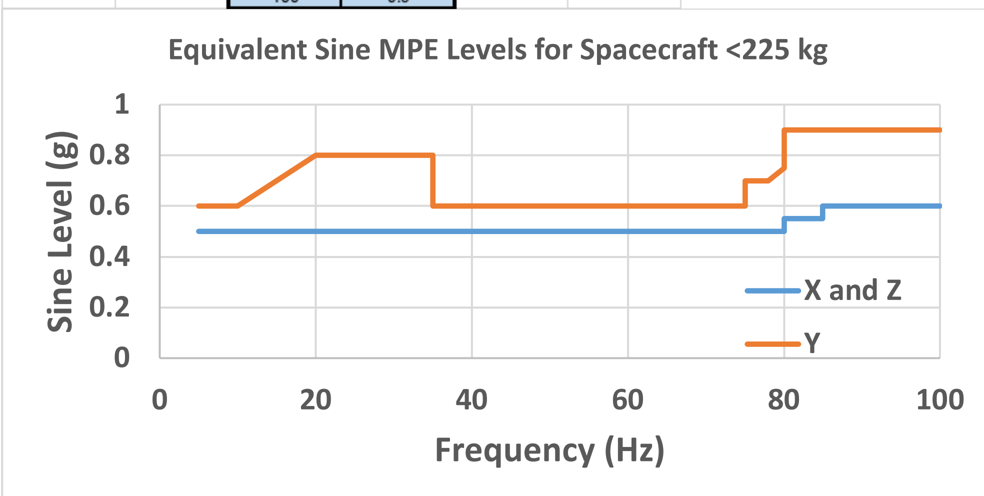
Random Vibration Environment:



Candidate LV Random Vibration Design Envelope (P95/50 MPE)	
Frequency [Hz]	**PSD [G^2/Hz]**
20	0.01
110	0.01
250	0.03
1000	0.03
1054	0.02316
2000	0.00644
Grms	**6.25**

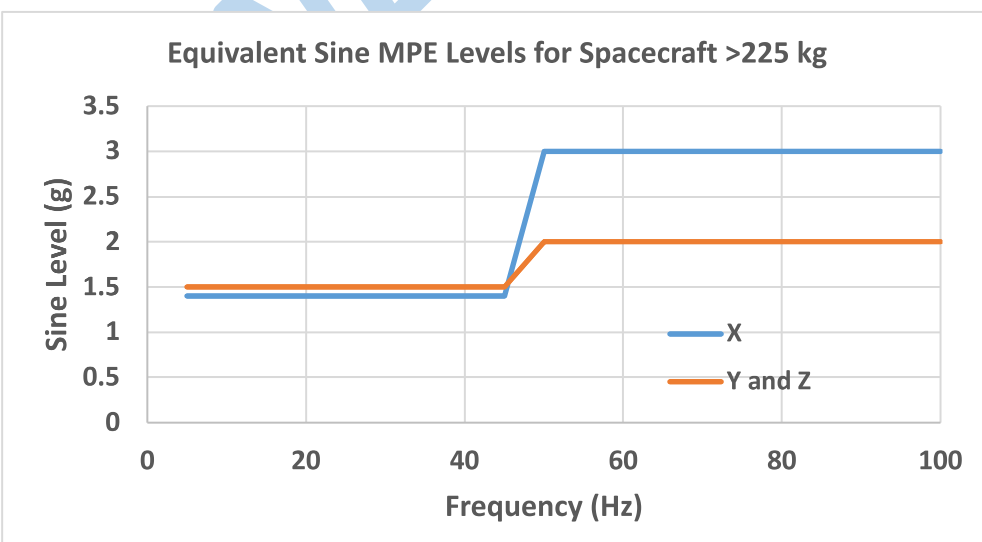
Sine Vibration Environment:

Equivalent Sine MPE Levels for Spacecraft <225 kg					
Frequency (Hz)	X (g)	Frequency (Hz)	Y (g)	Frequency (Hz)	Z (g)
5	0.5	5	0.6	5	0.5
80	0.5	10	0.6	80	0.5
80	0.55	20	0.8	80	0.55
85	0.55	35	0.8	85	0.55
85	0.6	35	0.6	85	0.6
100	0.6	75	0.6	100	0.6
		75	0.7		
		78	0.7		
		80	0.75		
		80	0.9		
		100	0.9		



X and Z: lateral levels
Y: thrust levels

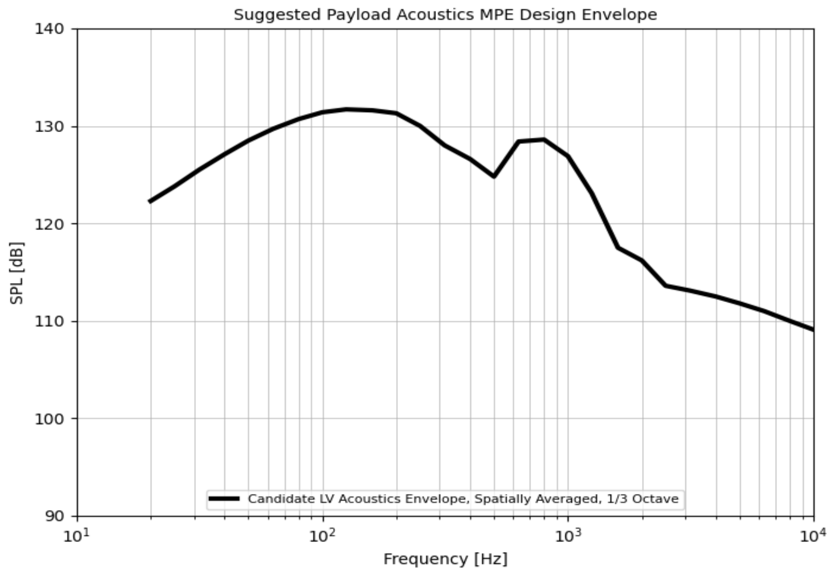
Equivalent Sine MPE Levels for Spacecraft >225 kg			
Frequency (Hz)	X (g)	Y (g)	Z (g)
5	1.4	1.5	1.5
45	1.4	1.5	1.5
50	3	2	2
100	3	2	2



X: radial levels
Y and Z: thrust & tangential levels.

Acoustic Environment:

* The suggested acoustics design envelope covers all candidate LVs in one spec and therefore may be extremely conservative.

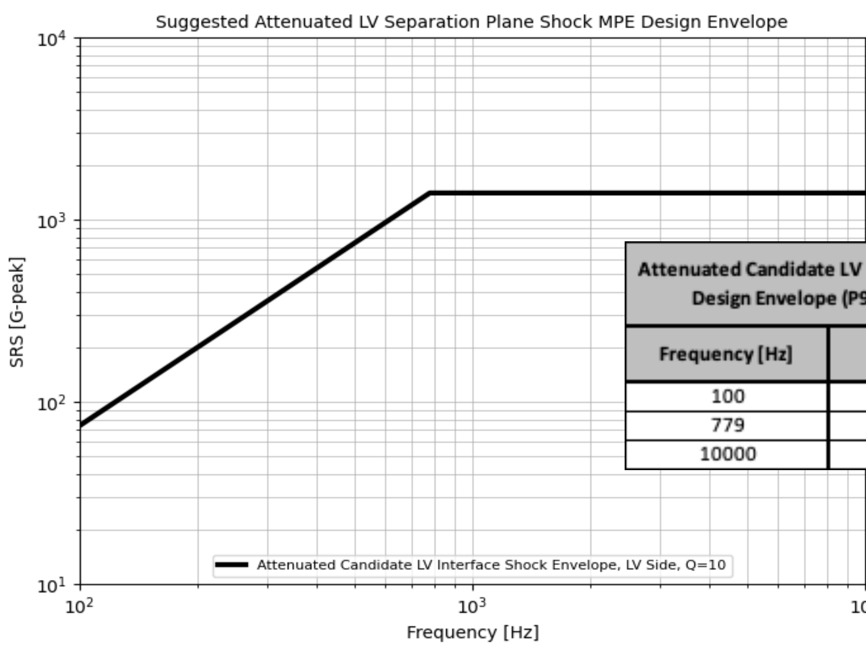


Candidate LV Payload Acoustics Design Envelope (P95/50 MPE)	
Frequency [Hz]	**SPL [dB]**
20	122.3
25	123.8
31.5	125.5
40	127.1
50	128.5
63	129.7
80	130.7
100	131.4
125	131.7
160	131.6
200	131.3
250	130
315	128
400	126.6
500	124.8
630	128.4
800	128.6
1000	126.9
1250	123.1
1600	117.5
2000	116.2
2500	113.6
3150	113.1
4000	112.5
5000	111.8
6300	111
8000	110
10000	109.1
OASPL	**141.6**

Shock Environment:

* All shock events including stage separation, fairing separation, and SC separation are included in this envelope.

* Separation system shock levels shown are attenuated levels based on the configuration of the secondary payload adapter. For this configuration, one joint with 30% attenuation was employed. Note that no distance attenuation was used because TBD rideshare adapter details are unknown. Please refer to NASA-HDBK-7003 for further information on shock attenuation calculations.



Attenuated Candidate LV Separation Shock Design Envelope (P95/50 MPE)	
Frequency [Hz]	**SRS [G-peak]**
100	74
779	1400
10000	1400